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Modelling coagulant dosage in drinking water treatment plant using hybrid machine learning based on empirical wavelet transform

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INTRODUCTION

The coagulation (Fig. 1) is fundamental process in conventional drinking water treatment plants (DWTPs), primarily used to remove suspended solids (i.e., colloids) from raw water **[1]**.

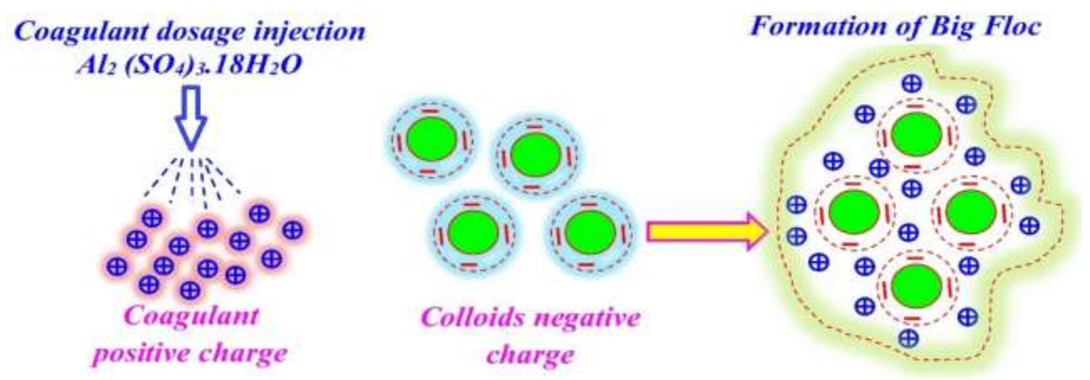


Fig. 1. Mechanisms of coagulation in DWTPs using polyaluminium sulphate as a hydrolyzing metal salt

The Jar-Test (JT) is a well-known method for determining the optimal coagulant dosage in water treatment. However, it has several limitations **[2]**. To address the limitations, alternative methods involving the development of nonlinear models can improve coagulant dosage determination by linking dosage rates to various raw water quality measurements at the DWTP inlet. Artificial intelligence models are particularly effective in solving the complex nonlinear processes encountered in water treatment plants **[3]**.

METHODS

The Boudouaou DWTP in Algeria, is located about 7 km from the Keddara dam, which supplies potable water to Algiers. With a production capacity of 540.000 m³ per day, it serves over four million people. The raw water database consists of 725 samples of six input variables (turbidity, conductivity, temperature, dissolved oxygen, UV254, and pH) collected over 24 months and used for modeling coagulant dosage.

In this study, multilayer perceptron neural network (MLPNN) (Fig. 1), random forest regression (RFR) (Fig. 2), and empirical wavelet transform (EWT) (Fig. 3) are used.

Fig. 1. The architecture of MLPNN

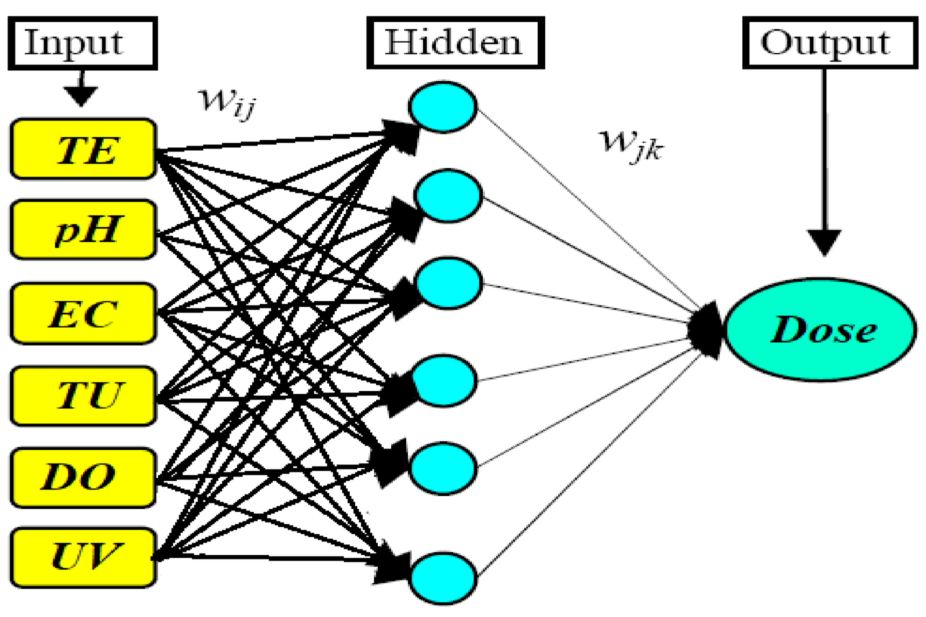


Fig. 2. The architecture of RFR

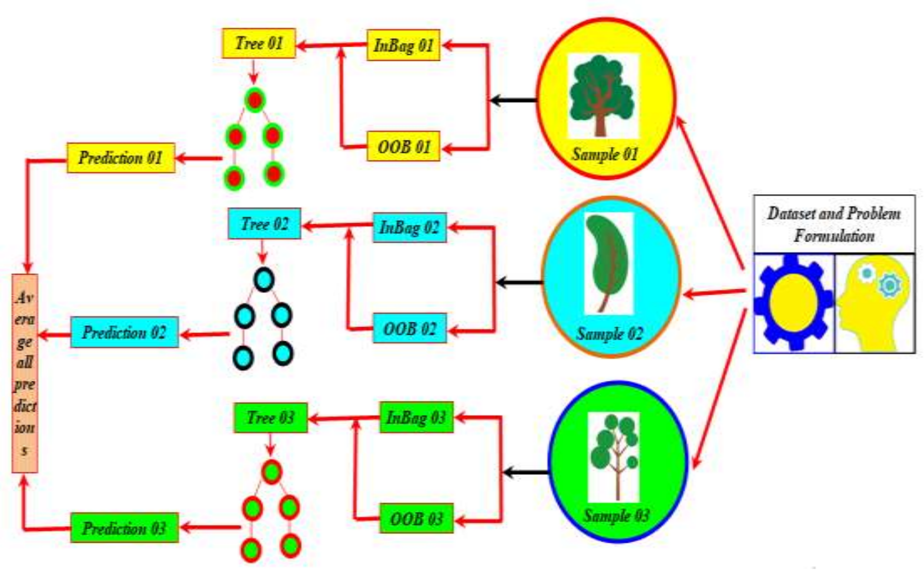
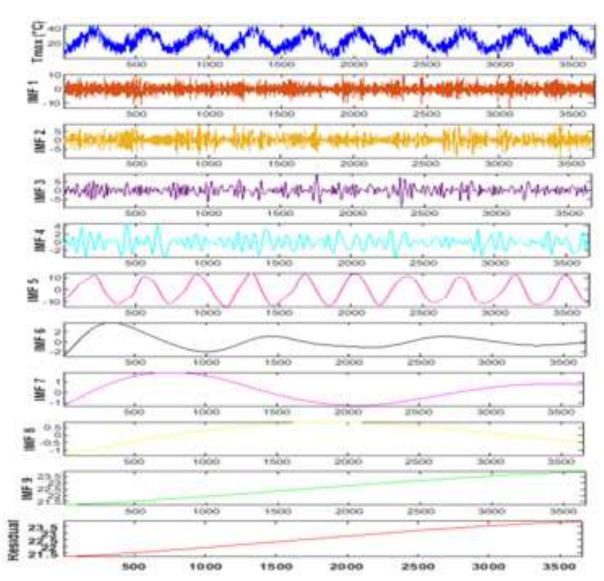


Fig. 3. An example of raw water temperature (TE) signal decomposition using EWT algorithm



RESULTS & DISCUSSION

In this investigation, we compared between standalone models, i.e., MLPNN and RFR, and hybrid models based on EWT signal decomposition. Furthermore, we compared six input combinations to demonstrate the impact of varying model inputs on prediction accuracy.

According to the obtained results using MLPNN and RFR, the model performances was low, the averages values of R and NSE were (0.771 and 0.594) and (0.761 and 0.576), for MLPNN and RFR models, respectively.

In the second part of this study, we attempted to improve coagulant dosage prediction accuracy by applying the EWT signal decomposition. The use of the EWT improves the models performances for all hybrid models. The best results are obtained by the MLPNN-EWT model **(R≈0.935, NSE≈0.901, RMSE≈2.812, and MAE≈1.923)**, exhibiting improvement rates of approximately **≈18.11%, ≈39.84%, ≈48.68%, and ≈49.61%**, compared to the standalone MLPNN.

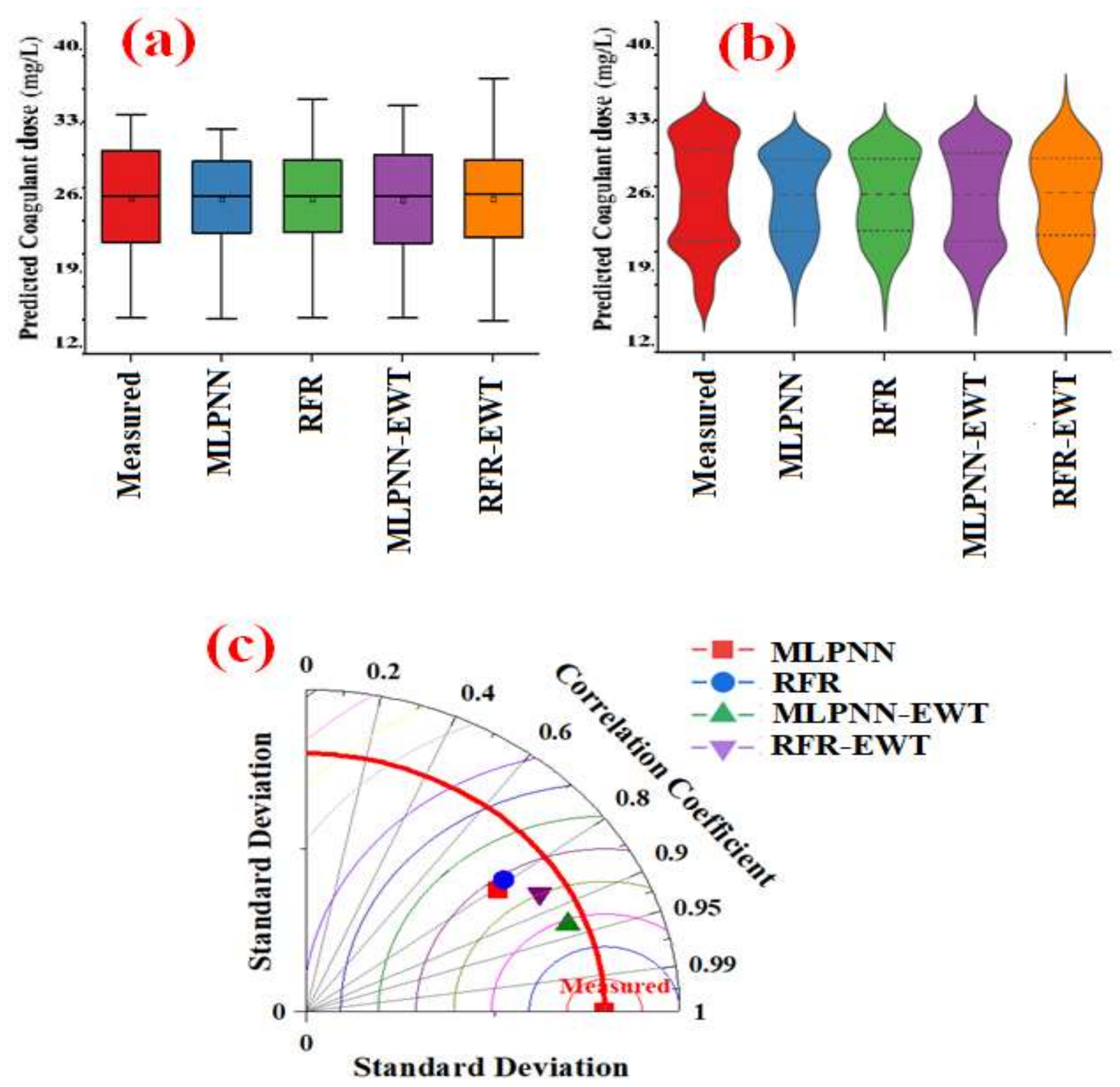


Fig. 4. Graphs showing the comparison between measured and predicted coagulant dosage during the validation stage: (a) boxplot, (b) violin plot, and (c) Taylor diagram

CONCLUSION

- The modeling results demonstrate that the proposed technique can accurately predict the coagulant dosage. Consequently, it holds significant potential to replace the conventional Jar Test method due to its rapid response, cost-effectiveness, and ability to be applied in real-time processes. Once fully developed, this model could serve as a valuable tool for determining the optimal coagulant dosage, potentially supplanting current methods.
- This new method could be suitable for calculating the dosage of other chemicals, and it warrants further testing to draw robust conclusions.

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