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MULTIPLE LINEAR REGRESSION MODEL TO PREDICT THE WATER QUALITY PARAMETERS OF MUSI RIVER NEAR HYDERABAD, INDIA

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ABSTRACT

The river Musi is one of the tributaries of river Krishna. The water quality of any river deteriorates due to the discharge of untreated municipal and industrial wastewater. Assessment of river water quality is necessary to know the extent of contamination of the river Musi. Four multiple linear regression (MLR) equations are developed to predict sodium adsorption ratio (SAR), electrical conductivity (EC), biological oxygen demand (BOD) and dissolved oxygen (DO) using the monthly water quality data for the year 2021 of river Musi at four measuring stations near Hyderabad. The open access online database of Telangana State Pollution Control Board (TSPCB) is used. Multiple linear regression (MLR) models are developed using regression tool available in Microsoft Excel. F-tests ant t-tests are used to measure the goodness of fit of MLR equations developed. The MLR model predicting EC has the highest multiple correlation coefficient (multiple R) value of 0.77 and it is followed by MLR model predicting SAR with multiple R value of 0.76. The values of coefficient of multiple determination (R square) of four MLR models developed indicate that the explained variance is 0.58, 0.59, 0.48 and 0.3 respectively. From this we can conclude that the unexplained variance is 0.42, 0.41, 0.52 and 0.7 respectively. The F observed values are higher than the F critical values for single-tailed test obtained from the standard tables at 5% level of significance. This shows that all the independent variables are statistically related to the dependent variables used for prediction at 95% confidence level. t- statistic observed values of all the independent variables are higher than the t-critical values obtained from the standard tables for single-tailed test at 5% level of significance except in two cases.

Keywords: Sodium adsorption ratio, Electrical conductivity, Biological Oxygen demand, Dissolved oxygen, F-test, t- test, Single-tailed test, Multiple R, R square.

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1. INTRODUCTION

Multiple linear regression (MLR) model is developed to predict the dissolved oxygen (DO) concentration, using three independent variables (pH, biological oxygen demand (BOD) and water temperature (WT)) at three different places in Yamuna river near Agra city (Abba et al., 2017). MLR model is developed to predict the water quality index (WQI) with five parameters (turbidity (TURB), electrical conductivity (EC), chemical oxygen demand (COD), total hardness (TH), and pH) using the monthly water quality data sets from ten stations on the Tigris River within Baghdad, Iraq (Ewaid et al., 2018). Dissolved solids are predicted using multiple linear regression model with one independent variable (Specific conductance) in the Little Arkansas River, South-Central Kansas (Christensen et al., 2000). Total dissolved solids are predicted using a MLR model with six independent variables (Na, Mg, SO4, HCO3, Cl, and Ca) in Maknassy Basin, Central Tunisia (Chenini et. al., 2009). MLR is applied to generate a new water quality index (WQI) equation with only three variables: phosphorus, dissolved oxygen (DO) and thermotolerant coliforms in Mirim Lagoon in the state of Rio Grande do Sul, Brazil (Valentini et al., 2021). MLR model is developed to simulate DO, total Phosphorus (TP), Chlorophyll a (Chl a) cotent, and secchi disk depth (SD) in the Mingder Reservoir of central Taiwan (Chen and Liu, 2015). MLR model is developed to predict the water demand with four independent variables (demography, economic growth, water losses and water restrictions) in the City of Cape Town (Lawensa, and Mutsvangwa, 2018).A MLR is developed to predict both the total trihalomethanes (THM) and individual species concentrations in finished drinking water with five independent variables (chlorine dose, chlorophyll a, temperature, pH and bromide) of raw water in Menidi Treatment Plant of Athens (Golfinopoulos, S. K. and Arhonditsis, 2002)

2. MATERIALS AND METHODS

2.1. Study Area

The study area selected along the stretch of Musi river near Hyderabad lies within latitudes of 17º 21′ 7.2″ to 17º 23′ 0.88″ N and longitudes of 78º 33′ 34.7.″ to 78º 40′ 12″ E. Musi river data for the year 2021 on monthly basis are taken from the online available environmental data of Telangana State Pollution Control Board (TSPCB, 2021). This data are taken at four locations of Nagole, Peerzadguda, Pratapasingaram and Pillaipalli. These forty-eight values of Musi river data are fitted for multiple linear regression (MLR) to predict water quality parameters.

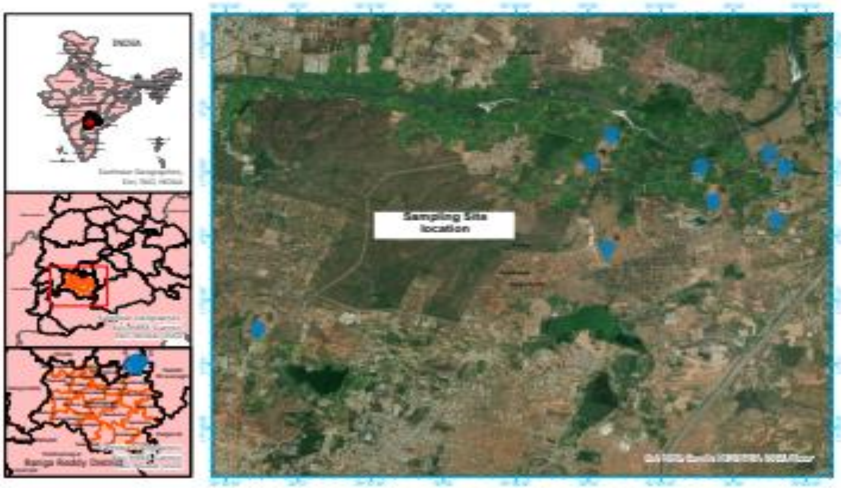

Figure 1 Study area map

2.2. Methodology

Multiple linear regression (MLR) using Microsoft Excel is used to predict the water quality parameters. Four multiple linear regression models are fitted to predict sodium adsorption ratio (SAR), electrical conductivity (EC), biological oxygen demand (BOD) and dissolved oxygen (DO). Regression models are suitable to investigate the existing relationship between dependent and independent variables. The general MLR model is expressed as follows:

$$Y = b_0 + b_1 x_1 + b_2 x_2 + \ldots b_i x_i \ldots \quad (1)$$

Where Y is the dependent variable to be predicted, x_i is the value of the i^{th} independent variable, b_0 is the regression constant, and b_i is the coefficient of the i^{th} independent variable.

Steps involved in Microsoft Excel to develop multiple linear regression model:

Step1: Data analysis tool of Microsoft Excel is to be used. The observed monthly values of SAR, EC, BOD and DO are taken as dependent variables to be predicted. Four Types of multiple regression equations are developed and the results are tabulated in Table (9). In each model the input parameters are as given in Table (9).

Step2; Regression window is activated and input observed values of the dependent variable is kept in Y range (in each of the four regression models the dependent variables to be predicted are SAR, EC, BOD and DO respectively). The input observed values of independent variables are kept in X range with confidence level of 95%. The output range is to be selected.

Step3: The regression output consists of Multiple Correlation Coefficient (multiple R), Coefficient of Multiple Determination (R square), Standard error of estimate, Regression Coefficients, Sum of squares (SS), Mean squares (MS), Probability values (p-value), Residual outputs, Probability outputs and Predicted SAR, EC, BOD and DO.

3. RESULTS AND DISCUSSION

3.1. Prediction of Sodium adsorption Ratio (SAR)

Multiple linear regression model is developed to predict the sodium adsorption ratio (SAR) with four independent variables of electrical conductivity (EC), boron (B), Free ammonia (NH_3) and the potential of hydrogen (pH) in Musi river. The multiple regression equation developed to predict SAR is as follows:

$$SAR = 0.002\ EC - 2.98\ B + 3.28\ NH_3 - 1.35\ pH + 9.59 \ldots\ldots (2)$$

Table 1(a) Regression Statistics of MLR to Predict SAR

Multiple R	0.766225264
R Square	0.587101156
Adjusted R Square	0.548691961
Observations	48

Table. 1(b) Analysis of Variance (ANOVA) of MLR to Predict SAR

	df	SS	MS	F	Significance F
Regression	4	13.764471	3.44111778	15.285	7.49724E-08
Residual	43	9.6803321	0.225124005		
Total	47	23.444803			

Table. 1(c) Analysis of Variance (ANOVA) of MLR to Predict SAR

	Coefficients	t Stat (observed)	P-value
Constant	9.591147	3.720185546	0.00057257
EC	0.002886	7.543910318	2.11735E-09
B	-2.989994	-3.495540365	0.001111034
NH_3	3.284165	2.122557446	0.039589026
pH	-1.351381	-3.823728453	0.000419438

P-values of Electrical conductivity (EC), Boron (B), Ammonia (NH_3) and Potential oh hydrogen (pH) are smaller than 0.05 and this is an effective model for predicting the Sodium adsorption ratio (SAR) in Musi river water.

Table 2(a) F-Test Results of MLR to predict SAR

Regression *df*	**Residual *df***	$F_{observed}$	$F_{critical}$ **at 5% level of significance**	$F_{critical}$ **at 10% level of significance**
4	43	15.285	2.589	2.080

The $F_{observed}$ value of 15.285 is greater than the $F_{critical}$ values of 2.589 and 2.080 at a 5% level of significance and at a10% level of significance respectively. Hence, the dependent variable Sodium adsorption ratio (SAR) is significantly related to the independent variables of Electrical conductivity (EC), Boron (B), Free Ammonia (NH_3) and Potential of Hydrogen (pH) at a 5% level of significance.

Table. 2(b) t-Test Results of MLR to predict SAR

S. No.	Independent Variables	t-statistic observed	t- critical at 5%	t critical at 10%
1	Constant	3.720	-	-
2	EC	7.54	1.678	1.30
3	B	-3.49	1.678	1.30
4	NH_3	2.12	1.678	1.30
5	pH	-3.82	1.678	1.30

The t-statistic observed value of electrical conductivity, boron (B), ammonia and potential of Hydrogen (pH) are greater than the t-statistic critical values at a 5 % level of significance. Hence the independent variables of electrical conductivity, boron (B), Free ammonia and potential of Hydrogen (pH) are significantly related to the dependent variable Sodium adsorption ratio (SAR) at a 5% level of significance in the single-tailed test. The variation of predicted and observed values of Sodium Adsorption Ratio of river water is shown in Fig (2)

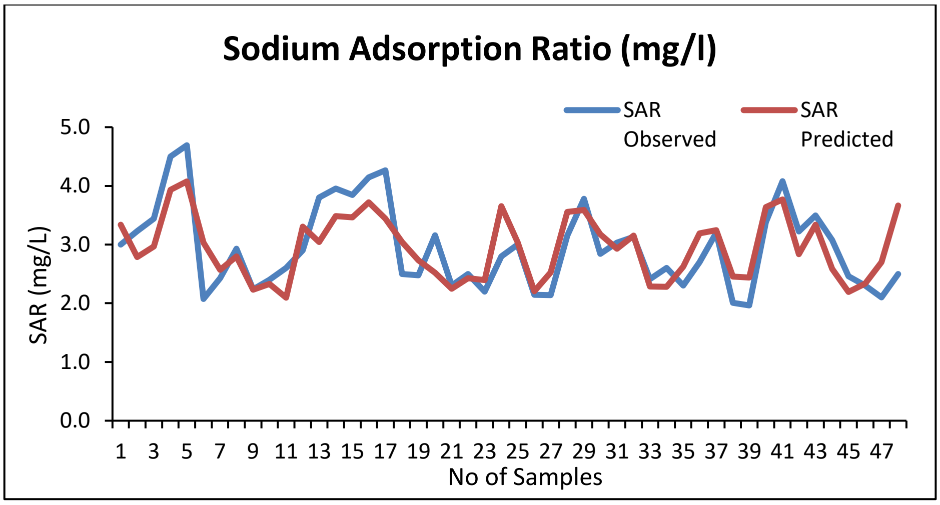

Figure 2. Variation of Predicted and observed values of Sodium Adsorption Ratio of Musi river water

3.2. Prediction of Electrical Conductivity (EC)

Multiple linear regression equation models are developed to predict the electrical conductivity (EC) with three independent variables Potential of Hydrogen (pH), Sodium adsorption ratio (SAR) and Boron (B) in Musi river water.

$$EC = 373.21\ pH + 190.68\ SAR + 532.65\ B - 2111.94 \quad \ldots\ldots (3)$$

Table 3 (a) Regression Statistics of MLR to predict EC

Multiple R	0.771232346
R Square	0.594799331
Adjusted R Square	0.567172013
Observations	48

Table. 3(b) Analysis of Variance (ANOVA) of MLR to predict EC

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	1074435.94	358145.31	21.529	9.84432E-09
Residual	44	731947.97	16635.18		
Total	47	1806383.91			

Table. 3(c) Analysis of Variance (ANOVA) of MLR to predict EC

	Coefficients	**t Stat**	**P-value**
Constant	-2111.948903	-2.927501947	0.005391707
pH	373.2102494	4.014903532	0.000228218
SAR	190.6829673	7.061773273	9.28154E-09
B	532.6572296	3.513041734	0.00103816

Table. 4(a) F-Test Results of of MLR to predict EC

Regression *df*	**Residual *df***	**F observed**	**F critical at 5% level of significance**	**F critical at 10% level of significance**
3	44	21.52	2.816	2.213

The $F_{observed}$ value of 21.52 is greater than $F_{critical}$ values of 2.816 and 2.213 at a 5% level of significance and at a 10 % level of significance respectively. Hence, the dependent variable electrical conductivity (EC) is significantly related to the independent variables of potential of hydrogen (pH), sodium adsorption ratio (SAR) and Boron (B) at a 5% level of significance.

Table. 4(b) t-Test Results of MLR to predict EC

S. No.	Independent Variables	t- statistic observed	t- critical at 5%	t -critical at 10%
1	Constant	-	-	-
2	pH	4.014	1.678	1.30
3	SAR	7.061	1.678	1.30
4	B	3.513	1.678	1.30

The t-statistic observed value of potential of Hydrogen (pH), sodium adsorption ratio (SAR) and boron (B) are greater than the t-statistic critical values at a 5 % level of significance. Hence the independent variables of potential of hydrogen (pH), sodium adsorption ratio (SAR) and boron (B) are significantly related to the dependent variable electrical conductivity at a 5% level of significance in single-tailed test. The variation of predicted and observed values of electrical conductivity of river water is shown in Fig (3)

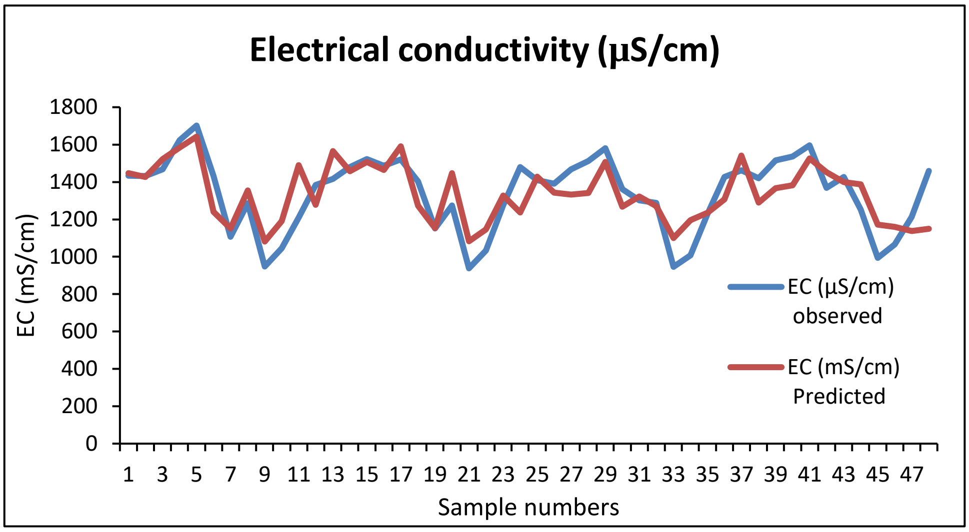

Figure 3. Variation of Predicted and observed values of electrical conductivity of Musi river water

3.3. Prediction of Biological Oxygen Demand (BOD)

Multiple linear regression equation model is developed to predict the Biological oxygen demand (BOD) with three independent variables of Potential of Hydrogen (pH), Dissolved oxygen (DO) and Sodium adsorption Ratio (SAR) in Musi river water.

$$BOD = 0.46\ pH - 2.45\ DO + 2.84\ SAR - 1.10 \ldots \quad (4)$$

Table: 5(a) Regression Statistics of MLR to predict BOD

Multiple R	0.693425263
R Square	0.480838596
Adjusted R Square	0.445441227
Observations	48

Table 5(b) Analysis of Variance (ANOVA) of MLR to predict BOD

	df	SS	MS	F	Significance F
Regression	3	427.43	142.4772843	13.584	2.08198E-06
Residual	44	461.49	10.48859425		
Total	47	888.93			

In Table 5(c), P- values of Dissolved oxygen and Sodium adsorption ratio are 0.0004 and 0.0001 respectively which are smaller than 0.05 these two variables have statistically significant correlation with dependent variable Biochemical oxygen demand (BOD).

Table. 5(c) Analysis of Variance (ANOVA) of MLR to predict BOD

	Coefficients	***t Stat***	***P-value***
Constant	-1.10012096	-0.060854491	0.951750674
pH	0.461773783	0.198686165	0.843423482
DO	-2.45975645	-3.806563436	0.000432307
SAR	2.846468379	4.091819394	0.000179693

Table. 6(a) F-Test Results of of MLR to predict BOD

Regression *df*	**Residual *df***	$\mathbf{F_{observed}}$	$\mathbf{F_{critical}}$ **at 5% level of significance**	$\mathbf{F_{critical}}$ **at 10% level of significance**
3	44	13.584	2.816	2.213

$F_{observed}$ value of 13.584 is greater than $F_{critical}$ values 2.816 and 2.213 at 5% level of significance and at 5% level of significance respectively. Hence, the dependent variable Biological oxygen demand (BOD) is significantly related to the independent variables of potential of Hydrogen (pH), Dissolved oxygen (DO) and Sodium adsorption ratio (SAR) at 5% level of significance.

Table. 6(b) t-Test Results of of MLR to predict BOD

S. No.	**Independent Variables**	**t-observed**	**t-critical at 5%**	**t-critical at 10%**	**t-critical at 20%**	**t-critical at 25%**	**t-critical at 30%**	**t-critical at 40%**	**t-critical at 45%**
1	Constant	-	-	-	-	-	-	-	-
2	pH	0.198	1.678	1.30	0.850	0.680	0.528	0.254	0.126
3	DO	-3.806	1.678	1.30	0.850	0.680	0.528	0.254	0.126
4	SAR	4.091	1.678	1.30	0.850	0.680	0.528	0.254	0.126

The t-statistic observed value of Dissolved oxygen (DO) and Sodium adsorption ratio (SAR) are greater than the t-statistic critical values at a 5 % level of significance. Hence the independent variables of Dissolved oxygen (DO) and Sodium adsorption ratio (SAR) are significantly related to the dependent variable of Biochemical oxygen demand (BOD) at a 5% level of significance in single-tailed test. The variation of predicted and observed values of biological oxygen demand of river water is shown in Fig (4)

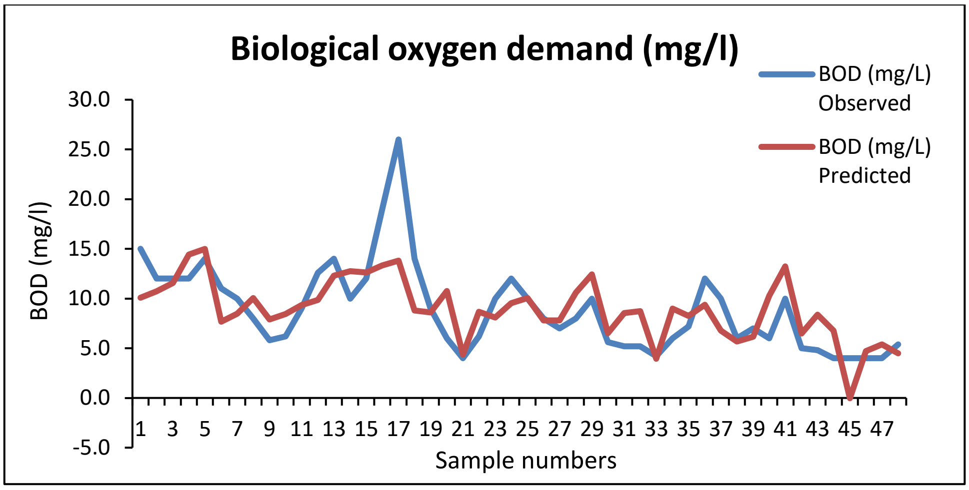

Figure 4. Variation of predicted and observed values of Biological oxygen demand of Musi river water

3.4. Prediction of Dissolved Oxygen (DO)

The Multiple linear regression equation models are developed to predict the Dissolved Oxygen (DO) with two independent variables of Potential of Hydrogen (pH) and Biochemical oxygen demand (BOD) in Musi river water.

$$DO = -0.538\ pH - 0.091\ BOD + 5.6 \ldots. \qquad (5)$$

Table 7(a) Regression Statistics of MLR to predict DO

Multiple R	0.54883331
R Square	0.301218002
Adjusted R Square	0.270161024
Observations	48

Table. 7(b) Analysis of Variance (ANOVA) of MLR to predict DO

	df	SS	MS	F	Significance F
Regression	2	8.21063795	4.10531897	9.69888328	0.00031454
Residual	45	19.0474871	0.42327749		
Total	47	27.258125			

In Table 7(c), the p-value of Biochemical oxygen demand (BOD) is 0.00011 which is smaller than 0.05. BOD is statistically significantly correlated at a 5% level of significance with Dissolved oxygen (DO).

Table 7(c) Analysis of Variance (ANOVA) of MLR to predict DO

	Coefficients	t Stat	P-value
Constant	5.60784920	1.64727161	0.106468735
pH	-0.5381417	-1.18858761	0.240836853
BOD	-0.0919731	-4.21384306	0.000119143

Table 8(a) F-Test Results of MLR to predict DO

Regression *df*	Residual *df*	Fobserved	F critical at 5% level of significance	F critical at 10% level of significance
2	45	9.698	3.204	2.425

The F $_{observed}$ value of 9.698 is greater than F $_{critical}$ values of 3.204 and 2.425 at a 5% level of significance and at a 10% level of significance respectively. Hence, the dependent variable Dissolved oxygen (DO) is significantly related to the independent variables of potential of Hydrogen (pH) and Biological oxygen demand (BOD) at a 5% level of significance.

Table. 8(b) t-Test Results of MLR to predict DO

S. No.	Independent Variables	t observed	t critical at 5%	t critical at 10%	t critical at 20%	t critical at 25%	t critical at 30%	t critical at 40%	t critical at 45%
1	pH	-1.188	1.677	1.30	0.850	0.680	0.528	0.254	0.126
2	BOD	-4.213	1.677	1.30	0.850	0.680	0.528	0.254	0.126

The absolute t-statistic observed value of the potential of Hydrogen (pH) is greater than the t-statistic critical values at a 20 % level of significance and the t-statistic observed value of Biological oxygen demand (BOD) is greater than the t-statistic critical value at a 5 % level of significance. Hence the independent variables of potential of Hydrogen (pH), and Biological oxygen demand (BOD) are significantly related the dependent variable of Dissolved Oxygen (DO) at a 20% level of significance and at a 5 % level of significance respectively in single-tailed test. The variation of Predicted and observed values of dissolved oxygen of river water is shown in Fig (5)

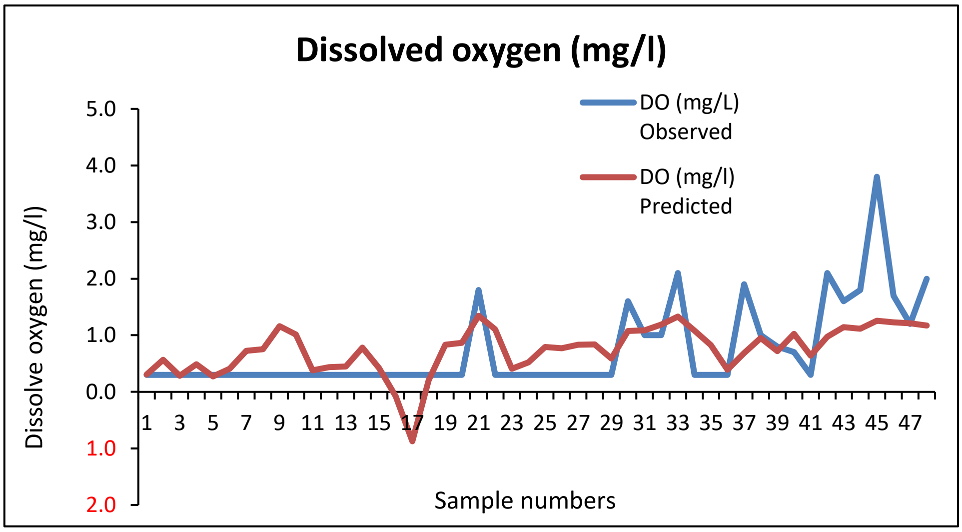

Figure 5. Variation of predicted and observed values of dissolved oxygen of Musi river water

Table. 9 Results of four multiple linear regression equations developed

Sl. No.	Input model parameters	MLR model equations	Multiple R	R Square
1	EC, B, NH_3, pH	SAR = 0.002 EC - 2.98 B + 3.28 NH_3 - 1.35 pH + 9.59	0.76	0.58
2	pH, SAR, B	EC = 373.21 pH + 190.68 SAR + 532.65 B -2111.94	0.77	0.59
3	pH, DO, SAR	BOD = 0.46 pH - 2.45 DO + 2.84 SAR - 1.10	0.69	0.48
4	pH, BOD,	DO = -0.538 pH -0.091 BOD + 5.6	0.54	0.30

The coefficient of multiple determination (R square) is the ratio of explained to total variance. From the Table (9), the value of R square are given as 0.58, 0.59, 0.48 and 0.3 for the MLR models developed for the prediction of SAR, EC, BOD and DO respectively. It indicates that the explained variance is 0.58, 0.59, 0.48 and 0.3 respectively for MLR models and the unexplained variance is 0.42, 0.41, 0.52 and 0.7 respectively. The fourth MLR model predicting DO has the highest unexplained variance. From Table (9), the values of multiple R are given as 0.76, 0.77, 0.69, and 0.54. The MLR model predicting EC has the highest multiple R value of 0.77 followed by MLR model predicting SAR with multiple R value of 0.76.

4. CONCLUSION

Four MLR models are developed to predict sodium adsorption ratio (SAR), electrical conductivity (EC), biological oxygen demand (BOD) and dissolved oxygen (DO). F-tests and t-tests are carried out to measure the goodness of fit of the MLR models developed. F-test determines the significant relation between the dependent variable and the independent variables. The F observed values of (Tables 2(a) 4(a), 6(a) and 8(a)) are higher than the F critical values for single-tailed test obtained from the standard tables at 5% level of significance. This shows that at 95% confidence level all the independent variables are statistically related to the dependent variables used for prediction.

t- statistic observed values of all the independent variables (Tables 2(b) 4(b), 6(b) and 8(b)) are higher than the t-critical values obtained from the standard tables for single-tailed test at 5% level of significance except in two cases. Hence all the independent variables are significant and useful in prediction at 5% level of significance. But t-statstic critical value of pH in MLR equation to predict BOD is significant at 45% level of significance and t- statistic critical value of pH in the MLR model to predict DO is significant at 20% level of significance.

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CONFLICT OF INTERESTS

The authors declare that there is no Conflict of interest regarding the publication of this paper

ABBREVIATIONS USED

List of Abbreviations Used			
MLR	**Multiple linear regression**	**THM**	**Trihalomethane**
Mutiple R	Multiple Correlation Coefficient	SAR	Sodium adsorption ratio
R square	Coefficient of multiple determination	DO	Dissolved oxygen
df	Degrees of freedom	COD	Chemical oxygen demand
MS	Mean squares	pH	Potential of Hydrogen
SS	Sum of squares	BOD	Biological oxygen demand
F	F-test or Fisher's F ratio	NH_3	Free Ammonia
t	t- statistic in t- Test	TH	Total Hardness
p-value	Probability value	B	Boron
WQI	Water quality Index	WT	Water Temperature
TDS	Total dissolved soilds	HCO_3	Bicarbonate
TURB	Turbidity	Cl	Chloride
Na	Sodium	Chl a	Chlorophyll a
SO_4	Sulfate	SD	Secchi disk depth
EC	Electrical conductivity	SS	Suspended solids
Ca	Calcium	TN	Total nitrogen
Mg	Magnesium	TP	Total phosphorus

REFERENCES

[1] Abba, S.I., Hadi, S.J., Abdullahi, J., River water modelling prediction using multi-linear regression, artificial neural network, and adaptive neuro-fuzzy inference system techniques, Procedia Computer Science, Vol. 120, 2017, 75–82

[2] Ewaid, S.H., Abed, S.A., Kadhum, S. A., Predicting the Tigris River water quality within Baghdad, Iraq by using water quality index and regression analysis, Environmental Technology & Innovation Vol. 11, 2018, 390–398

[3] Christensen, V.G., Jian, X., and Ziegler, A.C., "Regression Analysis and Real-Time Water-Quality Monitoring to Estimate Constituent Concentrations, Loads, and Yields in the Little Arkansas River, South-Central Kansas, 1995-99", Water-Resources Investigations Report 00-4126, 200, 2000

[4] Chenini, I., and Khemiri, S., Evaluation of groundwater quality using multiple linear regression and structural equation modeling, International Journal of Environmental Science and Technology, Vol. 6, No. 3, 2009, 509-519

[5] Valentini, M., Gabriel Borges dos Santos, G.B.D., Vieira, B.M., Multiple linear regression analysis (MLR) applied for modeling a new WQI equation for monitoring the water quality of Mirim Lagoon, in the state of Rio Grande do Sul—Brazil, SN Applied Sciences (2021) 3:70, https://doi.org/10.1007/s42452-020-04005-1

[6] Chen, W.B. and Liu, W.C., Water Quality Modeling in Reservoirs Using Multivariate Linear Regression and Two Neural Network Models, Advances in Artificial Neural Systems Volume 2015, Article ID 521721, 12 pages http://dx.doi.org/10.1155/2015/521721

[7] Lawens, M. and Mutsvangwa C., Application of multiple regression analysis in projecting the water demand for the City of Cape Town, Water Practice & Technology Vol 13 No 3 Doi: 10.2166/wpt.2018.082, 2018

[8] Golfinopoulos, S. K. and Arhonditsis, G. B., Multiple regression models: A methodology for evaluating Trihalomethane (THM) concentrations in drinking water from raw water characteristics, Chemosphere 47 (2002) 1007–1018

[9] Telangana State Pollution Control Board (TSPCB), Environmental data, Musi river monthly data for the year 2021. https://tspcb.cgg.gov.in/Pages/Envdata.aspx