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Soft Computing Techniques for Predicting Aeration Efficiency of Gabion Weir

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Abstract—*The gabion weir is an environmental friendly weir, which is consists of a porous medium filled with different shape and size of coarser materials. The turbulence developed by the gabion weir will use to promote the aeration efficiency in the form of large number of bubbles. Aeration means air added to water and this is calculated in terms of dissolved oxygen. Dissolved oxygen is best indicator of water quality. DO is measured in terms of ppm(mg/l). This paper investigates the modelling performance of data taken from National Institute of Technology Laboratory for aeration efficiency (E20) and also comparing the result of modelling techniques with other empirical equation. For comparing the results of aeration performance of these techniques with other empirical equation, standard statistical performance parameters such as the coefficient of correlation (C.C), and root mean square error (RMSE), R^2 , and Nash Sutcliffe (N.S) have been used. SVM (Poly) technique gives the best result among all the modelling techniques and empirical equation used with C.C. 0.850, RMSE 0.068.*

1. INTRODUCTION

Oxygen is necessary for all forms of life and the oxygen concentration of water rises with rising atmospheric pressure. Oxygen concentration loses with rising temperature. Water quality totally depends on the dissolved oxygen. Dissolved oxygen is formed by the hydraulic structure which is increased due to turbulences. A lot of bubbles are made due to turbulences from which oxygen is added into water. What jet is formed from a weir is an example of this. Before jet separating into drops, the flow over the weir would be called as free jet. Most of the oxygen transfer is practiced in this type of structure during the breakup of the jet, and if the free jet jumps into a downstream water pool, then oxygen transfer will be contributed due to air entrainment and turbulence mixing in water. And from this process adding air to water is known as aeration. Gabion weir used as hydraulic structure made of porous medium filled with different shape and size of the coarser materials. The turbulence developed by gabion weir will promote aeration and working in aerobic decomposition of organic matter.

2. BACKGROUND

All period of time, the change in concentration of oxygen in a parcel of water when it travels through a hydraulic structure such as weir,

$$\frac{dm}{dt} = V\frac{dC}{dt} = k_L A(C_S - C) \tag{1}$$

Where:

C = Dissolved oxygen concentration

K_L = liquid film coefficient for oxygen

A = Surface area associated with the volume V, over which transfer occurs

C_S = Saturation concentration

t = time.

A/V = specific surface area (surface area per unit volume).

If assumption is made that C_S is constant. The aeration efficiency is given by:

$$E = \frac{C_d - C_u}{C_s - C_u} \quad (2)$$

E > 1, downstream water is supersaturated (when $C_d > C_S$).

E =1, transfer of full oxygen to the saturation value,

E = 0 means no transfer.

U and d are used as subscripts, representing upstream and downstream locations.

Equation is used for calculate the aeration efficiency at the 20 °C:

$$1 - E_{20} = (1 - E)^{\frac{1}{f}} \quad (3)$$

Where, E = aeration efficiency at the water temperature; E20 = aeration efficiency at the 20 °C;

And,   f = the exponent expressed as:

$$f = 1.0 + 0.02103(T - 20) + 8.261x10^{-5}(T - 20)^2 \quad (4)$$

T = Temperature of water.

3. POPULAR PREDICTIVE MODELS

Some researchers have given predictive mathematical models for computing E20 which has been discussed below:

Table 1: Well known predictive equations for oxygen transfer efficiency at various hydraulic structures.

Sr. no.	Equation source	Equations
1	Avery and Novak (1978)	$E20 = 1 - (\frac{1}{1 + 0.24 * 10\text{^}{-4} Fr^{1.78} \mathrm{Re}^{0.53}})^{1.115}$
2	Nakasone (1987)	$E20 = 1 - \exp\left(-0.0785 \mathrm{H}_0^{1.31} q^{0.428} h_w^{0.310}\right)$
3.	Watson et al. (1998)	$E20 = 1 - \left(\frac{1}{1 + 0.0010 Fr^2 \mathrm{Re}^{0.32} (\frac{h_w}{H_0})^{0.7}}\right)$

4. DATA SET

Data set used in the paper consists of 60 observations. Out of 60 observations chosen randomly 42 observations were used for training data and 18 chosen for testing data. Input variable consist of drop height, mean size, porosity, discharge, Reynolds number and Froude number. And the oxygen transfers efficiency (E20) of gabion weir is taken as output.

5. GAUSSIAN PROCESS POLYKERNAL

GP is the optimization technique of an unknown function in many areas of science and engineering. To improve modelling performance and overcome associated problems, the non-parametrical probabilistic models are proposed, such as GP by Murray-Smith (1999). 1999).In GP models, evaluation of variance in predicted output were computed by the view of neural network. GP model can be characterized in the form of Poly Kernel and PUK. These output is represented as mean and covariance function.

Poly Kernel: There are two user defined parameters of GP used in Poly Kernel i.e. E (exponent) and noise.

Table no.2: Optimization values of user- defined parameter of GP with Poly Kernel

Gaussian noise	E
1	1

6. SUPPORT VECTOR MACHINES (SVM)

Support Vector Machines are based on the concept of decision planes that characterize choice limits. A choice plane is one that isolates between a lot of items having distinctive class participations. Support Vector Machine (SVM) is primarily a classier method that performs classification tasks by constructing hyper planes in a multidimensional space that separates cases of different class labels.

Kernel functions

$$k(X_i.X_j) = X\begin{cases} X_i.X_j \rightarrow linear \\ (\gamma X_i.X_j + C)^d \rightarrow polynomial \\ \exp(-\gamma\left|X_i - X_j\right|^2) \rightarrow RBF \\ \tanh(\gamma X_i X_j + C) \rightarrow sigmoid \end{cases}$$

Where $K(\mathbf{X_i}, \mathbf{X_j}) = \phi(\mathbf{X_i}) \bullet \phi(\mathbf{X_j})$

7. RESULTS AND DISCUSSION

Table 3: Details of the training data set.

Parameters	Training		
	Range	Mean	Std. Deviation
D_{50}	0-18.32	13.705	6.361
n	0-49.1	34.625	16.815
H_0	0.902-0.955	0.921	0.016
q	0.0052-0.0196	0.0196	0.005435967
Re	52000-196000	133047.619	54359.66599
Fr	9.863207-19.7802	13.18001025	0.015594
E20	0.449-0.856	0.609015033	0.098496

Table 4. Details of the tetsting data set.

	Testing		
Parameters	Range	Mean	Std. Deviation
D_{50}	14.66-18.32	13.705	6.285117
n	30.1-49.1	34.625	16.61365
H_0	0.902-0.935	0.9212	0.011229
q	0.0052-0.0196	0.0118	0.005170524
Re	52000-196000	118888.88	118837.8295
Fr	10.058-19.465	13.925	13.65216
E20	0.00632-0.0107	8.78E-03	0.106671

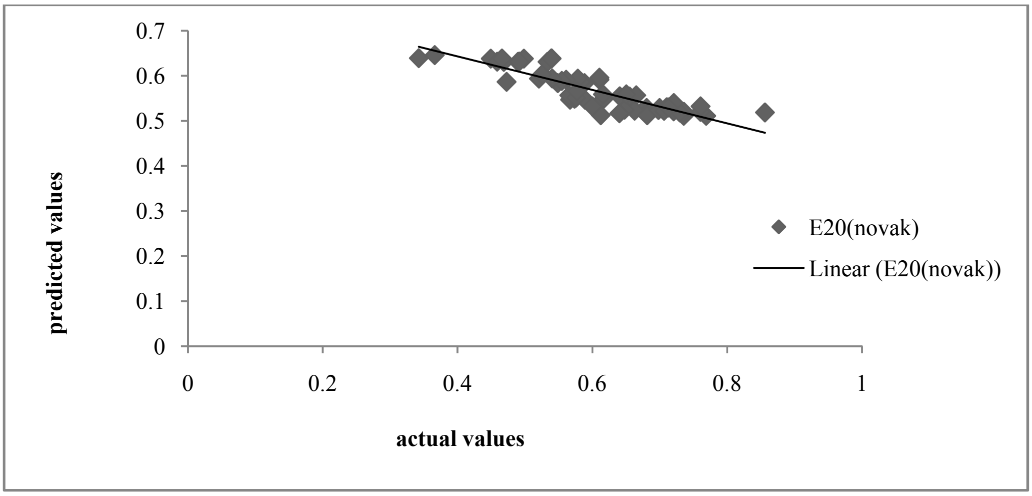

Fig 1. Performance of Avery and Novak (1978) equation to calculate E_{20}.

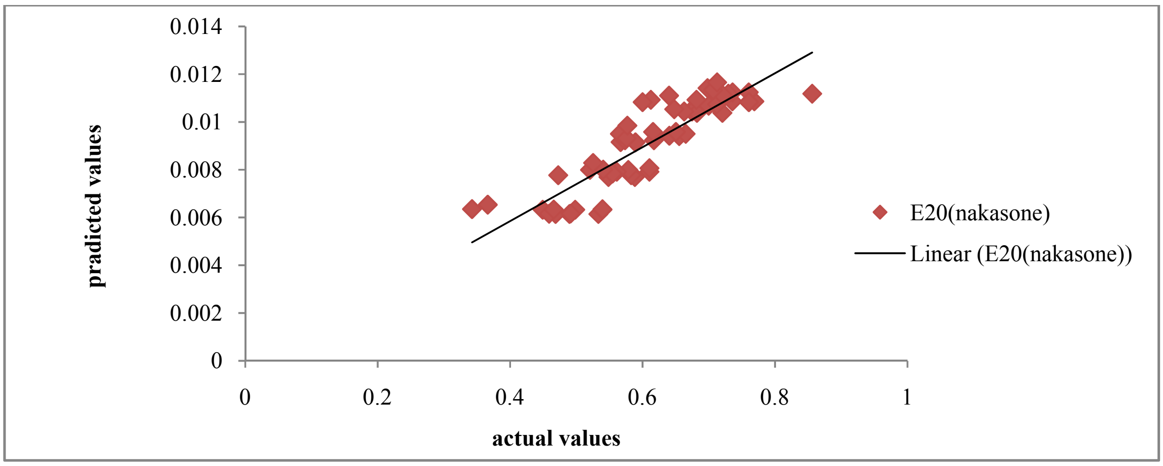

Fig 2. Performance of Nakasone (1987) equation to calculate E_{20}.

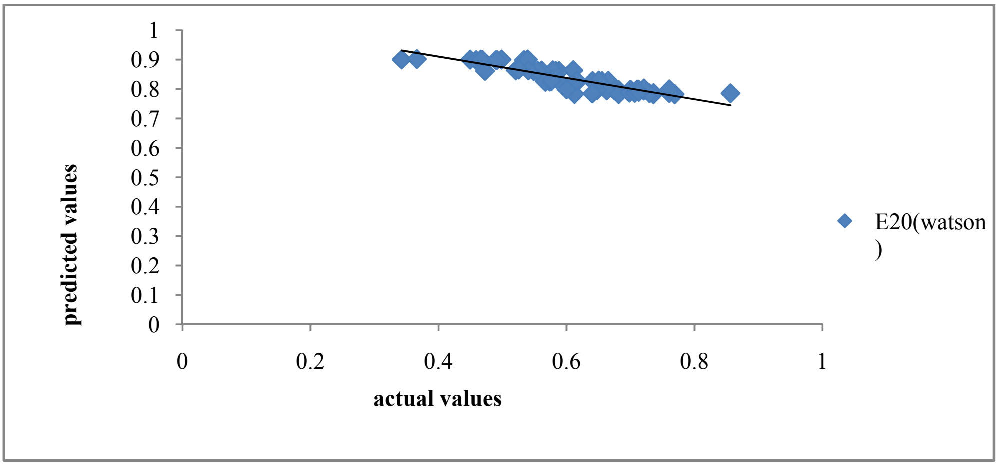

Fig 3. Performance of the Watson et al. (1998) equation to calculate E_{20}.

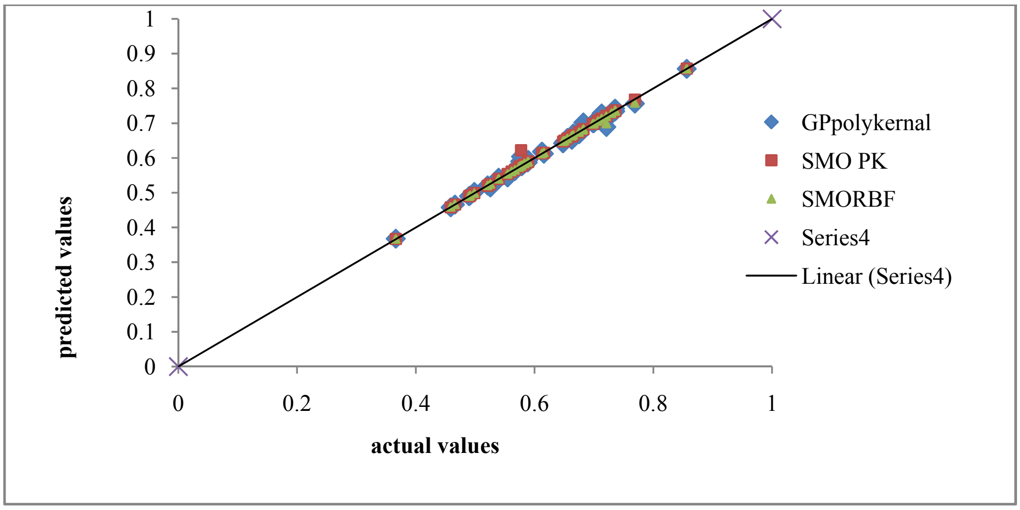

Fig 4. Figure of Actual v/s predicted values using artificial intelligence modelling techniques for training data set.

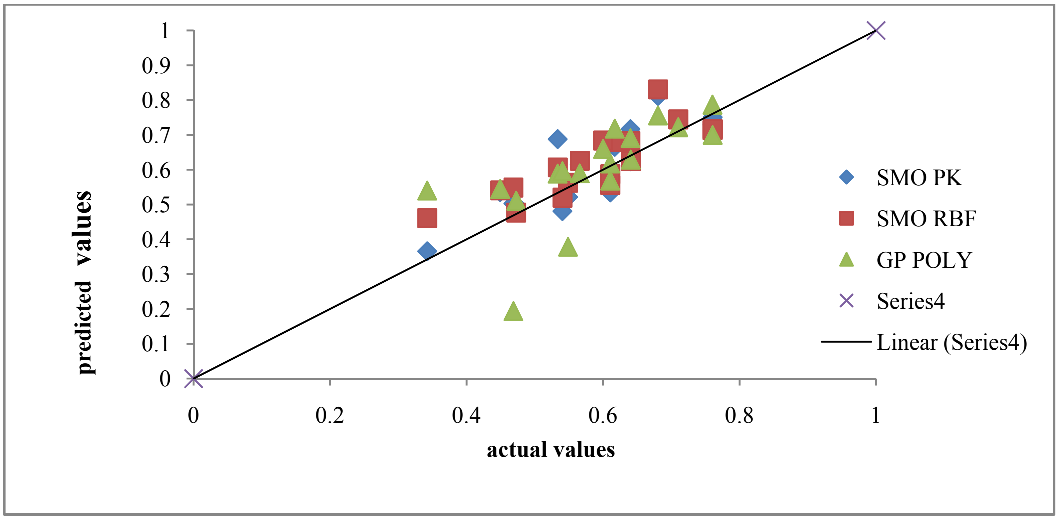

Fig 5. Figure of Actual v/s predicted values using artificial intelligence modelling techniques for testing data set.

Table 5. Performance of empirical equations.

Sr No.	Equation source	CC	RMSE	R^2	NSE
1	Avery and Novak (1978)	0.867	0.148	0.753	0.741
2	Nakasone (1987)	0.874	0.608	0.765	0.0276
3	Watson et al. (1998)	0.876	0.266	0.768	0.575

Table 6. Performance of AI based modelling techniques using the testing data set.

Techniques	CC	R^2	RMSE	NSE
SVM (poly)	0.850	0.723	0.066	0.287
SVM(RBF)	0.836	0.7001	0.068	0.262
GP (poly)	0.681	0.463	0.102	0.675

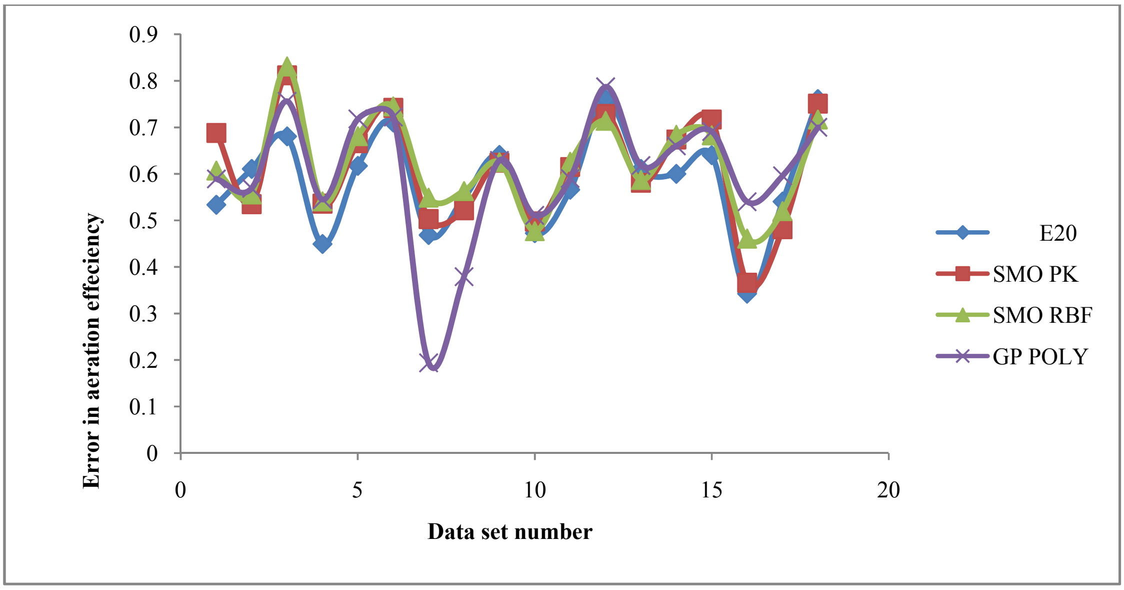

Fig 6. Error variation values of Aeration Efficiency (E20).

8. CONCLUSION :

Oxygen concentration is very important to sustain the aquatic life, different efforts has been made to maintain its required concentration in water. In this paper Artificial Intelligence based modelling techniques are used for predicting the aeration efficiency of Gabion weir and also comparing the result of modelling techniques with other empirical equation. This result shows that, SVM (Poly) gives the best result with C.C. 0.850, RMSE 0.068.

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