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Interrelationships between Physicochemical Water Pollution Indicators: A Case Study of River Pandu

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***Abstract*—**Water samples were collected from river Pandu at six stations where human and animal activities were high. Composite samples were analyzed for dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD) , pH values during dry and wet seasons as well as the harmattan period. The total data points were used to establish relationships between the parameters and data were also subjected to statistical analysis and expressed as mean ± standard error of mean (SEM) at a level of significance of $p<0.05$. Regression analysis was carried out to establish relationships if any between studied parameters and relationships in form of scatter plots were obtained between DO/BOD, COD/DO, BOD/COD, COD/pH, BOD/pH and DO/pH. The high to moderate correlation coefficient observed, R^2 ranged from 0.68 to 0.15 between these parameters.

***Keywords*—**BOD, DO, COD, pH, Regression analysis.

I. INTRODUCTION

RIVER Pandu a small perennial tributary of the river Ganga owes its origin from the pumped storage of the Lower Ganga canal approximately 110 Kilometers north-west of Kanpur. It flows on the southern out-skirt of Kanpur through Panki Industrial Estate [PIE] covering a distance of about 64 kms, before its confluence with river Ganga in south-west of Kanpur in Fatehpur district. During its course through Kanpur, five major drains carrying sullage water, sewage and industrial wastes discharge their wastes into it. While passing through Panki Industrial Estate (PIE), it receives effluents from diverse industries located in that area, mainly Panki Thermal Power Plant [PTPP], fertilizer unit of Duncans Industries Limited (D.I.L.): Ordinance Factory, Small Arms Factory, Lohia Machines Ltd [LML] and various other small industries, manufacturing chemicals, synthetic dyes etc. Waste effluents from these industrial units are likely to contain heavy metals, urea, acid-paint residues and pesticides etc producing undesirable deleterious effects on the river-ecosystem.

Mathematical modelling has become increasingly popular in recent years [1]. The aim of this study is to determine the levels of some pollution indicators and to study the statistical relationships between them. Among modelling approaches, multiple regression models (MRMs) have intermediate complexity. This approach has been used widely [2]. A MRM aims to estimate a single variable by means of a set of other explanatory variables. The scatter plots differ from one pollutant to another and from one model to another. Different model and different pollutant means different modelling errors.

Regression equations will also be established in a view to providing an idea on the levels of pollution by the parameters investigated and possibly proffering a preventive measure [3]. Moreover, regression equations can be designed which will provide a simple and precise means of interpreting results leading to satisfactory findings [4].

II. METHOD AND MATERIALS

Waste effluents from drains, and algal and water samples from six selected stations of the river were periodically collected as per standard procedure covering the entire stretch of the river passing through Kanpur. Samples were invariably collected from the proper mixing zones. Random sampling was done at each station and the samples were then compounded to get a composite sample. Physical and Chemical analysis of the samples has been done as per Standard procedure prescribed by American Public Health Association [5].

Temperature: Recorded by centigrade thermometer. Transparency: It has been measured by using Secchi disc of 20 cm diameter and has been expressed in cms. Hydrogen Ion Concentration (pH) has been estimated on the sampling stations itself by B.D.H. universal indicator and in the laboratory with the help of electronic pH meter. Dissolved Oxygen (D.O) has been estimated by Winkler's Azide modification method [5]. Bio-Chemical Oxygen Demand ($B.O.D_5$) has been estimated as the difference of sample's initial D.O. and sample's D.O. after 5 days incubation at 20 ° C in a B.O.D. incubator. Dilution technique and seeding technique has also been applied at times for assessing the B.O.D. of grossly polluted samples. Chemical Oxygen Demand (C.O.D.) has been estimated by open reflux method [5]. Total Hardness (T.H.) has been estimated by E.D.T.A. [Ethylene: amine tetraacetic acid] Titrimetrc method.

Polynomial regression attempts to model the relationship between two variables by fitting a linear equation to observed data. One variable is considered to be an explanatory variable,

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and the other is considered to be a dependent variable [6]. Moreover simple linear regression line has an equation of the form Y = a + bX, where **X** is the explanatory variable and **Y** is the dependent variable. The slope of the line is b, and a is the intercept (the value of y when x = 0)

III. Results and Discussion

The results of the analysis for all the parameters used as test data are presented in Table I& II and relationships between the parameters in form of scatter plots are shown in Fig. 1(a-f). The periodic fluctuations in DO, BOD, COD and pH values are depicted in Fig. 2 (a-d). The regression analysis carried out to relate DO, BOD, COD and pH values. The high to moderate correlation coefficient observed, R^2 ranged from 0.68 to 0.15 between these parameters as reported by [7] for Gagan river. Significant Interrelationships were observed between DO and BOD indicators where reliable correlations were established using regression analysis as observed by [8].

A. *Temperature* ranged from 17.5°C to 33.0°C and was well within the bio-kinetic range and as such temperature variations had no direct impact on the aquatic organisms due to their wide temperature tolerance. At high temperature, microbial activity is enhanced leading to rapid oxygen consumption and thereby decline in dissolved oxygen content of the river. This obviously is the reason for reported low dissolved oxygen content of the river especially at stations-2 to 5, which receive different proportion of wastes. Higher temperature at polluted stations as has been reported in the present study is in concordance with the findings of [9],[10] and may be attributed to a lot of chemical activities as a result of waste discharge into the river.

B. Transparency ranged from 1 cm to 36 cms, minimum at station-2 and maximum at station-6. It was virtually nil during monsoon, high in winters and low in summers. During monsoon high precipitation, high water velocity and turbulence resulted in turbidity due to high concentration of suspended soil particles, which flowed into the river as run-off water from the surrounding catchments area. Low transparency during summer may be attributed to lesser dilution and enhanced algal population.

C. *Total Solids* high concentration of total solids in water is undesirable as it reduces euphotic zone, light penetration, transparency and thus interferes with plankton community and primary productivity of the river and creates imbalance for aquatic life. In the present study, their least concentration has been noticed at station-1 while maximum at station-2 receiving fly ash rich effluents from PTPP drain. In general, low values have been recorded at stations-1, 5 and 6 as compared to stations-2, 3 and 4, which receive huge quantities of wastes.

D. pH of the river water ranged from 6.9 to 9.3 maintaining a high buffering capacity. In natural waters, pH usually ranges from 6 to 9. Lethal effects of most acids appear below pH 5 and those of alkali near pH 9.5. In general, pH was higher in summers than in winters or rains. High pH of water in the summer may be attributed to the utilization of free carbon dioxide in algal photosynthesis resulting in high algal population.

E. Dissolved Oxygen (Do) concentration ranged from nil to 8.2 mg^{-1}. The maximum value has been recorded at station-1 and its concentration declined to nil twice at station-3 in August and May. Many workers [11],[10] who have assessed the dissolved oxygen in diverse Indian rivers, reported low dissolved oxygen in the polluted stretches of the rivers studied by them. Similar observation has been made in the present study. As regard the periodic fluctuation, dissolved oxygen was maximum in winters when temperature as well as microbial activity was low and minimum in summers, when temperature as well as the microbial activity enhanced leading to its depletion. Similar results have been reported by [12] in Yamuna, [13] in Moosi, [14] in Ganga and [10] in river Pandu. In the present study: dissolved oxygen concentration has invariably been below the saturation level all through the entire stretch investigated and frequently fell below the prescribed limit of 4 mg^{-1} [15] during summer.

F. Biochemical Oxygen Demand (Bod) values ranged from 10 mg^{-1} to 80.6 mg^{-1}. Maximum value has been noticed at station-3 and lowest at station-1. As all the major drain discharges their wastes into the river in between station-1 to 4, therefore low dissolved oxygen and high B.O.D. values, as has been reported in the stretch of the river, are not paradoxical. The continuous addition of industrial and municipal wastes beyond the assimilating capacity of the river rendered the entire stretch of the river passing through Kanpur grossly polluted and river could not regain its original upstream water quality till last station-6.

In general, BOD was higher in rains, low in winters but maximum in summers. Reference [16] noticed high BOD values in springs and summers and attributed them to short heavy bursts of rainfall, which washed biodegradable wastes into the river along with runoff water from the catchments area. The same explanation may be held for high BOD values obtained during monsoon in the present study.

G. Chemical Oxygen Demand (Cod) in the river water varied with the nature and amount of the waste discharged into it. It ranged from 12.6 mg^{-1} to 543.6 mg^{-1}. In general, high values have been recorded at downstream stations 2 to 5 and may be attributed to the presence of readily oxidizable organic matter in the industrial effluents that are discharged into the river through drains, which also carry community sewage. No definite trend could be noticed regarding the COD values which fluctuated widely.

H. Total Hardness

Hardness ranged from 440 mg^{-1} to 1552 mg^{-1}. Minimum value has been noticed at Station- 1 in September and maximum at station-4 in March. Reference [10] too reported high hardness values ranging from 402 mg^{-1} to 1556 mg^{-1} in the same river. No definite trend could be noticed regarding the appearance of peak, which appeared in different months at different stations. This may be attributed to the variable nature and amount of wastes discharged in proximity of different stations. United States Geological Survey (U.S.G.S.) has classified waters with hardness ranging from 0 to 60 mg $^{-1}$ as soft; 61 to 120 mg $^{-1}$ as moderately hard; 121 to 180 mg^{-1} as hard and with values exceeding 180 mg^{-1} as very hard. Present values indicate that river water is very hard and the higher limit has exceeded the prescribed limit of hardness by ISI [15].

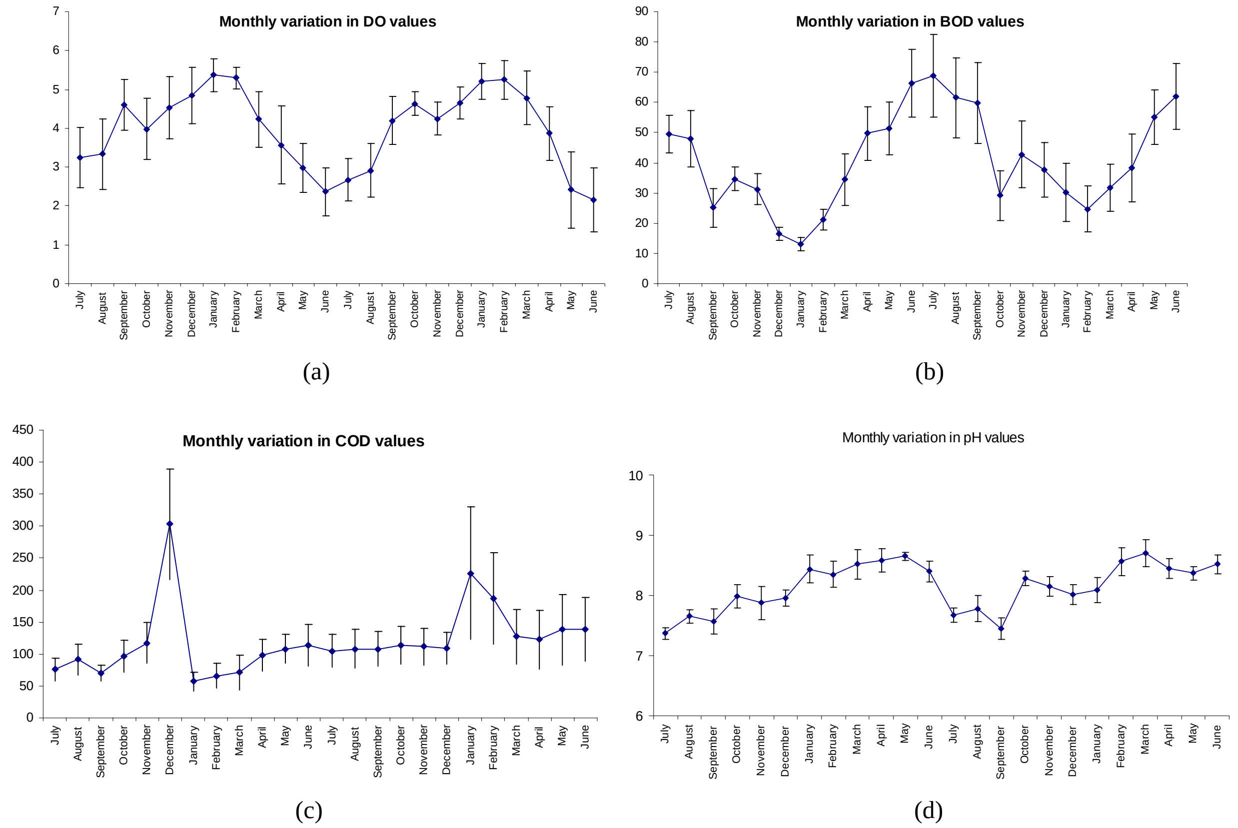
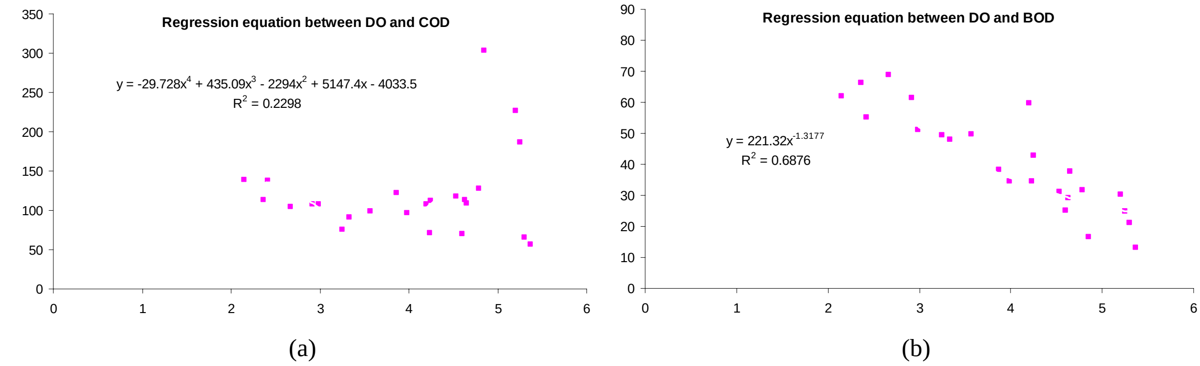
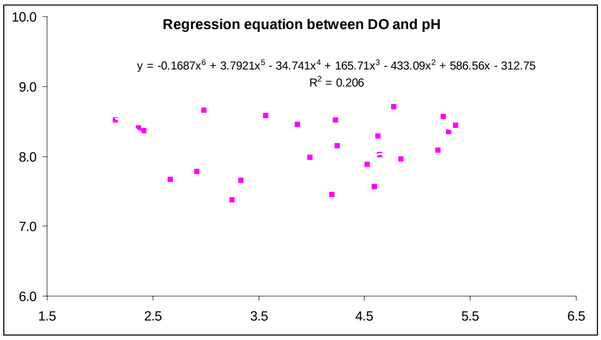
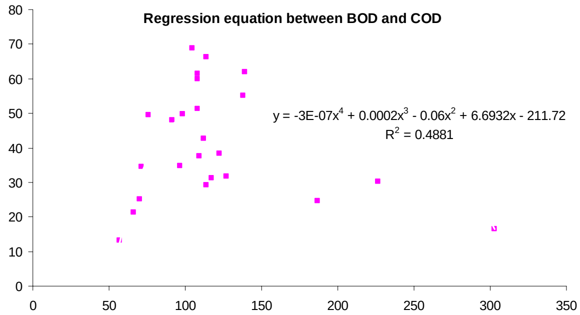


Fig. 1 Periodic fluctuations in DO, BOD, COD and pH values

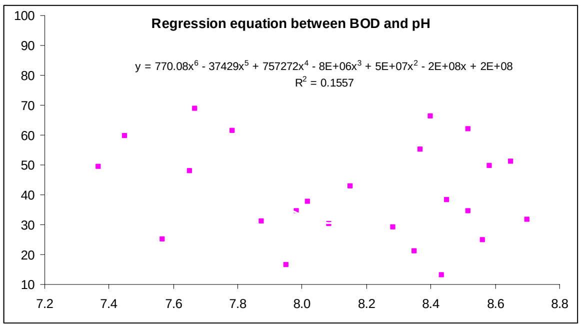




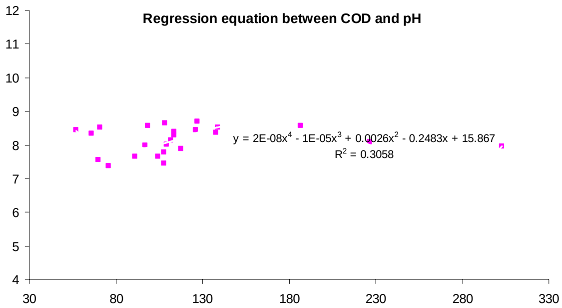
(c)



(d)



(e)



(f)

Fig. 2 Regression analysis of DO, BOD, COD and pH values

TABLE I
ESTIMATED LEVELS OF DO, BOD, COD AND PH VALUES (MEAN + SEM)AT DIFFERENT STATIONS

	DO		BOD		COD		pH	
Station 1	5.20	0.23	20.56	1.45	19.35	0.90	7.82	0.09
Station 2	2.61	0.28	38.80	2.90	222.40	27.64	8.26	0.14
Station 3	3.00	0.33	44.80	4.52	164.58	24.04	8.14	0.13
Station 4	4.04	0.29	65.62	6.56	143.64	12.44	8.33	0.11
Station 5	3.48	0.33	44.18	4.46	98.02	9.68	8.08	0.09
Station 6	5.52	0.16	31.87	3.74	67.93	5.87	8.22	0.09

TABLE II
RANGE OF WATER QUALITY PARAMETERS AT STATIONS

	Station1		Station 2		Station 3		Station 4		Station 5		Station 6	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Temperature	17.5	30	20.7	33	18	30.4	19.8	32.8	18.4	30.6	19.8	32
Transparency	6.0	32	1.0	8.0	1.5	21	2.0	14	5.0	25	2.0	36
Total solids	104	142	800	1200	300	900	500	1200	200	600	200	780
Total hardness	440	1041	513.3	1238	456	1220	430	1552	527	997	401	900

IV. CONCLUSION

Interrelationships were established between some physicochemical water pollution indicators where reliable correlations were established using regression analysis. This indicates the reliability of the relationships which suggests that it can be used to predict the levels of pollution by the parameters investigated and possibly offering a preventive measure prior in pollution monitoring system.

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