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# Development of Water Quality Index and Regression Model for Assessment of Groundwater Quality

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**Abstract** Groundwater samples were collected from 35 locations in Ranipet, Vellore district; Tamil Nadu was assessed in the Monsoon, Post Monsoon and Pre Monsoon season from July 2012 to May 2013. Water quality assessment was carried out for the parameters like pH, Total hardness, Total dissolved solids, Total alkalinity, Electrical conductivity, Chloride, Calcium, Magnesium, Sodium, Potassium, Nitrate, sulfate, Phosphate, Iron, Chromium. The Water Quality Index values and Correlation coefficient values were calculated to check the exceedingly allied and interconnected with water quality parameters (WQPs). The Regression equations involving these known and linked with parameters were formulated for greatly correlated WQPs. Assessment of experimental and predictable values of the different WQPs parameters reveals that the regression equations developed in the study can be very well used for making water quality monitoring by observing the above parameters alone. The result of examination has been used to recommend a model for predicting water quality, the investigation reveals that the ground water of the area desires some extent of treatment before utilization, and it also needs to be confined from the perils of pollution.
**Keywords** *Groundwater; Physico-Chemical Parameters; Seasons, WQI; Correlation and Regression Analysis*

## 1. Introduction

The water is being a worldwide solvent has been and is being utilized by mankind era and now. Of the total amount of large scale water, only 2.4% is circulated on the main land, of which only a small portion can be utilized as fresh water. The accessible clean water to man is only just 0.3-0.5% of the total water available on the earth and therefore, its sensible use is essential (Mondal et al., 2005). The fresh water is a predetermined and partial resource (Yogendra et al., 2008). The consumption of water from ages has lead to its over use together with the increasing population along with enhanced standard of living as a effect of scientific innovations (Todd, 1995 and Indra Raj, 2000). This pollution of groundwater is not away from the harms of improvement. Thus, eminence of groundwater is failing at a earlier speed suitable to contamination vary from septic tanks (Nanda Balan et al., 2012), land fill leachates, domestic sewage agricultural runoff/ agricultural fields (Mishra et al., 2012) and industrial wastes. Contamination of groundwater also depends on the geology of the region and it is fast in hard rock areas mainly in lime stone regions where wide cavern systems are lower the water table (Manguidya et al., 2013). This is an aspect common, not only in urbanized countries but also in developing countries like India. The changes in excellence of groundwater reply to difference in physical, chemical and biological environments throughout which it passes (Bharti et al., 2011). The most important are to extend a WQI of the study area and Regression model for estimation of groundwater parameter.

## 2. Materials and Methods

### 2.1. Study Area

In the present study area about 154.52 Sq.Km lies between Latitude N 12°52′30’’ – 12°57′30’’ and Longitude E 79°15’00’’–79°25′00’’ is situated in North of Tamil Nadu in India. It includes Ranipet, Walajapet, Arcot and Melvishram and is mainly Palar River and Ponnai River. The Ranipet area is a chronic contaminated area and one of the biggest exporting centers of tanned leather. Many small-scale tanneries are dealing out the leather in the study area and discharging their effluents on the open land and nearby water bodies (Elangovan et al., 2013). There are 240 tannery industrial units located like ceramic, refractory, boiler auxiliaries plant, and chromium chemicals. Studies of groundwater also indicated the high concentrations of chromium in Palar river basin, which is much more than the permissible limit in drinking water. These tanneries are polluting in the Palar River, causing ecological degradation and health hazards (Ramakrishnaiah et al., 2009). In nature the study area is covered by crystalline rocks of Archaean age consisting of Granites and some essential invasive bodies.

## 3. Methodology

### 3.1. Sample Collection and Processing

The study area out of 35 Water samples was collected during July 2012 - May 2013 (Figure 1). The water samples were full in pre-cleaned polyethylene bottles; after collection the samples was directly placed in mysterious boxes and processed within 6 hr of collection (Neerja Kalra et al., 2012). The collected samples were analyzed by using physical and chemical water quality parameters like pH, EC, TDS, TA, chloride, Total hardness sulphate, sodium, calcium, magnesium, and potassium, iron, nitrate and chromium as per APHA standard. In the present study, 14 parameters were considered and calculated the WQI and correlation coefficients along with water quality characteristics.

### 3.2. WQI (Water Quality Index)

WQI is defined as a method of ranking that provides the composite power of individual water quality parameter on the overall quality of water. It is premeditated from the point of view of human utilization. Water quality and its suitability for drinking purpose can be examined by influential its quality index. The standards for drinking purpose (Rosario Arun Kumar et al., 2012) have been measured for calculation of WQI. In this method the weight age for various water quality parameters is implicit to be inversely proportional to the suggested standards for the resultant parameters (Yogendra et al., 2008). The WQI has been calculated to assess the suitability of groundwater quality of the study area for drinking purposes. The WHO (2004) standards for drinking purposes have been measured for the computation of WQI. For the calculation of WQI, Fourteen parameters such as: pH, EC, Total Hardness, TDS, Calcium, Magnesium, Sodium, Potassium, Iron, Fluorides, Chlorides, Sulphates Nitrates and Chromium) have been used.

In the first step, fourteen parameters have been assigning a weight ($w_i$) according to its virtual significance in the overall quality of water for drinking purposes (Table 1). The maximum weight of 5 has been allocated to parameters such as Nitrate due to their major importance in water quality assessment (Neerja Kalra et al., 2012). The remaining parameters like sodium and potassium, calcium, magnesium were assigned a weight between 1 and 5 depending on their significance in the overall quality of water for drinking purposes.

In the second step, the relative weight ($W_i$) is determined using a weighted arithmetic index formula (Brown et al., 1972; Horton, 1965; Tiwari and Manzoor, 1988).

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$$

Where, $w_i$ is the weight of each parameter and n is the number of parameter.

In the third step, quality rating scale ($Q_i$) for each parameter is calculated by dividing its concentration in each water sample ($C_i$) by its relevant standard $S_i$ according to the rule of WHO (2004) and then multiplied by 100.

$$Q_i = (C_i / S_i) \times 100$$

In the forth step, the Sub index of ith parameter $SI_i$ is determined for each chemical parameter, which is used to determine the WQI as per the following equation.

$$SI_i = W_i \times Q_i$$

**Correlation Coefficient (r):** Let x and y be any two variables and (Xi, Yi) be n pairs of observed values of these variables (I =1,2,3…………..n). The correlation coefficient r between the variables x and y is given by equation

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

Where, the summations are taken above 1 to n (n=number of observations). The values of observed parameters a and b were considered with the help of equations 2 and 3.

$$a = \frac{n \Sigma x y - \Sigma x \Sigma y}{n \Sigma x^2 - (\Sigma x)^2} \text{------- (2)}$$

**Regression equation**

$$y = a x + b \text{ ------------------------------- (3)}$$

The study of correlation between various water quality parameters, the regression analysis was carried out using software SPSS 18.

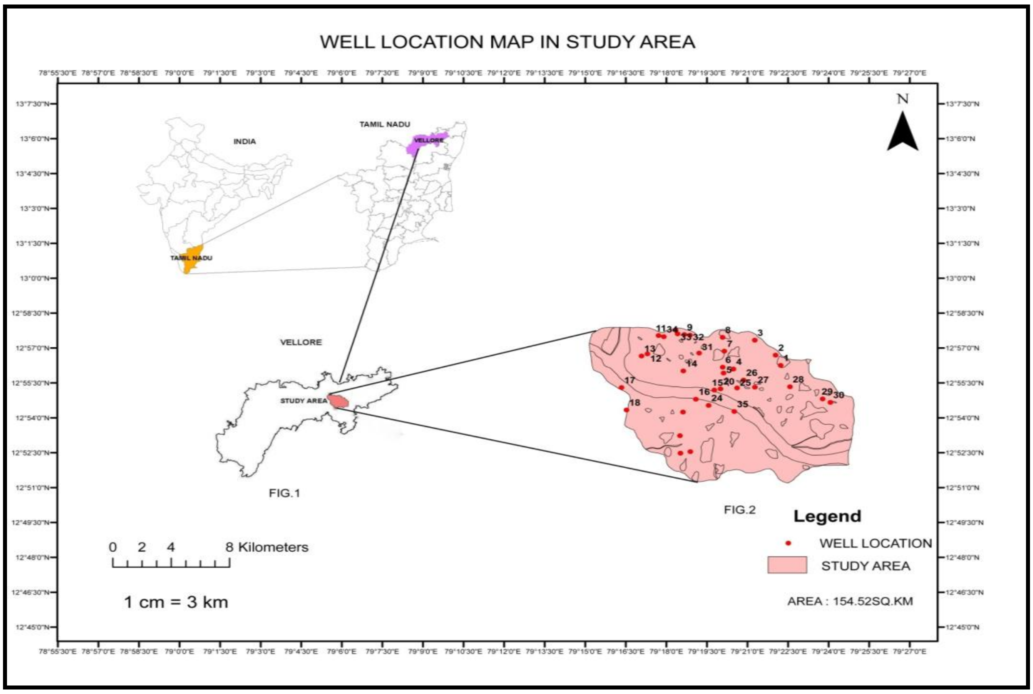


***Figure 1:*** *Well Sampling Stations of the Study Area*

***Table 1:*** *WHO Standards Weight ($W_i$) and Calculated Relative Weight ($W_i$) for Each Parameter*

| Parameters | Standard Permissible Value (Si) (Who, 2004) | Weight ($W_i$) | Relative Weight ($W_i$) |
|---|---|---|---|
| pH | 6.5 - 8.5 | 4 | 0.09 |
| TDS | 500 | 4 | 0.09 |
| EC | 500 | 4 | 0.09 |
| Th | 200 | 3 | 0.06 |
| Ca | 75 | 2 | 0.04 |
| Mg | 50 | 1 | 0.02 |
| Nitrate | 45 | 5 | 0.11 |
| Chloride | 250 | 3 | 0.06 |
| Fluoride | 1-1.5 | 4 | 0.09 |
| Sodium | 200 | 2 | 0.04 |
| Potassium | 200 | 2 | 0.04 |
| Iron | 1 | 4 | 0.09 |
| Sulphate | 250 | 4 | 0.09 |
| Chromium | 0.05 | 5 | 0.11 |
| | **Total** | **47** | **1.00** |

***Table 2:*** *Normal Statistics of Water Quality Parameters of Groundwater Samples*

| Statistics for Monsoon | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WQPs | pH | TDS | EC | TH | Ca | Mg | $NO_3$ | Cl | F | Na | K | Iron | $SO_4$ | Cr |
| Minimum | 7.0 | 362.0 | 516.0 | 212.0 | 48.0 | 22.0 | 2.0 | 42.0 | 0.3 | 28.0 | 4.0 | 0.1 | 29.0 | 0.0 |
| Maximum | 7.4 | 4232.0 | 6046.0 | 1200.0 | 320.0 | 96.0 | 70.0 | 1609.0 | 0.9 | 790.0 | 50.0 | 0.5 | 486.0 | 0.0 |
| Mean | 7.2 | 1838.9 | 2626.9 | 487.8 | 117.9 | 46.0 | 29.4 | 507.5 | 0.5 | 358.9 | 25.6 | 0.3 | 219.5 | 0.0 |
| Std. Deviation | 0.1 | 910.1 | 1300.0 | 223.1 | 64.4 | 17.0 | 21.6 | 340.2 | 0.2 | 187.3 | 12.1 | 0.1 | 102.7 | 0.0 |
| Variance | 0.0 | 828228.9 | 1689879.4 | 49773.3 | 4144.3 | 288.1 | 464.9 | 115728.1 | 0.0 | 35073.5 | 146.5 | 0.0 | 10538.5 | 0.0 |
| **Statistics for Post Monsoon** | | | | | | | | | | | | | | |
| WQPs | pH | TDS | EC | TH | Ca | Mg | $NO_3$ | Cl | F | Na | K | Iron | $SO_4$ | Cr |
| Minimum | 6.8 | 358.0 | 300.0 | 140.0 | 28.0 | 16.0 | 2.0 | 60.0 | 0.1 | 0.0 | 3.6 | 0.0 | 4.0 | 0.0 |
| Maximum | 8.5 | 3790.0 | 5414.0 | 1230.0 | 256.0 | 153.0 | 50.0 | 2100.0 | 2.0 | 113.3 | 53.3 | 10.0 | 66.0 | 0.5 |
| Mean | 7.6 | 1334.0 | 1833.6 | 543.1 | 108.9 | 64.0 | 8.0 | 481.4 | 0.7 | 58.2 | 15.6 | 0.7 | 45.3 | 0.2 |
| Std. Deviation | 0.5 | 652.8 | 954.1 | 289.9 | 58.7 | 35.7 | 8.1 | 377.3 | 0.6 | 33.3 | 12.0 | 1.8 | 12.5 | 0.1 |
| Variance | 0.2 | 426157.8 | 910287.6 | 84063.4 | 3446.2 | 1277.7 | 64.9 | 142377.3 | 0.4 | 1109.3 | 143.3 | 3.1 | 155.9 | 0.0 |
| **Statistics for Pre Monsoon** | | | | | | | | | | | | | | |
| WQPs | pH | TDS | EC | TH | Ca | Mg | $NO_3$ | Cl | F | Na | K | Iron | $SO_4$ | Cr |
| Minimum | 6.5 | 586.0 | 836.0 | 200.0 | 40.0 | 24.0 | 0.0 | 50.0 | 0.3 | 6.7 | 0.2 | 0.0 | 23.0 | 0.0 |
| Maximum | 8.0 | 4422.0 | 6317.0 | 1550.0 | 310.0 | 186.0 | 30.0 | 1685.0 | 5.0 | 57.3 | 5.1 | 0.1 | 99.0 | 0.8 |
| Mean | 7.4 | 1685.4 | 2411.4 | 574.3 | 114.9 | 68.9 | 14.9 | 525.3 | 1.1 | 25.5 | 1.1 | 0.0 | 72.1 | 0.4 |
| Std. Deviation | 0.4 | 854.9 | 1220.6 | 335.1 | 67.0 | 40.2 | 6.3 | 342.1 | 0.7 | 11.3 | 1.0 | 0.0 | 19.6 | 0.2 |
| Variance | 0.2 | 730787.0 | 1489803.9 | 112284.0 | 4491.4 | 1618.5 | 39.6 | 117005.8 | 0.6 | 128.6 | 1.0 | 0.0 | 385.6 | 0.0 |

## 4. Results and Discussion

Statistics for three season based on parameters values shown in Table 2. The computed WQI values ranges from 48.69 to 245.24 for monsoon period, values range from 0 to 351.02 for Post monsoon period and 0 to 344.62 for Pre monsoon period had shown in Table 3.

***Table 3:*** *Water Quality Classification Based On WQI Values of the Study Area*

| Water Quality | WQI Values | WQI Of samples for Monsoon | % of water samples (Monsoon) | WQI Of samples for Post Monsoon season | % of water samples (Post Monsoon) | WQI Of samples for Pre Monsoon season | % of water samples (Pre Monsoon) |
|---|---|---|---|---|---|---|---|
| Excellent water | <50 | **48.69** | **9%** | **0** | **0%** | 0 | **0%** |
| Good water | 50-100 | **88.12** | **17%** | **89.91** | **11%** | 0 | **0%** |
| Poor water | 100-200 | 135.06 | **26%** | 136.34 | **17%** | 166.17 | **22%** |
| Very poor water | 200-300 | 245.24 | **48%** | 223.45 | **28%** | 236.29 | **32%** |
| unfit for use | >300 | - | - | 351.02 | **44%** | 344.62 | **46%** |

The relationship between two variables is the correlation coefficient which shows how one variable predicts the other. Associated with correlation coefficient is r, which is the percentage of variance in the dependent variable, explained by the independent variable (Tiwari et al., 2011). The results of the correlation analysis are considered in the subsequent interpretation. A high correlation coefficient (nearly 1 or -1) means a good relationship between two variables, and a correlation coefficient around zero means no relationship. Positive values indicate a positive relationship while negative values of r indicate an inverse relationship. The correlation coefficients (r) among various water quality parameters of ground water of the study area in monsoon, post monsoon and pre monsoon seasons were calculated and the values of correlation coefficients (r) are given in Table 4, 5 and 6, respectively.

***Table 4:*** *Correlation Matrices for Water Quality Parameters during Monsoon Season*

| WQPs | pH | TDS | EC | TH | Ca | Mg | $NO_3$ | Cl | F | Na | K | Iron | $SO_4$ | Cr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1 | | | | | | | | | | | | | |
| TDS | .250 | 1 | | | | | | | | | | | | |
| EC | .251 | **1.000** | 1 | | | | | | | | | | | |
| TH | .231 | **.959** | **.959** | 1 | | | | | | | | | | |
| Ca | .228 | **.941** | **.941** | **.988** | 1 | | | | | | | | | |
| Mg | .231 | **.907** | **.907** | **.935** | **.872** | 1 | | | | | | | | |
| No3 | .057 | .219 | .219 | .227 | .254 | .160 | 1 | | | | | | | |
| Cl | .279 | **.928** | **.928** | **.907** | **.873** | **.898** | .168 | 1 | | | | | | |
| F | .312 | .410 | .410 | .352 | .360 | .299 | -.072 | .407 | 1 | | | | | |
| Na | .239 | **.988** | **.988** | **.917** | **.898** | **.868** | .228 | **.897** | .393 | 1 | | | | |
| K | .261 | **.841** | **.841** | .776 | .742 | .767 | .252 | .772 | .238 | **.859** | 1 | | | |
| Iron | .241 | .289 | .289 | .303 | .332 | .193 | .189 | .314 | .257 | .305 | .187 | 1 | | |
| $SO_4$ | .029 | **.844** | **.844** | **.857** | **.832** | **.826** | .180 | **.860** | .173 | **.827** | .696 | .302 | 1 | |
| Cr | -.254 | -.321 | -.321 | -.318 | -.320 | -.297 | .147 | -.345 | -.149 | -.310 | -.360 | -.182 | -.254 | 1 |

The results of the statistical analysis which are shown in table 4 (Monsoon season) gave an indication that TDS has positive and significant correlation with EC, TH, Ca, Mg, ,$Cl^-$, Na, K and $SO_4^{2-}$, weak correlation with Nitrate and negative correlation with Chromium. EC has a positive and signification correlation with TH, Ca, Mg, Cl, Na, K and $SO_4^{2-}$, weak correlation with Nitrate and negative correlation with Chromium. Total hardness has positive and signification correlation with Ca, Mg, Cl, Na, K and $SO_4^{2-}$, weak correlation with Nitrate and negative correlation with Chromium. Calcium has positive and signification correlation with Mg, $Cl^-$, Na, K and $SO_4^{2-}$, weak correlation with Nitrate and negative correlation with Chromium.  Magnesium has positive and signification correlation with $Cl^-$, Na, K and $SO_4^{2-}$, weak correlation with Nitrate and negative correlation with Chromium. Chloride has positive and signification correlation with Na, K and $SO_4^{2-}$, weak correlation with Nitrate and negative correlation with Chromium. Nitrate and Chromium are weakly correlated with most of the water quality parameters.

***Table 5:*** *Correlation Matrices for Water Quality Parameters during Post Monsoon Season*

| WQPs | pH | TDS | EC | TH | Ca | Mg | $NO_3$ | Cl | F | Na | K | Iron | $SO_4$ | Cr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1 | | | | | | | | | | | | | |
| TDS | .074 | 1 | | | | | | | | | | | | |
| EC | -.013 | **.882** | 1 | | | | | | | | | | | |
| TH | -.099 | **.816** | .741 | 1 | | | | | | | | | | |
| Ca | -.095 | **.814** | .740 | **1.000** | 1 | | | | | | | | | |
| Mg | -.099 | **.811** | .736 | **.982** | **.983** | 1 | | | | | | | | |
| $NO_3$ | -.194 | .190 | .163 | .378 | .374 | .374 | 1 | | | | | | | |
| Cl | .032 | **.906** | .783 | .643 | .638 | .642 | .011 | 1 | | | | | | |
| F | .177 | .559 | .515 | .739 | .739 | .741 | .333 | .422 | 1 | | | | | |
| Na | .072 | -.034 | -.093 | .061 | .068 | .098 | .133 | -.203 | .050 | 1 | | | | |
| K | .325 | -.085 | -.138 | -.281 | -.278 | -.245 | -.176 | -.045 | -.299 | .096 | 1 | | | |
| Iron | -.034 | .139 | .091 | .294 | .292 | .289 | **.876** | -.107 | .366 | .253 | -.130 | 1 | | |
| $SO_4$ | -.168 | -.181 | -.233 | -.280 | -.284 | -.281 | -.432 | .012 | -.350 | .027 | -.024 | -.473 | 1 | |
| Cr | .074 | .622 | .559 | .616 | .621 | .640 | .101 | .561 | .700 | .005 | -.252 | .117 | -.214 | 1 |

In post monsoon (Table 5), TDS has positive and signification correlation with EC, TH, Ca, Mg and $Cl^-$ weak correlation with iron and negative correlated with Sodium, Potassium, and Sulphate. EC has positive and signification correlation with TH, Ca, Mg, $Cl^-$, weak correlation with iron and negative correlated with Sodium, Potassium, sulphate. Total hardness has positive and signification correlation with calcium, magnesium and fluoride, weak correlation with sodium and negative correlation with potassium, sulphate. Calcium has positive and signification correlation with Mg and Fluoride, weak correlation with sodium and negative correlation with potassium, sulphate. Nitrate has positive and signification correlation with iron, weak correlation with chloride, and negative correlation with potassium and sulphate.

In pre monsoon season (Table 6), TDS has positive and signification correlation with EC, TH, Ca, Mg, $Cl^-$, weak correlation with potassium and negative correlated with Nitrate, iron and chromium. EC has positive and signification correlation with TH, Ca, Mg, $Cl^-$, weak correlation with potassium and negative correlated with Nitrate, iron and chromium. Total hardness has positive and signification correlation with calcium, magnesium and chloride, weak correlation with sulphate and negative correlation with nitrate, fluoride, potassium, iron and chromium. Calcium has positive and signification correlation with Mg and chloride, weak correlation with sulphate and negative correlation with nitrate, fluoride, potassium, iron and chromium. Chloride has positive and signification correlation with sodium, weak correlation with fluoride, and negative correlation with iron and chromium.

***Table 6:*** *Correlation Matrices for Water Quality Parameters during Pre Monsoon Season*

| WQPs | pH | TDS | EC | TH | Ca | Mg | $NO_3$ | Cl | F | Na | K | Iron | $SO_4$ | Cr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1 | | | | | | | | | | | | | |
| TDS | .255 | 1 | | | | | | | | | | | | |
| EC | .256 | **1.000** | 1 | | | | | | | | | | | |
| TH | .307 | **.895** | **.893** | 1 | | | | | | | | | | |
| Ca | .307 | **.895** | **.893** | **1.000** | 1 | | | | | | | | | |
| Mg | .305 | **.895** | **.892** | **1.000** | **1.000** | 1 | | | | | | | | |
| $NO_3$ | -.022 | -.081 | -.081 | -.252 | -.252 | -.256 | 1 | | | | | | | |
| Cl | .176 | **.953** | **.955** | .760 | .760 | .760 | -.015 | 1 | | | | | | |
| F | .001 | .043 | .043 | -.109 | -.109 | -.110 | .452 | .112 | 1 | | | | | |
| Na | .229 | .758 | .763 | .545 | .545 | .544 | .075 | **.855** | .350 | 1 | | | | |
| K | -.075 | .004 | .005 | -.190 | -.190 | -.189 | .296 | .143 | .685 | .376 | 1 | | | |
| Iron | .017 | -.225 | -.228 | -.061 | -.061 | -.060 | -.191 | -.282 | .322 | -.158 | .165 | 1 | | |
| $SO_4$ | .138 | .686 | .688 | .457 | .457 | .456 | .178 | .672 | .135 | .627 | .124 | -.396 | 1 | |
| Cr | .069 | -.214 | -.214 | -.192 | -.192 | -.192 | -.105 | -.202 | -.205 | -.098 | .001 | -.072 | -.073 | 1 |

***Table 7:*** *Least Square of the Relation (Y = AX + B) Among Significantly Correlate Parameters*

| Y (dependent) | X (Independent) | correlation | b | a | Regression Equation | R Square |
|---|---|---|---|---|---|---|
| | | | Monsoon Season | | | |
| EC | TDS | 1.000 | 0.099 | 1.428 | EC = 1.428 TDS +0.099 | 1.000 |
| EC | TH | 0.959 | -98.079 | 5.586 | EC = 5.586 TH – 98.079 | 0.919 |
| EC | $Cl^-$ | 0.928 | 826.993 | 3.547 | EC = 3.547 $Cl^-$ +826.993 | 0.861 |
| EC | $SO_4{}^{2-}$ | 0.844 | 280.881 | 10.689 | EC = 10.689 $SO_4{}^{2-}$+ 280.881 | 0.712 |
| EC | $Mg^{2+}$ | 0.907 | -570.628 | 69.467 | EC = 69.467 $Mg^{2+}$ - 570.628 | 0.823 |
| EC | $Na^{2+}$ | 0.988 | 165.103 | 6.859 | EC = 6.859 $Na^{2+}$ + 165.103 | 0.976 |
| TDS | TH | 0.959 | -68.922 | 3.911 | TDS = 3.911 TH – 68.922 | 0.919 |
| TDS | $Cl^-$ | 0.928 | 579.012 | 2.483 | TDS = 2.483 $Cl^-$ + 579.012 | 0.861 |
| TDS | $SO_4{}^{2-}$ | 0.844 | 196.596 | 7.483 | TDS = 7.483 $SO_4{}^{2-}$ + 196.596 | 0.712 |
| TDS | $Ca^{2+}$ | 0.941 | 269.311 | 13.308 | TDS=13.308 $Ca^{2+}$ +269.311 | 0.886 |
| TDS | $Mg^{2+}$ | 0.907 | -399.486 | 48.631 | TDS=48.631 $Mg^{2+}$ - 399.486 | 0.823 |
| TH | $SO_4{}^{2-}$ | 0.857 | 79.140 | 1.862 | TH=1.862 $SO_4{}^{2-}$ +79.140 | 0.734 |
| TH | $Ca^{2+}$ | 0.988 | 84.100 | 3.423 | TH=3.423 $Ca^{2+}$ + 84.100 | 0.975 |

| | | | | | | |
|---|---|---|---|---|---|---|
| TH | $Mg^{2+}$ | 0.935 | -77.731 | 12.287 | TH=12.287 $Mg^{2+}$ - 77.731 | 0.874 |
| $Ca^{2+}$ | $Mg^{2+}$ | 0.872 | -34.208 | 3.306 | $Ca^{2+}$=3.306 $Mg^{2+}$ - 34.208 | 0.760 |
| $Ca^{2+}$ | $SO_4{}^{2-}$ | 0.832 | 3.471 | 0.522 | $Ca^{2+}$=0.522 $SO_4{}^{2-}$ + 3.471 | 0.692 |
| $Ca^{2+}$ | TDS | 0.941 | -4.519 | 0.067 | $Ca^{2+}$=0.067 TDS – 4.519 | 0.886 |
| $Mg^{2+}$ | $SO_4{}^{2-}$ | 0.826 | 16.046 | 0.137 | $Mg^{2+}$ =0.137 $SO_4{}^{2-}$ + 16.046 | 0.683 |
| $Mg^{2+}$ | TDS | 0.907 | 14.922 | 0.017 | $Mg^{2+}$=0.017 TDS + 14.922 | 0.823 |
| $Na^{2+}$ | $Cl^-$ | 0.897 | 108.343 | 0.494 | $Na^{2+}$ =0.494 $Cl^-$ + 108.343 | 0.804 |
| K | $Cl^-$ | 0.772 | 11.663 | 0.027 | K =0.027 $Cl^-$ + 11.663 | 0.596 |
| $Cl^-$ | TDS | 0.928 | -130.454 | 0.347 | $Cl^-$ =0.347 TDS – 130.454 | 0.861 |
| $SO_4{}^{2-}$ | TDS | 0.844 | 44.398 | 0.095 | $SO_4{}^{2-}$=0.095 TDS + 44.398 | 0.712 |
| $Na^{2+}$ | TDS | 0.988 | -15.014 | 0.203 | $Na^{2+}$ =0.203 TDS – 15.014 | 0.976 |
| **Post Monsoon** | | | | | | |
| EC | TDS | 0.882 | 113.718 | 1.289 | EC = 1.289 TDS +113.718 | 0.778 |
| EC | TH | 0.741 | 508.707 | 2.439 | EC = 2.439 TH –508.707 | 0.550 |
| EC | $Cl^-$ | 0.783 | 880.867 | 1.979 | EC = 1.979 $Cl^-$ +880.867 | 0.613 |
| EC | $Mg^{2+}$ | 0.736 | 576.977 | 19.644 | EC = 19.644 $Mg^{2+}$ + 576.977 | 0.542 |
| TDS | TH | 0.816 | 336.457 | 1.837 | TDS = 1.837 TH +336.457 | 0.665 |
| TDS | $Cl^-$ | 0.906 | 579.048 | 1.568 | TDS = 1.568 $Cl^-$ + 579.048 | 0.822 |
| TDS | $Ca^{2+}$ | 0.814 | 348.392 | 9.049 | TDS=9.049 $Ca^{2+}$ + 348.392 | 0.662 |
| TDS | $Mg^{2+}$ | 0.811 | 386.051 | 14.818 | TDS=14.818$Mg^{2+}$ + 386.051 | 0.658 |
| TH | $Ca^{2+}$ | 1.000 | 5.407 | 4.937 | TH=4.937$Ca^{2+}$ + 5.407 | 0.999 |
| TH | $Mg^{2+}$ | 0.982 | 33.381 | 7.969 | TH= 7.969 $Mg^{2+}$ + 33.381 | 0.965 |
| $Ca^{2+}$ | $Mg^{2+}$ | 0.983 | 5.651 | 1.614 | $Ca^{2+}$=1.614$Mg^{2+}$ + 5.651 | 0.966 |
| $Ca^{2+}$ | TDS | 0.814 | 11.293 | 0.073 | $Ca^{2+}$=0.073TDS + 11.293 | 0.662 |
| $Mg^{2+}$ | TDS | 0.811 | 4.706 | 0.044 | $Mg^{2+}$=0.044TDS + 4.706 | 0.658 |
| $Cl^-$ | TDS | 0.906 | -217.469 | 0.524 | $Cl^-$ =0.524 TDS -217.469 | 0.822 |
| **Pre Monsoon Season** | | | | | | |
| EC | TDS | 1.000 | 113.718 | 1.289 | EC = 1.289 TDS +113.718 | 0.778 |
| EC | TH | 0.893 | 508.707 | 2.439 | EC = 2.439 TH + 508.707 | 0.550 |
| EC | $Cl^-$ | 0.955 | 880.867 | 1.979 | EC = 1.979 $Cl^-$ + 880.867 | 0.613 |
| EC | $Mg^{2+}$ | 0.892 | 576.977 | 19.644 | EC = 19.644 $Mg^{2+}$ +576.977 | 0.542 |
| TDS | TH | 0.895 | 336.457 | 1.837 | TDS = 1.837 TH + 336.457 | 0.665 |
| TDS | $Cl^-$ | 0.953 | 579.048 | 1.568 | TDS = 1.568 $Cl^-$ + 579.048 | 0.822 |
| TDS | $Ca^{2+}$ | 0.895 | 348.392 | 9.049 | TDS=9.049 $Ca^{2+}$ +348.392 | 0.662 |
| TDS | $Mg^{2+}$ | 0.895 | 386.051 | 14.818 | TDS= 14.818 $Mg^{2+}$ + 386.051 | 0.658 |
| TH | $Ca^{2+}$ | 1.000 | 5.407 | 4.937 | TH=4.937 $Ca^{2+}$ + 5.407 | 0.999 |
| TH | $Mg^{2+}$ | 1.000 | 33.381 | 7.969 | TH=7.969 $Mg^{2+}$ +33.381 | 0.965 |
| $Ca^{2+}$ | $Mg^{2+}$ | 1.000 | 5.651 | 1.614 | $Ca^{2+}$= 1.614 $Mg^{2+}$ +5.651 | 0.966 |
| $Ca^{2+}$ | TDS | 0.895 | 11.293 | 0.073 | $Ca^{2+}$=0.073 TDS +11.293 | 0.662 |
| $Cl^-$ | TDS | 0.953 | -217.469 | 0.524 | $Cl^-$ =0.524 TDS -217.469 | 0.822 |

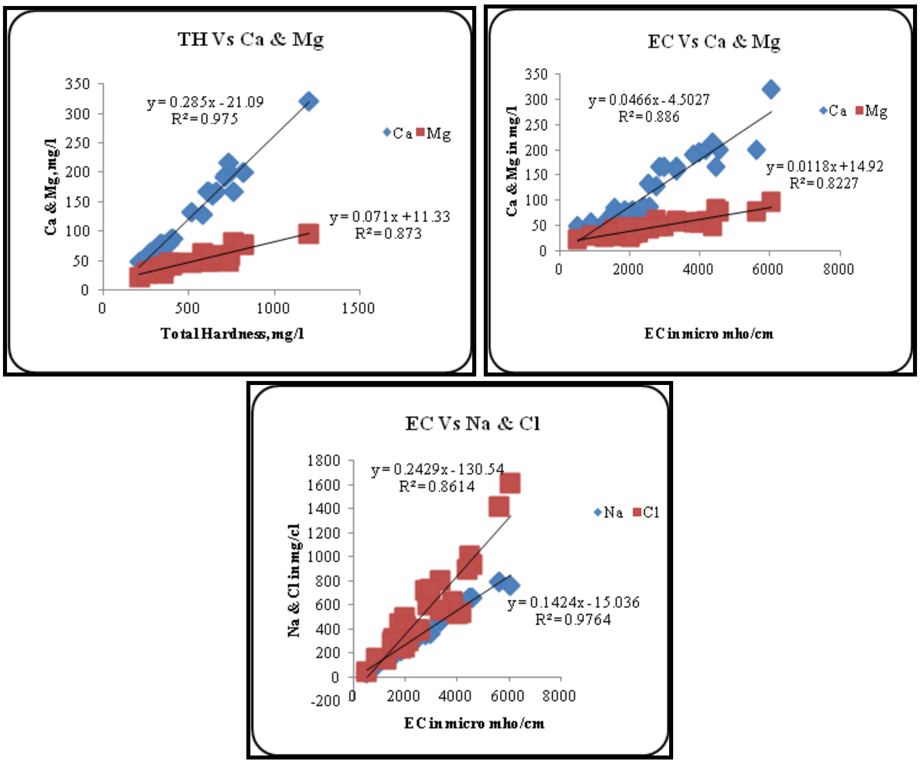


***Figure 2:*** *Linear Plot between TH Vs Ca & Mg, EC Vs Ca & Mg and EC Vs Na and Cl of groundwater in Monsoon Season*

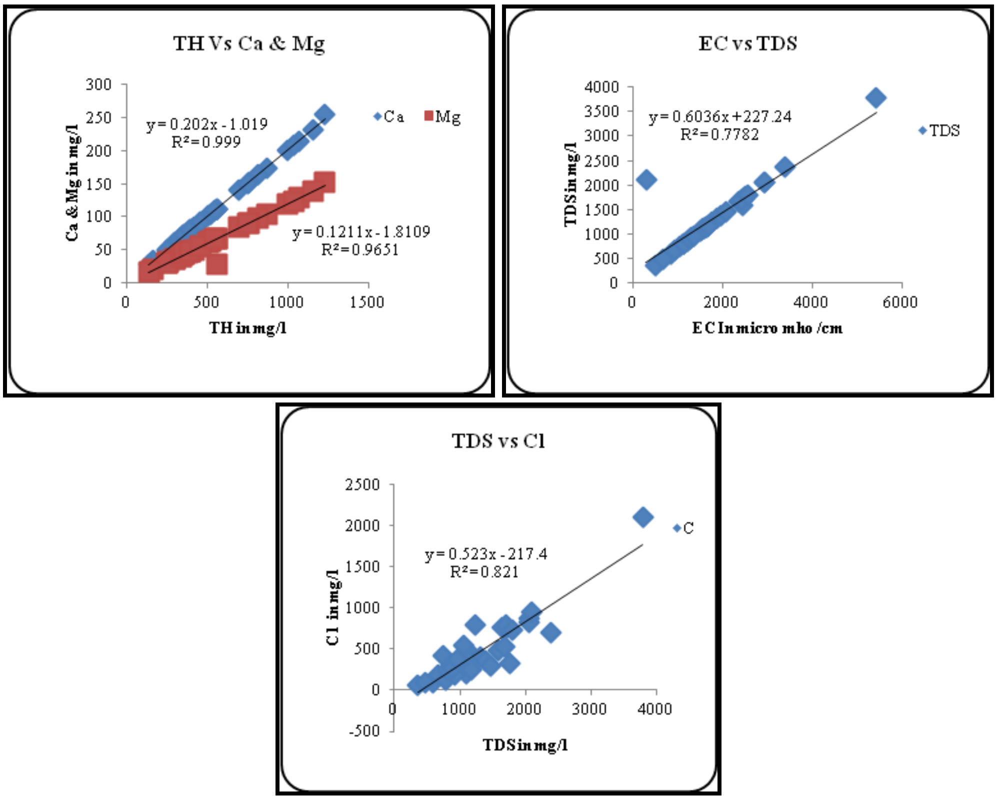


***Figure 3:*** *Linear Plot between TH Vs Ca & Mg, EC Vs TDS and TDS Vs Cl of groundwater in Post Monsoon Season*

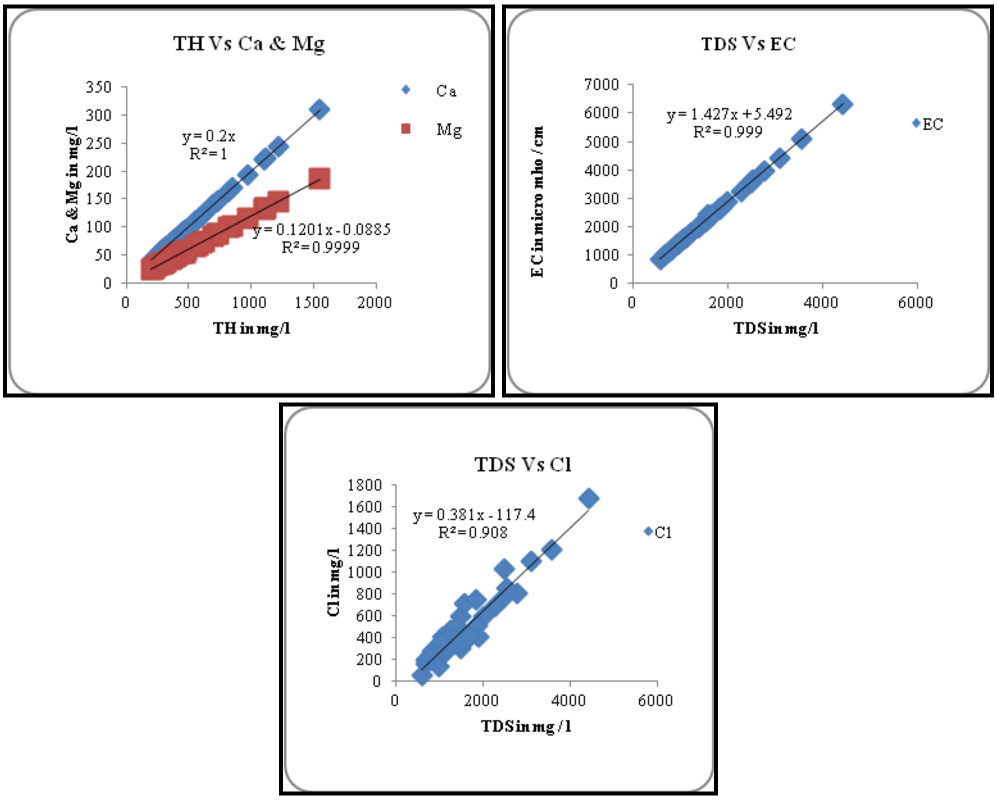


***Figure 4:*** *Linear Plot between TH Vs Ca & Mg, TDS Vs EC and TDS Vs Cl of groundwater in Post Monsoon Season*

## 5. Conclusion

The experimental study of groundwater by means of 14 physical and chemical parameters of the study area identify with the intention of water quality was poor, very poor and inappropriate for drinking purpose. The calculated WQI values lies between 48.69 to 245.24 during monsoon period, values lies between 0 to 351.02 during Post monsoon period and values lies between 0 to 344.62 during Post monsoon period respectively. The Percentage of water quality index shows that maximum in post and pre monsoon and minimum in monsoon period. Results of correlation analysis show that EC, TH and TDS are having high correlation with most of the parameters for all the seasons. Since, the EC and TH find high correlation with the Ca and Mg, Na and Cl (Figure 2) during Monsoon season. Since the TH, EC and TDS find high correlation with the Ca and Mg, TDS and Cl (Figure 3) during post monsoon season. Similarly the EC, TH and TDS find high correlation with the Ca and Mg, TDS and Cl (Figure 4) during pre-monsoon season. Regression equations relating the EC, TDS, TH and these parameters were formulated are given in Table 7. 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 very important 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. It is also recommended that water analysis should be carried out from time to time to monitor the rate and kind of contamination. It is need of human to expand awareness among the people to maintain the cleanness of water at their highest quality and purity levels to achieve a healthy life.

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