Governance of artificial intelligence techniques in wastewater treatment: bibliometric analysis，critical review and future challenges

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1. Introduction

Artificial Intelligence (AI) technology, as a science that systematically integrates theoretical methods and practical applications, can realize the intelligent use of objects by imitating human intelligence. The pollutant removal in the wastewater treatment process is quite complex with some key points such as pipeline network assessment, facilities maintenance, operational status monitoring, and fault analysis. In addition to meeting the emission standards, it is also necessary to realize the multi-objective requirements of energy saving, resource recovery, and cost reduction. In the field of wastewater treatment, AI technology has great potential for application.

2. Data and method

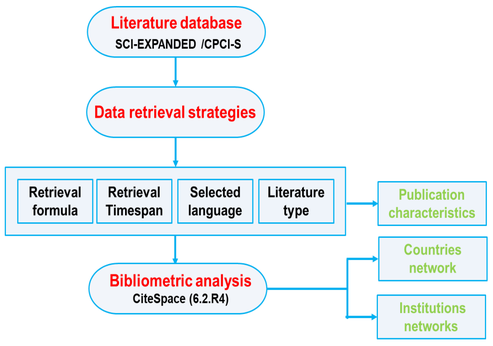

Fig.1: Outline of bibliometric analysis

The research used the SCI-EXPANDED and CPCI-S as the databases, and the literature was searched using the following retrieval strategy: (1) the retrieval formula was TS = ("artificial intelligence" OR "machine learning") AND TS = ("wastewater" OR "waste water" OR "sewage"), which indicates that the corresponding terms will be extracted from the title, abstract and keywords; (2) the retrieval timespan was set from January 1, 2000 to December 31, 2022; (3) the language was selected as English; (4) the literature type was set as Article / Review / Meeting to exclude book chapters and retracted publications. Finally, 848 documents were obtained, which were imported into CiteSpace software for analysis.

3. Result and discussion

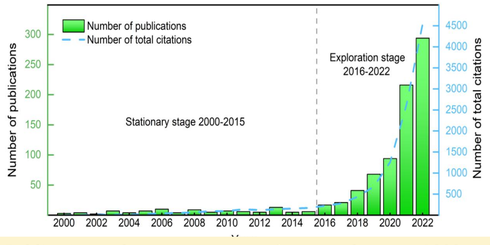

Fig.2: Publication and citation output performance between 2000 and 2022

3.1 Results of bibliometrics

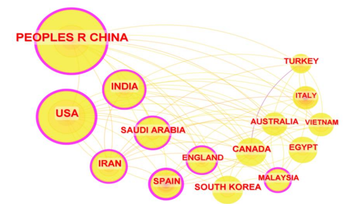

Fig.3: The cooperation network of Top 15 productive countries

Fig.4: The cooperation network of Top 15 productive institutions

The bibliometrics analysis on countries and institutions helps recognize the research interests and clarify the cooperation relationship. Fig. 2 and Fig.3 show the cooperation network of the Top 15 publication countries and institutions. It can be seen that China, India, and the United States have published the most papers in this field, with the greatest financial and policy support.

3.2 Introduction of AI

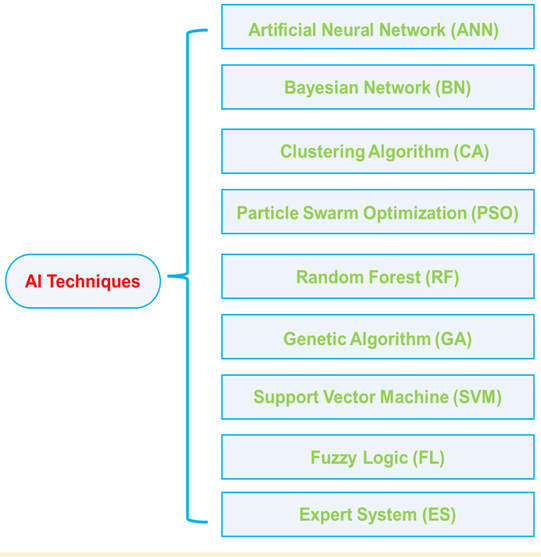

Fig.5: Classification of AI technology applied in wastewater treatment

3.3 Applications of AI

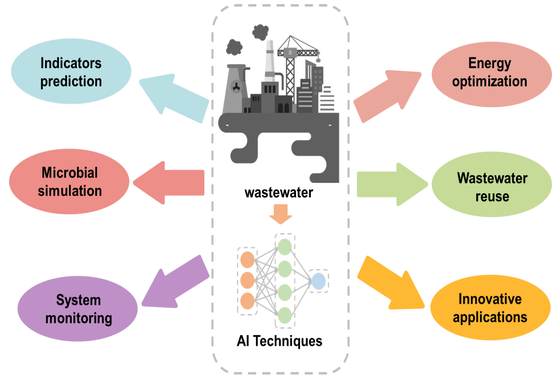

Fig.6: Applications of AI technology in wastewater treatment

AI technology is widely used in wastewater treatment, which plays a vital role in indicators prediction, microbial simulation, system monitoring, energy optimization, wastewater reuse, and innovative applications. AI technology can predict the quality and quantity of influent in the wastewater treatment process, which is significant for adjusting operation mode. In the processes unit which microorganisms play an important role, AI technology can simulate biochemical processes to replace complex reaction derivation, thus simplifying the operation of the system. In addition, AI technology can effectively identify anomalies in pipeline networks, reactors, and auxiliary systems of wastewater treatment systems, which will make maintenance management less difficult.

3.4 Limitations of AI applications

Table 1: Summary of AI technology for bioreactors simulation

Bioreactor type	AI technology	Input parameters	Output parameters	References
Modified sequencing batch reactor	Bayesian network	Influent COD, TP, TN concentration; water temperature; cycle period of SBR; anoxic mixing time; aerobic aeration time	Effluent COD, TP, TN concentration	[1]
Sequencing batch reactor	Multi-layer perceptron and radial basis function artificial neural networks	Influent COD, NH_4^+-N, TP, TSS, MLVSS concentration; filling time; reaction time; aeration intensity; sludge residence time	Effluent COD, NH_4^+-N, TP, TSS concentration	[2]
Sequencing batch reactor	Feedforward backpropagation artificial neural network	Influent SCOD, NH_4^+-N, MLVSS concentration; time; pH, DO	COD and NH_4^+-N removal efficiency	[3]
Biofilm system	Stacked denoising auto-encoders deep learning network	Influent COD, NH_4^+-N, TN concentration of biofilm system; effluent COD, NH_4^+-N, TN concentration of anoxic biofilm reactor; influent flow; reflux ratio of biofilm system	Effluent COD, NH_4^+-N, TN concentration of biofilm system	[4]
Anaerobic bioreactor	Non-dominated sorting genetic algorithms-II and genetic algorithm–artificial neural network	Influent COD concentration; inflow flow rate; pH; temperature	Effluent COD concentration; biogas flow rate	[5]
Anaerobic fluidized bed reactor/Anaerobic filter/ Up flow anaerobic sludge blanket	Fast predicting neural fuzzy model	Organic loading rate; hydraulic loading rate; alkalinity loading rate	Volumetric methane production; effluent TOC and total VFA concentration	[6]

AI technology is of great help to the operation and management of wastewater treatment. However, it is affected by complex external factors and the limitations of technology, which pose certain obstacles to the promotion of AI technology. In addition, there may still be a certain gap between the actual operating performance of the wastewater treatment system and the target results predicted by AI technology. The main shortcomings of AI technology in the application of wastewater treatment are as follows: (1) the algorithm design of AI technology may lead to defects in the case of the lack of theoretical wastewater treatment knowledge of the developers; (2) the application of AI technology in wastewater treatment currently lacks more large-scale engineering operational data, which reduces the predictive accuracy of the model;(3) the innovative application of AI technology in the wastewater treatment requires a large amount of investment in system resources and hardware facilities, which means more financial support.

4. Conclusion

In the future, the application of AI technology in wastewater treatment will be more and more broad prospects with the development of technology. The application of AI technology will be based on the combination of multi-technology and multi-disciplinary, a comprehensive wastewater treatment system will be established with the important functions of real-time monitoring, online control, and intelligent decision-making. In addition, with the continuous enrichment of engineering databases and expert databases, AI technology will have better adaptability to the process parameters of wastewater treatment. In the future, due to the increasing demand for automation and intelligence in wastewater treatment, the production of hardware smart devices related to AI technology will also grow rapidly. This will bring opportunities for the development and expansion of some industries.

5. References

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