Genetic Programming based Modeling Method for Prediction of Phosphate in Water Hyacinth based Wetland System

S.Vanitha, C.Sivapragasam, K.Rohini, A.Malathy

Abstract*: Phosphate Removal is very essential while discharging into natural water bodies. In this study, water hyacinth based wetland system is created at lab scale level, the inlet phosphate, outlet phosphate is studied daily till maximum removal is obtained. Weather parameters namely Apparent temperature (Ta) and wastewater temperature (Tw) are collected. Genetic Programming (GP) based mathematical model is developed and influence of weather parameter and wastewater temperature is studied. It is seen Genetic programming based mathematical model can predict the behaviour of wetland system accurately and the influence of weather is not evident in small level wetland system because of less in variation of Ta and Tw. Also it is recommended to conduct the experiments with variation of Ta and Tw to understand the major input parameter affecting the wetland system.

***Keywords* : phosphate removal, genetic programming, weather parameters, mathematical modeling**

I. INTRODUCTION

The presence of even small amount of phosphate in treated wastewater causes eutrophication while discharging in natural water bodies. Excess phosphorous increases the growth of algae which leads to collapse of total ecosystem in water bodies. Chemical Precipitation (CP) and Biological Nutrient Removal (BNR) are the two most commonly used methods for removal of phosphate from municipal and industrial wastewater [1]. In general, CP and BNR processes are reported to be effective in reducing phosphate levels in municipal wastewater.

There is growing interest towards macrophyte based phosphate removal system in now adays because of low economy, low energy (zero energy) and ease in handling of plants. Many free floating macrophytes are used for nutrient removal in water and wastewater such as water lettuce, duckweed, water hyacinth etc., [2,3,4,5,6,7,11,12,13]. Free orthophosphate is the only from of phosphorous blelieved to be directly utilized by algae and macrophytes [2,3].

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Irrespective of method of treatment adopted for phosphate removal, modeling is necessary to obtain better insight about the process. Modeling reveals the behavior of the system at preliminary level before implementation in full scale. Many researchers used modeling approaches for phosphate removal in the past [8,9]. Fytianos et al. 1998 developed mathematical model for chemical precipitation and tested with the experimental data. Reference [9] used Artificial Neural Network (ANN) and found that ANN

removal process of phosphorus using alum sludge in a 2.5cm diameter with the length of 20cm.

Wetland system phosphorous removal happens primarily through plant growth, adsorption and chemical precipitation. [2,3]. The work reported by [10], indicates the effect of high light intensity and a long period of warm temperature could result in a higher growth rate for the plant thereby removal process will be faster. Table1 shows different weather parameters effect on Nutrient removal. It is evident that the atmospheric parameters play a vital role in plant growth.

The main focus of the present work is to develop mathematical model using Genetic Programming (GP) for phosphate removal and to identify the weather parameter (if any) in the removal process and to identify the most prominent input variables affecting phosphate removal process.

II. METHODOLOGY

A. Study area description and experimental setup

The study area is located at the foothills of the Western Ghats in Virudhunagar District of the State of Tamil Nadu, India (latitude 9.57 N and longitude 77.68 E).The primary treated wastewater is collected from nearby treatment plant. Two experimental setups are created as shown in Figure

1. The experiments are conducted both under control condition and in the presence of water hyacinth.

Table I Weather Parameters Considered In Free Floating Wetland

References	***Type of plant used***	***Paramete rs***	***Weather parameter s***	***Type of waste water***	***Result***
[11]	Water hyacinth, duckweed , lettuce	PO_4^-, NO_3^-	Solar radiation, Atmospheric temperature	Domestic wastewater	Macrophyte is influenced by the weather parameters, the phosphate removal is efficient in summer and nitrate removal was average during the summer season.
[12]	Water hyacinth	PO_4^-, NO_3^-	Solar radiation, Atmospheric temperature	Domestic wastewater	The removal of pollutants and the plant growth is affected by both temperature and solar radiation.
[13]	Water Hyacinth	COD, TP, TN, DO	Atmospheric temperature	Domestic wastewater	The atmospheric temperature affects the removal efficiency of phosphate, nitrate and COD.

Fig. 1 Experimental setup

In both experimental setups 25 liters of wastewater is used. The samples are collected daily. Orthophosphate was determined by ammonium molybdate method and the wastewater temperature (T_w) is measured by thermometer. The meteorological parameters used in the analysis namely Relative Humidity (RH), Atmosphric temperature (T_{atm}) and Wind speed (U_w) are collected from the nearby meteorological station. The apparent temperature called feel like temperature (T_a) is calculated using standard charts and tables. Apparent temperature is considered as one of the weather parameter based in works reported by [14,15].

B. Genetic Programming

Operating on the principle of parse tree, Genetic Programming, which is a Darwinian theory based evolutionary algorithm, evolves equations connecting the dependent and independent variables. By the random combination of functional set (mathematical functions and arithmetic operators) and terminal set (variables of the process being studied and the constants), this algorithm generates an initial set of population (which are a set of equations). The quality of equations evolved crucially depends on the selection of variables that are assumed to affect the process being studied. Otherwise, the equations may be physically interpretable.

The initial population consisting of initial set of equations are subject to refinement to produce better equations using the operators such as mutation, cross over, elitist etc. The role of each of these operators have different influence in the convergence to best model. While cross over exchanges information between two parents, mutation broadens the search space to avoid getting into local optima. Based on number of generations, number of population and other relevant information, the GP run will converge to the specified fitness condition. [16]. GP is implemented using Discipulustool.

C. PerformanceMeasure

The best GP model is selected based on Root Mean Square Error (RMSE) as the performance measure which is calculated using “(1)”.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}[(X_m)_i - (X_s)_i]^2} \quad (1)$$

where, x is any variable subjected to modeling, m is observed value and s is simulated value and n is the number of values.

D. Modeling Studies

GP is used in modelling of phosphorous removal. Three case studies have been made and run using GP. The input and output used for three case studies is shown in Fig 2 to 4 respectively. In case study 1, Pin and time are used as inputs, whereas in cases study 2 time and Ta are used as inputs with Pin. In case study 3, Pin, time and Tw are taken as inputs. The percentage of training, testing and validation for GP modelling is kept as 50%, 35% and 15% respectively and the data used for training, testing and validation data is shown in Table 2.

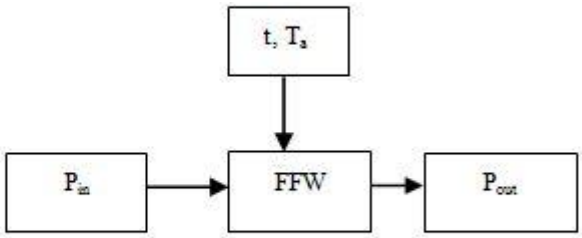

Fig. 2 Block Diagram for Case Study1

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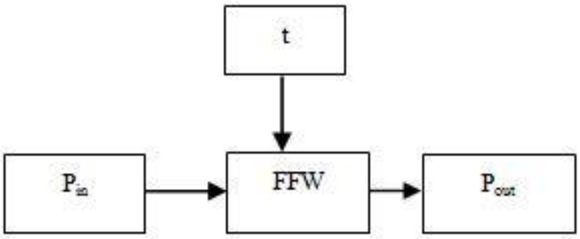

Fig. 3 Block Diagram for Case Study2

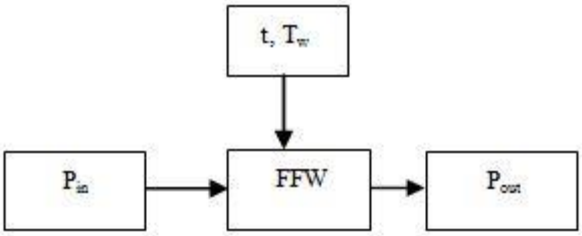

Fig 4: Block Diagram for Case Study3

III. RESULTS AND DISCUSSION

Table 3 shows the results of the three case studies after GP run. It is observed that the RMSE values for all three case studies looks almost same. Almost 10% error is obtained between observed and predicted output in all case studies which can be considered as acceptable within experimental error. It is understood that GP can model phosphate removal as well as it can predict the behaviour of system in water hyacinth based wetland system.

Table II Data Used For Model

Data	Pin (%)	Time (h)	Ta (°C)	Tw (°C)	Pout (%)
Training	100	168	31.40	26	11.3
	100	144	32.45	24.5	29.2
	100	144	33.35	25.5	49.2
	100	96	34.20	25.5	60.1
	100	120	33.20	25.0	34.6
	100	192	33.15	25.5	58
	100	48	35.05	26.0	76.4
	100	24	35.05	26.0	87.1
	100	48	34.30	26.5	54.4
	100	96	31.90	26.5	45.3
	100	24	33.40	25.5	69.3
	100	48	32.70	26.5	71.7
	100	96	32.30	25.5	51.3
	100	120	32.40	26.5	54.6
	100	24	33.55	25.5	82
Testing	100	72	31.95	26.0	61.9
	100	120	33.10	26.0	46
	100	216	33.30	25.0	28.8
	100	144	33.55	26.5	44.2
	100	24	32.75	26.5	75.2
	100	48	33.20	26.0	61.2
	100	192	33.80	27.0	31
	100	96	33.35	25.5	42.2
	100	72	34.6	25.5	67.3
	100	72	32.85	25.5	53.5
Validation	100	216	33.55	27.5	18.6
	100	144	31.90	25.5	55.4
	100	192	32.60	26.5	21
	100	72	33.15	26.5	45.4
	100	168	32.75	24.5	30

Table 3 RMSE Values of Different Case Studies

Case study	Input	Output	RMSE
1	$f(P_{in}, t)$	P_{out}	10.62
2	$f(P_{in}, t, T_a)$	P_{out}	11.64
3	$f(P_{in}, t, T_w)$	P_{out}	10.48

Different modeling equations are obtained for three case studies.

A. Modeling equation for case study 1

The GP based modeling equation is shown in "(2)". Residual phosphate in outlet and time is inversely related indicating with higher retention time higher removal is expected.

$$P_{out} = 80.94-(0.27\times t) \quad (2)$$

$$(24\ h < t < 288\ h)$$

where P_{out} =Residual phosphate in outlet (%) t = Time inhours

P_{in}= Inlet phosphate(%)

B. Modeling equation for case study2

GP based modeling equation is shown in equation (3).

$$P_{out} = 2.66T_a–(0.31 \text{ x } t) \quad (3)$$

$$(24\ h < t < 288\ h)$$

The Equation (3) shows the residual phosphate in outlet and T_a is directly related. It indicates when T_a is less, higher phosphate removal happens in the system. Careful comparison of "(2)" and "(3)" reveals both the equation are almost same. The first term in "(2)" has been represented as 2.66 ties T_a in equation approximately. It appears that T_a influence the phosphate removal. But this can be confirmed only experiments are done in large variation ofT_a.

C. Modeling equation for case study 3

The Equation (4) shows that residual phosphate in outlet and T_w are directly related. When T_w is less, higher removal efficiency is achieved and the square term of T_w indicates influence of T_w is greatly affecting the phosphate removalprocess.

$$P_{out} = T_w^2 + T_w\,(270\text{-}t)/100 \quad (4)$$

In equation (4) can be rewritten as "(5)" assuming average waste water temperature as 26^0 C.

$$P_{OUT} = 77.2 - 0.265t \quad (5)$$

Equation (5) looks almost similar to (2). Since variation in T_w is also minimum. The constant 80.94 obtained in (2) is represented as a combination of variables which have almost constant values. Hence it is concluded that T_a and T_W might not influence the process. In order to better insight it is recommended to conduct experiments with large variation of T_W and T_a.

IV. CONCLUSION

Phosphate removal is modeled with GP. There is 11% RMSE is obtained between observed and predicted data which can be considerd acceptable within experimental error. GP can predict the behavior of wetland system as well as it helps to identify the most prominent input parameter affecting phosphate removal. It is understood from modeling equation, large variation of T_a and T_W data is necessary for understanding the most prominent factor affecting wetlandprocess.

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