

## Statistical Analysis of Water Quality Parameters and Water Quality Index (WQI)

Swati Saxena

Department of Chemistry, Rajasthan College of Engineering for Women, Bhankrota, Jaipur, Rajasthan

### ARTICLE INFO

#### Article history:

Received: 5 November 2019;

Received in revised form:  
2 December 2019;

Accepted: 18 December 2019;

#### Keywords

Water Quality,  
Physico-Chemical Parameters,  
Water Quality Index (WQI),  
Correlation Coefficient,  
Regression Analysis.

### ABSTRACT

The present study is aimed to analyze the statistical relationship among various water quality parameters and water quality index (WQI). For this, observed results of physico-chemical analysis of 71 ground water samples of study area in pre- and post-monsoon season and calculated water quality index values for each respective sample were taken into consideration. Correlation coefficient between every water quality parameter and WQI values is calculated and for the pairs having highly significant correlation coefficient ( $0.8 < r < 1.0$ ) values; regression model is applied and scatter plots are drawn. The systematic correlation and regression study suggested the perfect linear relationship between Fluoride and WQI Values. The analysis provides essential information regarding the dependency of water quality rating on each water quality parameter.

© 2019 Elixir All rights reserved.

### 1. Introduction

Pure potable water is the basic requirement of all human beings as human health is directly related to the quality of water. In the present scenario of water quality deterioration due to excessive agricultural, industrial and urban developments; water quality monitoring is an important tool which gives suitable information about water quality management.

Water quality index explains the overall water quality of a particular location with respect to various water quality parameters with a single value/word i.e. it converts a large number of data sets into a form which is easily understandable for common people. In general, it eliminates the need of large assessment processes by individual experts and describes the water quality with a simple term (Chowdhury et al., 2012; Hussain et al., 2014; Khwakaram et al., 2012; Yogendra and Puttaiah, 2008;).

The systematic study of correlation and regression analysis provides extent of relationship between any two parameters. If two parameters are found to have significant correlation coefficient; the value of one constituent can be easily estimated on the basis of other with the help of regression equations (Daraigan et al., 2011; Dash et al., 2006 & 2010; Gajendran and Thamarai, 2008; Jothivenkatachalam et al., 2010; Venkatachalam and Jabenesan, 1998).

The present study has been carried out to estimate the actual relationship among water quality index (WQI) and various other water quality parameters i.e. pH, Total Alkalinity, Total Hardness, Calcium ions, Magnesium ions, Chloride, Nitrate, Fluoride, Total Dissolved Solids and Electrical Conductivity.

### 2. Study Area

Jaipur, the capital of Rajasthan is divided into 13 tehsils or sub-divisions. Our focused study area is Bassi sub-division out of these 13 sub-divisions having the total area 654.69 sq.km. Bassi constitute nearly 210 villages having no surface water sources; almost whole population is dependent on

ground water sources (open wells, tube wells and bore wells) for their drinking water requirement. A large number of ground water sources in the above area are reported to have fluoride, nitrate, total dissolved solids and electrical conductivity more than the permissible limits (Swati and Umesh, 2015; Saxena and Saxena, 2016; Saxena et al., 2015 & 2018).

### 3. Experimental

#### 3.1 Sample Collection

71 samples from the ground water sources of 50 villages of Bassi tehsil were collected in pre-monsoon (April, 2013) and post-monsoon (September-October 2013) seasons of year 2013 with appropriate precautions.

#### 3.2 Physico-chemical Analysis

Collected samples were analyzed for physico-chemical parameters i.e. pH, Total Alkalinity (TA), Total Hardness (TH), Calcium hardness (Ca H), Magnesium hardness (Mg H), Chloride, Nitrate, Fluoride, Total Dissolved Solid (TDS) and Electrical Conductivity (EC) with the suitable methods as mentioned in Saxena et al., 2018.

#### 3.3 Water Quality Index (WQI) Calculation

WQI was calculated with weighed arithmetic index method as depicted in Saxena et al., 2015 and each sample is categorized in particular category on the basis of resulting WQI values as per- excellent water quality (WQI value 0-25), good water quality (WQI value 26-50), poor water quality (WQI value 51-75), very poor water quality (WQI value 76-100) and unsuitable for drinking (WQI value >100).

#### 3.4 Correlation and regression analysis

Correlation coefficients (r) have been calculated between each water quality parameter and WQI value for the experimental data. If x and y are the two variables, then the correlation coefficient 'r' can be calculated by-

$$r = \frac{n \sum xy - \sum x \sum y}{\sqrt{n \sum x^2 - (\sum x)^2} \sqrt{n \sum y^2 - (\sum y)^2}}$$

n = Number of Observations

The values of correlation coefficient 'r' were classified into three categories highly significant ( $0.8 < r < 1.0$ ), moderate significant ( $0.6 < r < 0.8$ ) and significant ( $0.5 < r < 0.6$ ) values. Linear regression equation  $y = ax + b$  was developed for the pairs having highly significant 'r' values (Gajendran and Thamrai, 2008; Jothivenkatachalam *et al.*, 2010).

Where y = Dependent variable

x = Independent variable

a = Slope of line

b = Intercept on y – axis

'a' and 'b' can be calculated with the help of following equations- (Daraigan *et al.*, 2011).

$$a = \frac{n\sum(xy) - \sum x \sum y}{n\sum(x^2) - (\sum x)^2}$$

$$b = \frac{\sum y - a\sum x}{n}$$

For the development of regression equation it was assumed that change in dependent parameter (y) is either directly or indirectly proportional to the change in the independent parameter (Dash *et al.*, 2006, 2010). Values of 'R' explain the extent of dependency of dependent variable on independent variable. 'R<sup>2</sup>' and significance (p value) were also calculated for determination of the fitness of applied regression model using MS-Excel spreadsheet.

#### 4. Result and Discussions

##### 4.1 Physico-chemical Parameters

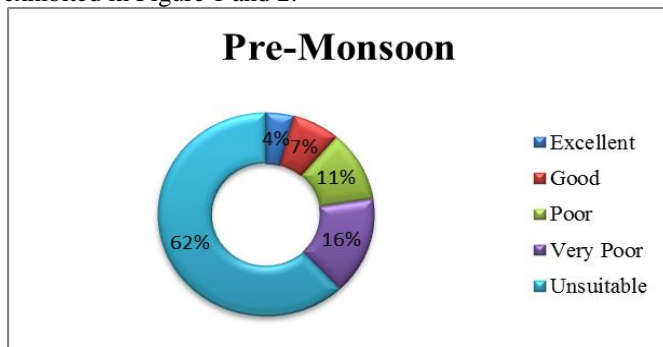
The observed values of all physico-chemical parameters are illustrated in Table 2 and 3 of Saxena *et al.*, 2018. According to these values; the samples exceeding the permissible values in both pre- and post- monsoon seasons are summarized in Table 1.

**Table 1. Number/ Percentage of samples exceeding the permissible values in Pre- and Post-monsoon season**

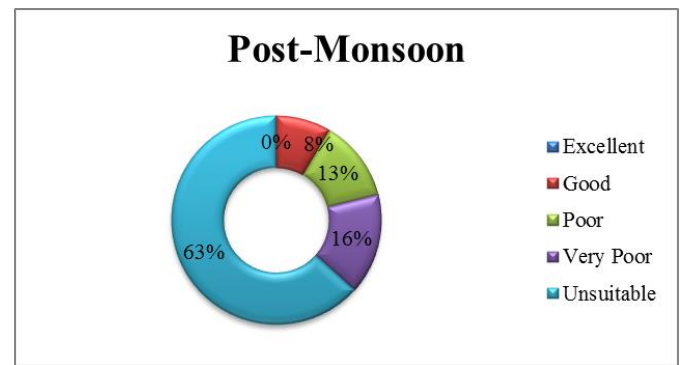
S.No.	Parameter	Number/ Percentage of samples exceeding the permissible values (Total- 71 samples)	
		Pre-monsoon Season	Post-monsoon Season
1.	Alkalinity	45 (63.38%)	49 (69.01%)
2.	Chloride	03 (4.22%)	01 (1.40%)
3.	Nitrate	12 (16.90%)	10 (14.08%)
4.	Fluoride	19 (26.76%)	20 (28.17%)
5.	TDS	25 (35.21%)	17 (23.94%)
6.	EC	41 (57.75%)	32 (45.07%)

##### 4.2 Water Quality Index Analysis

Calculated WQI values with respective quality ratings are mentioned in Table 8 of Saxena *et al.*, 2015. On the basis of these; the percentage of samples having excellent, good, poor, very poor and unsuitable for drinking purpose quality are exhibited in Figure 1 and 2.



**Figure 1. Percentage representation of water quality rating in Pre-monsoon season**



**Figure 2. Percentage representation of water quality rating in Post-monsoon season**

##### 4.3 Correlation and Regression Analysis

In the study correlation coefficients (r) between water quality parameters and WQI values has been calculated the values of 'r' are tabulated in Table 2 and 3 for pre and post-monsoon seasons respectively. The values of 'r' are represented in 10 x 1 correlation matrix.

**Table 2. Correlation matrix of water quality parameters and WQI in Pre Monsoon season**

Parameter	WQI
pH	0.20408
Alkalinity	0.41001
TH	-0.16258
Ca <sup>+2</sup>	-0.15104
Mg <sup>+2</sup>	-0.16312
Cl <sup>-</sup>	-0.22642
NO <sub>3</sub> <sup>-</sup>	-0.0806
F <sup>-</sup>	0.99965
TDS	-0.05197
EC	-0.0519

**Table 3. Correlation matrix of water quality parameters and WQI in Post Monsoon season**

Parameter	WQI
pH	0.12886
Alkalinity	0.41518
TH	-0.1191
Ca <sup>+2</sup>	-0.11857
Mg <sup>+2</sup>	-0.11675
Cl <sup>-</sup>	-0.04107
NO <sub>3</sub> <sup>-</sup>	-0.07873
F <sup>-</sup>	0.99961
TDS	0.10727
EC	0.10731

In pre-monsoon season out of 10 combinations 7 combinations are obtained with negative correlations and rest 3 combinations exhibit positive relationship while in post-monsoon season out of the 10 pairs 5 pairs are obtained with positive and remaining 5 are found to have negative relationship. In pre-monsoon season TDS-WQI and EC-WQI are exhibiting negative relationship whereas in post-monsoon season these parameters are showing positive values.

In both seasons, only one pair F<sup>-</sup>-WQI is observed with highly significant levels ( $0.8 < r < 1.0$ ) of correlation; that is in pre-monsoon 'r' value 0.99965 and in post-monsoon it is 0.99961. While the 'r' value of remaining 9 pairs are not even in the category of significant levels. Alkalinity-WQI in both seasons is exhibiting slightly higher values in comparison to other 8 parameters; in the range of 0.4.

On the basis of above observations, it can be clearly depicted that Fluoride has very noteworthy relationship with

WQI values instead other water quality parameters has not considerable relation with WQI values. Scatter diagrams for F<sup>-</sup>-WQI correlations in pre and post monsoon seasons are depicted in Figure 3 and 4.

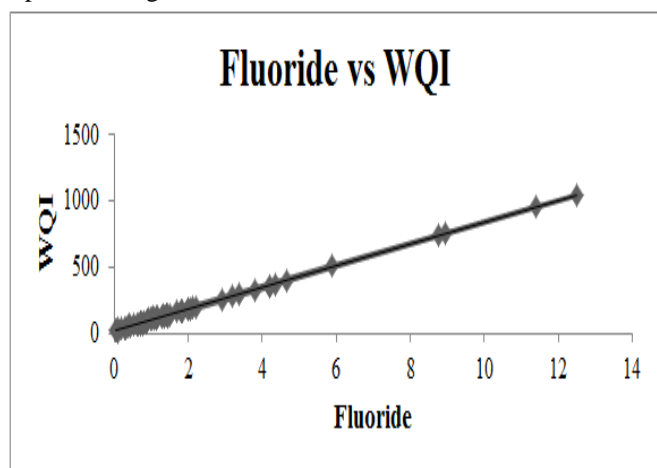


Figure 3. Correlation between Fluoride and WQI in pre-monsoon season

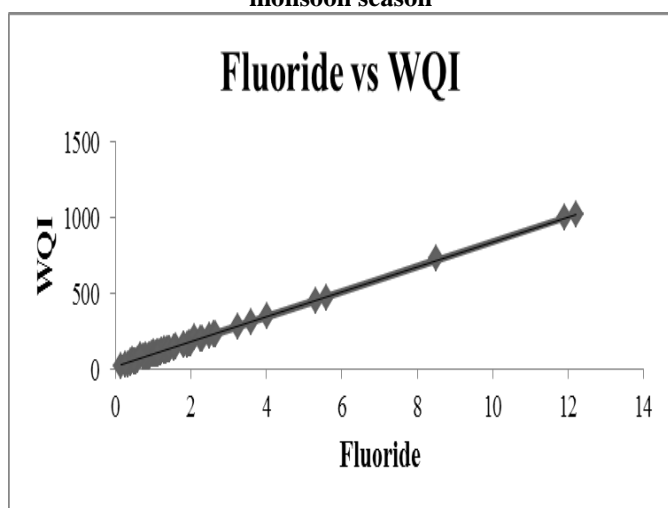


Figure 4. Correlation between Fluoride and WQI in post-monsoon season

Regression equation ( $Y = aX+b$ ) is developed for Fluoride-WQI pair and is found to have higher and better significance levels with their correlation coefficients. The equations are represented in Table 4 and 6. This equation is established with the particular assumption that change in dependent variable WQI (Y) is either directly or indirectly

proportional to the change in the independent variable Fluoride (X).

The dependent variable WQI is calculated by substituting the value of Fluoride (independent variable) in regression equation for both seasons. Observed, predicted values and percentage error (%e) are depicted in Table 5 and 7 respectively.

In the above Tables 4 and 6,  $R^2$  values of 0.9993 and 0.9992 means that 99.93% and 99.92% of the variation in WQI values can be explained by Fluoride values in pre and post-monsoon season respectively. Adjusted  $R^2$  values and  $R^2$  values are almost equal which also exhibits that WQI can be effectively predicted on the basis of Fluoride and significance (p-values) are less than 0.05 for both seasons illustrating that variables have genuine and significant relationship between them.

## 5. Conclusions

According to above result and discussions with respect to physico-chemical parameters and WQI values, it can be concluded that ground water samples of study area are not suitable to be used as potable water. There is an urgent requirement of continuous ground water quality monitoring and management programs to control drinking water pollution and enhance the water quality.

With respect to correlation and regression analysis, it can be depicted that out of all the water quality parameters only Fluoride exhibits highly significant correlation coefficient 'r'. Even, we can say that fluoride has perfectly linear relationship with WQI (water quality index). Rest other nine water quality parameters do not even have significant level of relationship. It can also be said that, Fluoride values have highest effect on WQI values or water quality rating of any particular ground water sample or it is the most important parameter in predicting the water quality of any sample.

Calculated  $R^2$  values explain that variation in dependent variable (WQI) can be well predicted by independent variable (Fluoride). Nearby values of  $R^2$  and estimated  $R^2$  supports the utility and relevance of applied regression model; these values also suggest the adequate predictive ability of WQI with the help of Fluoride values. Significance (p-values) less than 0.05 indicate that variables have actual and considerable relationship between them.

Table 4. Regression equation for Fluoride –WQI pair in Pre monsoon season

Pairs of Parameters	Correlation Coefficient	$R^2$	Adjusted $R^2$	Regression Coefficients		Regression Equation	p value
				A	B		
X-Y	R					$Y = aX + b$	Sig.
F <sup>-</sup> WQI	0.9996	0.9993	0.999	82.79	16.813	$WQI = 82.79 F + 16.813$	0.00

Table 5. Observed parameter, predicted parameter and percent error of Fluoride –WQI in Pre monsoon season

Pair of Parameters	Independent Variable	Dependent Variable	X value	Y (observed)	Y (predicted)	% Error
F <sup>-</sup> WQI	F	WQI	1.96	179.66	179.08	0.322

Table 6. Regression equation for Fluoride –WQI pair in Post monsoon season

Pairs of Parameters	Correlation Coefficient	$R^2$	Adjusted $R^2$	Regression Coefficients		Regression Equation	p value
				A	B		
X-Y	R					$Y = aX + b$	Sig.
F <sup>-</sup> WQI	0.9996	0.9992	0.999	82.88	16.059	$WQI = 82.88 F + 16.059$	0.00

Table 7: Observed parameter, predicted parameter and percent error of Fluoride –WQI in Pre monsoon season

Pair of Parameters	Independent Variable	Dependent Variable	X value	Y (observed)	Y (predicted)	% Error
F <sup>-</sup> WQI	F	WQI	1.82	166.94	166.90	0.023

**6. References**

1. Chowdhury R M, Muntasir S Y and Hossain M M "Water quality index of water bodies along Faridpur- Barisal road in Bangladesh". *Global Engineers & Technologists Review*, 2(3), 1-8(2012).
2. Daraigan S G, Wahdain A S, BaMosa A S and Obid M H "Linear correlation analysis study of drinking water quality data for AlMukalla City, Hadhramout, Yemen". *International Journal of Environmental Sciences*, 1(7), 1692-1701(2011).
3. Dash A K, Barik R N and Tiwari T N "Correlation and Regression Analysis of Some Physico-chemical Parameters of Bore Well Waters of Industrial Areas of Visakhapatnam". *Indian Journal of Environmental Protection*, 30(10), 857-861(2010).
4. Dash J R, Dash P C and Patra H K "A Correlation and Regression Study on the Ground water quality in rural areas around Angul-Talcher Industrial Zone". *Indian Journal of Environmental Protection*, 26(6), 550-558(2006).
5. Gajendran C and Thamarai P "Study on Statistical relationship between Ground Water Quality Parameters in Nambiyar River Basin, Tamil Nadu". *Indian Journal of Pollution Research*, 27(4), 679-683(2008).
6. Hussain H M, Al-Haidarey, M J S, Al-Ansari N and Knutsson N "Evaluation and Mapping Ground Water Suitability for irrigation using GIS in Najaf Governorate, Iraq". *Journal of Environmental Hydrology*, 22, 1-16 (2014).
7. Jothivenkatachalam K, Nithya A and Mohan S C "Correlation Analysis of Drinking Water Quality in and around Perur block of Coimbatore district, Tamil Nadu, India". *Rasayan Journal of Chemistry*, 3(4), 649- 654(2010).
8. Khwakaram A I, Majid S N and Hama N Y "Determination of water quality index (WQI) for Qalyasanstream in Sulaimani city/Kurdistan region of Iraq". *International Journal of Plant, Animal and Environmental Sciences*, 2(4), 148-157(2012).
9. Saxena S and Saxena U "Correlation and Regression Analysis of Ground Water of Bassi Tehsil, District Jaipur, Rajasthan, India." *International Journal of Plant, Animal and Environmental Sciences*, 6(1), 43-57(2016).
10. Saxena S, Saxena U and Sinha A K "Seasonal and Spatial Variation of Water Quality Index of Bassi Tehsil of District Jaipur, Rajasthan, India." *Global Journal of Science Frontier Research Chemistry*, 15(6), 9-19(2015 B).
11. Saxena S, Saxena U and Sinha A K "Spatial and Seasonal Variability of Physico-Chemical Characteristics of Ground Water in Bassi Tehsil, Jaipur, Rajasthan, India." *International Journal of Research and Scientific Innovation*, 5(1), 145-162(2018).
12. Swati S and Umesh S "Nemerow's Pollution Index: For Ground Water Quality Assessment." *Journal of Environmental Science and Pollution Research*, 1(1), 23-31(2015 A).
13. Venkatachalam M R and Jebanesan A "Correlation among water quality parameters for Groundwater in Chidambaram town. *Indian Journal of Environmental Protection*" 18(10), 734-738(1998).
14. Yogendra K and Puttaiah E T "Determination of Water Quality Index and suitability of an Urban water body in Shimoga Town, Karnataka." *Proceedings of Taal 2007: The 12th World Lake Conference*, 342- 346(2008).