Investigating Hydro-Biochemical Processes and River Water Quality Simulation using Multivariate Statistics and Soft Computing Techniques

by

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ABSTRACT

River dynamics involve composite interactions among flow, nutrients, transported material and channel type. Spatial and temporal variations are generally observed in biochemical parameters and concentration of dissolved chemicals in freshwater bodies, corresponding to its flow through different climatic, geographical and topographic environment. Discharge of domestic and industrial effluents from multiple sources accelerate the rate of variation in biochemical characterisation of water body. Inherent ability of water flow to assimilate organic load allow the self-purification of streams. Self-purification is an intricate phenomenon, comprising of physical, chemical and biological processes occur simultaneously to recover the native state of water body. The re-aeration capacity of the stream defines the net rate of oxygen transfer from atmosphere to air-water interface and depends significantly upon the degree of turbulence of the flowing stream, as the interface is constantly changing with the flow rate due to the mixing of the flowing water. Measure of re-oxygenation in river is equitable to the oxygen deficit, which is calculated as the variance between the oxygen content and the native oxygen concentration at specific temperature.

The assimilation capacity of the stream can be measured by estimating several indices like biota of the river, dissolved oxygen, temperature, and amount of flow, velocity, concentration of suspended and dissolved solids. Determination of re-aeration coefficient during re-oxygenation process in water body should depends on reasonable valuation of oxygen transfer rate across air-water interface. For years, several attempts have been made by researchers for envisaging the rate of oxygen transfer from defined physical and hydraulic properties of the river. However, the functional relationships between the hydraulic variables and the re-aeration coefficient are limited to specific boundary conditions. The relative significance of variables used to design the re-aeration equations such as depth, velocity, slope, and width are also not found reliable in the literature and applicable to the streams free from any organic load. The several predictive re-aeration models have been developed and applied on confined study areas having tremendous variability of channel types causes significant difference in the results of each model.

The improvement in the estimation of an adequate re-aeration coefficient is a vital requirement to simulate the river water quality. The hierarchical agglomerative cluster analysis (HACA), principal component analysis (PCA) and structural equation modelling (SEM) are employed to examine the similarities in water quality parameters, critical parameters and their indirect relationships. The combination of these statistical approaches helps to identify the role of different parameters in variation of water quality individually and to identify the significant source of pollutants. In this study, 17 predictive re-aeration models have been compared to reveal their applicability to the study area. Yamuna River has been selected as the study area, receiving the high organic load from anthropogenically influenced multiple point sources, which significantly affects the flow rate of the river. The river receives the wastewater from 17 major and minor drains, which causes significant fluctuations in the river physio-chemical properties. The error in the predictive re-aeration models is estimated using MAE, MAPE, MSE and MME; however, none of the reaeration model gives promising results with the observed values of the re-aeration coefficient.

The artificial neural network (ANN), adaptive neuro-fuzzy inference system (ANFIS) and autoregressive integrated moving average (ARIMA) have been applied to develop a new model for the estimation of the re-aeration coefficient. The ten different configurations of input parameters were used to design various ANN and ANFIS models, and the performance of models are assessed using R, R^2 and RMSE. The most optimal model among ANN and ANFIS is further integrated with ARIMA to improve the estimation of the re-aeration coefficient. The ANFIS-ARIMA model improves the estimation of the re-aeration coefficient for the degraded river in comparison to predictive re-aeration models.

The simulation of river water quality is performed using QUAL2Kw integrated with the ANFIS-ARIMA model to identify the impact of newly developed model for the estimation of re-aeration coefficient. The sensitivity analysis of the DO and the BOD is also carried out to examine the variations in parameters concentration and related river characteristics. The study reveals that the developed ANFIS-ARIMA model improves the estimation of re-aeration coefficient significantly and can be used in the prediction of water quality. The study would be useful to the decision-makers while structuring the pollution abatement methods, developing river water management policies, and defining the level of treatment that can be focused on the removal of sensitive contaminants or critical species that severely affect the river health.

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