The Application of Artificial Intelligence – Artificial Neural Networks – in Wastewater Treatment

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ABSTRACT: Wastewater treatment is essential because it reduces the pollutant in the water, promotes the water quantity, and protects the ecosystem from harmful and toxic elements in wastewater. Many uncertainties appear in wastewater treatment systems since the natural condition is complex, and the technology of wastewater treatment is limited. Artificial Intelligence (AI) is a novel and influential technology assisting with complicated work, including modeling. The advantages of AI are evident in wastewater treatment because of the high accuracy, which leads to cost, energy, and material saving. This article mainly focuses on introducing Artificial Intelligence in wastewater treatment, displaying the application of Artificial Intelligence Neural Networks in wastewater treatment, and analyzing the advantages and problems. Overall, the research demonstrates that applying Artificial Intelligence in wastewater treatment provides a promising future with benefits, such as cost-saving and high accuracy.

1. INTRODUCTION

Urbanization and industrialization, implicating prosperity, are goals that many countries are pursuing. However, the deterioration of wastewater links closely with them. In order to address the problem, wastewater is discharged into a wastewater treatment plant (WWTP), which uses myriads of intricate processes to clean the wastewater and remove pollutants. Any Wastewater Treatment Plant (WWTP) needs a solid model in order to anticipate its performance and serve as a foundation for managing how the process runs. Wastewater process models are crucial tools for comprehending pertinent elements of a wastewater treatment system, offering more alternatives for improvements and a better knowledge of the design of new plants as well as enhancements to operational controls [1].

Due to the complexity of the mechanisms in the treatment plant, influent quality, and strength of the wastewater, operational control of WWTPs is challenging. Unfortunately, most conventional and accessible models cannot deal with complicated systems and reach a higher accuracy level and cost-saving level. So, the necessity of producing a more effective and precise modeling approach has been highlighted.

Artificial Intelligence in recent years has been heated. It serves as a good assistance for human beings in the fields of Robotics and Sensory Systems, Neural Computing, and Intelligent Computer – Aided Instruction. The accuracy and productivity of AI are represented by features like feature engineering, deep learning, data input, and others. Not only does it serve as a powerful tool that reduces the difficulties and complexity associated with wastewater treatment, but it also serves the purpose of reducing expenses and maximizing chemical use, which lowers the cost of running the wastewater treatment process [2]. For example, an AI technology called Artificial neural networks (ANN) has lately gained popularity as a substitute for modeling these processes since they offer a number of benefits over the traditional model due to their capacities of self-learning and self-adapting.

The effective use of these technologies encourages additional study and invention in model structures to overcome some obstacles erected to their efficient functioning in the water treatment sectors. Although artificial intelligence increases efficiency and productivity and reduces human errors, it cannot be counted as a perfect tool. There are issues that need to be resolved in order to completely harness the capability of AI technologies in useful water treatment applications.

2. THE SIGNIFICANCE AND APPLICATION OF AI IN WASTEWATER TREATMENT

2.1 Introduction of Artificial Intelligence

Artificial Intelligence is nonhuman intelligence, the technology created by human beings. It processes vast amounts of data in ways that people are incapable of doing by using computers to perform tasks that normally need human intelligence. The goal is to do pattern recognition, judgment, and decision-making. To achieve this, people require a lot of data loaded into them. When
creating AI, humanity has learned a lot about what it is to be human, how the human brain is structured, and how humans learn and acquire competence [3].

AI is now applied in several areas. For instance, language understanding is the field that needs AI to respond to natural language: language translation, speech understanding, computational linguistics, and so on. In addition, AI technology is used in designing robots as well, in the areas of household, military, and transportation. AI is necessary for modeling, which can be used to forecast the interactions and behaviors of a group of real-world objects or entities. People can develop an intelligent system that performs adequately by fusing AI approaches with games like chess and checkers.

2.2 The Importance of Artificial Intelligence in Wastewater Treatment

Wastewater treatment, a complicated system, generates enormous amounts of data through online sensors, opening the possibility of using AI to enhance system performance. It was discovered that applied AI showed more promise for data analysis than traditional statistical evaluation.

The modeling abilities of AI techniques are quite conducive to wastewater treatment procedures since the automation of these facilities produced simple and inexpensive operations. Besides, there is a notable decrease in the incidence of human error.

Water is a kind of fluid, and studying fluid mechanics is necessary to enhance WWTPs’ performance. This subject develops out of watching fluid behavior and attempting to formulate it mathematically. There are still many phenomena that are not fully understood. With the help of AI, which has high sensitivity and efficiency, people can better predict and monitor.

2.3 The Artificial Neural Networks in Wastewater Treatment

2.3.1 Introduction of Artificial Neural Networks

Artificial neural networks are created based on the biological neural networks that make up the human brain. They also feature neurons that are interconnected to one another in different layers of the networks, resembling how neurons in an actual brain are linked to one another. The term for these neurons is nodes [4].

The node delivers the output signal to the following layer if the number rises above the threshold, much as how a signal is transferred across a synapse when the electrical activity is sufficient, all of which takes place in the binary system of 1s and 0s [5].

Figure 1. Nodes—artificial neurons—that make up an artificial neural network carry out calculations on input data and transmit the results as output data. [Owner-draw]

The late nineteenth and early twentieth century saw some background research for the field of ANNs. This mainly involved interdisciplinary study in the fields of neurophysiology, psychology, and physics. There were no detailed mathematical models of how neurons functioned in this early study, which instead focused on generic theories of learning, vision, conditioning, etc. [6]. Later, a wide variety of ANN types was studied. Numerous industries have used neural networks, including aerospace, automotive, banking, defense, recreation, engineering, medicine, oil and gas, environment, and others.

Figure 1 shows the typical artificial neural network.

The performance of a wastewater treatment facility can be predicted by using artificial neural network models that were created by using historical data [7]. ANN can predict the parameters affecting the effluent water quality with a correlation coefficient (R) between the observed and anticipated output values as high as 0.969 [8]. A wastewater treatment plant’s bulking conditions were examined by using feed-forward and backpropagation artificial neural network models for the first time by Capodaglio et al. in 1991. Auto-regressive transfer function (ARTF) and stochastic auto-regressive moving average (ARMA) models were used to compare the network’s prediction ability to theirs. The outcomes of a
20-day testing period revealed that ANN models performed best, increasing anticipating ability by 77% in comparison to forecasting which was equivalent to the average value throughout the 30-day period preceding the testing period [9].

Operational data can be collected by ANNS. The performance parameters of the procedure under study were the effluents, and five influents—TDS, TSS, COD, BOD, and O&G—were employed as input parameters to make predictions by using operational data obtained under various operating conditions. In this way, there are fewer trials, efforts, expenses, and time commitments [10].

3. DISCUSSION ABOUT ANNS

3.1 Advantages of ANNs

ANNs have the property of high accuracy, highly relying on the quality of historical data. Poor performance from ANN modeling could result from poor-quality historical data. But for ANN modeling to produce reliable prediction results, only a small amount of data is needed. By using this ANN modeling system, operating costs may be kept to a minimum, and the level of environmental stability can be assessed.

There are certain types of ANNs, such as Feed-forward Neural Networks (FFNN) and Cascade Forward Neural Networks (CFNN). The following graphs show the accuracy of ANNs when it predicts the result of BOD through CFNN and FFNN.

Through Figure 2 and Figure 3, it is easy to conclude that the predicted line and the actual line are generally the same, which represents the high accuracy of the model’s performance in ANNs.

Additionally, ANNs help with material and energy conservation. More than five years’ worth of historical operating data were provided by two sample facilities in Chongqing, China, with production capacities of 10,000 and 40,000 t/d. Using these historical and open-source data, two ANNs (GRA-CNN-LSTM model and PCA-BPNN model) were trained to forecast the inlets/outlets’ wastewater quality and quantity. The average estimation correctness of wastewater inlets/outlets indicators is more than 92.60% and 93.76%, respectively. Two weeks
in advance, the two models can be merged to create more efficient process operating strategies, which will save more than 11.20% and 16.91% of the expenses associated with energy and materials, respectively [11].

3.2 Challenges

High accuracy and prediction rates can be attained with the help of deep learning and deep ANNs. But it needs sufficient data to support experimental training, testing, locating local minima, and overfitting [12].

Under some conditions, the process performance anticipated by AI technologies may differ from the real outcomes. For instance, a sudden alteration in operational parameters or water quality may cause AI technologies to make improper predictions [13].

4. CONCLUSION

Similar to biological neural networks making up the human brain, AI is a prevalent choice in many areas. Based on statistical analysis and real-life examples, AI is a reliable technique that can improve WWTPs' performance. It has the potential to revolutionize the WWTPs. Due to various benefits, including the high predicted accuracy and the efficiency in saving cost, ANNs are increasingly used as a modeling approach for all processes to predict the effluent values of various wastewater sample parameters. Although AI technologies have many benefits, several drawbacks must be resolved before their full potential can be utilized in water treatment applications, such as dependence on a large amount of historical data and the lack of ability to deal with sudden changes. Despite these obstacles, the current state of research indicates that applications for AI technologies in water treatment have a promising future. Later research is needed to keep working with AI and look for ways to fill the holes that the utilization of AI brings.

REFERENCES