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# IDENTIFICATION OF INFLUENTIAL PARAMETERS AFFECTING WWQI USING STATISTICAL ANALYSIS WITH REFERENCE TO STP, SRIGANGANAGAR, RAJASTHAN

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**ABSTRACT**

**Treated wastewater generated from wastewater treatment plants can be considered as a source of 'new' water. This study aims to propose a single quality parameter, WWQI to evaluate overall performance of STP, Sriganganagar and to identify the main parameters affecting WWQI. Several physico-chemical parameters have been employed to evaluate wastewater quality index (WWQI) of secondary treated water. The study was carried for one year period from Feb.2020 to Jan. 2021 and the parameters were measured twice a month following standard methods. Each parameter was compared with its standard permissible limit as prescribed by BIS-2296. The Waste Water Quality Index (WWQI) reflected that secondary treated wastewater was of moderately good to good quality. The Karl Pearson Correlation matrix has approved the influence of pH, COD, BOD, TH, TA,TDS and $NO_3^-$ on WWQI with correlation coefficient (r) >0.5. These seven parameters were examined using multiple linear regression analysis. Relevance and utility of applied regression model was analyzed from R, $R^2$ and adjusted $R^2$values and significance of the regression model was indicated by p-value. Regression equations were developed considering significant parameters using MS-Excel software to calculate WWQI once again and to check degree of match. The results revealed that out of seven parameters only three parameters BOD, TH and $NO_3^-$ are statistically significant with p-value < 0.05, so are sufficient to predict treated water quality. The analysis provides an easy and rapid way to estimate as well as to monitor the water quality providing one step ahead towards treated water quality management.**

**KEY WORDS :** Sewage treatment plant, Secondary treated water, Physico-chemical, Correlation matrix, WWQI, Multiple linear regression equation

## INTRODUCTION

According to Central Pollution Control Board, 90% of the water supplied in India to the town and cities are polluted, out of which only 1.6% gets treated. Therefore, for the welfare of biodiversity, water quality management is fundamental (Madhuri *et al.*, 2004). Treatment capacity of installed STP's is only 37.5% of the total wastewater generated. Rest wastewater is contributing to environmental pollution directly or indirectly. (National status of waste water generation and treatment: Sulabh ENVIS Centre). The solution for this critical issue also lies in this "used water" which is one of the most under-exploited resources we have. Treated wastewater generated from wastewater treatment plants can be considered as an important component of water resources. In addition to nutrient and energy resource, perhaps most importantly, it is a source of 'new' water. To control contamination of receiving water bodies and to make wastewater fit for reclamation; it should be

**Abbreviations**
WWQI – Waste Water Quality Index, STP – Sewage Treatment Plant, COD – Chemical Oxygen Demand, BOD – Biochemical Oxygen Demand, TH – Total Hardness, TA – Total Alkalinity, TDS– Total Dissolved Solids

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adequately treated (Wastewater, The Untapped Resource, 2017).

Rajasthan state sewerage and wastewater policy-2016 has been framed to use every drop of water in an efficient safe manner. The main objective of wastewater treatment is to produce an effluent suitable for reuse in irrigation in accordance with WHO guidelines as a minimum requirement. Reuse of treated wastewater for other purposes shall be subject to appropriate specifications. Most of the secondary treated waste water in this agriculture belt of Rajasthan finds use in irrigation. So, quality assessment of treated wastewater for applicability in irrigation and seasonal variation of final effluent is of utmost importance as it will affect the quality and quantity of crops being irrigated with treated waste water (TWW).

The aim of this study is to assess the performance of sewage treatment plants working in Sriganganagar in terms of physicochemical parameters and to identify statistically significant parameters.

To determine the overall efficiency of treatment plant in physical, biochemical and microbiological removal efficiency terms, one common parameter should be defined (Jamwal, 2009). The WQI (Water Quality Index) is used to define a certain level of water quality which presents a cumulatively derived numerical expression reflecting the composite influence of various water quality parameters (Bordelo, 2006). It reduces large number of parameters into simpler expression and enables easy interpretation of monitoring data by giving a single value to the water quality (Bharti, 2011). In other words, WQI summarizes large amounts of water quality data into simple terms (e.g., excellent, good, bad, etc.) for reporting to management and the public in a consistent manner.It enables rapid assessment of water reuse for agricultural or recreational purpose as well as for comparing different wastewater treatment sequences (Verlicchi *et al.*, 2011). Similar approaches have been considered by many researchers which brought changes to the methodology depending on usage and parameters under consideration. 13 different parameters of equal weight were considered by Prati *et al.*, (1971) in their system. To compute WWQI, these steps are followed (Ramakrishna *et al.*, 2009)

a. The weights for various water quality parameters are assumed to be inversely proportional to the standards for the corresponding parameters:

$$W_i = k/S_i \qquad .. (1)$$

Where, $W_i$ is unit weight for the $i^{th}$ parameter, $S_i$ refers to acceptable limit as given in Indian standard (IS- 2296) and k is constant of proportionality (k is assumed unity for the sake of simplicity)

b. Calculation of the quality rating, $q_i$ for each of the water quality parameters used in the index

$$q_i = 100\ (V_i - V_{10})\ /\ (S_i - V_{10}) \qquad .. (2)$$

Where, $V_i$ is measured value of the $i^{th}$ parameter in water sample, $V_{10}$ is the ideal value of this parameter in pure water and

Since in general, the ideal value, $V_{10} = 0$ for most parameters. Equation (2) assumes that simple form for these parameters

$$q_i = 100\ (V_i/S_i) \qquad .. (3)$$

The above two equations ensure that $q_i = 0$ if the $i^{th}$ parameter is totally absent in the water sample and $q_i = 100$, if amount of this parameter is just equal to its permissible value $S_i$. But for pH the ideal values is 7.0 (for neutral water) and the permissible value is 8.5.

So the equation $q_i = 100(V_i - V_{10})/(S_i - V_{10})$ can be written as

$$q_{pH} = 100(V_{pH} - 7.0)/\ (8.5 - 7.0) \qquad .. (4)$$

c. Aggregation of these sub-indices into the overall index.

$$WWQI = \Sigma\, q_i W_i / \Sigma\, W_i \qquad .. (5)$$

**Statistical analysis**

These are generally used to identify the calculated WWQI isappropriate or not. For this purpose Correlation Analysis and Multiple Linear Regression analysis (MLR) were performed. The systematic calculation of correlation coefficient between water quality variables and multivariate analysis provide indirect means for rapid monitoring of water quality. The linear correlation is very useful to get fairly accurate idea of water quality by determining a couple of parameters experimentally (Jothivenkatachalam *et al.*, 2010)

**Correlation Analysis**

Correlation is a measure of degree of linear relationship between two quantitative variables. Correlation coefficients reveal the magnitude and direction of the relationships. A correlation coefficient has value ranging from -1 to +1. Negative values indicate negative linear relationship, i.e. as one variable goes high, the other comes down. (Gupta, 1999). Similarly, positive and higher correlation values indicate positive as well as strong linear relationship between the two variables. Values closer to 0 indicate that there is no linear relationship between two variables under study. That is how correlation analysis attempts to establish the nature of the relationship between the variables thereby providing a mechanism for prediction or forecasting (Mulla *et al.*, 2007). Correlation analysis for lower Maniar Reservoir was carried out by Thirupathaiah *et al.* (2012). Below Table 3 shows the correlation between different parameters, which are, applied toevaluate WWQI for treated wastewater. Correlation between different parameters was acknowledged by Florence *et al.* (2010) for Water Quality Index along with Correlation Study at Yercaud Taluk, Salem, Tamil Nadu, India.

**Multiple Linear Regression Analysis**

It is one of the very important statistical tools which are used in almost all fields of sciences. According to Rastogi (2011), the Statistical Regression Analysis is highly useful tool for correlating different parameters with two fold advantages. First, using correlation analysis it is easy to find out inter-relationship between different parameters. Second, the main parameters affecting the WWQI can be easily figured out. Also, WWQI was calculated again with the help of the regression equation and the degree of match is checked. It eliminates tedious laboratory work of determining all parameters and one can carry out its work only with the parameters that are significantly correlated in the regression equation. Regression analysis involves two types of variables-dependent variable and repressor or independent variables. The variable whose value isinfluenced is called dependent variable and the variables which influence the dependent variable are called explanatory (regressors) variables. And the model equation is:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + e \quad ..(6)$$

This model should be free from (as assumptions of applying this criteria), Multicolinearity (regressors are correlated), Heteroscedasticity (error variance is nonconstant), and Autocorrelation (error terms are correlated). In this study, WWQI is considered as dependent variable and measured parameters are considered as explanatory variables. Regression Equation was applied by Rene *et al.* (2008) for prediction of water quality indices. Multiple Linear Regression has been successfully

**Table - 1 Physico-chemical parameters of STP, Sri Ganganagar**

| Sample | Month | Temp. | pH | EC | COD | BOD | TH | TA | TDS | $Na^+$ | $K^+$ | $Ca^{+2}$ | $Mg^{+2}$ | $NO_3^-$ | $SO_4^{-2}$ | $Cl^-$ | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SS1 | February (1) | 17.8 | 7.2 | 1682 | 127 | 48.0 | 188 | 308 | 670 | 95 | 8.7 | 42.4 | 15.2 | 8 | 86 | 90 | 0.40 |
| SS2 | February (2) | 18.3 | 7.4 | 1520 | 168 | 55.0 | 218 | 297 | 702 | 98 | 8.7 | 46.2 | 19.2 | 9 | 88 | 96 | 0.41 |
| SS3 | March (1) | 21.2 | 7.5 | 1720 | 182 | 58.0 | 214 | 272 | 770 | 95 | 8.8 | 42.4 | 19.7 | 10 | 89 | 105 | 0.41 |
| SS4 | March (2) | 22.5 | 7.7 | 1815 | 165 | 73.0 | 256 | 290 | 723 | 91 | 10.0 | 43.8 | 18.7 | 10 | 86 | 102 | 0.42 |
| SS5 | May (2) | 26 | 8.1 | 2180 | 156 | 67.0 | 308 | 402 | 682 | 84 | 10.7 | 48.6 | 24.8 | 11 | 97 | 98 | 0.48 |
| SS6 | June (1) | 27.8 | 7.5 | 1870 | 132 | 62.0 | 202 | 382 | 580 | 78 | 9.6 | 51.8 | 25.4 | 12 | 91 | 95 | 0.46 |
| SS7 | June (2) | 28.1 | 7.3 | 1620 | 118 | 41.0 | 191 | 368 | 507 | 71 | 8.7 | 47.2 | 26.3 | 10 | 83 | 83 | 0.44 |
| SS8 | July (1) | 27.5 | 7.1 | 1090 | 102 | 34.0 | 176 | 460 | 420 | 68 | 8.0 | 46.2 | 22.5 | 9 | 74 | 68 | 0.42 |
| SS9 | July (2) | 26.7 | 7.1 | 1006 | 96 | 32.0 | 162 | 426 | 435 | 61 | 8.5 | 44.3 | 20.4 | 7 | 70 | 60 | 0.38 |
| SS10 | August (1) | 25.3 | 7.2 | 942 | 107 | 35.0 | 154 | 398 | 462 | 86 | 8.6 | 42.6 | 18.6 | 6 | 68 | 74 | 0.37 |
| SS11 | August (2) | 25.1 | 7.2 | 915 | 124 | 44.0 | 167 | 425 | 502 | 82 | 8.4 | 44.6 | 21.4 | 7 | 66 | 77 | 0.36 |
| SS12 | September (1) | 24.1 | 7.3 | 800 | 132 | 56.0 | 198 | 382 | 558 | 95 | 8.3 | 43.7 | 16.5 | 8 | 65 | 68 | 0.36 |
| SS13 | September (2) | 23.6 | 7.5 | 868 | 146 | 60.0 | 214 | 394 | 584 | 89 | 7.9 | 41.7 | 17.5 | 9 | 62 | 61 | 0.35 |
| SS14 | October (1) | 23 | 7.7 | 940 | 148 | 63.0 | 235 | 358 | 616 | 82 | 8.4 | 40.5 | 18.2 | 10 | 60 | 58 | 0.34 |
| SS15 | October (2) | 22.2 | 7.6 | 982 | 162 | 68.0 | 216 | 346 | 627 | 93 | 8.1 | 42.0 | 20.6 | 10 | 65 | 66 | 0.34 |
| SS16 | November (1) | 20.8 | 7.6 | 1100 | 168 | 71.0 | 202 | 337 | 642 | 83 | 7.9 | 36.2 | 18.2 | 9 | 69 | 70 | 0.35 |
| SS17 | November (2) | 19.1 | 7.5 | 1186 | 173 | 74.0 | 192 | 353 | 602 | 79 | 8.1 | 39.6 | 18.4 | 9 | 73 | 78 | 0.36 |
| SS18 | December (1) | 17.4 | 7.4 | 1270 | 176 | 75.0 | 195 | 326 | 620 | 87 | 8.2 | 36.5 | 17.2 | 8 | 78 | 85 | 0.37 |
| SS19 | December (2) | 16.9 | 7.4 | 1292 | 188 | 69.0 | 185 | 342 | 636 | 83 | 8.3 | 35.4 | 16.8 | 8 | 82 | 87 | 0.38 |
| SS20 | January (1) | 14.6 | 7.3 | 1390 | 158 | 62.0 | 192 | 334 | 652 | 87 | 8.5 | 38.7 | 15.4 | 7 | 84 | 91 | 0.40 |
| SS21 | January (2) | 15.6 | 7.2 | 1710 | 143 | 58.4 | 210 | 322 | 638 | 92 | 8.6 | 40.5 | 17.8 | 7 | 88 | 95 | 0.38 |

***All parameters are expressed in mg/L except Temp., pH and EC. Temp. is expressed in °C. EC is expressed in μmhos/cm.**

applied by Chenini *et al.,* (2009) for Evaluation of ground water quality.

**Study Area**

Present study area was confined to Sewage Treatment Plant, Chak 1F Chhoti village, Sriganganagar. The treatment plant works on SBR technology having treatment capacity of 10MLD. The secondary treated wastewater is used mainly for irrigation in this agri-rich area.

## MATERIALS AND METHODS

The secondary treated wastewater samples were collected from Chak 1F Chhoti area of STP, Sriganganagar. The sampling was done in morning hours between 8:30 am to 9:30 am for a period of one year from February, 2020 to January, 2021. The samples were collected quarterly in cleaned and washed glass bottles. The sample bottles were rinsed twice with the sample water. The collected samples were analyzed for various physico-chemical parameters- temperature, pH, electrical conductance (EC), chemical oxygen demand (COD), biochemical oxygen demand (BOD), total alkalinity (TA), total hardness (TH), total dissolved solids (TDS), chloride, sulphate, nitrate, sodium, potassium, magnesium, fluoride and calcium as per standard methods. Temperature and pH were measured at the sampling site. DO fixation was performed at the location itself by adding Manganese sulphate and Alkaline KI solution and samples were stored at 4 °C for determining other parameters. For sampling and testing the procedure described in standard methods IS 3025, APHA were adopted. All the reagents used were AR grade and double distilled water was used for solution preparation.

## RESULTS AND DISCUSSION

**Physico-chemical parameters:** The respective values of all measured physico-chemical parameters of secondary treated water samples of the studied area are summarized and are compared with BIS-2296 for agriculture water uses in Table 1. The results revealed that except COD, BOD and TA other parameters were within permissible limits for irrigation and other uses. All the measured parameters were considered to find out WWQI. The Waste Water Quality Index (WWQI) reflected that secondary treated wastewater was of good tomoderately good quality with values ranging from 58.56 to 104.40 (Table 2).

**Table - 2 Waste Water Quality Index (WWQI) of STP, Sri Ganganagar**

| Parameter | IS-2296 ($S_i$) | Unit Wt ($W_i$) | SS1 ($q_iW_i$) | SS2 ($q_iW_i$) | SS3 ($q_iW_i$) | SS4 ($q_iW_i$) | SS5 ($q_iW_i$) | SS6 ($q_iW_i$) | SS7 ($q_iW_i$) | SS8 ($q_iW_i$) | SS9 ($q_iW_i$) | SS10 ($q_iW_i$) | SS11 ($q_iW_i$) | SS12 ($q_iW_i$) | SS13 ($q_iW_i$) | SS14 ($q_iW_i$) | SS15 ($q_iW_i$) | SS16 ($q_iW_i$) | SS17 ($q_iW_i$) | SS18 ($q_iW_i$) | SS19 ($q_iW_i$) | SS20 ($q_iW_i$) | SS21 ($q_iW_i$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp. | 25 | 0.0400 | 2.85 | 2.928 | 3.392 | 3.600 | 4.160 | 4.448 | 4.496 | 4.400 | 4.272 | 4.048 | 4.016 | 3.856 | 3.776 | 3.680 | 3.552 | 3.328 | 3.056 | 2.784 | 2.704 | 2.336 | 2.496 |
| pH | 8.5 | 0.1176 | 1.57 | 3.137 | 3.922 | 5.490 | 8.627 | 3.922 | 2.353 | 0.784 | 0.784 | 1.569 | 1.569 | 2.353 | 3.922 | 5.490 | 4.706 | 4.706 | 3.922 | 3.137 | 3.137 | 2.353 | 1.569 |
| EC | 2250 | 0.0004 | 0.03 | 0.030 | 0.034 | 0.036 | 0.043 | 0.037 | 0.032 | 0.022 | 0.020 | 0.019 | 0.018 | 0.016 | 0.017 | 0.019 | 0.019 | 0.022 | 0.023 | 0.025 | 0.026 | 0.027 | 0.034 |
| COD | 100 | 0.0100 | 1.27 | 1.680 | 1.820 | 1.650 | 1.560 | 1.320 | 1.180 | 1.020 | 0.960 | 1.070 | 1.240 | 1.320 | 1.460 | 1.480 | 1.620 | 1.680 | 1.730 | 1.760 | 1.880 | 1.580 | 1.430 |
| BOD | 10 | 0.1000 | 48.00 | 55.000 | 58.000 | 73.000 | 67.000 | 62.000 | 41.000 | 34.000 | 32.000 | 35.000 | 44.000 | 56.000 | 60.000 | 63.000 | 68.000 | 71.000 | 74.000 | 75.000 | 69.000 | 62.000 | 58.400 |
| TH | 300 | 0.0033 | 0.21 | 0.242 | 0.238 | 0.284 | 0.342 | 0.224 | 0.212 | 0.196 | 0.180 | 0.171 | 0.186 | 0.220 | 0.238 | 0.261 | 0.240 | 0.224 | 0.213 | 0.217 | 0.206 | 0.213 | 0.233 |
| TA | 200 | 0.0050 | 0.77 | 0.743 | 0.680 | 0.725 | 1.005 | 0.955 | 0.920 | 1.150 | 1.065 | 0.995 | 1.063 | 0.955 | 0.985 | 0.895 | 0.865 | 0.843 | 0.883 | 0.815 | 0.855 | 0.835 | 0.805 |
| TDS | 500 | 0.0020 | 0.27 | 0.281 | 0.308 | 0.289 | 0.273 | 0.232 | 0.203 | 0.168 | 0.174 | 0.185 | 0.201 | 0.223 | 0.234 | 0.246 | 0.251 | 0.257 | 0.241 | 0.248 | 0.254 | 0.261 | 0.255 |
| $Na^+$ | 900 | 0.0011 | 0.01 | 0.012 | 0.012 | 0.011 | 0.010 | 0.010 | 0.009 | 0.008 | 0.008 | 0.011 | 0.010 | 0.012 | 0.011 | 0.010 | 0.011 | 0.010 | 0.010 | 0.011 | 0.010 | 0.011 | 0.011 |
| $K^+$ | 15 | 0.0667 | 3.87 | 3.867 | 3.911 | 4.444 | 4.756 | 4.267 | 3.867 | 3.556 | 3.778 | 3.822 | 3.733 | 3.689 | 3.511 | 3.733 | 3.600 | 3.511 | 3.600 | 3.644 | 3.689 | 3.778 | 3.822 |
| $Ca^{2+}$ | 75 | 0.0133 | 0.75 | 0.821 | 0.754 | 0.779 | 0.864 | 0.921 | 0.839 | 0.821 | 0.788 | 0.757 | 0.793 | 0.777 | 0.741 | 0.720 | 0.747 | 0.644 | 0.704 | 0.649 | 0.629 | 0.688 | 0.720 |
| $Mg^{2+}$ | 30 | 0.0333 | 1.69 | 2.133 | 2.189 | 2.078 | 2.756 | 2.822 | 2.922 | 2.500 | 2.267 | 2.067 | 2.378 | 1.833 | 1.944 | 2.022 | 2.289 | 2.022 | 2.044 | 1.911 | 1.867 | 1.711 | 1.978 |
| $NO_3^-$ | 50 | 0.0200 | 0.32 | 0.360 | 0.400 | 0.400 | 0.440 | 0.480 | 0.400 | 0.360 | 0.280 | 0.240 | 0.280 | 0.320 | 0.360 | 0.400 | 0.400 | 0.360 | 0.360 | 0.320 | 0.320 | 0.280 | 0.280 |
| $SO_4^{-2}$ | 400 | 0.0025 | 0.05 | 0.055 | 0.056 | 0.054 | 0.061 | 0.057 | 0.052 | 0.046 | 0.044 | 0.043 | 0.041 | 0.041 | 0.039 | 0.038 | 0.041 | 0.043 | 0.046 | 0.049 | 0.051 | 0.053 | 0.055 |
| $Cl^-$ | 250 | 0.0040 | 0.14 | 0.154 | 0.168 | 0.163 | 0.157 | 0.152 | 0.133 | 0.109 | 0.096 | 0.118 | 0.123 | 0.109 | 0.098 | 0.093 | 0.106 | 0.112 | 0.125 | 0.136 | 0.139 | 0.146 | 0.152 |
| $F^-$ | 1.5 | 0.6667 | 17.78 | 18.222 | 18.222 | 18.667 | 21.333 | 20.444 | 19.556 | 18.667 | 16.889 | 16.444 | 16.000 | 16.000 | 15.556 | 15.111 | 15.111 | 15.556 | 16.000 | 16.444 | 16.889 | 17.778 | 16.889 |
| $\sum W_i$ | | 1.0860 | | | | | | | | | | | | | | | | | | | | | |
| $\sum q_iW_i$ | | | 79.58 | 89.67 | 94.10 | 111.67 | 113.39 | 102.29 | 78.17 | 67.81 | 63.60 | 66.56 | 75.65 | 87.72 | 92.89 | 97.20 | 101.56 | 104.32 | 106.96 | 107.15 | 101.66 | 94.05 | 89.13 |
| **WWQI = $\sum q_iW_i / \sum W_i$** | | | **73.28** | **82.56** | **86.65** | **102.82** | **104.40** | **94.19** | **71.98** | **62.43** | **58.56** | **61.29** | **69.66** | **80.77** | **85.53** | **89.50** | **93.51** | **96.05** | **98.48** | **98.66** | **93.60** | **86.60** | **82.07** |

## CORRELATION

In the present study, Karl Pearson Correlation Matrix was used to identify statistically significantly correlated variables. Correlation coefficient (r) between any two parameters, x & y is calculated for all parameters including WWQI, water temperature, pH, electrical conductivity (EC), COD, BOD, total hardness (TH), total alkalinity (TA), total dissolved solids (TDS), sodium, potassium, nitrate, sulphate, chloride, fluoride, calcium and magnesium of the undertaken samples. The numerical values of correlation coefficients (r) are tabulated in Table 3. The degree of line association between any two of the water quality parameters as measured by the simple correlation coefficient (r) is presented as 17 x 17 correlation matrix. Positive correlation is obtained between 118 combinations (77.12 of the total number) and rest 35 combinations (22.88) exhibit negative correlation. The parameters exhibiting correlation coefficients (r)>0.5 with WWQI were chosen for regression analysis. It was found that WWQI is significantly correlated with pH, COD, BOD, TH, TA, TDS, $NO_3^-$ (r-value> 0.5). It shows that out of 17 parameters taken only 7 parameters are significantly correlated with WWQI. To check that WWQI is correctly drawn or not, multiple linear regression analysis was carried out using MS-Excel software.

### Multiple Linear Regression Analysis

Main motive of this study was to identify the main parameters affecting the treated water quality. To serve this purpose, Multiple Linear Regression (MLR)analysis was carried out using MS-Excel software.Correlation matrix shows parameters pH, COD,BOD, TH, TA, TDS and $NO_3^-$exhibit correlation coefficients (r) > 0.5 with WWQI. Out of these seven parameters, pH is correlated with almost all other six parameters viz. COD, BOD, TH, $NO_3^-$, TDS and TA (Table 3). As per requirement of regression model that it should be free from multicolinearity, pH was neglected. Multiple linear regression MLR was executed taking WWQI as dependent variable and

**Table-3 Correlation matrix of water quality parameters**

| | Temp. | pH | EC | COD | BOD | TH | TA | TDS | $Na^+$ | $K^+$ | $Ca^{+2}$ | $Mg^{+2}$ | $NO_3^-$ | $SO_4^{-2}$ | $Cl^-$ | $F^-$ | WWQI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Temp.** | 1 | | | | | | | | | | | | | | | | |
| **pH** | 0.054054974 | 1 | | | | | | | | | | | | | | | |
| **EC** | -0.101879219 | 0.391 | 1 | | | | | | | | | | | | | | |
| **COD** | -0.64464128 | 0.568 | 0.248 | 1 | | | | | | | | | | | | | |
| **BOD** | -0.508691627 | 0.694 | 0.236 | 0.879 | 1 | | | | | | | | | | | | |
| **TH** | -0.003259426 | 0.891 | 0.571 | 0.454 | 0.565 | 1 | | | | | | | | | | | |
| **TA** | 0.695408444 | -0.24 | -0.43 | -0.72 | -0.56 | -0.29 | 1 | | | | | | | | | | |
| **TDS** | -0.597642458 | 0.588 | 0.559 | 0.825 | 0.72 | 0.641 | -0.87 | 1 | | | | | | | | | |
| **$Na^+$** | -0.562352211 | 0.243 | 0.161 | 0.542 | 0.447 | 0.338 | -0.69 | 0.728 | 1 | | | | | | | | |
| **$K^+$** | 0.247621433 | 0.551 | 0.803 | 0.04 | 0.141 | 0.679 | -0.11 | 0.356 | 0.078 | 1 | | | | | | | |
| **$Ca^{+2}$** | 0.719822217 | 0.067 | 0.387 | -0.52 | -0.44 | 0.216 | 0.373 | -0.23 | -0.22 | 0.582 | 1 | | | | | | |
| **$Mg^{+2}$** | 0.761374506 | 0.215 | 0.357 | -0.34 | -0.27 | 0.203 | 0.436 | -0.31 | -0.52 | 0.45 | 0.768 | 1 | | | | | |
| **$NO_3^-$** | 0.367332025 | 0.701 | 0.483 | 0.28 | 0.4 | 0.649 | -0.13 | 0.365 | -0.02 | 0.474 | 0.476 | 0.585 | 1 | | | | |
| **$SO_4^{-2}$** | -0.216838523 | 0.211 | 0.954 | 0.26 | 0.165 | 0.408 | -0.43 | 0.514 | 0.167 | 0.699 | 0.323 | 0.266 | 0.319 | 1 | | | |
| **$Cl^-$** | -0.343912031 | 0.219 | 0.874 | 0.424 | 0.288 | 0.377 | -0.6 | 0.655 | 0.406 | 0.646 | 0.187 | 0.101 | 0.233 | 0.92 | 1 | | |
| **$F^-$** | 0.304388986 | 0.226 | 0.838 | -0.11 | -0.12 | 0.397 | 0.015 | 0.145 | -0.17 | 0.788 | 0.686 | 0.626 | 0.49 | 0.837 | 0.67 | 1 | |
| **WWQI** | -0.355099528 | **0.817** | 0.391 | **0.836** | **0.97** | **0.705** | **-0.5** | **0.731** | 0.387 | 0.34 | -0.24 | -0.08 | **0.562** | 0.293 | 0.377 | 0.089 | 1 |

**Table 4.** Coefficients for regression analysis (a)

| | Coefficients | Standard Error | t Stat | p-value |
|---|---|---|---|---|
| Intercept | 4.0369 | 13.9111 | 0.2902 | 0.7759 |
| COD | 0.0142 | 0.0436 | 0.3254 | 0.7497 |
| BOD | 0.8406 | 0.0705 | 11.9227 | 0.0000 |
| TH | 0.0569 | 0.9264 | 2.1527 | 0.0493 |
| NO3- | 1.1851 | 0.3499 | 3.3868 | 0.0044 |
| TA | 0.0163 | 0.0232 | 0.7019 | 0.4942 |

selected six parameters as regressors. From Table 4, unstandardized coefficients for the equation intercept, COD, BOD, TH,$NO_3^-$, TDS and TA as 4.0369, 0.0142, 0.8406, 0.0569, 1.1851, 0.0038, 0.0163 respectively. These coefficients were replaced with the coefficients of equation-6 and Y predicted is presented in equation 7. Table 5 shows that the model fit with 98.83% of accuracy.

$Y_{(E)} = 4.0369+0.0142\ X_1+0.8406\ X_2+0.0569\ X_3+1.1851\ X_4 + 0.0038\ X_5+ 0.0163\ X_6$...... (7)

Where, Y= WWQI, $X_1$= COD, $X_2$ = BOD, $X_3$ = TH, $X_4$ = $NO_3^-$, $X_5$ = TDS, $X_6$ = TA

This model is fitted significantly as F=196.86 (Sig F: 0.0000) (Table 6). Findings of regression analysis depicts p-value for BOD, TH and $NO_3^-$ less than 0.05. Taking these three parameters, the regression analysis was again executed in order to develop a new equation. So, COD, TDS and TA are dropped, recalculated the WWQI, again fitted the regression model and got the regression equation as follows (Equation 8) with 98.74 % of accuracy (Table 8).

$Y_{(E)} = 13.0550 + 0.8458\ X_1+ 0.0601\ X_2 + 1.2067\ X_3$ (Table 7)............(8)

Where, Y= WWQI after dropping COD, TDS and TA, $X_1$ = BOD, $X_2$ = TH, $X_3$ = $NO_3^-$

Each parameter has significant effect on WWQI, p-value of all the parameters less than 0.05 (Table 7). This model is fitted significantly as F=443.43 (Sig F: 0.0000) (Table 9). The graphical comparison for WWQI determined and predicted by two regression equations is shown in Fig. 1. The scatter plot indicates the determined values almost match the estimated values which clearly approve the selected model.

## CONCLUSION

WWQI was calculated using measured parameters to determine the overall quality of secondary treated wastewater of STP, Chak 1F Chhoti, Sriganganagar. Interrelationship between different parameters was found using Karl Pearson correlation with the help

**Table 5.** Regression Statistics (a)

| Multiple R | R Square | Adjusted R Square | Standard Error |
|---|---|---|---|
| 0.9911 | 0.9883 | 0.9833 | 1.7782 |

**Table 6.** Regression Statistics (a)

| df | 88 | MS | F | Significance F |
|---|---|---|---|---|
| Regression | 6 | 3735.0204 | 622.5034 | 196.8635 |
| Residial | 14 | 44.2695 | 3.1621 | |
| Total | 20 | 3779.2899 | | |

**Table 7.** Coefficients for regression analysis (b)

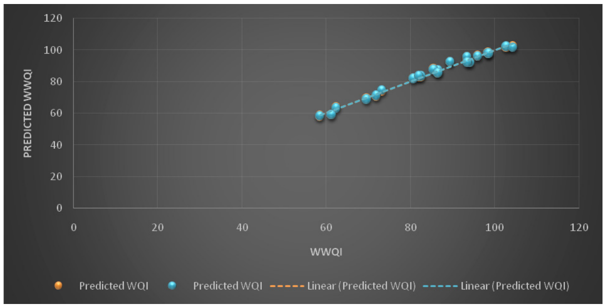
| | Coefficients | Standard Error | t Stat | p-value |
|---|---|---|---|---|
| Intercept | 13.0550 | 2.4915 | 5.2398 | 0.0001 |
| BOD | 0.8458 | 0.0335 | 25.2199 | 0.0000 |
| T II | 0.0601 | 0.0163 | 3.6941 | 0.0018 |

**Table 8.** Regression Statistics (b)

| Multiple R | R Square | Adjusted R Square | Standard Error |
|---|---|---|---|
| 0.9937 | 0.9874 | 0.9852 | 1.6748 |

**Table 9.** ANOVA (b)

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regresion | 3 | 3731.6334 | 1243.8678 | 443.4321 | 0.0000 |
| Residual | 17 | 47.6866 | 2.8051 | | |
| Total | 20 | 3779.2899 | | | |




of MS-Excel software. From this analysis it was found that WWQI is significantly correlated with pH, COD, BOD, TH, TA, TDS, $NO_3^-$ which means out of 17 parameters only 7 parameters are correlated with WWQI. Using these 7 parameters, two regression equations were developed with an accuracy of 98.83% and 98.74%. From regression analysis it is concluded that instead of analyzing all 17 parameters, only 3 parameters BOD, TH and $NO_3^-$ can provide results with sufficient accuracy of the order of 98%. This will definitely save much time, chemicals and money to carry on tedious procedures of testing and determining each and every parameter. High accuracy of the model eliminates chances of deviations from original WWQI. This is further supported by scatter plot of determined WWQI and two predicted WWQI values.

Regarding water quality, present study indicated that STP undertaken for study is capable of producing good to moderately good quality effluent with respect to physio-chemical parameters. So, there is a need of continuous monitoring of treated water quality. Based on these results and analysis of water samples, it is recommended to use water only after dilution for specific usage like irrigation or reuse to prevent adverse health effects.

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