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"A Review on Applications of Artificial Neural Network Approach for Troubleshooting of Sewage Treatment Plant Process"

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Abstract—The paper "Artificial Neural Network Approach for Troubleshooting of Sewage Treatment Plant Process" proposes an ANN-based troubleshooting model to optimize the operation and maintenance of sewage treatment plants (STPs). The model uses historical plant data to detect, predict, and resolve process anomalies, identifying potential problems before they escalate. It also suggests corrective actions to restore optimal plant performance. The model uses data from multiple sensors across different stages of the sewage treatment process, identifying correlations between variables and providing real-time insights. The results show that the ANN approach significantly improves troubleshooting accuracy and response time, reducing reliance on manual labor and expert intervention. This approach contributes to environmental sustainability by ensuring high-quality effluent discharge.

The methodology involves data collection from multiple sensors across different stages of the sewage treatment process. These data points include parameters such as chemical oxygen demand (COD), biochemical oxygen demand (BOD), pH levels, turbidity, and flow rates. The ANN model processes these inputs, identifies correlations between variables, and provides real-time insights into plant operations. The model's predictive capabilities allow operators to anticipate issues like aeration system failures, chemical imbalances, or sludge settling problems, and make timely adjustments.

The results of the study demonstrate that the ANN approach significantly improves troubleshooting accuracy and response time compared to conventional methods. By automating the detection and resolution of process anomalies, the ANN-based system reduces reliance on manual labor and expert intervention, leading to more consistent treatment outcomes and lower operational costs. Additionally, the system's ability to learn from new data enables continuous optimization and adaptation to changing environmental conditions.

In conclusion, the application of Artificial Neural Networks in the troubleshooting of sewage treatment plants represents a major advancement in wastewater management. This approach not only enhances the operational efficiency of STPs but also contributes to environmental sustainability by ensuring high-quality effluent discharge. The proposed ANN-based troubleshooting system offers a proactive and scalable solution that can be integrated into existing plant infrastructures, paving the way for smarter and more resilient sewage treatment operations in the future.

Keywords— Artificial Neural Network (ANN), Sewage Treatment Plant (STP), Wastewater Management, Troubleshooting, Process Optimization, Predictive Maintenance, Real-time Monitoring, Operational Efficiency, Data Analysis, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Environmental Sustainability, Sensor Data, Anomaly Detection, Automated System.

INTRODUCTION

Sewage treatment plants (STPs) are essential infrastructures for managing wastewater and safeguarding environmental and public health. As urban populations continue to grow, the demand for effective sewage treatment becomes increasingly critical. STPs are designed to remove contaminants from wastewater through various biological, chemical, and physical processes. However, these processes can be complex and susceptible to a range of operational issues, including fluctuations in influent quality, equipment failures, and human errors. Such challenges not only compromise the efficiency of the treatment process but can also lead to significant environmental impacts and regulatory non-compliance.

Traditional troubleshooting methods often rely on manual monitoring and empirical approaches, which can be labour-intensive and may not provide timely insights into the system's performance. Consequently, there is a pressing need for advanced techniques that can enhance the operational efficiency and reliability of STPs. Artificial intelligence (AI) and machine learning (ML) methodologies have emerged as promising solutions in various fields, including environmental

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engineering. Among these, artificial neural networks (ANNs) offer powerful predictive capabilities, enabling the analysis of complex datasets to identify patterns and relationships that are not easily discernible through conventional methods.

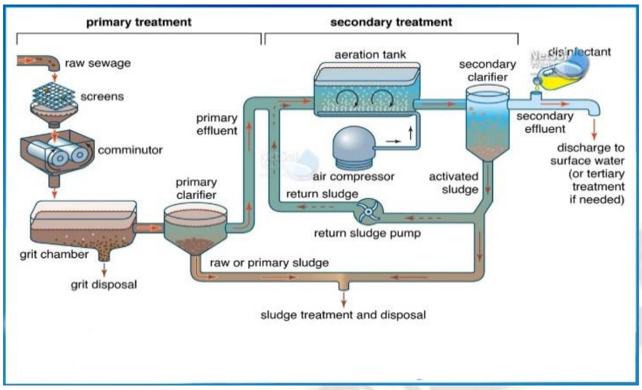

Figure1.1: Process for the Sewage Treatment Plant

This research aims to develop an ANN model specifically tailored for troubleshooting the sewage treatment process. By leveraging historical operational data and real-time monitoring parameters, the ANN will predict potential failures and provide actionable insights to optimize the treatment process. Additionally, the study will evaluate recent optimization strategies that can further enhance the economic viability of STP operations. Ultimately, the adoption of an ANN approach has the potential to transform how STPs operate, leading to improved performance, reduced costs, and enhanced environmental protection.

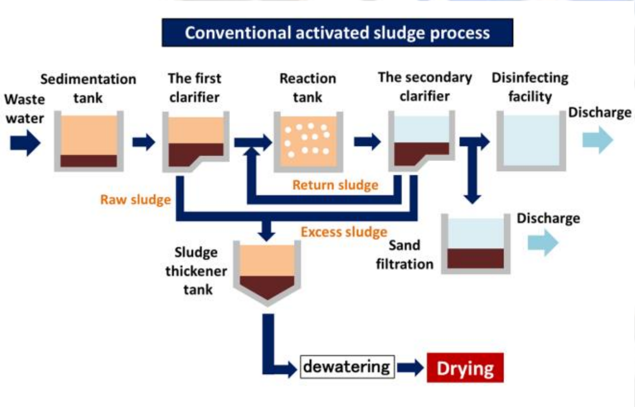

Figure1.2: Conventional Activated Sludge Process

LITERATURE REVIEW

Muhammad Ibrahim et al., ELSEVIER, Vol 362, 2024. "Artificial neural network modeling for the prediction, estimation, and treatment of diverse wastewaters: A comprehensive review and future perspective"

Artificial neural networks (ANNs) are increasingly being used in wastewater treatment plants (WWTPs) to improve efficiency and sustainability. This paper explores the effectiveness of ANNs in predicting, estimating, and treating various wastewater types. It examines their applicability in various processes, including membrane bioreactors, coagulation/flocculation, UV-disinfection processes, and biological treatment systems. The paper also analyzes pollutants from wastewater using both ANN and ANN-based models. The study highlights the economic and energy-effective benefits of ANNs in wastewater treatment, with potential energy savings of up to 30%.

Özgül Çimen Mesutoğlu et al., Science Report ,2024. "Prediction of COD in industrial wastewater treatment plant using an artificial neural network"

The Aksaray industrial wastewater treatment plant was modelled using artificial neural networks in MATLAB software. The study used daily data from the plant over 9 months, assessing treatment efficiency using chemical oxygen demand output. Principal component analysis was used for input, and the model's performance was evaluated using MSE, MAE, and R2.

Voravich Ganthavee et al., Springer, Volume 22, 2024. "Artificial intelligence and machine learning for the optimization of pharmaceutical wastewater treatment systems: a review"

Access to clean water is a major health issue due to pollution from industrialization and urbanization. Artificial intelligence and machine learning are being used to optimize pharmaceutical wastewater treatment systems, focusing on water quality, disinfection, renewable energy, biological treatment, blockchain technology, big data, cyber-physical systems, and automated smart grid power distribution networks.

Tran Nhat Minh et al., GIJASH, Vol. 8; Issue: 2,2024. "Artificial Neural Networks for Modeling Pollutant Removal in Wastewater Treatment: A Review"
Water pollution is a global issue, requiring effective wastewater treatment strategies. Artificial neural networks (ANNs) and adaptive neuro-fuzzy inference systems (ANFIS) are powerful tools for modeling and optimizing wastewater treatment. They can predict pollution removal efficiencies, reduce costs, and ensure regulatory compliance, paving the way for sustainable water management practices.

Osman Ucuncu et al., Unpaid Journal,2024. "Removal efficiency prediction model based on the artificial neural network for pollution prevention in wastewater treatment plants"

This study utilized Artificial Neural Networks (ANNs) to estimate the removal efficiency of biological oxygen demand, total nitrogen, total phosphorus, and total suspended solids in wastewater treatment effluent from various treatment methods in a wastewater treatment plant.

Esmaeel Mohammadi et al., arxiv,2024. "Deep Learning Based Simulators for the Phosphorus Removal Process

Control in Wastewater Treatment via Deep Reinforcement Learning Algorithms"

The study focuses on the application of Deep Reinforcement Learning (DRL) in wastewater treatment, specifically phosphorus removal. Despite high accuracy, uncertainty and incorrect predictions limited their performance over longer horizons. The researchers suggest creating simulation environments for DRL algorithms using SCADA data without complex system modeling or parameter estimation to improve process control.

M. Raissi et al., ELSEVIER,2024. "Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations"

The study introduces physics-informed neural networks, trained to solve supervised learning tasks while respecting physics laws. It presents two types of algorithms: continuous time and discrete time models, which form a new family of data-efficient spatial-temporal function approximators and allow for arbitrarily accurate implicit Runge–Kutta time stepping schemes. The effectiveness of the framework is demonstrated through classical problems.

Baochang Xu et al., Springer link, Volume 17, article number 19, 2024, "Fault Diagnosis of Wastewater Treatment Processes Based on CPSO-DKPCA"

The paper proposes an improved dynamic kernel principal component analysis (DKPCA) and Granger causality (GC) analysis model using chaotic particle swarm optimization (CPSO) to detect faults in wastewater treatment plants. The model uses a kernel function, training data, and a novel fault candidate variable selection method to locate root variables. The CPSO algorithm optimizes DKPCA's kernel function parameters, enhancing fault monitoring accuracy. The method achieves better detection rates of 95.83% and 93.33% in simulated and real WWTPs.

Sourabh Sarpanchal et al. IJEAST, Vol. 7, Issue 12,2023. "Analysis of efficiency of sewage treatment plant using data science"

The study used the Sewage Treatment Plant (STP) of New Naidu, near Naidu Hospital, to collect 304 days of daily inflow data from June 2021 to March 2022. The data was used to analyze time series and forecast wastewater inflow, and the water was categorized using pH, Total Suspended Solids, COD, and BOD.

Marina Salim Dantas et al., Water Science & Technology, Vol 88 No 6, 2023. "Artificial neural networks for performance prediction of full-scale wastewater treatment plants: a systematic review"

A systematic literature review on the use of artificial neural networks (ANNs) to predict effluent quality and removal efficiencies of full-scale wastewater treatment plants (WWTPs) revealed that most studies used feedforward neural network models with a backpropagation training algorithm. The findings may help in finding an optimal design modeling process for future studies of similar prediction problems.

Xinyi Qiu et al., EPPCT, 2023. "The Application of Artificial Intelligence – Artificial Neural Networks – in Wastewater Treatment"

Wastewater treatment is crucial for reducing pollutants, promoting water quantity, and protecting ecosystems. However, complex natural conditions and limited technology present uncertainties. Artificial Intelligence (AI) can help with complex tasks, leading to high accuracy and cost-saving benefits. This article introduces AI Neural Networks in wastewater treatment, highlighting its potential for future applications.

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Hayat Mekaoussi et al., Heliyon,2023. "Predicting biochemical oxygen demand in wastewater treatment plant using advance extreme learning machine optimized by Bat algorithm"

The paper presents a hybrid machine learning model based on the Bat algorithm for modeling five-day effluent biochemical oxygen demand (BOD5). The model combines the Bat algorithm for parameter optimization and the standalone ELM. It was tested against other models and found to be the most accurate when all six input variables were included. The model outperformed all other benchmark models in terms of predictive accuracy, with values of approximately 0.885, 0.781, 2.621, and 1.989, respectively.

Duarte MS et al., NIH,2023. "A Review of Computational Modeling in Wastewater Treatment Processes"

Wastewater treatment companies face challenges in optimizing energy efficiency, meeting water quality standards, and recovering resources. Computational models have been used to predict performance, but they often involve simplification and calibration. Data-driven models, which use relationships in available data, are becoming more attractive for real-time process simulation. This review discusses the implementation of machine learning models for WWTP effluent characteristics, wastewater inflows, anomaly detection, and energy consumption optimization. It also discusses hybrid models and critical gaps in mathematical modeling implementation in wastewater treatment processes.

M M Al-Khuzaie et al., EPPCT, 2023. "The Application of Artificial Intelligence – Artificial Neural Networks – in Wastewater Treatment"

Wastewater treatment is crucial for reducing pollutants, promoting water quantity, and protecting ecosystems. However, complex natural conditions and limited technology present uncertainties. Artificial Intelligence (AI) can help with complex tasks, leading to high accuracy and cost-saving benefits. This article introduces AI Neural Networks in wastewater treatment, highlighting its potential for future applications.

Wei Lin et al., Frontiers, Volume 10, 2022. "Prediction of wastewater treatment system based on deep learning"

This paper proposes a method to accurately model the IC reactor of a wastewater treatment system using an artificial neural network model. The model predicts the COD value of effluent in a papermaking wastewater treatment plant. Experimental results show the model's simulation prediction value is consistent with actual values, with a maximum relative error of 18.6%. The correlation coefficient is 0.7431.

Behrooz Mamandipoor et al., 2022 Unpaid Journal, "Monitoring and Detecting Faults in Wastewater Treatment Plants 2 using Deep Learning"

This study investigates a method using Deep Neural Networks to model faults in wastewater treatment plants. Using a real-life dataset with over 5.1 million sensor data points, the method achieves a fault detection rate of over 92%, outperforming traditional methods. The method is designed to capture temporal behavior of sensor data, enabling timely detection of collective faults.

M M Al-Khuzaie et al., STACLIM, 2022. "Optimization pollutants removals from wastewater treatment plant using artificial neural networks"

The study aims to improve the al-diwaniyah wastewater treatment plant (WWTP) operation and estimate quality parameters using artificial neural networks (ANNs). The ANNs predict the sludge volume index (SVI) using operational and influent quality characteristics. The best model, consisting of six input nodes, five hidden nodes, and one output layer, has an R2 value of 0.965. This tool can be used by WWTP operators to improve treatment process effectiveness and dependability.

Kamel Jafar et al., MDPI, 2022. "Predicting Effluent Quality in Full-Scale Wastewater Treatment Plants Using Shallow and Deep Artificial Neural Networks"

The research presents a novel machine learning approach for predicting wastewater treatment plant (WWTP) performance using artificial neural networks and nonlinear transformation (ANN) models. The models, including feed-forward neural network (FFNN) and random forest (RF), are based on pollution data collected over three years. The models provide an adaptive, functional, and alternative methodology for modeling WWTP performance. The results show that SNN can predict plant performance with a correlation coefficient of up to 88%, 90%, 93%, and 96% for single models and up to 88%, 96%, and 93% for ensemble models. However, DNN with three, four, and five hidden layers has low performance and accuracy due to small datasets.

Mark McCormick et al., MDPI.2022. "An Artificial Neural Network for Simulation of an Upflow Anaerobic Filter Wastewater Treatment Process"

This study developed a problem-solving approach and simulation tool for specifying wastewater treatment process equipment design parameters. The approach used an artificial neural network (ANN) numerical model for supervised learning and process simulation on a new dataset. The model accurately predicted calorific value reduction, with a root-mean-square error of 0.101 and a coefficient of determination of 0.66. The model's capacity to distinguish differences in equipment design parameters was assessed, and the values of the three mechanical feature parameters from the highest ranked simulated experiment were recommended for industrial scale upflow anaerobic filters for wastewater treatment.

Ivan Pisa Dacosta et al., UAB,2022. "Artificial Neural Networks in the Wastewater Industry from Conventional to Data base Industrial Control"

Industry 4.0 has led to the adoption of data-driven methodologies in industries, including soft-sensors and predictive maintenance processes. However, traditional controllers still play a crucial role in managing industries. This thesis aims to explore the application of Deep Learning methodologies, particularly Artificial Neural Networks (ANN), in a Wastewater Treatment Plant (WWTP). ANNs support conventional controllers by predicting effluent concentrations, allowing them to actuate before violations occur, resulting in improved control performance.

Yue Zhang et al., IEEE,2022. "Prediction and Detection of Sewage Treatment Process Using N-BEATS Autoencoder Network"

The study proposes a method for predicting multivariate time series data in sewage treatment plants using neural expansion analysis and an N-BEATS autoencoder network. The method outperforms other methods, improving prediction results by

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22% and anomaly detection accuracy by 98%. The model is more scientific and flexible, with systematic potential and significant improvement in sewage treatment processes.

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Nasser Mehrdadi et al., NMCE,2022. "Modeling of Tehran South Water Treatment Plant Using Neural Network and Fuzzy Logic Considering Effluent and Sludge Parameters"

This study uses Matlab software, a neural network model, and an adaptive neuro-fuzzy inference system (ANFIS) to predict qualitative parameters of wastewater and sludge at a south Tehran sewage treatment plant. The models were validated and compared with standard values, providing suitable classification for reuse. The results showed acceptable errors in both systems, with the adaptive neuro-fuzzy inference system being more effective in estimating treated wastewater and sludge quality.

Sanja Radović et al., Unpaid Journal, 2022. "Machine learning as a support tool in wastewater treatment systems – a short review"

Machine learning (ML) is a subset of artificial intelligence (AI) that teaches computers to learn from data and improve with experience. It has been increasingly used in ecological and environmental engineering solutions, such as wastewater treatment systems (WWTS). ML helps understand the correlation between input features and output targets through a data-driven approach. Common ML models include artificial neural networks (ANN), deep neural networks (DNN), support vector machines (SVM), and random forest models. ML has been shown to optimize material synthesis, reduce the number of runs needed for optimal results, and save time and cost.

Vahid Nourani et al., ELSEVIER,2021. "Artificial intelligence ensemble modeling of wastewater treatment plant using jittered data"

The study used black box artificial intelligence models like FFNN, SVR, and ANFIS to predict effluent biological and chemical oxygen demand at the Tabriz wastewater treatment plant. The autoregressive integrated moving average (ARIMA) linear model was used to compare linear and non-linear models' abilities in complex processes prediction. Data post-processing ensemble and jittering data pre-processing methods were used to improve prediction accuracy. The SVR model provided better results, while jittering and ensemble models increased prediction accuracy up to 20% at the verification phase.

Ziad Al-Ghazawi et al., ELSEVIER, Vol 44, 2021. "Use of artificial neural network for predicting effluent quality parameters and enabling wastewater reuse for climate change resilience – A case from Jorda"

This study developed artificial neural network (ANN) models to predict the quality of treated effluent from the Wadi Arab wastewater treatment plant (WWTP)-Phase1. Four ANN models were developed, based on input parameters like influent flow rate, temperature, pH, BOD5, COD, SS, and NH4-N. The models were found to be highly sensitive to influent pH and slightly sensitive to influent SS. The results suggest ANN models are beneficial for managing the treatment process, producing effluent quality within Jordanian standards, and protecting the Jordan Valley ecosystem.

Francesco Facchini et al., MDPI, 2021"A Neural Network Model for Decision-Making with Application in Sewage Sludge Management"

Wastewater treatment is crucial for ecosystem health and human well-being. Sewage sludge produced during treatment can be disposed of in landfills or used for fertilizer, building materials, or fuel. This study developed a decision model using an Artificial Neural Network (ANN) to identify the most effective sludge management strategy economically. The model identifies suitable SS treatments based on multiple factors, supporting decision-making and user requirements.

Abdalrahman Alsulaili et al., Reasearch gate, Vol 88 No 6, 2021. "Artificial neural network modeling approach for the prediction of five-day biological oxygen demand and wastewater treatment plant performance"

The study explores the use of artificial neural networks (ANNs) to predict influent BOD5 concentration and wastewater treatment plants (WWTPs) performance. The results show that the ANN model for BOD concentration performed best among three outputs, with optimal performance influenced by influent temperature and conductivity. The model achieved high accuracy, making it a viable soft sensor for online control and management systems in WWTPs.

Selami DEMİR et al., SJENS,2020. "Artificial neural network simulation of advanced biological wastewater treatment plant performance"

This study presents an artificial neural network (ANN) simulation of chemical oxygen demand, total nitrogen, and total phosphorus removal efficiencies in an advanced biological wastewater treatment process. Seven input parameters were used, including influent COD, TN, TP concentrations, internal recycle ratios, wastewater temperature, and hydraulic retention time. Open-source ANN tools were found to be reliable and efficient.

Hubert Jenny et al., ADB, 2020. "Using Artificial Intelligence for Smart Water Management Systems"

Unaccounted-for-water (UFW) is a crucial benchmarking indicator for water utilities' operational and financial performance. Despite increased use of numerical tools, the water sector is lagging in digital transformation. Cost-effective sensors and IoT are transforming smart water management. Policy action should focus on enabling ethics, issuing smart water roadmaps, and piloting Hydraulic Modeling 2.0 for UFW.

Fu-Xing Liu et al., NEPT, Vol. 18, No. 5.2019. "Research on Sewage Treatment Computer System Based on ADP Iterative Algorithm"

The paper proposes a computer system using an iterative ADP algorithm to control and optimize the concentration of dissolved oxygen and nitrate nitrogen in sewage treatment, addressing the complex and time-varying nature of the process due to uncertainties in water and environmental factors.

Sani Isah Abba et al., NAU,2019. "Wastewater treatment plant performance analysis using artificial intelligence – an ensemble approach"

The study uses artificial intelligence-based non-linear models, SVM approaches, and the MLR method to predict the performance of Nicosia wastewater treatment plant. Results show that simple averaging ensemble, weighted averaging ensemble, and neural network ensemble improve AI modeling efficiency by up to 14%, 20%, and 24%, respectively. The ELM model outperforms the MLP model in prediction accuracy. The study also proposes two nonlinear system identification models (HW and NARX) for estimating effluents characteristic of total suspended solids (TSSeff) and pHeff, proving to be reliable modeling tools for the plant's performance.

Heni Fitriani et al., ICANCEE, 2018. "Economic analysis of the wastewater treatment plant"

The paper discusses the economic feasibility of installing a Wastewater Treatment Plant (WWTP) to address municipal and domestic wastewater issues. It focuses on determining feasible rates based on users' ability to pay (ATP) and willingness to pay (WTP). The study found that higher ATP values made the NPV and BCR economically feasible. The study suggests local government subsidies could help with construction and operation costs.

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Min Qiu et al., NEPT, Vol. 17, 2018. "Study on Modelling and Neural Network Control Algorithm in Sewage Treatment Process"

The study addresses environmental pollution caused by sewage discharge in industries. Using an activated sludge method and neural network control algorithm, the study aims to improve water quality and dissolved oxygen concentration in wastewater treatment. The proposed neural network predictive control algorithm effectively achieves nitrate nitrogen requirements, achieving effective sewage treatment.

Mihaela Miron et al., ICSTCC,2018. "Artificial Neural Network Approach for Fault Recognition in a Wastewater Treatment Process"

The paper discusses fault detection and recognition for a Wastewater Treatment Plant using a feed-forward neural network. Tested on a simulated WWTP, the network demonstrated good recognition in 97.2% of cases, despite six fault types.

Anil Kumar Bisht et al., IJFRCSCE, Volume: 3 Issue: 8,2017. "An Investigation of Assessment and Modelling the Water Quality of Rivers Based on Artificial Neural Networks- An Initiative towards the River Ganga"

Research on assessing and modeling water quality in rivers in India and abroad is focusing on artificial neural networks (ANNs) for complex, non-linear problems. ANNs are increasingly used for prediction and forecasting in areas like climate, rainfall, and water quality. This paper investigates existing research on ANNs and finds them efficient for water quality modeling and forecasting. Future work will focus on the Ganga River's water quality modelling.

Ms. Ekta S Dhande et al., IJERT, Vol. 3 Issue 9, 2014. "Wastewater Quality Forecasting by using Artificial Neural Network"

Urbanization has increased wastewater generation, putting pressure on treatment plants. A study developed an Artificial Neural Network (ANN) model for wastewater quality forecasting. Using influent parameters from Kasarwadi wastewater treatment plant, the model used multilayer perceptron's and recurrent network models. The results showed ANN can efficiently analyze and predict wastewater

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quality, ensuring higher-quality treated wastewater at lower costs.

Shilpi Rani et al., IJSR ,2012. "Application of Artificial Neural Network (ANN) for Reservoir Water Level Forecasting"

Future water level forecasts help determine reservoir storage capacity for irrigation, water supply, and hydropower. Artificial neural network (ANN) is a reliable model for water resource management. Inflow, water level, and released water are inputs. Using parameters like room mean square error, correlation, and discrepancy ratio, the best model was determined for the Sukhi Reservoir Project in Gujarat, India. Feed Forward distributed time delay ANN is the most suitable predictor for real-time water level forecasting.

Mohammed S. Jami et al., African Journal of Biotechnology, Vol. 10,2011. "Simulation of ammoniacal nitrogen effluent using feedforward multilayer neural networks"

The Department of Environment, Malaysia has added ammoniacal nitrogen as a monitoring parameter in domestic wastewater treatment plants. This study investigates the effectiveness of artificial neural networks in solving complex problems similar to wastewater treatment plant conditions. Data from Bandar Tun Razak Sewage Treatment plant was used.

P. Subbaraj et al., IJCA, Volume 9– No.7, 2010. "Artificial Neural Network Approach for Fault Detection in Pneumatic Valve in Cooler Water Spray System"

This paper presents a design and development of an artificial neural network-based model for fault detection of a pneumatic valve in a cement industry cooler water spray system. The model detects 19 faults, generated through real-time fault creation in a laboratory experimental model. The model's performance is satisfactory for real-time fault diagnosis, ensuring safe plant operation.

M. B. Saidutta et al., JUEE, v.2, n.1, 2008. "Prediction of bod and cod of a refinery wastewater using multilayer artificial neural networks"

Artificial neural networks (ANNs) have shown the ability to learn and capture non-linear behavior among variables, making modelling possible with minimal knowledge. In a study, 12 ANN-based models were proposed to predict Biochemical Oxygen Demand and Chemical Oxygen Demand concentrations of wastewater from a petrochemical industry effluent treatment plant. The network was trained using 103 data points and tested, revealing its accuracy and efficacy in predicting unknown water quality parameters.

Gap of Study

AI in Sewage Treatment Plants: Challenges and Opportunities

- Limited AI application for real-time troubleshooting.
- Insufficient use of historical operational data in training ANN models.
- Gap in cross-plant validation due to studies confined to specific STPs.
- Limited integration of ANN-driven approaches with conventional systems.

Goal of the Research

The study aims to evaluate recent optimization strategies that could enhance the overall efficiency and cost-effectiveness of sewage treatment operations."

Objectives

The goal this study is to develop and suggest a model using artificial neural network which will be capable to predict the parameters required to optimize the sewage treatment process.

The objectives of research can be summarized as follows:

- To Identify the effect of the current sewage treatment plant process control variables on effluent quality and efficiency sewage treatment plants.
- To study current status of sewage treatment plant process optimization and design and develop an ANN model for improvement of process performance in sewage treatment.
- To investigate the feasibility of developing artificial neural network model for improvement of sewage treatment plant process.

Problem Statement

This research proposes the development of an artificial neural network (ANN) model to enhance the troubleshooting process in sewage treatment plants (STPs). The ANN can analyze historical operational data, predict potential failures, and recommend corrective actions. This innovative approach aims to improve the efficiency, reliability, and economic viability of STPs, ultimately leading to better environmental outcomes.

"STPs: Enhancing Troubleshooting Processes"

- STPs crucial for public health and environmental sustainability.
- Operational challenges include inefficiencies, malfunctions, and environmental violations.
- Traditional methods are time-consuming and insufficient.
- Lack of real-time predictive capabilities in existing systems.

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- Proposed solution: artificial neural network model for operational data analysis, failure prediction, and corrective action recommendations.

RESEARCH METHODOLOGY

Artificial Neural Network

A Brief History of ANN: The history of CNN can be divided into the following three eras –

ANN during 1940s to 1960s

Some key developments of this era are as follows -
1943 - It has been assumed that the concept of neural network started with the work of physiologist, Warren McCulloch, and mathematician, Walter Pitts, when in 1943 they modelled a simple neural network using electrical circuits to describe how neurons in the brain might work.

1949 - Donald Hebb's book, The Organization of Behaviour, put forth the fact that repeated activation of one neuron by another increases its strength each time they are used.
1956 - An associative memory network was introduced by Taylor.
1958 - A learning method for McCulloch and Pitts neuron model named Perceptron was invented by Rosenblatt.
1960 - Bernard Widrow anumarana Hoff developed models called "ADALINE" and "MADALINE."

ANN during 1960s to 1980s

Some key developments of this era are as follows -
1961 - Rosenblatt made an unsuccessful attempt but proposed the "backpropagation" scheme for multilayer networks.
1964 - Taylor constructed a winner-take-all circuit with inhibitions among output units.
1969 - Multilayer perceptron MLP was invented by Minsky and Papert.
1971 - Kohonen developed Associative memories.
1976 - Stephen Grossberg and Gail Carpenter developed Adaptive resonance theory.

ANN from 1980s till Present

Some key developments of this era are as follows -
1982 - The major development was Hopfield's Energy approach.
1985–Boltzm ANN machine was developed by Ackley, Hinton, and Sejnowski.
1986 - Rumelhart, Hinton, and Williams introduced Generalised Delta Rule.
1988 - Kosko developed Binary Associative Memory BAM and gave the concept of Fuzzy Logic in ANN.
The historical review shows that significant progress has been made in this field. Neural network-based chips are emerging and applications to complex problems are being developed. Surely, today is a period of transition for neural network technology.

Biological Neural Networks

Some attractive features of the biological neural network that make it superior to even the most sophisticated A1 computer system for pattern recognition tasks are the following:

(a) **Robustness and Fault Tolerance:** The decay of nerve cells does not seem to affect the performance significantly.
(b) **Flexibility:** The network automatically adjusts to a new environment without using any pre-programmed instructions.
(c) **Ability to deal with a variety of Data Situations**: The network can deal with information that is fuzzy, probabilistic, noisy and inconsistent.
(d) Collective computation: The network performs routinely many operations in parallel and also a given task in a distributed manner.

The features of the biological neural network are attributed to its structure and function. The description of the biological neural network in this section is adapted from [Muller and Reinhardt, 1991]. The fundamental unit of the network is called a neuron or a nerve cell. Figure shows a schematic of the structure of a neuron.

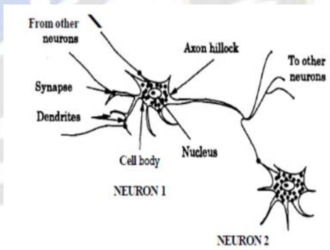

Figure 1.3: Biological Neural Network

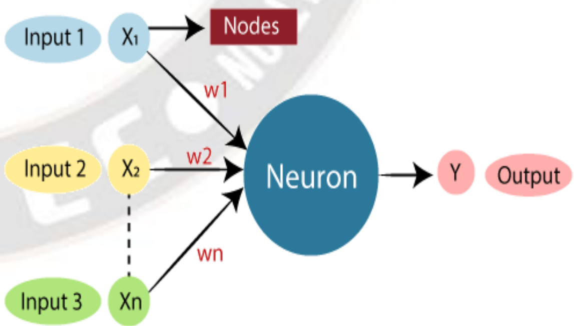

Figure 1.4: Basics of ANN

As shown in **Fig.**, it consists of a cell body or soma where the cell nucleus is located. Treelike nerve fibres called dendrites are associated with the cell body. These dendrites receive signals from other neurons. Extending from the cell body is a single long fibre called the axon, which eventually branches into strands and sub-strands connecting to many other neurons at the synaptic junctions, or synapses. The receiving ends of these junctions on other cells can be found both on the dendrites and on the cell bodies themselves. The axon of a

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typical neuron leads to a few thousand synapses associated with other neurons.

Neural Network Model

Neural model Neural networks are parallel computing devices, which is basically an attempt to make a computer model of than of the brain. The main objective is to develop a system to perform various computational tasks faster than the traditional systems. These tasks include pattern recognition and classification, approximation, optimization, and data clustering.

Artificial neural networks employ a mathematical simulation approach, that adopts a biological system in order to process the acquired information and derive the output(s) after the network has been trained properly for pattern recognition. The main theme of CNN model is, it considers the brain as a parallel computational device for various computational tasks that were performed relatively poorly by traditional serial computers. The neural network structure in the present study possessed adopts a three-layer learning network consisting of an input layer, a hidden layer and an output layer consisting of output variable(s) as shown in

Fig. The input nodes pass on the input signal values to the nodes in the hidden layer unprocessed. The values are distributed to all the nodes in the hidden layer depending on the connection weights between the input node and the hidden nodes. Connection weights are the interconnecting links between the neurons in successive layers. Each neuron in a certain layer is connected to every single neuron in the next layer by links having an appropriate and an adjustable connection weight.

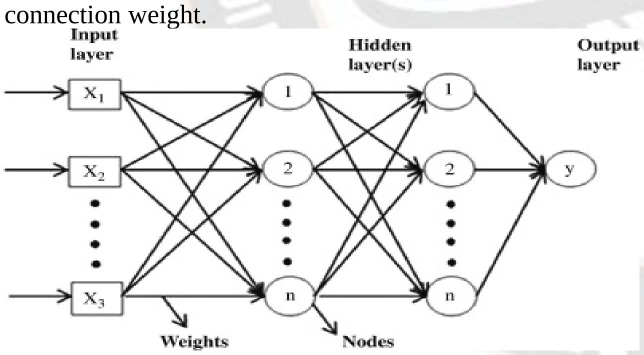

Figure 1.5: Architecture of the Neural Network Model Used in this Study

In the present study, the Feed Forward Back Propagation (FFBP) algorithm was used for training using Levenberg–Marquardt optimization technique. This optimization technique is reported to be more powerful than the conventional gradient descent techniques (Najjar andAli, 1998). The study showed that the Marquardt algorithm is very efficient when training networks which has few hundred weights. Although the computational requirements are much higher in iterations of the Marquardt algorithm its efficiency is higher. This is especially true, when high precision is required. The Feed Forward Back Propagation (FFBP) distinguishes itself by the presence of one or more hidden layers, whose computation nodes are correspondingly called hidden neurons or hidden units. The function of hidden neurons is to intervene between the external input and the network output in useful manner.

Feed forward Network:

It is a non-recurrent network having processing units/nodes in layers and all the nodes in a layer are connected with the nodes of the previous layers. The connection has different weights upon them. There are no feedback loop means the signal can only flow in one direction, from input to output. It may be divided into the following two types -

Single Layer Feed Forward Network -The concept is of feedforward CNN having only one weighted layer. In other words, we can say the input layer is fully connected to the output layer.

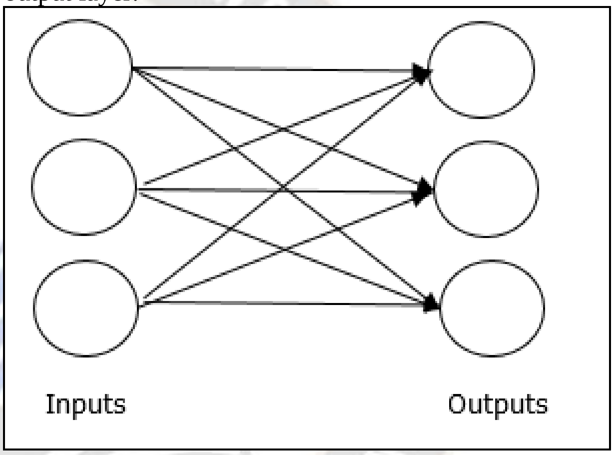

Figure 1.6: Single Layer Feed Forward Network

Multilayer feedforward network -The concept is of feedforward CNN having more than one weighted layer. As this network has one or more layers between the input and the output layer, it is called hidden layers.

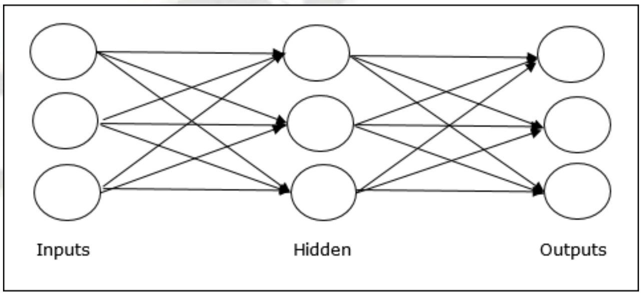

Figure 1.7: Multilayer Feed Forward Network

Feedback Network:

As the name suggests, a feedback network has feedback paths, which means the signal can flow in both directions using loops. This makes it a non-linear dynamic system, which changes continuously until it reaches a state of equilibrium. It may be divided into the following types-

a) Recurrent Networks -They are feedback networks with closed loops. Following are the two types of recurrent networks.

Fully Recurrent Network - It is the simplest neural network architecture because all nodes are connected to all other nodes and each node works as both input and output.

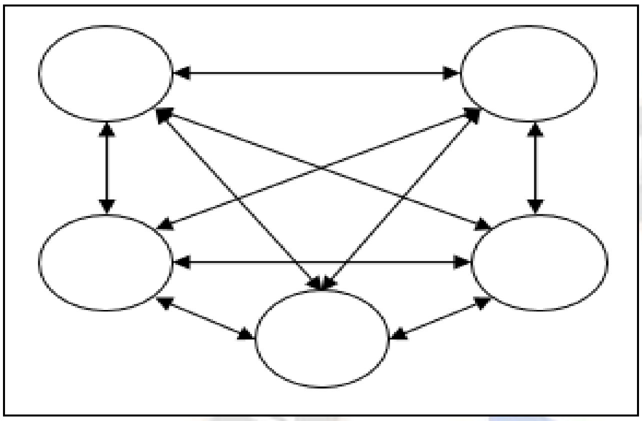

Figure 1.8: Fully Recurrent Network

Jordan Network - It is a closed loop network in which the output will go to the input again as feedback as shown in the following diagram.

CONCLUSION

Artificial neural networks (ANN) can improve sewage treatment plant (STP) processes by analyzing complex datasets and real-time monitoring parameters. This allows for accurate predictions of potential failures and inefficiencies, enabling timely corrective measures. This not only optimizes the process but also reduces operational costs and environmental non-compliance risks. Future research should focus on refining the model and exploring its application across different STP types.

The implementation of an artificial neural network (ANN) approach for troubleshooting sewage treatment plant (STP) processes presents a significant advancement in enhancing the operational efficiency and reliability of wastewater management systems. This research highlights the potential of ANNs to analyze complex datasets derived from historical operational data and real-time monitoring parameters, allowing for accurate predictions of potential failures and operational inefficiencies.

By effectively identifying patterns and interdependencies within the treatment processes, the ANN model can provide actionable insights that enable plant operators to implement timely corrective measures. This not only optimizes the sewage treatment process but also reduces operational costs and minimizes the risk of environmental non-compliance. Furthermore, the exploration of recent optimization strategies demonstrates the importance of integrating innovative technologies in the management of STPs.

In conclusion, adopting an ANN-based approach can significantly improve the troubleshooting capabilities of STPs, leading to more sustainable and economically viable wastewater treatment practices. Future work should focus on further refining the model through extensive validation and exploring its application across different types of STPs, ultimately contributing to the development of smarter and more efficient wastewater management solutions.

Future Scope

Artificial neural networks (ANNs) can be used to improve sewage treatment plant (STP) processes by enhancing predictive accuracy and robustness. Future research can include refining the ANN model by incorporating diverse datasets, integrating real-time data, combining ANNs with other machine learning techniques, conducting cost-benefit analyses, assessing environmental impact, and expanding the methodologies to other wastewater treatment processes. Additionally, creating user training programs and implementation guidelines for operators can facilitate the effective adoption of ANN-based tools. These advancements can lead to enhanced sustainability and efficiency in wastewater management. By pursuing these future directions, researchers and practitioners can significantly advance the capabilities of sewage treatment processes.

Limitations

- Artificial Neural Networks in Sewage Treatment Plants
- Enhances predictive accuracy and robustness.
- Future research includes refining ANN model, real-time data integration, and machine learning techniques.
- Conducts cost-benefit analyses, assesses environmental impact, and expands methodologies.
- Creates user training programs and implementation guidelines.
- Aims for enhanced sustainability and efficiency in wastewater management.

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