Journal of Information & Optimization Sciences
ISSN 0252-2667 (Print), ISSN 2169-0103 (Online)
Vol. 46 (2025), No. 3, pp. 773–782
DOI : 10.47974/JIOS-1796

An effective exploration on water waste management problems using computational intelligence based techniques of optimization

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Abstract

Water is the most essential environmental component in life and water management also become one of the most important topics discussed in the recent trends. Water management encompasses harvesting, preserving, organizing available resources, and precise distribution to users. For these purposes, we need to analyze more efficient computational intelligence-based technique for water waste management problems of optimization in different disciplines which is effectively analyzed in the present manuscript. In recent trends Computational Intelligence (CI) monitoring software and algorithms which gives a precise evolution of water quality and demonstrates its strength in supporting decision

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making in several areas like agriculture, finance, space exploration, automobile industry etc. Computational intelligence is a cost effective including better planning and tracking.

Subject Classification: *68T20.*

Keywords: *Optimization, Water waste management, Computational intelligence, Algorithm.*

1. Introduction

Artificial intelligence or Machine intelligence (MI) is also known as the Computational intelligence (CI) which is widely applied in diverse fields [1-4] including education, agriculture, metrology, transportation, healthcare, and space exploration [5]. It utilizes a range of disciplines including information engineering, statistic, logic, computer science, data science, ontology etc. CI [6] works on some critical models such as Particle Swarm Model, Ant Colony Model, Genetics Algorithms, Deep leaning, and Fuzzy Algorithms. Recently, the new technology used in these models to reduce the human efforts and increasing the efficiency. There are various water-waste management problems which can be solve by CI for efficient solutions. Due to rise in population, we need more water for usage which result in increase in the amount of water from natural resources. However, 71% of Earth's surface is water, with about 95% being salty. Thus, it is essential to conserve fresh water. Although, one billion lack safe drinking water, causing two million deaths yearly from poor sanitation [7] contaminated water. Low water quality poses economic challenges, requiring resources for infrastructure upgrade when issues arise.

Also, water demands across agriculture, public supply, industry, hydro power, aquaculture and mining are increased [8], requiring better water management [9]. India's industries, the second largest water consumer, are significant polluters due to improper waste disposal [8]. The world water development report forecasts rising water demand. Hence, conserving water resource and responses and responsibly treating wastewater are essential [1]. There are number of traditional mathematical formulas to solve complex water waste management problems [10]. In this paper, we are highlighting some effective computational base technique for water waste management problems.

2. Some Efficient Computing Algorithms for Problems of Waste Water Management in Recent Trends

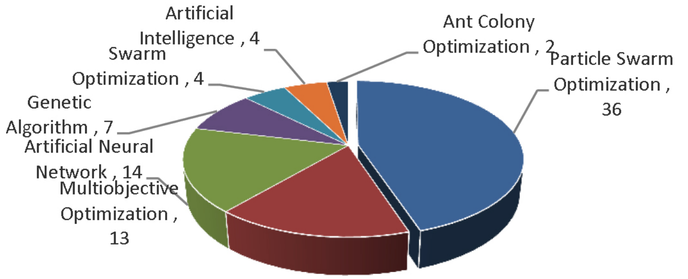
A systematic approach for calculating wastewater reuse potential and analyzing costs and profit in various places was presented by Junying Chu *et al.* in 2004 [11]. The discussed framework is useful for improving the China's water management. A linear optimization is created. Under some constraints key parameters and reuse quality decision making was considered. A variety of options for changing the price of water are simulated and assessed based on the robust counterpart optimization efficiency and sensitivity are analyzed. High in sewerage discharge or liquid waste release from the industry is one of the reasons of wastewater. To avoid these temporary excess influent multiagent shows a suitable methodology which manage all the information. To solve this complex problem optimization technique has been proposed in 2012 by Marta *et al.* [12]. In this work multi-constraints are imposed. The author uses two forms of Ant colony optimization which are *s*P and *g*P. Both these forms provide a cost solution which aim to maximizes complete wastewater discharge without discharge.

In 2016, [13] a framework of data has done by Zijun, *et al.* [14] that combines the mathematical modeling, data mining, and computational intelligence to improve the performance of wastewater pumping system. To reduce the usage of energy and increase the rate flow of the wastewater a bi-objective optimization model is used and is solved by artificial immune network algorithm. The model's solution offered the most effective pump speed configuration. Energy usage could decrease while still upholding pumping system performance through calculated measures. Wastewater treatment plant process optimization relies on biological optimization which is often affected by the quality and quantity of the inflow which can sometimes destabilized the biological system is limited by flow and nutrient load constraints. Their management is complex due to which in 2016 [14] Verdaguer, *et al.* uses two Ant colony optimization techniques. Both these techniques Max-Min system (MM) and Hyper-Cube (HC) algorithm use constrained pheromone trails to solve the challenges that arises when trying to discover optimal solutions within flow constraints. The sequence of wastewater discharge relates to a cost function which is to maximized by MM and HC algorithm. Overall, the work suggests that these methods are used to improve the management of urban wastewater system.

Yousefi et at. [15] has developed cropping pattern optimization model in 2018. This model increases the benefits and reduce the possible drawback of qualitative-qualitative conjunction utilizing treated wastewater and groundwater as non-traditional surface water for agricultural irrigation. The authors consider three objective functions. Using PSO and MOPSO algorithms to develop the model. For single and three-objective optimization in the Varamin irrigation network in Iran, MOPSO is used and PSO is for additive weighting method and then the model's outcome has been compared. The result by using PSO algorithm optimize the result in enhanced cropping patterns, increase water consumption productivity, and improve aquifer recharge and increased by 7%, 49%, 20% respectively while from MOPSO were increased by 7%, 47%, 15% respectively.

Municipal wastewater treatment network is considered as an effective method for attaining the optimal utilization of resources and also enhancing the plant efficiency at reduced cost. In 2019 a study was carried [15] out in which multi-hybrid partial swarm optimization (MAHPSO) is developed. A compressed real-world scenario is taken from the urban St. John's, Canada MAPSO proved its efficacy and sustainability. GA and hybrid PSO algorithm was used for comparison. The outcome showed that the suggested strategy worked better in terms of computing performance as well as in network's cost. Municipal wastewater treatment network is considered as an effective method for attaining the optimal utilization of resources and also enhancing the plant efficiency at reduced cost. In 2019 a study was carried [15] out in which multi-hybrid partial swarm optimization (MAHPSO) is developed. A compressed real-world scenario is taken from the urban St. John's, Canada MAPSO proved its efficacy and sustainability. GA and hybrid PSO algorithm was used for comparison. The outcome showed that the suggested strategy worked better in terms of computing performance as well as in network's cost.

In 2020 [16] a new optimization technique for treated wastewater (TW) is developed. NSGA-II formed the basis for a multi-objective optimization model aimed at improvement the primary goals of leader which includes i) lowering the TW transfer costs and ii) decreasing the demand of supply deficiency across all area. The proposed approach used by Ghorbani Mooselu, Mehrdad *et al.* in a case study of the eastern of Tehran region, Iran. By using a mutli-criteria decision making model, the optimal solution obtained on Pareto-front. To determine how sensitive the model was nine distinct weighting cases were used. The result indicates the framework's sensitivity to weighting situation, that also future provide compromises for a complicated system that supply partially water demand. The goal of Jorquera-Bravo *et al.* [17] is to optimize Chile's waste water treatment system while taking social environmental, and economic considerations into account. In order to evaluate sustainability of the system, it maximizes phosphorus extraction and manpower needs while minimizing costs and environmental effect through multi-objective optimization. By identifying Pareto frontiers, non- dominated sorting genetic algorithm (NAGA-II) produces non-dominated and compromise solution. These solutions integrate economic environmental, social sustainability objectives to design sustainable wastewater treatment plants.



Computing Algorithms Analyzed

3. Analysis on Results and Discussion

Chu, et al. [10], the study highlights the importance of evaluating wastewater reuse potential and cost to enhance water resource management in different regions of China. Nationwide, only 6.3% (1.78 BCM) of urban wastewater is currently reusable due to high costs, limited recycling efforts, and insufficient water pricing data. Guangdong, Jiangsu, Beijing, and Liaoning contribute to 44.6% of the country's total potential for wastewater reuse. Water shortage in Beijing and Liaoning justifies increased water price. Southeast China's Jiangsu and Guangdong region use more water because of their warmer temperature and placement downstream of the Changjiang and Zhejiang River. Hubei and Ningxia are two more area that are inappropriate for utilization in the context. The result demonstrates that water policies, including price reforms, can elevate both costs and benefits of wastewater reuse, encouraging increased qualities, profits, and opportunities for constructing treatment and reuse infrastructure.

Verdaguer et al [11] considered two different versions of ACO which is based on ant cycle process. During construction, the algorithm uses two penalties, *sP* and *gP*, tied to volume and pollutant loads to demonstrate a new industrial wastewater discharge approach. With 500 iteration and 100 ants each iteration, the simulation was conducted using calibrated*sP* and *gP*, and the average of the result was obtained across 10 repeats. Also, the author has taken three scenarios. Scenario 1 demonstrates that both algorithm variant release the maximum amount allowed in WWTP.In Scenario 2 the g*P*version provides the optimal solution. And in scenario the s*P*and g*P* have slight of similar solution w.r.t discharge. Therefore, the outcome is thatglobal penalty (g*P*) approach, considering multiple factors in wastewater treatment plant discharge was found to be cost-effective, especially for fluctuating pollutant concentrations.

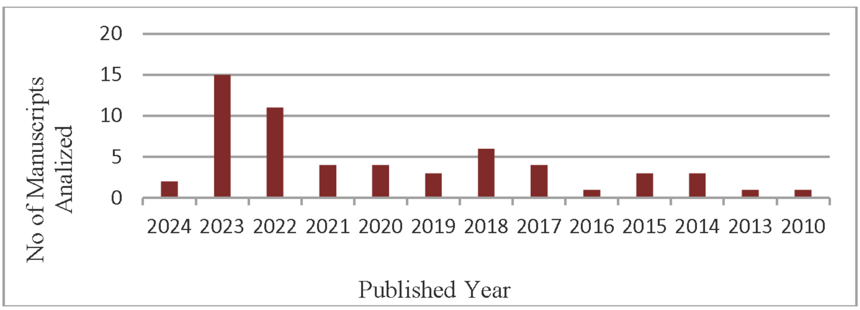
The proposed data-driven approach by Zhang, Z. et al [9] using neural network models for pump system control in wastewater plants, optimizing energy consumption and flow rates. The authors have taken four configurations of the pumps. Also, the bi-objective model is used which reduce enrgy use and optimize the flow rate of wastewater. The conclusion shows that by properly adjusting the speed of pump, pumping system's the efficiency of could be improved. Utilizing both the MM and Hc algorithm, Verdaguer, M et al [10] aims to optimize a cost function associated with the wastewater discharge sequence. The most expensive WWTP influent will be one with largest feasible volume and pollutant loads allowed by treatment standards. It was evident from the case study [10] simulations that the MM algorithm produced the greatest discharge costs. Ten iterations of the trails were required, as calculated by the stochastic technique using the MM and Hc algorithms. There were 500 iterations in each repeat with 5min run time approximately. The author considers the four scenarios. Scenario 1, MM algorithm's wastewater discharge costs were 1.5%, 3.6%, 0.6% and 28.5% higher than the Hc approach. Hc algorithm neared maximum values in scenarios 2 and 3. For scenario 4, both algorithms discharged less than the maximum WWTP allowance. The work overall concludes that these methods are used to improve the management of urban wastewater system.

Yousefi, M. [11] used the PSO method and additive weighting technique to create a three- objective model in MATLAB. Objective 1: optimizes crop pattern benefits, considering costs like treated wastewater, groundwater, fertilizer expenses. Objective 2: minimizes total nitrogen leaching into soil. Objective 3: aims to improve aquifer recharge rates. PSO algorithm converged in 100 iterations, whereas MOPSO code in MATLAB took 3mintes for same, with longer time for increased population and iteration. Combining MPSO with TOPSIS to enhance cropping pattern benefits by 7%, 15% more aquifer recharge and 47% more productive water use. The difference in objective function values between the PSO and MOPSO algorithm varied from 0.4 to 4 $, suggesting and closeness of PSO optimal solutions and MOPSO's superior performance in optimizing the objective function.

Using a real-world case study, the technique optimized waste water treatment network planning for seven communities in St. John's, Newfoundland, Canda [12]. Every city tried to construct a wastewater treatment plant (WWTP) in order to improve the quality of the water, even though one city might establish a sludge process centre (SPC) for the treatment of the sludge waste. The MAHPSO model, developed using MATLAB 2017b, involving runs with 50 iterations each.The method was tested, resulting in an overall cost reduction of US. membrane bioreactors (MBRs) are advised for major cities; smaller cities may select oxidation ditches (ODs) or sequencing batch reactors (SBRs) depending on the water demand.

The study in eastern Tehran (9200km2) examined by Mooselu, M. G. et al [16] four water usage scenarios, including local wastewater use and fulfilling demand with wastewater from different districts. Using the NSGA-II model with specified parameters, solution 1 focused on reducing transfer costs, allocating 0.25-5.92(Mm3) of treated wastewater to districts 1-4. Conversely, solution 2 aimed to minimize deficiency, providing 5.77-91.84(Mm3) of treated wastewater to the same districts.

Employing crossover and mutation operators at rates of 65% and 5%, respectively, a population of 4,00 was utilized. Optimal solutions are compared in pairs and tried to select the best visuals [17-20].



4. Conclusion

The present manuscript builds a systematic framework for analyzing wastewater management problems with the support of computational intelligence methods, including evolutionary algorithm, genetic algorithm ant colony, particle swarm etc. using that methodology, the proposed study offers a number of insights on waste water management. Analysis also discusses recent optimization models which challenges wastewater problems and helps to optimizes the wastewater management problems for the protection of the economics and environment. Analysis on results also concludes that there are various meta-heuristic optimization algorithms which not always gives the quicker and precise aimed outcome. As by No Free Lunch theorem that there is never exists the "best" optimization algorithm which always give the best result in each and every class of problems and there is always a need for developing an improved computing method for problem solving in real life situations.

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Received September, 2024