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HYDROCHEMICAL STUDIES OF NATURAL WATERS OF UPPER HINDON BASIN, U.P.

S.B.Joshi[1], D.C. Singhal[1], A.K.Seth[2], R.P.Mathur[3] and B.B.S. Singhal[2]

ABSTRACT

The present work attempts to study the hydrochemical characteristics of surface water and ground water from the Upper Hindon River basin near Saharanpur town, Uttar Pradesh by principal component analysis and to compare the results with those obtained by conventional methods. A DO-BOD Model for multiphased data in a selected stretch of Upper Hindon River polluted by paper wastes has also been developed using a computer programme (DOSAG-I). The study has revealed contribution of organic matter and toxic metals released with the effluents discharged from the paper mill into the Hindon river system within the study area. Though the dissolved constituents in the natural waters are within the allowable limits, the low D.O. levels and high concentrations of cadmium and lead render the water unfit for drinking or fish culture in some stretches of the river, especially during summer months.

INTRODUCTION

The explosive population growth, development and industrialisation have contributed largely to increase in the demand of the water. Ninety six percent of water pollution problem in India is due to indiscriminate discharge of municipal wastes (Chaudhary, 1981). These wastes being biodegradable produce a series of directional but predictable changes in water bodies. Industrial effluents are responsible for pollution to a lesser extent but the effects produced by them may be more serious as nature is unable to assimilate them.

In order to maintain the desired water quality, the possible sources of its pollution are required to be identified and proper scientific methods for its abatement should be applied. In order to minimise the incoming wastes into the river systems some realistic programme for identification of pollution source and minimization of the pollution in the river system can be put into practice by conducting systematic studies.

The pollution of natural waters may be defined as an undesirable change in physical, chemical, physiological or biological characteristics of natural waters directly or indirectly related with the activities of human beings even by natural forces, which makes the water hazardous or harmful for its various uses, (Handa, 1983).

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1. Deptt. of Hydrology, University of Roorkee, Roorkee 247667
2. Deptt. of Earth Sciences, University of Roorkee, Roorkee-247667
3. Deptt. of Civil Engineering, University of Roorkee, Roorkee 247667

With a view to assess the quality of natural waters of Upper Hindon river basin, Saharanpur(Uttar Pradesh), a study was undertaken in which overall effects of disposal of major effluents into the drainage were assessed. In addition, the impact of a Paper mill effluent on the river waters has also been studied.

PRESENT STUDY

The area under present study is located in the Indo-gangetic plain and lies in the upper Hindon basin bounded between latitude 29°52' and 30°0' N and longitude 77°32' 30" and 77°37'15" E (Fig.1). The river stretch of interest is about 11 km. starting from the confluence of a drain carrying paper mill waste to Hindon river near village Pairagpur to just before the junction of Dhamola nalla with the Hindon river near village Sadauli Hariya.

The climate of the Hindon river basin in the area of interest is of moderate to subtropical monsoon type. Thus, the hydrometeorologic parameters like precipitation, temperature, pressure, wind velocity, relative humidity show well marked seasonal variations.

The Hindon river has four tributaries and sub tributaries named Pandhoi Nalla, Dhamola Nalla, Nagdeo Nalla, and Padli-Nalla (Fig. 1). The Hindon river is an ephemeral river in its upper portion and changes to a perennial stream near Behreki village (Fig.1). The river finally meets Yamuna River System near Okhla (Delhi).

In the vicinity of the town of Saharanpur, a variety of industries have come up such as those relating to paper, sugar food processing, dairy products, metal plating, lime and brick kilns, engineering and cottage industry products. In particular, the star paper mill and Indana Milk products factory are significant industries in the area (Fig.1).

Several underground lined drains with uncertain origins meet Dhamola Nalla at various points. Verma and Mathur(1971) have conducted studies on characteristics and pollutional effect of paper mill wastes on Hindon river. A significant amount of work has been on the studies of the pollution of Hindon river in relation to fish and fisheries by Verma, Shukla and Dalela (1980). They considered that quality wise the water of Hindon river is not suitable for propagation of fish culture and related aquatic life.

Goel (1983) has studied the pollutional effect of cadmium on natural waters in some parts of Uttar Pradesh in which he has reported a cadmium content of 1 microgram/litre in river Yamuna around Saharanpur area. Another study on pollution of natural waters by industrial waste effluents in some parts close to Hindon river has been conducted by Handa (1983, 1986), in which higher values of lithium, strontium, zinc, nitrates and **cadmium** have been reported, in Hindon river waters, and groundwater of the area. Adarsh Kumar(1983) has made an attempt to estimate the pollutional effect of lead in natural water in Uttar Pradesh. He has reported a concentration of 15 µ gm/ litre in Saharanpur area.

Patel(1985) has carried out hydrochemical studies of natural waters with reference to the waste effluents disposal in the upper Hindon basin in the Saharanpur area. A Dissolved Oxygen sag model, using streeter and Phelps equation, for a 6.5 km. stretch of the Hindon river starting from the confluence point between a paper effluent drain with Hindon river was developed.

Studies regarding the Hydrological Aspects of waste Disposal in Upper Hindon Basin, U.P. have been in progress since June, 1984 at University of Roorkee, Roorkee and two progress reports of the research work have been released. A research group in National Institute of Hydrology, Roorkee (1986) has attempted to analysis the water quality data given by Patel et al. (1985) for the month of April-May,1985 using DOSAG-I Programme.

PRINCIPAL COMPONENT ANALYSIS

Multivariate methods are extremely powerful as it allows the investigator to manipulate more variables then he can assimilate himself. However, multi-variate methods are complicated both in their theoretical structure and in their operational methodology.

The principal component analysis mainly consists of finding the principal components which are the eigen vectors of a variance - covariance matrix. Davis (1973) has described the methods to determine the eigen vectors and eigen values from a small matrix of coordinates of points in space.

Physically, we can think of two points represented by a 2x2 matrix as lying on the boundary of an ellipse whose centre is the origin of the coordinate system. The ellipse is in effect an envelope which just encloses these two points. The eigen values represent the length of the major and minor axis of the ellipse. The slopes of the major and minor axes of the ellipse can be equated to the eigen vectors.

In the present study,the principal component analysis has been carried out for the 13 month chemical analysis data for the ground and surface water of the Upper Hindon Basin with an objective to determine the dominant ions (variables) with their respective contribution to the chemical quality of water. The computer program used is taken from Davis (1973). The respective contribution of each of the variables to the chemical character of the water sample can be easily ascertained from the results of above analysis.

DOSAG MODEL

In the present study attempt has also been made to compute parameters of the Streeter Phelps equation for a port of the upper Hindon basin. The parameters have been computed by using a computer programme (DOSAG-I) developed by Texas Water Development Board (1970). The experimental and field data for the season September/October, 1986 and January, 1987 of the study area have been used for the computation of the parameters of the Streeter Phelps equation. The river stretch considered for the development of DO Sag Model is from sampling location SW21 near village Santhagarh, just downstream of the confluence of paper mill drain to the Hindon river upto sampling location SW11, just upstream of the confluence of Dhamola Nalla with the Hindon river (Fig.1).

Computation of Parameters for Dissolved Oxygen SAG Model

The field data aquisition for developing the Dissolved Oxygen Sag Model of a part of the Upper Hindon basin (from SW9 to SW11, Figure 1) was planned considering the requirements of model calibration. In the study, sedimentation in the river was not considered and accordingly rate of BOD removal(K_r') was taken equivalent to deoxygenation coefficient(K_1'). Elaborate water sampling and analysis for enabling calculation of deoxygenation coefficient (K_1') and reaeration coefficient(K_2') carried out for the three seasons i.e. end of rainy season(September-October, 86), winters (January, 1987) and summers (July 87). The summarised data used in the computations are given in Table 1. It was observed that during July, the paper mill effluents were considerably reduced in quantity and no flows were recorded in some reaches of Hindon river down-stream of the confluence (SW21). This data could not be utilised in the studies. The computed and observed values of D.O. about the river stretch are shown in the Figure 2 and 3. The D.O. values computed for the months i.e. October 1986, January, February, 1987 do not show any sag in the dissolved oxygen concentration. But for the months of April, May, 1987 a slight sag in the DO value is noticeable. It is felt that no sag in DO curves is observed in winter months probably due to low temperature and increased post monsoon flows. However for summer months(April, May 1987), the sag is reflected due to low flows and high temperatures.

DISCUSSION OF RESULTS:

The results of principal component analysis of ground waters indicate that the major ions influencing its chemical composition are alkalinity and conductivity, Cd^{+2} and Phosphorous (in January, 1985), Cl^-, Cd^{+2} and Zn^{+2} (in April, 1985), conductivity and Zn^{+2} (in June, 1985), conductivity, zinc and phosphorous (in September, 1985) and conductivity and Cr^{+3} (in November, 1985).

However, these constituents with the exceptions of Cd^{+2}, Pb^{+2}, Cr^{+3} and Fe^{+2} are within tolerable limits as suggested by ICMR(1975) and WHO(1971).

The results of PCA of surface waters indicate that the major ions influencing its chemical composition are as under:

Month	Deminant ions
Nov., 1984	Alkalinity, D.O., No$_2^-$ Nitrogen
Jan., 1985	Conductivity, D.O., Cadmium
May, 1985	Conductivity, Cadmium, Phosphorous
Aug., 1985	Calcium, Iron, Chromium
Oct., 1985	Alkalies, COD, Phosphorous
Jan., 1986	Conductivity, Phosphorous, Lead
March, 1986	Zinc, D.O., Cadmium
May, 1986	Conductivity, Ammonical Nitrogen, D.O.

From the PCA, it was observed that D.O. levels during cooler months seem to be having higher influence while in the warmer months like May, the BOD/COD value shows rise in the concentration and the amount of D.O. has lesser influence. In general, the concentration of Cd^{+2}, is found to be high in the vicinity of location SW10.

Joshi(1987) reported a study of Piper trilinear plots for ground water that almost all ground water samples have alkaline earths and strong acids as dominant ions. Accordingly, the ground water has a chemical character with high non carbonate hardness (or secondary salinity). This finding is partially from results of PCA, as in Nov., 1984, and Aug., 1985. In other corroborated periods, the overall dissolved salts/EC have dominated the chemical character of the waters. However, the total salinity of the natural waters is within the limits allowed for drinking purposes (WHO, 1971; ICMR, 1975). The trace elements like Pb, Cd, Cr, Fe in the ground water are also having relatively high concentrations, especially in case of Cd^{+2} (Joshi, 1987). The permissible limits of Cd^{+2}, Cr^{+3}, Pb^{+2} and Fe^{+3} are 0.01, 0.05, 0.1 and 0.3 mg/l (ICMR, 1975) respectively.

As compared to the BOD, COD values observed in the past (Patel, 1985), the values of BOD, COD are generally lower in the surface waters probably due to the fact that pretreatment of effluents discharged from factories has started recently. Presence of NH$_4^+$, NO$_2^-$, NO$_3^-$ Nitrogen may indicate that nitrogeneous BOD may be present especially as seen from the unstable species of Nitrogen, like NH$_4^+$-N and NO$_2^-$-N.

Amongst non-conservative constituents, the five days BOD values in surface water show considerable variation. The tolerance limit of BOD in drinking waters is 2 mg/l (CBPCWP, 1979-80). It is seen that at most places BOD$_5$ values are higher than this limit indicating presence of organic waste effluents. Similarly the lower permissible limit of D.O. in drinking water is 6 mg/l, whereas at many of the sampling locations (like downstream of location SW9), the D.O. concentrations are lower than this value indicating severe depletion in D.O. levels of the surface waters.

The D.O. Sag models developed for different periods for the stretch downstream of location SW9 of Hindon river highlight the effect of paper mill waste on the quality of surface water in Hindon river. The D.O. Sag pattern obtained using DOSAG-I model indicates that there is generally low oxygen level observed for the warmer months. Thus, for these months (April-May, 1987), computed D.O. levels have noticeable Sags in the D.O. curves

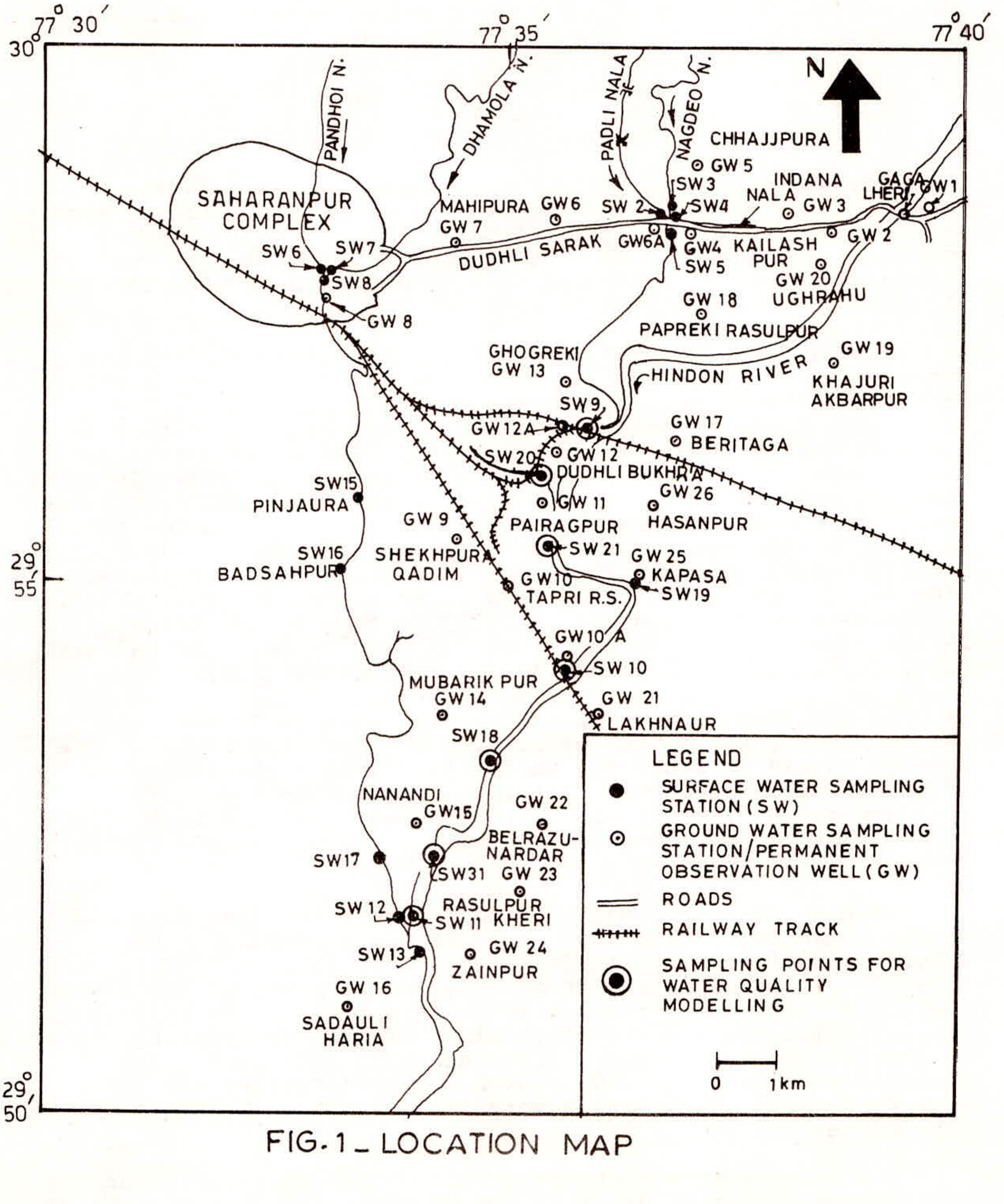

FIG. 1 _ LOCATION MAP

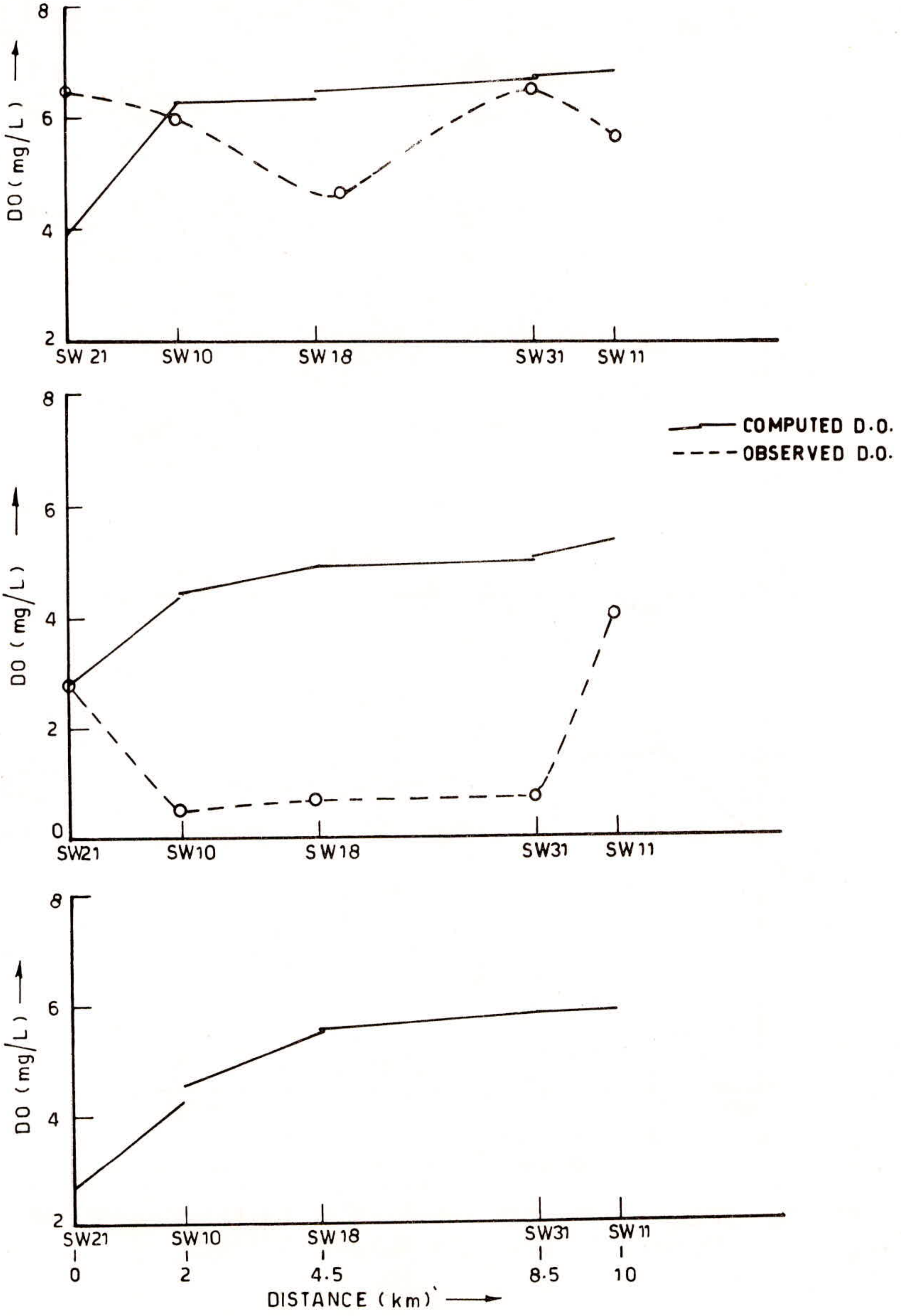

FIG. 2 – PLOTS OF DO PROFILES OBTAINED FROM DOSAG-I QUALITY ROUTING MODEL

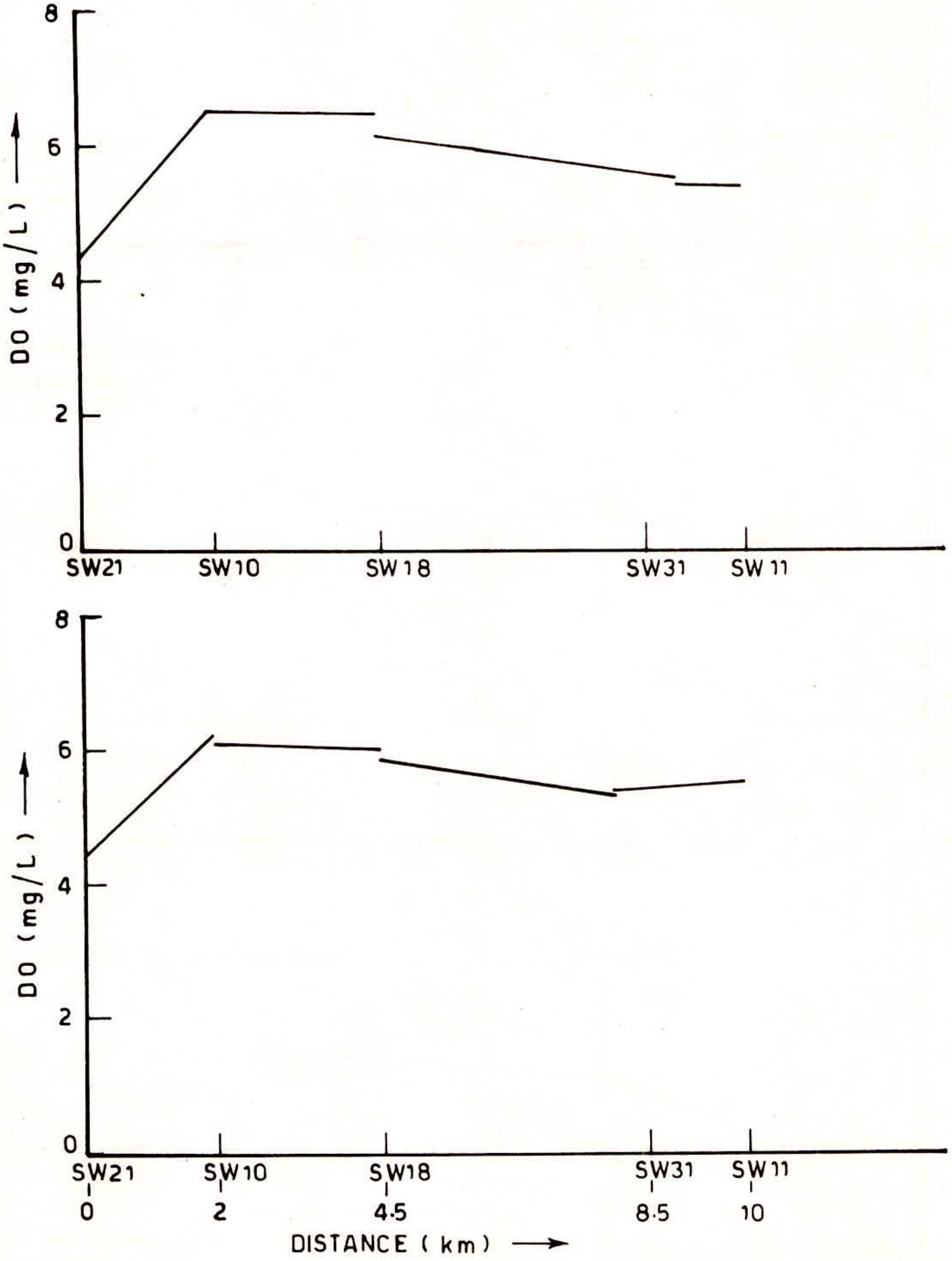

FIG. 3 _PLOTS OF DO PROFILES OBTAINED FROM DOSAG-I QUALITY ROUTING MODEL

TABLE 1: CALCULATION OF K'_2 VALUES

Sampling Location	Average depth (m)	Average Velocity (m^3/sec)	K'_2 (day^{-1})	D.O. Observed mgl^{-1}	K'_1 (day^{-1})
(1)	(2)	(3)	(4)	(5)	(6)
Oct.86					
SW21	0.185	0.2833	33.868	6.4	0.118
SW10	0.266	0.2125	17.012	6.0	-do-
SW18	0.285	0.2833	17.713	5.2	-do-
SW31	0.175	0.3188	39.046	6.5	-do-
SW11	0.208	0.3400	31.121	5.7	-do-
Jan.87					
SW21	0.272	0.2772	16.808	2.8	0.468
SW10	0.2133	0.2056	20.843	0.5	-do-
SW18	0.2600	0.2452	16.916	0.7	-do-
SW31	0.2566	0.2452	17.243	0.7	-do-
SW11	0.2843	0.6375	23.856	4.0	-do-
Feb.87					
SW21	0.256	0.1465	13.365	Not available	0.471
SW10	0.199	0.1545	20.114	-do-	-do-
SW18	0.229	0.3446	24.298	-do-	-do-
SW31	0.239	0.3643	23.432	-do-	-do-
SW11	--Not available--		23.432 (assumed)	-do-	-do-
Apr.87					
SW21	0.16	0.4553	49.716	Not Available	0.509
SW10	0.097	0.2656	80.270	-do-	-do-
SW18	0.217	0.3696	28.358	-do-	-do-
SW31	0.218	0.2833	24.658	-do-	-do-
SW11	--Not available-		24.658 (assumed)	-do-	-do-
May.87					
SW21	0.134	0.3643	62.102	-do-	0.584
SW10	0.07	0.696	102.403	-do-	-do-
SW18	0.229	0.3188	26.084	-do-	-do-
SW31	0.15	0.3148	48.900	-do-	-do-
SW11	0.195	0.3188	33.195	-do-	-do-

NOTE: Field temperature is considered constant for all the sampling locations down stream of the mixpoint and that is found by mass balance equation for the mix point.

TABLE 2:DETAILS OF RELEVANT PARAMETERS FOR DOSAG MODEL

Parameters	Oct. 86	Jan. 87	Feb. 87	Apr. 87	May. 87
(1) Discharge m^3/sec.					
SW9	0.4432	0.2869	0.2246	0.3344	0.2145
SW20	0.2382	0.3297	0.2805	0.1275	0.1913
SW21	0.6814	0.6785	0.3004	0.6193	0.5528
SW21(computed)	0.6814	0.6166	0.5051	0.4619	0.4058
(2) Temperature°C.					
SW9	32	22	23	27	29
SW20	29	30	29	31	33
SW21	31	21	30	31	32
SW21(Computed)	31	26.3	26.3	28	31
(3) D.O.mg/l					
SW9	5.0	5.3	-	-	-
SW20	0^{+}	0	-	-	-
SW21	6.4	2.8	-	-	-
SW21(Computed)	3.25	2.47	-	-	-
(4) BOD ultimate mg/l					
SW9	12	17	-	-	-
SW20	125^{+}	175.14^{+}	-	-	-
SW21	10.11^{+}	57.11^{+}	-	-	-
SW21(Computed)	51.50	101.50	-	-	-
(5) D.O.Saturated mg/l (C_s)					
SW21	7.51	8.99	-	-	-
SW21(Computed)	7.51	8.22	-	-	-
(6) DO Deficit DO= Cs-c mg/l					
SW21	1.11	6.19	-	-	-
SW21	4.22	5.75	-	-	-

$^{+}$ The discharge,temperature data for the paper mill drain not available are computed considering the observed value for the mix point.

$^{+}$ The B.O.D. ultimate values for paper mill drain and mix point are not available but BOD at 5 day is available. Using the K_1 calculated by Patel (1985) for these location the BOD ultimate values are calculated with available BOD 5 days values.

around the sampling points SW31 (Fig.**2,3**), but for other month the amount of SAG is negligible. The value of computed D.O. continues to rise for some distance downstream of the confluence point (SW21) indicating thereby the incomplete mixing conditions at this point.

The divergence between the D.O. observed and D.O. computed (Fig.**2,3**)**can** be explained due to benthic sludge demand, photosynthetic activity, Nitrogeneous BOD, errors in extrapolation in the BOD curves for estimating $BOD_u (L_o)$, insufficient calibration of the model, and assumption of uniform K_1' and BOD ultimate values for whole studied stretch of the river.

In some reaches (around location SW10) of Hindon river, the observed D.O., values are very low (close to zero) and are associated with the higher BOD values indicating septic condition in these reaches which is also supported by the foul gases (resembling H_2S, CH_4 etc.) and nuisance smells in these areas. These facts altogether reflect the degradation of water quality of the Hindon river due to mixing of industrial waste.

RECOMMENDATIONS AND FURTHER RESEARCH NEEDS

The D.O.Sag models should be developed for the area considering the effects of photosynthesis, benthic sludge demand, and should be calibrated with observed data. If necessary, the flow augmentation and extent of required treatment may also be evaluated from the model.

The study regarding the pollutant transport in the porous media to determine the distribution coefficients and retardation factors in the aquifer zones should also be carried out so that the ground water pollution may be ascertained.

The above studies have brought out the chemical character of the surface and ground water of the study area both with respect to the conservative and non-conservative constituents. The present state of water quality in the Hindon river especially with respect to organic pollution has been highlighted.

ACKNOWLEDGEMENTS

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