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DEVELOPMENT OF REGRESSION MODEL FOR THE PANCHAGANGA RIVER WATER QUALITY IN KOLHAPUR CITY, M.S.

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ABSTRACT

In the present work river water samples are collected from four different stations of Panchaganga river in Kolhapur city and water quality assessment is carried out from october 2009 to March 2010 on weekly basis. Then correlation-regression study is carried out and correlation coefficients (R) are determined using correlation matrix to identify the highly correlated and interrelated water quality parameters. The correlations among 8 water quality parameters for each station are determined. Out of 36 pairs 7 pairs of parameters are selected having significant R and regression models are developed namely RGMS-1, RGMS-2, RGMS-3 and RGMS-4 for the four different stations. To test the significance of the pair of parameters P-value test is carried out and in order to test the joint effects of several independent variables, without necessarily taking the separate effects of each variable into account, F-test is also used. The comparison of the observed and predicted values of the different parameters using regression equations revealed that the regression model can be used to provide a mean for easier and faster monitoring of water quality in a location. The correlation study and correlation coefficient values can help in selecting the treatments to minimize contaminants in river water.

*Keywords- **Coefficient of Variation, F-value, P-value, Regression equation, Water quality***

I. INTRODUCTION

The riverine system is most important resources of water supply in different countries of the world. At the source of a river, the water is relatively pure as it flows todards downstream. In India the riverine systems are getting polluted day by day. Today acute pollution prevails in many rivers such as Krishna, Tapti, Bramhaputra, Ganga, Hoogly, Brahmani etc. As the water flows downstream, it picks up silt, minerals and mineral salts from the soil and rock in the river bed. Many other pollutants enter river water as it flows downstream, including animal waste, human sewage, agricultural runoff, urban runoff, industrial effluents, and mining effluents, due to which unfortunately, most of the rivers are facing pollution problem or under threat of pollution *(M. M. Khan et al.; 2009).* Water quality degradation also leads to increased conflict between downstream and upstream users.

As this paper relates a case study of Kolhapur city which is located on the bank of Panchaganga river which is the main source of water. Increased developmental activities due to urbanization and industrialization are greatly responsible for water pollution in Kolhapur city. The estimated municipal wastewater is to the tune of 90 Million Liters per Day (MLD) which reaches the river Panchaganga through two natural nallahs, namely Jayanti nallah and Dudhali nallah. The discharge locations are about 500 m upstream the Bawada water works which supplies more than 50 percent of municipal water to the city. *(MPCB Report; 2005-06, S. K. Deshmukh et al.; 2001).* Due to the water pollution, there is a problem of adequate supply of potable water. Water pollution has created serious impact on human life due to various water borne diseases leads to decreased food intake and nutrient absorption, malnutrition, reduced resistance to infection, and impaired physical growth and cognitive development Thus it is worthwhile to assess the quality of the Panchaganga river water to study its possible environmental impacts.

II. STUDY AREA

Kolhapur city is located at 16° 42' N and 74° 14' E, having mean sea level of 570 m, stands on rising ground on the south bank of the river Panchaganga. The river Bhogawati is renamed as Panchaganga from Prayag Chikhali, after the confluence with 5 rivers namely Kumbhi, Kasari, Tulshi, Dhamani and Bhogawati. The river flows towards south-north side and meets river Krishna at Narsinhwadi, Tal: Shirol, Dist: Kolhapur. The entire catchment area of Panchaganga river lies in Kolhapur district *(Study Report on Panchaganga River)*. Kolhapur city is subjected to recurring outbreaks of water borne diseases and epidemics like, hepatitis and gastrointestinal diseases. This is due to the fact that pollution of Panchaganga river is one of the most important and burning problem till date.

Panchaganga river gets polluted by the discharge of the municipal and industrial wastewater through various nallahs viz. Jayanti nallah (49 MLD), Dudhali nallah (17 MLD), Bapat Camp nallah (10 MLD) and Line Bazaar nallah (6 MLD). There is no underground drainage in the city and drainage is mainly by surface drains. The drains are let into the Jayanti nallah and the Panchaganga river. Municipal water supply to Kolhapur city is through two sources viz, Balinga water works having a capacity of 41 MLD and Kasaba Bawada water works with a capacity of 36 MLD. This supply is augmented by 2 MLD from Kalamba water works as well as from ground water supply through private bore wells. Consequently residents of Kolhapur city are anguished by the constant threat of outbreaks of epidemics *(MPCB Report; 2005-06)*. Thus it is worthwhile to assess the quality of the Panchaganga river water to study its possible environmental impacts.

Sampling of water from Panchaganga river at selected 4 stations is being done on a weekly basis. Manual method of sample collection is preferred considering all site conditions. Station-1 is located near Balinga pumping station (Nagdevwadi) upstream of river, away from city; Station-2 is located near Mahadev temple, Shivaji pool naka which is 15 km downstream of Station-1. Station-3 is located near Kasaba Bawada 8 km downstream of Station-2. This site receives effluents from large number of small scale industrial units situated at Shivaji Udyam nagar. Large stream carrying city sewage namely Jayanti nallah, which pass through the central areas of the city, and is discharged into Station-3 and Station-4, is located near NH-4 Highway Bridge (Shiroli naka). This site receives industrial waste from MIDC, Shiroli and civic population. *(Smita Kabir Mulani et al.; 2009)*

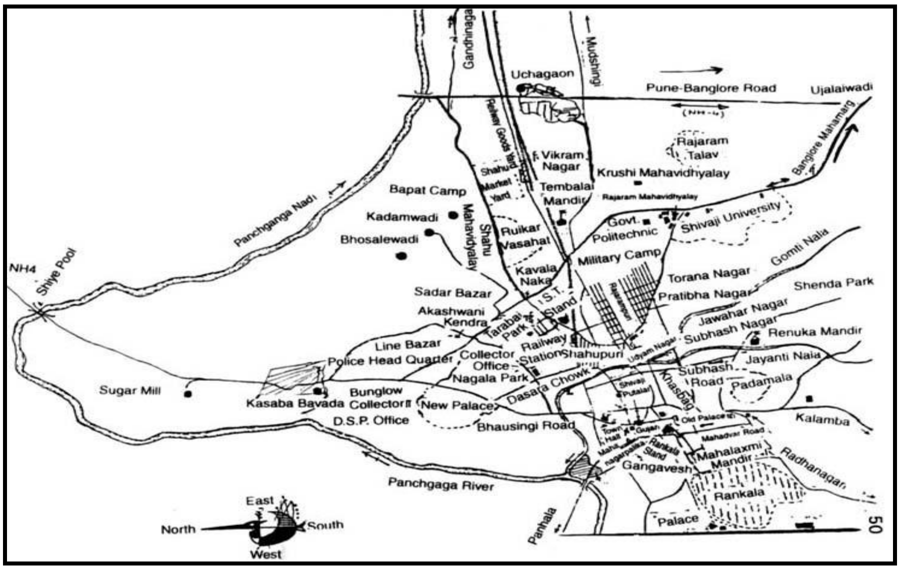

Fig. 1. Map of Kolhapur city

III. MATERIALS AND METHODS

In Kolhapur city the total quantity of water used is about 120 MLD. The estimated municipal wastewater for Kolhapur city is approximately 90 MLD. The Kolhapur Municipal Corporation (KMC) has provided primary treatment of the capacity 43.5 MLD. It is observed that about 50% effluent is directly used for irrigation by the farmers and 10% evaporation losses and 10% percolation losses. There is no underground drainage in the city and drainage is mainly by surface drains. Drainage of 'A' and 'D' wards is mainly let into Panchaganga river. Drainage of Shahupuri, Rajarampuri, Laxmipuri, Khasbag, 'C' Ward and 'B' Ward is mainly let into Jayanti nallah having capacity of 49 MLD which is the main source of Panchaganga river pollution. *(MPCB report; 2008-09, KMC Report 2008-09, S.K.Deshmukh et al.; 2001).*

In order to assess the impact of Jayanti nallah on Panchaganga river water quality four stations are selected and 4 river water samples are collected for the laboratory analysis and water quality assessment is carried out. In the present work correlation-regression study is used and correlation coefficients (R) are determined using correlation matrix to identify the highly correlated water quality parameters. The correlations among 8 water quality parameters are determined for each station and are shown in Tables 2 to 5. Each table gives 36 pairs of parameters out of which 7 pairs of parameters are selected having significant correlation coefficient (R) and regression models are developed namely: RGMS-1, RGMS-2, RGMS-3 and RGMS-4 for the four different stations. The correlation coefficients are determined to identify the highly correlated and interrelated water quality parameters and the linear regression equations are developed for the pairs having strong correlation and also for the pair of parameters, which have influence on each other. Then from these linear regression equations non-linear regression equations relating these identified parameters are formulated. Hence, the regression models developed can provide a mean for easier and faster monitoring of water quality in a location with the help of regression equations. The correlation study and correlation coefficient values can help in selecting the treatments to minimize contaminants in river water.

Table 1: Coefficient of Variation (CV %) for the river water samples

Parameter	**Desirable Limit as per IS-10500,(1991)**	**Station-1**		**Station-2**		**Station-3**		**Station-4**	
		Mean	**CV %**	**Mean**	**CV %**	**Mean**	**CV %**	**Mean**	**CV %**
Temperature ^{o}C	Maximum 40 ^{o}C	33.75	8.54	32.80	8.6	34.25	6.89	34.05	6.84
pH	6.5-8.5	6.38	11.66	7.29	7.23	7.36	8.63	7.44	6.18
EC µmhos/cm	---	411.99	40.24	409.56	43.17	458.31	30.77	466.94	32.61
TDS mg/l	Maximum 500 mg/l	225.05	47.8	202.25	42.59	198.05	26.22	155.30	48.03
Turbidity NTU	25 NTU	7.18	27.5	7.68	17.12	10.83	35.88	12.79	47.29
DO mg/l	Minimum 5.0 mg/l	5.75	8.74	6.22	14.21	5.78	14.26	4.92	23.18
BOD mg/l	Maximum 3.0 mg/l	3.75	17.32	6.64	20.19	6.84	17.71	8.16	17.34
COD mg/l	Maximum 10 mg/l	37.40	27.49	18.55	12.18	22.53	16.99	18.70	15.14

(Source: S. K. Maithi; "Handbook on Water and Wastewater Analysis", Maharashtra Pollution Control Board)

Table 2: Correlation Coefficients for station-1 (RGMS-1)

	log Temp	**log pH**	**log EC**	**log TDS**	**log Turbidity**	**log DO**	**log BOD**	**log COD**
log Temp	1							
log pH	**0.626**	1						
log EC	0.287	0.100	1					
log TDS	0.257	0.047	**0.917**	1				
log Turbidity	0.312	0.328	0.259	**0.785**	1			
log DO	**0.421**	**0.348**	0.062	0.007	0.217	1		
log BOD	0.096	0.318	-0.075	-0.169	0.191	**0.530**	1	
log COD	-0.005	0.286	-0.051	-0.150	0.083	0.257	**0.701**	1

Table 3: Correlation Coefficients for station-2 (RGMS-2)

	log Temp	log pH	log EC	log TDS	log Turbidity	log DO	log BOD	log COD
log Temp	1							
log pH	**0.509**	1						
log EC	0.069	0.012	1					
log TDS	0.117	0.032	**0.842**	1				
log Turbidity	0.065	-0.213	0.329	**0.673**	1			
log DO	**0.483**	**0.652**	0.116	0.111	0.095	1		
log BOD	0.340	0.407	-0.016	0.100	0.181	**0.634**	1	
log COD	0.076	-0.084	-0.281	-0.341	-0.131	-0.042	**-0.403**	1

Table 4: Correlation Coefficients for station-3 (RGMS-3)

	log Temp	log pH	log EC	log TDS	log Turbidity	log DO	log BOD	log COD
log Temp	1							
log pH	**0.785**	1						
log EC	0.133	0.278	1					
log TDS	0.281	0.292	**0.553**	1				
log Turbidity	0.416	0.319	0.181	**0.749**	1			
log DO	**0.743**	**0.542**	0.036	0.254	0.422	1		
log BOD	-0.335	-0.415	-0.194	-0.029	-0.055	**-0.741**	1	
log COD	-0.316	-0.254	-0.089	0.117	0.046	-0.399	**0.684**	1

Table 5: Correlation Coefficients for station-4 (RGMS-4)

	log Temp	log pH	log EC	log TDS	log Turbidity	log DO	log BOD	log COD
log Temp	1							
log pH	**0.864**	1						
log EC	0.315	0.192	1					
log TDS	0.356	0.189	**0.737**	1				
log Turbidity	0.313	0.157	0.281	**0.847**	1			
log DO	**0.586**	**0.668**	-0.183	-0.082	0.041	1		
log BOD	-0.377	-0.387	0.246	0.037	-0.016	**-0.702**	1	
log COD	-0.376	-0.379	0.008	-0.207	-0.075	-0.410	**0.636**	1

Table 6: Regression equations for station-1 (RGMS-1)

Pair of Parameters	**Correlation Coefficient**	**Regression Coefficients**		**Non-Linear Regression Equation**
	R	**A**	**B**	
Temp-pH	0.626	-0.497	0.8508	pH = 0.3184 $Temp^{0.8508}$
pH-DO	0.348	0.5468	0.2629	DO = 3.5220 $pH^{0.2629}$
EC-TDS	0.917	-0.1471	0.9527	TDS = 0.7127 $EC^{0.9527}$
TDS-Turbidity	0.785	-0.3247	0.5039	Turbidity = 0.4735 $TDS^{0.5039}$
Temp-DO	0.421	0.0977	0.4323	DO = 1.2524 log $Temp^{0.4323}$
DO-BOD	0.530	-0.2564	1.0867	BOD = 0.5541 $DO^{1.0867}$
BOD-COD	0.701	0.9171	1.1276	COD = 8.2623 $BOD^{1.1276}$

Table 7: Regression equations for station-2 (RGMS-2)

Pair of Parameters	Correlation Coefficient R	Regression Coefficients A	Regression Coefficients B	Non-Linear Regression Equation
Temp-pH	0.509	0.1994	0.4373	$pH = 1.5827\ Temp^{0.4373}$
pH-DO	0.652	-0.3176	1.285	$DO = 0.4813\ pH^{1.2850}$
EC-TDS	0.842	0.0377	0.8659	$TDS= 1.0907\ EC^{0.8659}$
TDS-Turbidity	0.673	0.291	0.2594	$Turbidity = 1.9543\ TDS^{0.2594}$
Temp-DO	0.483	-0.4514	0.8195	$DO = 0.3537\ Temp^{0.8195}$
DO-BOD	0.634	0.1198	0.8791	$BOD = 1.3176\ DO^{0.8791}$
BOD-COD	0.403	1.4711	-0.253	$COD = 29.5869\ BOD^{-0.2530}$

Table 8: Regression equations for station-3 (RGMS-3)

Pair of Parameters	Correlation Coefficient R	Regression Coefficients A	Regression Coefficients B	Non-Linear Regression Equation
Temp-pH	0.785	-0.6572	0.9925	$pH = 0.2201\ Temp^{0.9925}$
pH-DO	0.542	-0.042	0.9238	$DO = 0.9078\ pH^{0.9238}$
EC-TDS	0.553	0.8823	0.5292	$TDS = 7.6261\ EC^{0.5292}$
TDS-Turbidity	0.749	-0.869	0.8245	$Turbidity = 0.1352\ TDS^{0.8245}$
Temp-DO	0.743	-1.7008	1.6026	$DO = 0.0199\ Temp^{1.6026}$
DO-BOD	0.741	1.455	-0.8273	$BOD = 28.5102\ DO^{-0.8273}$
BOD-COD	0.684	0.7728	0.6926	$COD = 5.9265\ BOD^{0.6926}$

Table 9: Regression equations for station-4 (RGMS-4)

Pair of Parameters	Correlation Coefficient R	Regression Coefficients A	Regression Coefficients B	Non-Linear Regression Equation
Temp-pH	0.8644	-0.3139	0.7735	$pH = 0.4854\ Temp^{0.7735}$
pH-DO	0.6684	-1.5151	2.5226	$DO = 0.0305\ pH^{2.5226}$
EC-TDS	0.7370	-0.6953	1.0712	$TDS = 0.2017\ EC^{1.0712}$
TDS-Turbidity	0.8473	-0.4495	0.7084	$Turbidity = 0.3552\ TDS^{0.7084}$
Temp-DO	0.5858	-2.3483	1.9783	$DO = 0.0045\ Temp^{1.9783}$
DO-BOD	0.7018	1.2564	-0.5154	$BOD = 18.0468\ DO^{-0.5154}$
BOD-COD	0.6365	0.744	0.5775	$COD = 5.5463\ BOD^{0.5775}$

Table 10: P-Value and F-Value test results for the river water sampling stations

Pair of Parameters	Station-1		Station-2		Station-3		Station-4	
	P-Value	F-Value	P-Value	F-Value	P-Value	F-Value	P-Value	F-Value
Temp-pH	0.00318	11.5707	0.02204	6.2786	$4.103E^{-05}$	28.9522	$8.90E^{-07}$	53.2045
pH-DO	0.13234	2.4852	0.00185	13.2898	0.01366	7.4684	0.00127	14.5369
EC-TDS	$1.324E^{-08}$	94.9893	0.000003	43.6773	0.011366	7.9462	0.00021	21.4077
TDS-Turbidity	$4.097E^{-05}$	28.9596	0.00116	14.8737	0.000144	23.0296	$2.43E^{-06}$	45.8161
Temp-DO	0.06451	3.8780	0.03086	5.4860	0.000173	22.2178	0.00665	9.4034
DO-BOD	0.01615	7.0439	0.00268	12.1020	0.000186	21.9213	0.00056	17.4742
BOD-COD	0.00057	17.4345	0.07827	3.4858	0.000892	15.7841	0.00255	12.2576

IV. RESULTS AND DISCUSSION

The mean values of the water quality parameters at four different stations with their desirable limits as per IS 10500, (1991) and coefficient of variation (CV %) obtained in the statistical analysis is shown in Table 1 *(S. K. Maithi; "Handbook on Water and Wastewater Analysis", MPCB)*. It is observed that for Station-1 all the selected pairs of parameters are having positive correlation coefficient (R). Out of remaining pairs negative R is found in 5 cases as shown in Table 2. The pairs having less R are poorly correlated for which the results are not significant. Then the regression analysis is done and the regression equations hence obtained for Station-1 are shown in Table 6. It is observed that for Station-2 all the selected pairs of parameters are having positive R except (log BOD–log COD) which is having negative R. Out of remaining pairs negative correlation is found in 8 cases as shown in Table 3. The regression equations obtained for Station-2 are shown in Table 7. It is observed that for Station-3 all the selected pairs of parameters are having positive R except (log DO–log BOD) which is having negative R. Out of remaining pairs negative correlation is found in 10 cases as shown in Table 4. The regression equations obtained for Station-3 are shown in Table 8. It is observed that for Station-4 all the selected pairs of parameters are having positive R except (log DO–log BOD) which is having negative R. Out of remaining pairs negative correlation is found in 11 cases as shown in Table 5. The regression equations obtained for Station-4 are shown in Table 9. This is mainly due to regular addition of domestic and industrial wastewater into the river Panchaganga at the selected sampling stations through various sources.

Since there is still variability in the data, the value in parenthesis, called the "P-value" for a particular parameter, gives the probability that the parameter is as high (or low) as the parameter estimate simply by chance. A very low P-value (say<= 0.05) means that we have a great deal of confidence that the coefficient is truly different from zero. A high P-value suggests that the true value of the parameter may be zero and therefore, its associated variable may have no effect. In order to test the joint effects of several independent variables, without necessarily taking the separate effects of each variable into account, F-test can be used for this purpose. In the present study "F-test" is used to test the overall significance of a regression equation. F-test is the ratio of two scaled sums of squares reflecting different sources of variability.

The numerical values of R, P-values and F-values are tabulated in Table 10. It is observed from Table 10 that for Station-1 the P-values for (pH–DO) and (Temperature–DO) are 0.13233 and 0.06451 respectively; whereas for Station-2 the P-value for (BOD-COD) is 0.07827, which are more than 0.05. The F-test revealed that the calculated F-values for Station-1 for (pH–DO) and (Temperature–DO) are 2.4852 and 3.8780 respectively and for Station-2 the calculated F-value for (BOD-COD) is 3.4858, which are less than the tabulated F-value (i.e. 4.4139) for the available degree of freedom. These values revealed that the above 3 pairs of parameters are not having significant results and hence not considered in further analysis. The P-values and F-values for Station-3 and 4 revealed that all the pairs are having significant results and hence are considered for the further analysis.

V. CONCLUSION

The present study is aimed to develop a water quality prediction model for which the Correlation-Regression study is carried out for the four different stations at Panchaganga river, where the water samples are collected and analyzed in the laboratory. To assess the environmental impacts on the river water quality the study is carried out and the results are been discussed in 'Results and Discussion'.

From the results of present investigation it is concluded that:

1. Due to non-availability of the adequate land and full-fledged treatment facilities, large quantity of agricultural, municipal and industrial wastewater enters into river Panchaganga through Jayanti nallah which deteriorate the quality of river water.
2. There is a decreasing trend in Dissolved Oxygen (DO) level which is mainly due to the presence of oxygen depleting substances that reduces the available DO.
3. There is a gradual increase in the Biochemical Oxygen Demand (BOD) from upstream to downstream.
4. The correlation analysis and 'coefficient of variation (CV %)'on water quality parameters revealed that all parameters are more or less correlated with each other.
5. The different water quality characteristics are calculated by developing regression equations and are compared with the observed values. This study revealed that there is a variation in the values but the trend is same as that of the observed values.
6. As shown in the Table 10, the 'P-Tests' and 'F-Tests' for regression models revealed that the pair of parameters (pH-DO) and (Temperature-DO) for station-1 and (BOD-COD) for station-2 are not confirming to these tests and hence are not considered in further study, whereas all other pairs are accepted for the further analysis.
7. The Correlation-Regression study provides a mean for easier and faster monitoring of water quality at the location and to predict the various water quality parameters.
8. The study also helps in selecting the treatments to minimize contaminants in river water.

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