Environment Conservation Journal 7 (1-2) 89-94, 2006
(ISSN 0972-3099)

Numerical Identification Of BOD_5 And DO Profiles Using Beck Modified Khanna Bhutiani (BMKB) Model

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Abstract

Seeing the mounting public pressure at water bodies the need to protect it from pollution is essential where mathematical modeling is the best alternative as accepted by the decision makers. The use of system analysis and mathematical modeling for formulating and solving river pollution is of relatively recent vintage and has been used widely during last three decades. The present study was aimed to verify the BMKB model for river Ganges. The results of BOD_5 shows the correlation $DF_{(1,2)}$ =2, n=3, F=. 588, r =. 603 between two values i.e. obtained by Winkler's method and by model, which is significant. The regression model with the two value for BOD_5 is found as r^2 = .307 and BOD_5 (t)= 9.6 - 0.03 BOD_5 (m). while the result of DO shows the correlation $DF_{(1,2)}$ =2, n=3, t=. 407, r =0.120 between the two value which is significant. The regression model with the two value is found as r^2 = .300 and DO (t) = 8.4 + 0.30 DO (m).

Key Words: *DO, Mathematical models, BOD_5- DO interaction, BMKB Model.*

Introduction

Water quality can be described in terms of physical, chemical and biological characteristics. Water bodies offers a convenient option for the disposal of domestic, agricultural and industrial effluents and wastewaters, all of which can significantly affect the natural physical, chemical and biological characteristics of receiving waters. Although biologists have been studying the effects of human activities on aquatic systems and organisms for decades, their findings have only relatively recently been translated into methods suitable for monitoring the quality of water bodies. A very fundamental concern with the existing approach is the fact that dissolved oxygen is one of the most important variables in water quality analysis. With most other substances, the less there is in the water, the better is the quality. But the situation is reversed for DO, higher the concentration of dissolved oxygen; the better is the water quality.

Bacteria and other microorganisms use organic substances for growth and these microorganisms consume oxygen dissolved in water to metabolize organic material .The organics are broken down into simpler compounds, such as CO_2 and H_2O, and microbes use the released energy for their growth and reproduction. If oxygen is not continually replaced in the water by artificial or natural means, then the DO level will decrease as the organics are decomposed by the microbes. This need for oxygen is called the Biochemical oxygen demand. Hence it is a sensitive indicator of the health of the aquatic system. Indeed the interaction between BOD_5 and DO is a complex process, which depends upon the several important factor for any given river systems. Complexity is an issue that is gaining much attention in the field of research.

Knowing the significance of BOD_5-DO interaction it is very important to think about BOD_5 - DO models based upon mathematical equation and some physical law. Beck (1974) has given a detailed discussion of processes governing BOD_5 - DO interaction. Before Beck it seems that Streeter and Phelps (1925) used mathematical models, for BOD_5 and DO for the first time. There after a number of models were suggested/developed and applied by Masch *et al*. (1970), Moley (1979), Orlob (1983), Vogler and Scherfig (2000).

Our study uses the recently developed BMKB model (Bhutiani 2006) based upon Beck model (1974), regarding DO (dissolve oxygen) and BOD_5 (biochemical oxygen demand) to assess the extent of pollution load in river Suswa.

Materials And Methods

Study Sites

Total five Sampling sites were selected to verify BMKB model for the first time in Ganga river from Rishikesh to Haridwar. The sites were selected because at Rishikesh the turbulent velocity of river Ganga is high in comparison to Haridwar. This turbulent velocity plays an important role in BOD_5-DO interaction therefore to know the change in reaeration coefficient it is important to know the complexity of interactions occuring between Rishikesh to Haridwar.

Following five sampling Sites were selected for the Study, which are situated at a stretch of approximately 35 Kms.

C1 : Triveni Ghat Rishikesh
C2 : Lakkar Ghat Rishikesh
C3 : Gohri Ghat , Haridwar
C4 : Bhimgoda barrage, Haridwar
C5 : Chandighat, Haridwar

Analysis for state variables

Two state variables i.e BOD_5 and DO were analyzed in laboratory for twelve months (Jan to Dec.2005). BOD_5 and DO were measured by Winkler's method following the standard methods of APHA (1998), Trivedi and Goel (1984) and Khanna and Bhutiani (2005).

Model application

The BMKB model is the modified form of an earlier developed BOD_5 - DO model given by Beck (1974). The two multiple input/single output models given by Beck (1974) is as follows:

$$\text{DO}: \; y_1(k) = 0.715\, y_1(k-1) + 0.174\, u_1(k-1) + 0.057\, u_3(k) + 0.044\, u_3(k-1) + 0.554\, n_1(k)$$

$$\text{BOD}: \; y_2(k) = 0.751\, y_2(k-1) + 0.102\, u_2(k-1) + 0.048 u_3(k-2) + 0.060\, u_3(k-4) + 0.618\, n_2(k) - 0.313 n_2(k-1)$$

Where,
y_1, y_2 = downstream observation of DO, BOD_5 respectively, i.e. $y_1(k, z_1)$, $y_2(k, z_1)$
u_1, u_2 = upstream observation of DO, BOD_5 respectively, i.e. $u_1(k, z_0)$, $u_2(k, z_0)$
n_1, n_2 = stochastic noise sequences
$u_3(k)$ = an observation of the sunlight incident on the system during the kith day (hr/day).

Using these governing processes Bhutiani and Khanna (2006) developed BMKB model (Beck modified Khanna Bhutiani Model), which is used to obtain input/output, relationships of BOD_5 and DO between upstream and downstream of river system. BMKB model largely motivated by a case study of river CAM (Beck, 1974) encompasses the parameters λ_1, λ_2, U_1 and e_1.

$$\textbf{DO: } \lambda_1 (S) = C_1 \lambda_1 (S-1) + C_2 U_1 (S-1) + C_3 e_1 (S)$$

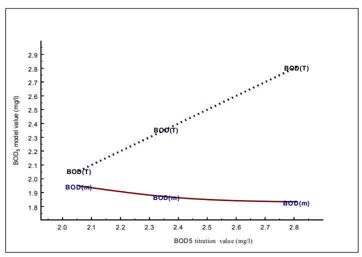
$$\textbf{BOD: } \lambda_2 (S) = C_4 \lambda_1 (S-1) + C_5 U_1 (S-1) - C_6 e_1 (S)$$

Where,
λ_1 (S)= value of DO (mg/l) to be obtained in particular season.
λ_2 (S)= value of BOD (mg/l) to be obtained in particular season
λ_1 (S-1)=DO/BOD observation of same place in previous season
U_1 (S-1)= DO/BOD observation of upstream in previous season
e_1 (S) = errors of possibility.
C_1, C_2, C_3, C_4, C_5 and C_6 are constants

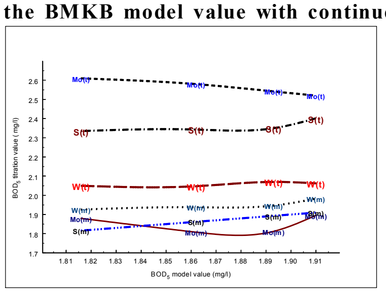
We use the BMKB model to verify the concentration of BOD_5 and DO of Ganga River from Rishikesh to Haridwar by comparing the model values with manually obtained values using Winkler's method.

Results

Model verification of any system depends upon the experimental result, which shows the model output and its interrelationship with other variables present in that particular system. The analyzed result of BOD_5 and DO were putted in the model .The value of BOD_5 obtained manually by Winkler's method and as obtained by model are shown in graph 1. The result shows the correlation $DF_{(1,2)}$ =2, n=3, F=. 588, r =. 603 between these two values, which is significant. The regression model with the two value is found as r^2 = .307 and BOD_5 (t)= 9.6 - 0.03 BOD_5 (m).

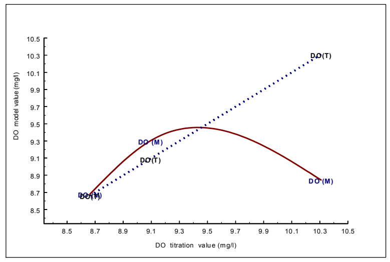


Graph 1. Showing the comparison between BOD_5 value obtained by Winkler's method in BOD (t) symbol with doted line; while the BOD (m), shows the BMKB model value with continues line.

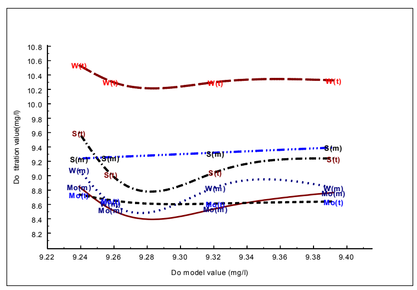


Graph 1(a). Showing the comparison between the model output and Winkler's method value for BOD_5 at different sampling site of Ganga: Symbols used are W (t) is titration value in winter season, W (m) model value in winter, Mo (t), Mo (m) titration value and model value in monsoon season respectively, S (t) and S (m) are value of output by titration method and model respectively in summer.

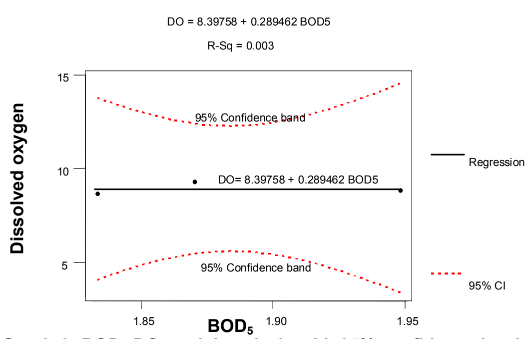
Similarly the values of DO obtained by Winkler's method and the model outputs are shown in graph 2. The result show the correlation DF $_{(1,2)}$ =2, n=3, t=. 407, r =0.120 between these two value which is significant. The regression model with the two value is found as r^2 = .300 and DO (t) = 8.4 + 0.30 DO (m).



Graph 2. Show the comparison between DO values of Winkler's method in DO (t) symbol with doted line; while the DO (m), shows the BMKB model value with continues line.



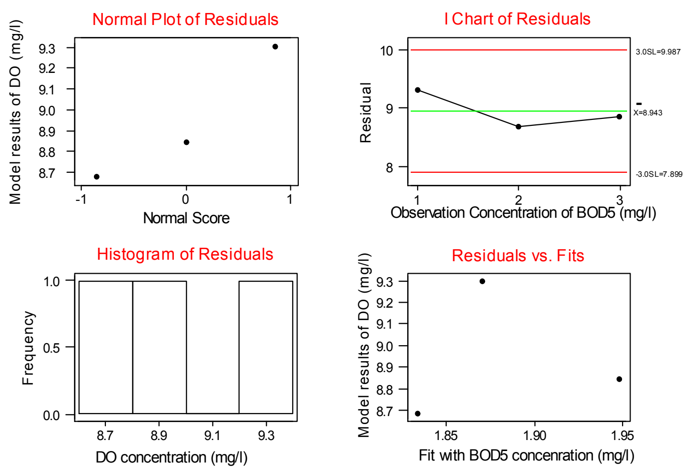
Graph 2 (a) Show the comparison between the model output and Winkler's method value for DO at different sampling site of Ganga: Symbols used are W (t) is titration value in winter season, W (m) model value in winter, Mo (t), Mo (m) titration value and model value in monsoon season respectively, S (t) and S (m) are value of output by titration method and model respectively in summer.



Graph-3: BOD_5-DO model analysis with 95% confidence level

Graph 3 and 4 shows, the BOD_5 and DO profiles, both predicted and measured, for verification of BMKB model for Ganga River. In graph 3 Regression plot of BOD_5-DO concentration has been shown in 95% confidence level. Both the values were derived form the model input. The result in graph 3 show that all the value are in 95% confidence band that verifies the data accuracy. Graph 4 shows, the residual plot and the data Fit in different comparative graph. Nevertheless, correlation between observed and predicted values seems quite good. Of course, DO data shows better agreement in comparison with BOD_5 data, which is expected to be a better one.

Error analysis of BMKB model (Graph-4)



Discussion

Although acceptable water quality may need to be defined principally in relation to the use with the highest quality requirements and defined by any associated quality standards, the quantity of the resource available may have an important role in defining the acceptable quality. Determining the degree and structure of the interaction between variables and model components is difficult to quantify. A comparison of sensitivity estimates may provide some indications of the degree of interaction, but determining the quality of a model must often be based on many other theoretical considerations.

BOD_5 and DO modeling plays an important role in maintaining the river water quality. Recall that various models have been developed based on the classical Streeter's-Phelps approach, including models, which incorporate oxygen demands by sediments and oxygen supply by photosynthesis. In addition there are lake and reservoir models as well as models of surface water quality are in Biswas (1981), Grimsrud *et al.* (1976), and a state of the art book on water quality modeling is James (1993). In the present study we used BMKB models for BOD_5 and DO with multiple inputs and single output. These models do not assume explicit knowledge of pre-biochemical reaction, such as the explicit pre-reaction concentration. In this paper firstly, there is a designs of input/ output model (Beck model); secondly, it represents each process of material input, interaction and output by an BMKB model respectively, where the additional equations representing processes exploit the information of BOD_5 and DO relation reactions; and thirdly, it shows that the three-steps model has the advantage of prediction and control, using the numerical solutions model. Other parameters i.e. error analysis has little effect on the river DO over the range of variation were the flow rate is tributary. BOD_5 has also effected very little by the error analysis in out study.

The model is considerably in agreement with our findings at all the sampling sites of river Ganga similar results have been obtained by Bhutiani and Khanna (2006) in river Suswa. An internally descriptive model exploits the available information on the phenomena determining the system's behaviors, e.g. the physical and biochemical mechanisms which control the internal descriptions.

Conclusion

In this study, we have investigated two water pollution models based on BMKB model (the input/output model (Beck model). The above findings show that BMKB model may be characterized as 'White Box model' and this model is the simplest model used for any river system. The model uses multiple inputs with single output and both BOD_5 and DO models have good potential for control applications. This paper present the true verifica tion and comparison of BMKB model with the experimental data. It seems that this modified model is the simplified once with competition to the Beck model (1974). Input and output results are quite accurate and equation derivation with data is easier.

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