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Statistical Study on Physio-chemical Characteristics of Ground Water of Coimbatore South Zone

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Ground water samples were collected from 18 wards of Coimbatore city south zone, among which 2 samples were collected from 2 different locations from each ward, totaling 36 samples. Water quality assessment was carried out for the parameters, like temperature, odour, taste, colour, turbidity, pH, electrical conductivity, total dissolved solids, chlorides, hardness, alkalinity, Calcium, Sodium and Potassium. Correlation coefficients were determined to identify the highly correlated and interrelated water quality parameters. Regression equations relating these identified parameters were formulated. Comparison of observed and estimated values of the different parameters reveals that the regression equations developed in the study can be very well used for making water quality monitoring by observing the above said parameters alone. This provides an easy and rapid method of monitoring of water quality.

KEYWORD

Water quality, Monitoring, Electrical conductivity, Correlation, Regression equation.

INTRODUCTION

Water is renewable natural resource of earth and is essential for all living organisms for their existence and metabolic processes in the world. Water is not only the most important essential constituent of all animals, plants and other organisms but also the pivotal for the survivability of mankind in the biosphere (Sharma, 2000). Major water sources on the earth are saline water sources, which are seas and ocean. They are about 99% of the total water available. Remaining 1% of water sources include the fresh water bodies on the earth and the ground water sources. The meager quantity ground water is an important source of water for agricultural (about 45% of our country's agriculture demand is met), domestic (about 88% of rural areas in our country) and industrial purposes. Ground water is the only alternative option for even the urban centres having well planned, designed and executed water supply systems, like Coimbatore, during the periods of water scarcity due to shortfall of rain or its non-occurrence. Also normally the ground water is the water sources for the different locations, where the municipal water supply facilities are not made available. Nowadays, the groundwater potential and its quality level in major cities and urban centres is getting deteriorated due to the population explosion, urbanisation, industrialsation and also the failure of monsoon and improper management of rain water. The ground water quality is normally charcterised by different physio-chemical characteristics. These parameters change widely due to the type of pollution, seasonal fluctuation, ground water extraction, etc. Hence a continuous monitoring on ground water becomes mandatory in order to minimize the ground water pollution and have control on the pollution causing agents. Continuous monitoring on ground water may become easier with the development of rapid water quality measurement techniques without making much compromise on the accuracy of measurement.

Sunitha *et al.* (2005) identified that the EC finds higher level correlation significance with many of the water quality parameters, like total dissolved solids, chlorides, total alkalinity, sulphates, carbonates, total hardness and

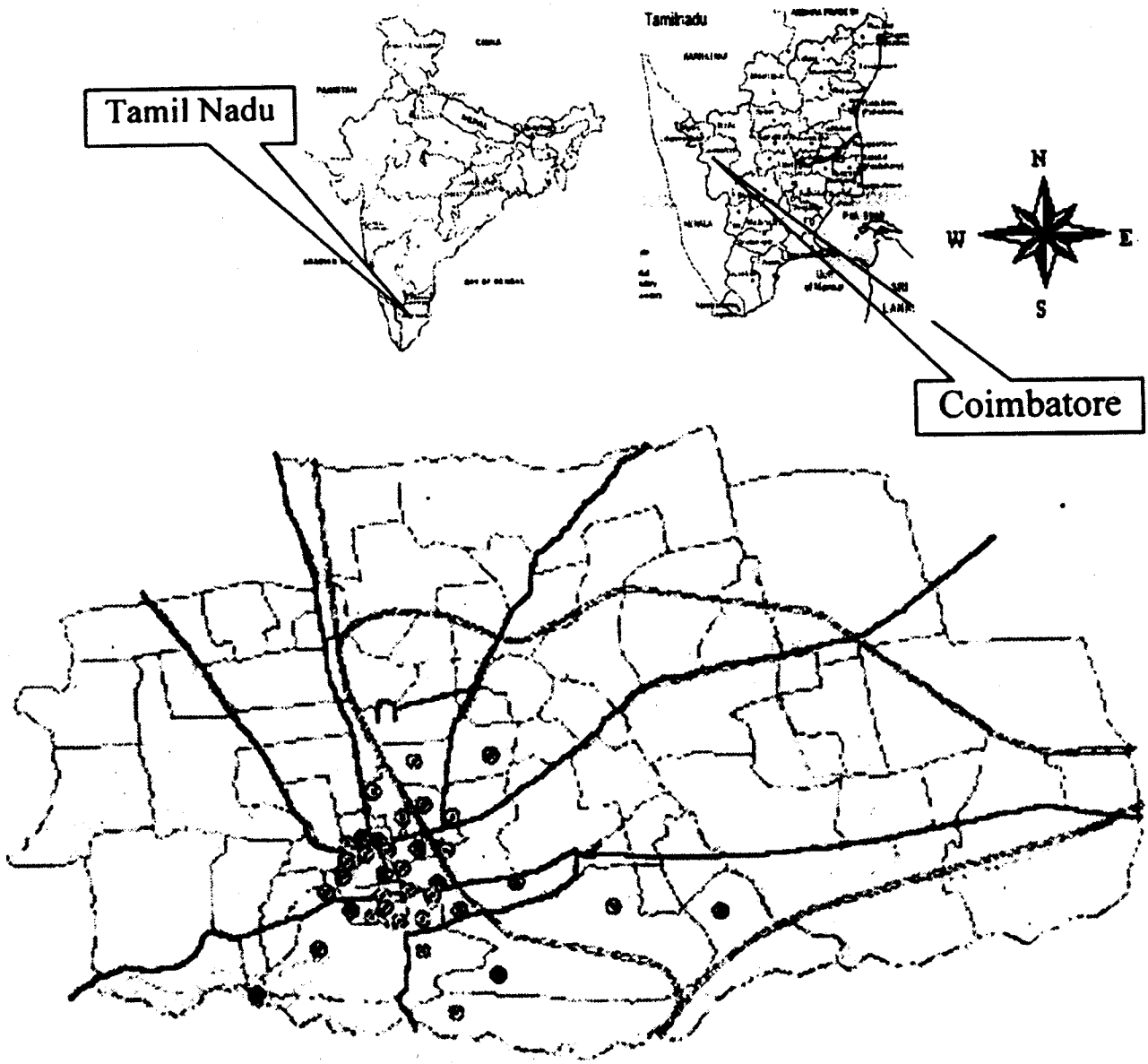

Figure 1. *Coimbatore city map shown for the South Zone sampling locations, City Municipal wards, National highways and Railway lines*

mangesium. Mahajan *et al.* (2005) identified that all the parameters are more or less correlated with others in the correlation and regression study of the physio-chemical parameters of ground water. Kalyanaraman (2005) identified that the water quality of ground water can be predicted with sufficient accuracy just by the measurement of EC alone. This provides a means for easier and faster monitoring of water quality in a location. Achuthan Nair *et al.* (2005) concluded that the correlation study and correlation coefficient values can help in selecting treatments to minimize contaminants in ground water. Reviews made in the journals and publications reveal that electrical conductivity of ground water has significant correlation with the other water quality parameters, like total dissolved solids, chlorides, total alkalinity, sulphates, total hardness, calcium, magnesium, etc. and also a better correlation exists among other parameters. This strong correlation existing between these interrelated water quality characteristics permits to develop equation of the best fit for the data input of electrical conductivity and

Table 1. *Results obtained in statistical analysis on observed water quality characteristic values showing range, mean, standard deviation, standard error and coefficient of variation, in mg/L*

Parameter	Range	IS Standard		Mean	Standard deviation	Standard error	Coefficient of variation
		P	E				
Turbidity	0.00-0.38	5	25	0.09	0.09	0.02	100.00
Temperature	32.2-35.6	–	–	33.44	0.61	0.10	1.82
pH	7.00-8.60	6.5	8.5	7.70	0.43	0.07	5.58
EC, μ mhos/cm	670-9820	1400	–	2633.06	2302.56	383.76	87.45
TDS	420-6290	1000	–	1615.56	1510.76	251.79	93.51
Total hardness	70-1540	300	600	467.78	324.62	54.10	69.40
Chlorides	54-786	250	1000	212.03	176.64	29.44	83.31
Alkalinity	320-1280	200	600	810.28	229.18	38.20	28.28
Sulphates	156-418	200	400	234-48	60.22	10.04	25.68
Calcium	17-406	75	200	110.78	93.59	15.60	84.48
Sodium	20-386	200	–	173.16	81.22	13.54	46.90
Potassium	2-95	–	–	19.78	17.77	2.96	89.94

P-Permissible limit, E-Excessive limit.

other parameters by the systematic calculation and interpretation of the correlation coefficients. These equations could be used effectively for predicting water quality by making observation on electrical conductivity alone or any one of the other parameters. This enables the monitoring of water quality an easy and quick method. This may also be considered as rapid method of water quality monitoring.

MATERIAL AND METHOD

In the present study correlation coefficients among all the water quality characteristics were calculated. The linear regression equations were developed for the pairs having strong correlation and also for the pair of parameters, which have influence on each other. The correlation analysis on water quality parameters reveals that all parameters are more or less correlated with each other. The characteristics were calculated using the regression equation and they are compared withe the observed values.

Study area

The Coimbatore city area is divided into 4 zones, namely North, South, West and East zones and each zone is further divided into 18 Wards. For the present study, south zone was selected and in each ward two bore wells, which are extensively used for drinking, and household purposes were identified. While selecting the bore well locations, the spatial distribution of sampling locations in individual wards and in the City as a whole was considered. The groundwater samples from the sampling locations were taken after operating the hand pumps or motor pumps for about 10 to 15 min. The samples were collected in the pre-cleaned polypropylene bottles with necessary precautions. All the samples were tested for the environmentally significant parameters, like temperature, odour, taste, colour and also TDS in the field itself. Turbidity, pH, electrical conductivity, total dissolved solids, chlorides, hardness, alkalinity, calcium, sodium and potassium were estimated at the laboratory. Figure 1 shows the Coimbatore city and the south zone sampling locations, City Municipal wards, national highways and railway lines.

RESULT AND DISCUSSION

Physio-chemical characteristic analysis made on groundwater collected from the 36 locations of the study area revealed that there were considerable deviations in the water quality parameters from the water quality

Table 2. *Correlation coefficients (r) among various water quality parameters*

Water quality parameter	Electrical conductivity	Total dissolved solid	Total hardness	Chlorides	Sodium	Potassium
Electrical conductivity	1.000					
TDS	0.992	1.000				
Total hardness	0.900	0.893	1.00			
Chlorides	0.909	0.897	0.880	1.000		
Sodium	0.250	0.237	0.226	0.270	1.000	
Potassium	-0.020	0.013	0.091	-0.043	-0.035	1.000
Sulphates	0.449	0.430	0.507	0.482	0.294	0.019
Calcium	0.418	0.420	0.325	0.356	0.449	-0.102
Alkalinity	0.329	0.272	0.375	0.183	0.085	0.044
pH	-0.038	-0.055	-0.105	0.008	0.001	-0.227
Temperature	0.101	0.096	-0.020	0.127	0.192	0.017
Turbidity	0.029	0.020	0.019	0.010	0.162	-0.021

Table 2. *(cntinue)*

Water quality parameter	Sulphates	Calcium	Alkalinity	pH	Temperature	Turbidity
Electrical conductivity						
TDS						
Total hardness						
Sodium						
Potassium						
Sulphates	1.00					
Calcium	0.209	1.00				
Alkalinity	0.229	-0.080	1.000			
pH	-0.015	-0.295	-0.052	1.00		
Temperature	0.371	0.180	-0.088	0.099	1.000	
Turbidity	-0.085	-0.021	0.018	0.274	-0.119	1.000

Table 3. *Linear correlation coefficient (r) and regression equation for some pairs of parameters which have significant value of correlation*

Pair of parameters	r	Regression coefficient		Regression equation
		a	b	
EC and TDS	0.992	-98.5596	0.6510	TDS = -98.5596 + 0.6510 (EC)
EC and Hardness	0.900	133.6841	0.1269	Hardness = 133.6841 + 0.1269 (EC)
EC and Chlorides	0.909	28.3220	0.0698	Chlorides = 28.3220 + 0.0698 (EC)
TDS and Hardness	0.893	157.6548	0.1920	Hardness = 157.6548 + 0.1920 (TDS)
TDS and Chlorides	0.897	42.5997	0.1049	Chlorides = 42.5997 + 0.1049 (TDS)
Chlorides and Hardness	0.880	124.7047	1.6180	Hardness = 124.7047 + 1.6180 (Chlorides)

standards. And also the variation in the concentration for each parameter is wider.

Table 4. *The observed and predicted (using regression equation developed using better correlated parameters) values of chemical characteristics of ground water and correlation coefficients*

Ward no.	Correlation coefficient / Source/Area	Electrical conductivity	0.992			0.900	0.893	0.880		0.909	0.897
			TDS			Total hardness				Chlorides	
			Obs	Cal (EC)	Obs	Cal (EC)	Cal (TDS)	Cal (Cl)	Obs	Cal (EC)	Cal (TDS)
12	Near vellalore road	9820	6080	6294	1130	1380	1325	1397	786	713	680
	Vellalore road	9120	6290	5839	1240	1291	1365	863	456	665	702
13	Near byepass road	8090	5180	5168	1210	1160	1152	1255	698	593	586
	Pulianthoppu	8450	5340	5402	1540	1206	1183	1253	697	618	603
25	Near Shanthi theatre	2100	950	1269	500	400	340	403	172	175	142
	Near govt. arts college	2800	1820	1724	310	489	507	432	190	224	234
27	Near VOC Park	1160	600	657	220	281	273	212	54	109	106
	Near VOC Park	1950	900	1171	260	381	330	284	98	164	137
28	Opp central jail	2640	1640	1620	250	469	473	366	149	213	215
	Ramani apt	2390	1030	1457	320	437	355	432	190	195	151
36	Syrian church	2350	1330	1431	400	432	413	344	136	192	182
	Coimbatore weaving mills	2510	1080	1535	510	452	365	432	190	203	156
37	Police head quarters	1050	670	585	120	267	286	345	136	102	113
	B.V. road	670	420	338	130	219	238	265	87	75	87
38	Head post office	2370	1260	1444	400	434	400	403	172	194	175
	V.H. road	2030	1160	1223	490	391	380	344	136	170	164
39	Near royal theatre	2000	1330	1203	350	387	413	329	127	168	182
	Ukkadam byepass	2290	1440	1392	390	424	434	373	154	188	194
40	Near ukkadam bus stand	1930	1280	1158	430	379	403	710	362	163	177
	Near market	1620	1050	956	510	339	359	681	344	141	153
41	Opposite to ukkadam temple	1630	1050	963	560	341	359	432	190	142	153
	Near bus stand	1590	650	937	480	335	282	446	199	139	111
42	Near periyakulam road	2590	1400	1588	450	462	426	378	157	209	189
	Perur road	2250	1440	1366	420	419	434	431	190	185	194
43	Big bazar street area	1940	1230	1164	400	380	394	429	188	164	172
	Big bazar street	2180	1410	1321	380	410	428	446	198	180	191
44	Raja street	1190	900	676	340	285	330	300	108	111	137
	Near raja street junction	1290	770	741	400	297	305	271	90	118	123
45	Edayarstreet	1560	1060	917	290	332	361	344	136	137	154
	R.G. street	1860	1200	1112	290	370	388	300	108	158	168
46	Sukrawarpet cross road	1960	1250	1177	660	382	398	344	136	165	174
	Karumbu kadai road	1750	1160	1041	630	356	380	417	181	150	164
47	Sukrawarpet	1260	830	722	160	294	317	329	127	116	130
	Poomarket road	1360	880	787	70	306	327	286	99	123	135
54	Near periakulam	1020	730	565	260	263	298	281	96	99	119
	Near noyyal river	2020	1350	1216	340	390	417	282	98	169	184

The mean values of 12 parameters of ground water quality considered for 36 sampling locations and with their standard deviation, standard error and coefficient of variation obtained in the statistical analysis are presented in table 1. The average value for the turbidity was 0.09 NTU and it was ranging from 0.00 to 0.38 NTU. The IS standards recommendation for the turbidity is 5.0 NTU. The temperature measured shows that the variation was in the range of temperature 32.2 to 35.6°C. The mean temperature was 33.44°C. The pH of all the samples was found to be alkaline. Mean pH value was 7.70. The pH variation was observed to be in the range of 7.00 and 8.60; all the samples fall in the range of recommended standard prescribed by IS for the pH (that is 6.5 to 8.5), except one sample having pH of 8.60. And also the coefficient of variation observed for the pH was 5.58% only. It shows that the variation in the pH value among its measured value at different locations is not high and variation range is very narrow.

The average value for the electrical conductivity was 2633.06 μ mho/cm and it was ranging from 670 to 9820 μ mho/cm. The standards recommendation for the electrical conductivity is only 1400 μ mho/cm. In 28 different locations, the EC value was found to be exceeding the standard value of 1400 μ mho/cm. The coefficient of variation for the measured EC values was 87.45%. This shows that the variation in the observed EC values was very high. The total dissolved solids averaged a value of 1615.56 and it was ranging from 420 to 6290. The standards recommendation for the total dissolved solids is only 1000 ppm. And also coefficient of variation observed for the TDS was 93.51%. It shows that the variation in the TDS value among its measured value at different locations is high and variation range is too high. The average value for the total hardness was 467.78 ppm and it was ranging from 70 to 1540 ppm. The standards recommendation for the total hardness is only 300. The chlorides concentration was ranging from 54 to 786 mg/L and its average value was 212.03. The standards recommendation for the chlorides is 250 ppm. The coefficient of variation for the chlorides values is very high. The alkalinity value was ranging from 320 to 1280 mg/L and its average value was 810.28. The standards recommendation for the alkalinity is 120 ppm. The sulphates concentration averaged a value of 234.48 and it was ranging from 156 to 418. The standards recommendation for the sulphates is only 200 ppm. The calcium concentration measured shows that the variation was in the range of 17 to 406 mg/L and its mean value was 110.78. The IS standards recommendation for the calcium is 200 ppm. And the coefficient of variation observed for the calcium is 84.48%. It shows that the variation in the calcium values measured among the samples of different locations is high and variation in the calcium values measured among the samples of different locations is high and variation range is very high. The sodium concentration was ranging from 20 to 386 ppm and its average value is 173.16. The standards recommendation for the sodium is 200 ppm. The coefficient of variation for the sodium values measured is 46.90%. This shows that the variation in the observed sodium values is high. The potassium concentration was ranging from 2 to 95 and its average value is 19.78. The coefficient of variation for the potassium values measured was 89.94%. This shows that the variation in the observed potassium values is very high.

The table 1 and discussion made show that most of the parameters have the concentration level greater than the permissible value. And also the observed coefficient of variation for the parameters shows that the variation in the electrical conductivity (87.45%), total dissolved solids (93.51%), total hardness (69.40%), chlorides (83.31%), calcium (84.48%), sodium (46.9%) and potassium (89.84%) are of very high. From this it is concluded that the various parameters concentrations are varying highly in the different locations. The correlation coefficients (r) among various water quality parameters were calculated and the numerical values of correlation coefficients (r) are tabulated (Table 2).

Out of the 78 correlation coefficients, 6 correlation coefficients (r) between the EC and TDS (0.992), EC and total hardness (0.900), EC and chlorides (0.0909), TDS and total hardness (0.893), TDs and chlorides (0.897) and total hardness and chlorides (0.880) were found to be with significant levels. Negative (inverse) correlation values were found in 18 cases. Alkalinity and pH were to be with negative correlation with other parameters. Turbidity, temperature, calcium and alkalinity did not show significant correlation with any of the other parameters.

The linear regression analysis was done for the water quality parameters which were found to have better and higher level of significance in their correlation coefficient. The regression equations obtained from the analysis are given in the table 3. The different dependent characteristics of water quality were calculated using the developed regression equation and by substituting the values for the independent parameter in the equations. Table 4 gives the experimentally estimated and calculated values using the regression equations.

CONCLUSION

The statistical analysis of the experimentally estimated water quality parameters on water samples yielded the range of the variation, mean, standard deviation and coefficient of variation. Since the correlation coefficient gives the interrelationship between the parameters, correlation coefficients were calculated. Results of correlation analysis show that electrical conductivity and total dissolved solids are having high correlation with most of the other parameters. Electrical conductivity, total dissolves solids, chlorides, hardness, calcium and potassium are found to be with higher values of coefficient of variation. This indicates that the variation in their concentration at different locations was highly fluctuating in the study area. For the better results in statistical approach, numbers of sampling locations are to be increased. Since the electrical conductivity finds high correlation with the total dissolved solids, hardness and chlorides, regression equations relating the EC and these parameters were formulated. The total dissolved solids finds high correlation with the hardness and chlorides, regression equations were formulated. Similarly the regression equation between the hardness and chlorides was also established.

It was observed that pH, alkalinity, potassium and turbidity didnot find any correlation with any of the other parameters. The calculated values for the water quality parameters, using the regression equations developed, were compared with the observed values. There is variation in the values but the trend is the same as that of the calculated values. The electrical conductivity, total dissolved solids, hardness and chlorides are having better correlation. Hence by making measurement of the electrical conductivity, concentration of the better related parameters, like total dissolved solids, hardness and chlorides, can be estimated. Since other parameters are not having deviation from the IS standards recommendation, the measurement of EC alone and calculation of total dissolved solids, hardness, chlorides and sodium using the regression equations can be adopted as a method of finding the suitability of the water for domestic and other purposes. This may be treated as the rapid method of water quality monitoring.

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