

Correlation and Regression Analysis of Water Quality Parameters for SARAS Dairy Effluent Treatment Plant- Hanumangarh, Rajasthan, India

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Abstract

The present paper is focused on the statistical analysis of the measured physico-chemical parameters of the secondary treated water of SARAS dairy effluent treatment plant, Hanumangarh, Rajasthan, India. The samples were collected from the outlet of ETP for a period of one year from February 2020 to January 2021 and analyzed for sixteen physico-chemical parameters. The measured parameters were used to calculate WWQI (waste water quality index). To identify the statistical relationship among water quality parameters and WWQI, correlation matrix was applied using MS excel data analysis for every pair of parameters and regression equation were formulated for pairs having highly significant ($0.8 < r < 1.0$) and moderately significant ($0.6 < r < 0.8$) correlation coefficients. The experimentally observed and predicted values for the dependent parameter are compared followed by the percentage error (% error) calculation. Scatter diagram for highly significant positive correlation (COD-BOD, COD-WWQI, BOD-WWQI, pH- WWQI, TH - Ca²⁺, TH - Mg²⁺, TA - WWQI and NO₃⁻ - SO₄²⁻) were plotted for clear depiction of the statistical observations. The parameters displaying significant correlation among each other indicate high interaction of the constituents in treated water. The present analysis provides an easy and rapid way to monitor the water quality of the study site.

Keywords: Effluent treatment plant; Water quality; Correlation coefficient; Regression equation; Scatter plot

1. Introduction

The rural areas are in general identified as milk production centers. To meet the milk and milk product requirements of dense population in urban areas, milk processing and milk product manufacturing industries, known as dairy plants are established. These dairy plants consume a large volume of water for various processes and produce wastewater or dairy effluent accordingly. It is reported that dairy industries produce 2.0 to 10.0 L of wastewater for processing 1.0 L of milk [1]. The dairy effluent contains large quantities of milk constituents like casein, fats, carbohydrates and inorganic salts, detergents, sanitizers used for washing and cleaning. These components significantly raise chemical oxygen demand (COD) and biochemical oxygen demand (BOD) of the effluent [2]. The level of various pollutants depends on the quantity of milk processed and type of milk products produced like milk powder, curd, cheese, butter milk, sweets etc. The pungent smell of the effluent generates houseflies and mosquitoes and should be immediately treated. To meet the discharge standards mentioned by CPCB and state pollution control boards, effluent treatment plants are being set in the boundaries of every industry. Physico-chemical characteristics of the dairy effluent were studied by [3] and found high levels of pH, BOD, COD, TSS. They suggested installation of proper wastewater treatment systems for protection of environmental health and ecological balance. Physico-chemical properties of wastewater generated from dairy industry were studied by [4] and they concluded that wastewater quality can be maintained within safe limits by better handling of treatment plant. The present paper is focused on the statistical analysis of the measured physico-chemical parameters of the secondary treated water of SARAS dairy effluent treatment plant, Hanumangarh, Rajasthan, India.

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2. Materials and methodology

2.1. Study Area and sampling

Our focused area of present study is effluent treatment plant (ETP) located in SARAS Dairy Hanumangarh of Rajasthan, India. Effluent treatment plants are installed in industries to meet regulating norms governed by pollution control boards. SARAS is famous and leading milk and milk product brand in Rajasthan. The ETP of SARAS dairy, Sri Ganganagar Zila Dugdh Utpadak Sehkari Sangh Ltd. Hanumangarh having capacity to treat 500m³ per day of effluent was selected for present study.

Activated sludge system with fixed type surface aerator is designed to handle waste water with high organic content and suspended solids. Aerobic Biological Reactor works as heart of the system. Present setup of SARAS dairy states that its current milk collection is 100,000 liter per day with daily water requirement of 2.0 liter per liter of milk processed. The various processing units in industry are milk pasteurizing, cheese, Whey and milk powder etc. SARAS has boiler section with water softening provisions and all safety measures. Regular CIP (Cleaning inside procedure) is carried out to maintain healthy and clean environment [5]. Samples were collected directly from the discharge point in clean washed and rinsed glass bottles for a period of one year from February 2020 to January 2021. The composite method of sampling was adopted and samples were collected in morning and evening at an interval of fifteen days. 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.

2.2. Physico-chemical analysis

The collected samples were analyzed for various physico-chemical parameters temperature, pH, electrical conductance (EC), Chemical Oxygen Demand (COD), biological oxygen demand (BOD), total alkalinity (TA), total hardness (TH), total dissolved solids (TDS), sodium (Na⁺), potassium (K⁺), calcium (Ca²⁺), magnesium (Mg²⁺), chloride (Cl⁻), sulphate (SO₄²⁻), nitrate (NO₃⁻) and fluoride (F⁻) as per standard methods. Temperature and pH were measured at the sampling site. [5]. For sampling and testing the procedure described in standard methods were adopted [6,7]. All the reagents used were AR grade and double distilled water was used for solution preparation.

2.3. Statistical Analysis

As water quality is described in terms of numerical datasets, statistical approach of data analysis is key in water quality study. In this paper, data of measurement was used to identify statistically significantly correlated variables. For this, the Karl Pearson Correlation Matrix and Linear Regression analysis was performed using MS-Excel software and results are presented in Table-2. The correlation matrix explains the connection between variables and the importance of each parameter in study of various impact factors.

3. Results and discussions

To express the overall water quality of the studied effluent treatment plant, in a numeric expression, waste-water quality index (WWQI) was calculated using measured values of various physicochemical parameters (table-1). The WWQI was used to assess the compliance of treated water quality with the quality requirement of water disposal.

In the present study, the Karl Pearson Matrix was used to identify statistically significantly correlated variables. Correlation coefficient (r) between any two parameters x and y is calculated for all the measured parameters and WWQI. The degree of line association between any two of the water quality parameters as measured by simple correlation coefficient (r) is presented as 17*17 correlation matrix (Table-2).

Positive correlation is obtained between 127 combinations (83.0 % of the total number) and the rest 26 combinations (17.0 % of the total number) exhibit negative correlation.

Table 1 Waste Water Quality Index (WWQI) of SARAS ETP, Hanumangarh.

Parameter	IS-2296 (Si)	Unit Wt (Wi)	EH1 (qi Wi)	EH2 (qi Wi)	EH3 (qi Wi)	EH4 (qi Wi)	EH5 (qi Wi)	EH6 (qi Wi)	EH7 (qi Wi)	EH8 (qi Wi)	EH9 (qi Wi)	EH10 (qi Wi)	EH11 (qi Wi)	EH12 (qi Wi)	EH13 (qi Wi)	EH14 (qi Wi)	EH15 (qi Wi)	EH16 (qi Wi)	EH17 (qi Wi)	EH18 (qi Wi)	EH19 (qi Wi)	EH20 (qi Wi)	EH21 (qi Wi)
Temp.	25	0.0400	2.83	2.912	3.328	3.520	4.096	4.448	4.544	4.400	4.224	4.000	3.968	3.872	3.712	3.600	3.520	3.248	2.992	2.720	2.624	2.304	2.480
pH	8.5	0.1176	10.20	10.980	11.765	12.549	13.333	14.118	11.765	10.196	7.059	7.843	8.627	9.412	10.196	10.196	10.980	9.412	8.627	10.196	10.980	10.196	9.412
EC	2250	0.0004	0.01	0.014	0.015	0.015	0.017	0.016	0.015	0.015	0.014	0.014	0.015	0.014	0.014	0.013	0.014	0.014	0.015	0.015	0.015		
COD	100	0.0100	0.53	0.570	0.720	0.770	0.840	0.704	0.650	0.558	0.486	0.566	0.602	0.488	0.500	0.467	0.520	0.480	0.450	0.470	0.490	0.520	0.480
BOD	10	0.1000	28.00	32.00	37.00	40.00	44.00	36.00	32.00	27.00	24.00	28.00	32.00	26.00	28.00	25.00	28.00	24.00	22.00	25.00	23.00	27.00	25.00
TH	300	0.0033	0.10	0.100	0.097	0.113	0.129	0.122	0.120	0.107	0.100	0.098	0.102	0.104	0.108	0.116	0.111	0.107	0.102	0.098	0.108	0.100	0.096
TA	200	0.0050	0.32	0.320	0.330	0.360	0.370	0.350	0.340	0.330	0.320	0.305	0.320	0.308	0.325	0.315	0.338	0.303	0.320	0.328	0.335	0.315	0.305
TDS	500	0.0020	0.10	0.087	0.102	0.114	0.137	0.126	0.142	0.131	0.113	0.107	0.118	0.109	0.100	0.094	0.110	0.118	0.107	0.113	0.094	0.087	0.084
Na+	200	0.0050	0.17	0.180	0.175	0.185	0.205	0.195	0.183	0.163	0.155	0.145	0.160	0.155	0.178	0.168	0.183	0.188	0.200	0.213	0.193	0.185	0.173
K+	15	0.0667	3.33	3.156	3.644	2.667	2.844	3.333	2.756	2.756	2.667	2.844	2.844	2.978	3.022	3.067	3.067	3.200	3.289	3.333	3.422	3.378	3.200
Ca ²⁺	75	0.0133	0.36	0.341	0.327	0.384	0.427	0.412	0.412	0.384	0.327	0.299	0.341	0.348	0.391	0.398	0.384	0.370	0.363	0.327	0.363	0.341	0.299
Mg ²⁺	30	0.0333	1.19	1.133	1.111	1.300	1.511	1.400	1.344	1.133	1.189	1.244	1.189	1.211	1.133	1.300	1.244	1.189	1.111	1.133	1.244	1.133	1.189
NO ₃ ⁻	50	0.0200	0.04	0.048	0.052	0.056	0.068	0.056	0.052	0.064	0.072	0.068	0.056	0.048	0.044	0.052	0.056	0.064	0.052	0.044	0.040	0.040	0.032

SO4-2	400	0.00 25	0.00	0.00 3	0.00 4	0.00 4	0.00 4	0.00 4	0.00 4	0.00 4	0.00 4	0.00 4	0.00 4	0.00 4	0.00 4	0.00 4	0.00 4	0.00 4	0.00 4	0.00 4	0.00 4	0.00 3	0.00 3
Cl-	250	0.00 40	0.06	0.06 7	0.06 9	0.07 5	0.07 7	0.07 5	0.06 7	0.06 9	0.07 2	0.06 6	0.06 4	0.05 9	0.07 0	0.07 8	0.06 6	0.07 0	0.07 4	0.06 6	0.08 0	0.07 2	0.06 1
F-	1.5	0.66 67	5.78	4.88 9	4.44 4	6.22 2	7.11 1	4.44 4	5.33 3	6.22 2	7.55 6	7.11 1	6.66 7	7.55 6	7.11 1	7.55 6	6.22 2	7.11 1	8.00 0	7.11 1	7.55 6	6.66 7	7.11 1
ΣW_i		1.08 99																					
$\Sigma q_i W_i$			53.0 2	56.8 0	63.1 8	68.3 3	75.1 7	65.8 0	59.7 3	53.5 3	48.3 6	52.7 1	57.0 8	52.6 7	54.9 1	52.4 2	54.8 2	49.8 8	47.7 1	51.1 7	50.5 5	52.3 4	49.9 2
$WWQI = \Sigma q_i W_i / \Sigma W_i$			48.6 5	52.1 2	57.9 7	62.7 0	68.9 7	60.3 8	54.8 0	49.1 1	44.3 7	48.3 7	52.3 7	48.3 2	50.3 8	48.1 0	50.3 0	45.7 6	43.7 7	46.9 5	46.3 8	48.0 2	45.8 0

Table 2 Correlation Matrix of Water Quality Parameters of ETP SARAS, Hanumangarh

	Temp.	pH	EC	COD	BOD	TH	TA	TDS	Na+	K+	Ca+2	Mg+2	NO3-	SO4-2	Cl-	F-	WWQI
Temp.	1.0000																
pH	0.1373	1.0000															
EC	0.2109	0.5877	1.0000														
COD	0.4272	0.7233	0.6417	1.0000													
BOD	0.3727	0.7318	0.5576	0.9762	1.0000												
TH	0.5342	0.7008	0.4809	0.5619	0.5387	1.0000											
TA	0.3560	0.7940	0.7213	0.7853	0.7563	0.7341	1.0000										
TDS	0.7823	0.3162	0.6277	0.5181	0.4268	0.6217	0.5578	1.0000									
Na+	-0.3253	0.5732	0.6365	0.2031	0.2044	0.3624	0.5318	0.1626	1.0000								
K+	-0.6730	0.1832	-0.0185	-0.2148	-0.1955	-0.3079	-0.2106	-0.5208	0.4062	1.0000							
Ca+2	0.4738	0.6640	0.3536	0.4206	0.4116	0.9308	0.6746	0.5765	0.4083	-0.2306	1.0000						
Mg+2	0.4925	0.5964	0.5403	0.6288	0.5914	0.8743	0.6567	0.5401	0.2240	-0.3414	0.6366	1.0000					

NO3-	0.7161	-0.0962	0.2175	0.3516	0.2792	0.3055	0.2395	0.6436	-0.2320	-0.5836	0.2292	0.3445	1.0000				
SO4-2	0.6124	-0.0817	0.3090	0.2056	0.1378	0.3621	0.2842	0.6616	0.0247	-0.4924	0.3208	0.3437	0.8886	1.0000			
Cl-	0.0501	0.3858	0.2785	0.2525	0.1836	0.5197	0.5114	0.0937	0.4391	0.0563	0.5363	0.3968	0.2129	0.2942	1.0000		
F-	-0.0402	-0.4247	-0.0724	-0.4733	-0.5035	0.0353	-0.2099	-0.0524	0.0443	-0.1457	-0.0188	0.1026	0.0642	0.3782	0.2431	1.0000	
WWQI	0.4057	0.8086	0.6169	0.9681	0.9816	0.6668	0.8298	0.4873	0.2971	-0.1885	0.5419	0.6889	0.2737	0.1900	0.2863	-0.4047	1.0000

Table 3(a) Regression Equation for Pairs of Parameters Having Highly Significant Correlation Coefficients ($0.8 < R < 1.0$) of SARAS ETP, Hanumangarh

Pairs of Parameters	R value	R ²	Adj. R ²	Regression Coefficients		Regression Equation	Significance
				A	B	$Y = a + bx$	
BOD - COD	0.9762	0.9530	0.9505	-0.159	0.520	$Y = -0.159 + 0.52x$	4.464E-14
TH - Ca ²⁺	0.9308	0.8664	0.8594	20.521	3.713	$Y = 20.521 + 3.713x$	9.559E-10
TH - Mg ²⁺	0.8743	0.7644	0.7520	12.275	7.626	$Y = 12.275 + 7.626x$	2.210E-07
WWQI - pH	0.8086	0.6538	0.6356	-148.541	23.987	$Y = -148.541 + 23.987x$	9.169E-06
WWQI - COD	0.9681	0.9373	0.9340	18.930	0.570	$Y = 18.93 + 0.57x$	7.005E-13
WWQI - BOD	0.9816	0.9635	0.9616	19.431	1.086	$Y = 19.431 + 1.086x$	4.058E-15
WWQI - TA	0.8298	0.6886	0.6723	-47.165	0.753	$Y = -47.165 + 0.753x$	3.272E-06
SO ₄ ²⁻ - NO ₃ ⁻	0.8886	0.7897	0.7786	3.907	1.615	$Y = 3.907 + 1.615x$	7.417E-08

Table 3(b) Percentage Error of the Pairs of Parameters Having Highly Significant Correlation Coefficients ($0.8 < R < 1.0$) of SARAS ETP, Hanumangarh

Pairs of Parameters	Independent Variable	Dependent Variable	X Value	Y (observed)	Y (predicted)	% error
BOD - COD	COD	BOD	56.480	29.191	29.190	-0.00343%
TH - Ca ²⁺	Ca ²⁺	TH	20.340	96.048	96.048	0.00000%
TH - Mg ²⁺	Mg ²⁺	TH	10.990	96.048	96.048	0.00000%
WWQI - pH	pH	WWQI	8.320	51.121	51.122	0.00196%
WWQI - COD	COD	WWQI	56.480	51.121	51.122	0.00196%
WWQI - BOD	BOD	WWQI	29.191	51.121	51.122	0.00196%
WWQI - TA	TA	WWQI	130.480	51.121	51.122	0.00196%
SO ₄ ²⁻ - NO ₃ ⁻	NO ₃ ⁻	SO ₄ ²⁻	1.320	6.040	6.038	-0.03311%

WWQI has been found to show positive correlation with all the parameters except K⁺ and F⁻ ions. Out of the 153 correlation coefficients, correlation coefficient (r) between COD-BOD (0.9762), COD-WWQI (0.9681), BOD-WWQI (0.9816), pH-WWQI (0.8086), TH - Ca²⁺ (0.9308), TH - Mg²⁺ (0.8743), TA - WWQI (0.8298) and NO₃⁻ - SO₄²⁻ (0.8886) are observed with highly significant levels ($0.8 < r < 1.0$). 25 correlation coefficients give the moderate significant ($0.6 < r < 0.8$) level of r values and there are 21 values of r which belong to the significant levels ($0.5 < r < 0.6$) (table-2).

Values of adjusted R² are very close to estimated R² values. That mean the variables have adequate predictive ability for dependent variables and it also indicate the relevancy and utility of regression model. The parameters which have 0.00 to 0.05 significance value (p -value) indicate that they are significantly related to their independent variable and applied model is significantly good enough in predicting the dependent variable [9]. The parameters which have slightly higher significance value (> 0.05) indicate that they are less significantly correlated to their independent variable. The parameters displaying significant correlation among each other indicate high interaction of the constituents in treated water.

4. Conclusions

Linear correlations are very useful to get inter-relationship of various parameters and correlate to treated water quality. Correlation matrix shows that out of 16 parameters taken only 8 parameters are significantly correlated with WWQI. This study has provided information on the treated water quality as well the main parameters affecting water quality of the dairy industry. COD and BOD has positive strong correlation among themselves as well as with WWQI and can be used as a check parameter to evaluate performance of the ETP for quick action and may also assist in monitoring the presence of toxic and non-biodegradable substances. The dairy and cheese industry waste mainly contains organic and biodegradable products and can be easily treated to maintain aquatic and terrestrial ecosystems. However, oily and greasy sludge discharge during the treatment process requires proper and usable alternatives.

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