IEEE Access
Multidisciplinary Rapid Review Open Access Journal

Received 6 November 2023, accepted 9 December 2023, date of publication 14 December 2023, date of current version 22 December 2023.

Digital Object Identifier 10.1109/ACCESS.2023.3343150

SURVEY

Wastewater Treatment and Multi-Criteria Decision-Making Methods: A Review

TINA SHARMA[1], ANUJ KUMAR[2], SANGEETA PANT[3], AND KETAN KOTECHA[4]
[1]Department of Mathematics, University of Petroleum and Energy Studies, Dehradun 248007, India
[2]School of Computer Science Engineering and Applications, D. Y. Patil International University (DYPIU), Akurdi, Pune 411044, India
[3]Department of Applied Sciences, Symbiosis Institute of Technology, Symbiosis International (Deemed University) (SIU), Lavale, Pune, Maharashtra 412115, India
[4]Symbiosis Institute of Technology, Symbiosis International (Deemed University) (SIU), Lavale, Pune, Maharashtra 412115, India

Corresponding authors: Sangeeta Pant (sangeeta.pant@sitpune.edu.in), Ketan Kotecha (director@sitpune.edu.in), and Anuj Kumar (anuj.kumar@dypiu.ac.in)

This work was supported by the Research Support Fund of Symbiosis International (Deemed University), Pune, India.

ABSTRACT Incorporating numerous technical, economic, environmental, and social benchmarks makes multi-criteria decision-making (MCDM) a reliable decision-making tool in sustainable development. To achieve sustainability target six, related to clean water and sanitation, wastewater technology comes into play. They bring complicated scenarios with several indicators, criteria, and conflicting objectives. This article provides a thorough review of MCDM methods, including pure techniques such as AHP, TOPSIS, VIKOR, ELECTRE, and others, as well as hybrid MCDM approaches like the non-structural fuzzy decision support system (NSFDSS) in conjunction with Artificial Neural Network (ANN), applied to wastewater treatment technologies or processes to remove water contamination. This review draws upon articles sourced from the ''Scopus'' and ''Web of Science (WoS)'' databases, covering the period from 2015 to 2023. The primary aim of this endeavor is to offer a current and comprehensive review of the literature about MCDM to aid researchers and environmental engineers in their quest to identify the most appropriate techniques for tackling the complex challenges associated with wastewater treatment (WWT). The results demonstrate the versatile application of MCDM in various scenarios to remove water contaminants effectively. For example, these applications encompass assessing the efficacy of adsorbents for the removal of pollutants and effluents from wastewater, determining the optimal WWT technology from a range of alternatives, evaluating the performance of both metallic (such as ZnO and MnO) and non-metallic (like activated carbon) nanomaterial adsorbents, and scrutinizing strategies to minimize water consumption. Furthermore, within the context of specific WWT technologies, MCDM identifies and highlights critical criteria that are instrumental in enhancing system efficiency for removing pollutants. Ultimately, MCDM methods represent a contemporary decision support system. In future research, the potential utilization of MCDM can extend to tracking the environmental impacts of nanomaterial adsorbents released from treatment plants into the surrounding ecosystem.

INDEX TERMS Multi-criteria decision-making, wastewater treatment, water pollution, AHP, TOPSIS.

I. INTRODUCTION

It is inevitable that the global population has doubled, resulting in a significant increase in water consumption, which is expected to continue growing over the coming decades. Consequently, this has led to a rise in water scarcity, water pollution, and wastewater generation. Furthermore, agrochemicals, toxic dyes in the textile sector, chemical industries, construction activities, coking wastewater, microplastics, and untreated sewage contribute significantly to environmental degradation and health issues. According to the Water Council, by 2030, an estimated 3.9 billion people

The associate editor coordinating the review of this manuscript and approving it for publication was Francisco J. Garcia-Penalvo.

will inhabit regions characterized as 'water-scarce' [1]. The substantial increase in water demand has created a supply deficit, which can be mitigated through comprehensive water management, including water recycling and treatment.

According to the 2021 report from the Central Pollution Control Board, only 22,963 MLD (37%) of wastewater generated in India is currently being treated [2]. To achieve the sustainable goal of 'Clean Water and Sanitation,' it is imperative to establish appropriate, effective, and affordable surface water and WWT methods. Water treatment involves removing contaminants from sewage or used water, ensuring that it is converted into effluents free from toxins before being released into the environment. This is especially critical when dealing with water containing recalcitrant contaminants [3].

Various methods are employed for water and wastewater treatment, including nanofiltration, biological treatment, activated carbon adsorption, ultrafiltration, reverse osmosis, and sedimentation. Figure 1 illustrates different types of water treatment plants.

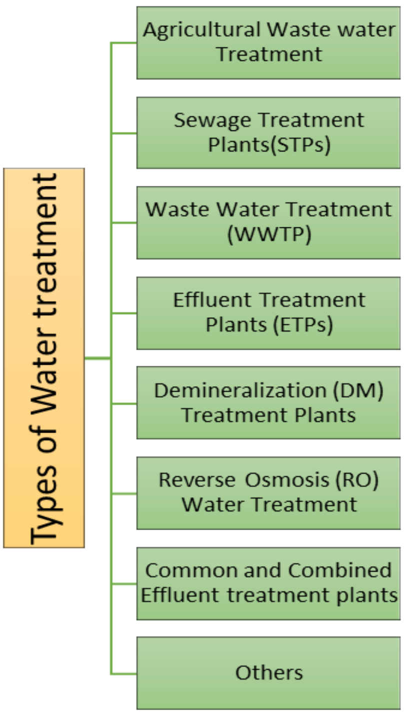

FIGURE 1. Types of water treatment.

Different treatments operate on different mechanisms. Water treatment can be classified as physical, chemical, physicochemical, and biological [4]. These treatments are used based on the need or contaminants present in surface water or wastewater. For example, nanofiltration utilizes a semipermeable membrane capable of removing bacteria and various multivalent ions. The membrane's pore size can be adjusted in response to the effluents present in the water [5], [6]. Figure 2 illustrates the classifications of physical, chemical, biological, and physico-chemical treatment methods. The treatment stages for wastewater are typically

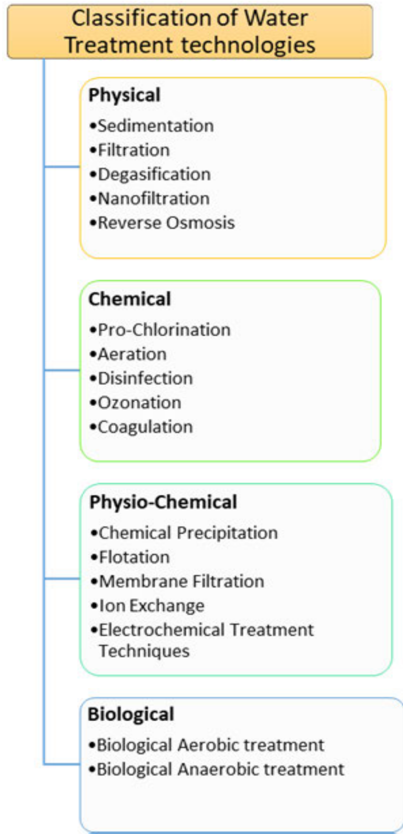

FIGURE 2. Classification of water treatment.

divided into preliminary, primary, secondary, and tertiary processes, each targeting the removal of different contaminants. Water can be treated using a variety of operations (based on physical forces) and processes (involving chemical forces), depending on the treatment level [7].

Across the globe, water is becoming contaminated due to the production and discharge of industrial effluents. Traditional water treatment methods are often ineffective against these industrial effluents. In recent years, there has been a growing interest in using various types of nanomaterials as part of emerging technologies [8]. This is why several activated carbon nanomaterials have been developed and employed to mitigate environmental pollutants [9].

While nanotechnology-based treatments offer significant advantages for eliminating emerging contaminants [10], researchers must also emphasize the selection of the appropriate nanomaterial, considering various criteria for which MCDM techniques have proven to be beneficial. For example, Badawi et al. [11] applied MCDM to determine the optimal nanomaterial adsorbent, choosing between nano-zero-valent iron (nZVI) and activated carbon (AC).

Discharging untreated or inadequately treated wastewater can negatively impact three significant sectors: human health, the environment, and economic activity [12]. Even when treatment solutions are technically advanced, economically viable, and incorporate appropriate safety measures, the risk of failure remains due to insufficient consideration of technical, economic, social, and environmental criteria. Water treatment technologies are intricate systems with specific treatment methods designed to degrade particular contaminants or toxins. Consequently, different criteria are associated with various types of treatment technologies, and the performance of these technologies may vary based on different factors. To address these criteria, decision support systems, such as MCDM techniques, come into play. These methodologies are widely employed to manage complex systems involving conflicting criteria, uncertainty, and multiple objectives.

MCDM approaches have continually evolved and expanded, progressing from single MCDM approaches to fuzzy and hybrid decision-making methods [13]. Broadly, MCDM can be categorized into three types: 'Single MCDM,' 'Fuzzy MCDM,' and 'Hybrid MCDM,' as illustrated in Figure 3. Single approaches like AHP and TOPSIS have found extensive use not only in sustainability development [14] but also in engineering [15], energy management [16], and science. On the other hand, fuzzy MCDM and hybrid MCDM approaches are gaining popularity due to their applicability and ability to handle the uncertainty inherent in criteria, particularly those associated with complex systems like sustainability criteria. Since water treatment systems are complex, they involve multiple decision-making processes at various levels. MCDM approaches can be applied to various decision-making tasks, including adsorbent selection, wastewater reuse technology selection, site location selection, and water quality index analysis. Moreover, MCDM is adept at addressing uncertainty, ambiguity in expert assessments, and real-world parameter variations, making it an ideal tool for decision-making in numerous fields of sustainable development, including waste management [18].

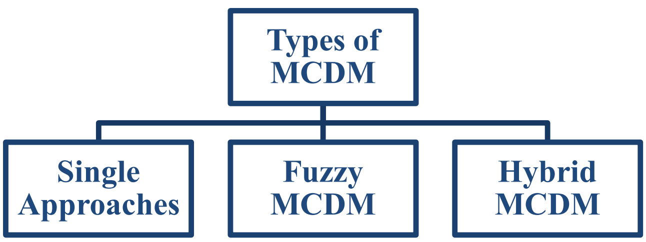

FIGURE 3. Classification of MCDM Methods.

MCDM has proven to be an effective tool for addressing a wide array of water treatment issues in various situations. In recent years, numerous studies have concentrated on the applicability of MCDM in tackling water treatment challenges. This article comprehensively evaluates these studies published between 2015 and 2023. MCDM models based on water treatment technologies are considered successful Decision Support Systems (DSS). This study aims to evaluate the potential of MCDM models for selecting the most suitable water treatment technology.

The following research questions (RQ) are raised and answered in this study:

Q1: Why is AHP widely applied in the field of water treatment?

Q2: What are the various applications of MCDM techniques used in the field of water treatment, encompassing both surface water treatment and wastewater treatment, during the period from 2015 to 2023?

Q3: What are the strengths, drawbacks, and robustness of MCDM in water treatment?

Q4: What is the scope of MCDM in water treatment based on nanotechnology?''

A. EXISTING REVIEW

Notably, the present study is the first to investigate the effectiveness of MCDM methods in water treatment, encompassing both surface water and wastewater treatment, while considering technical, social, economic, environmental, and sustainability criteria. Rakshit et al. [19] authored a review article on MCDM and its application to various wastewater treatment issues. They briefly discussed selected MCDM methods, such as AHP, TOPSIS, DEMATAL, ANP, EDAS, and PROMETHEE, illustrating their use in decision-making for wastewater treatment (WWT). A limited portion was covered in [13] regarding MCDM for wastewater treatment technology.

Greater emphasis has been placed on the overall decision support system employed in wastewater treatment (WWT) technology. However, in this literature review, the author has provided an extensive overview of almost all the MCDM methods used for water treatment, whether WWT or surface water treatment. This review will aid researchers in gaining insight into the various MCDM methods, including single MCDM approaches, fuzzy MCDM, and coupled/hybrid MCDM, used in water treatment, whether for criteria selection or location. Table 1 outlines the diverse methods and treatments, along with the criteria considered for the treatment, acknowledging that the quest for the optimal MCDM procedure for selection problems may remain ongoing. Thus far, no comparable studies on MCDM techniques for water treatment have been documented, and it is expected that the aforementioned study will serve as a foundational and pioneering work for other experts in the field.

This study is structured into nine sections, including Section I, which provides a brief introduction to water treatment technology and MCDM methods, along with an overview of existing review papers and our contribution. Section II describes the data collection process. Section III focuses on Single Approaches/MCDM for the treatment of water pollutants. Section IV highlights Fuzzy MCDM for wastewater treatment. Section V discusses the significance of hybrid multi-criteria Decision-making Approaches in WWT. Section VI presents additional applications of MCDM methods in WWT. A bibliometric analysis is presented in Section VII. Section VIII delves into the findings

TABLE 1. Existing review information.

Author	Number of articles reviewed	Technology	Journal
Rakshit et al. [19], 2021	33	Waste Water treatment	International Journal of Research Publication and Review
Mannina et al. [20], 2022	157	Wastewater treatment	Bioresource technology

and suggests future directions. Finally, Section IX offers the conclusion.

II. INFORMATION COLLECTION

To begin, studies that used MCDM in water treatment were identified using databases such as Scopus, WoS, ScienceDirect, and Google Scholar by using combined keywords such as "Multi-criteria Decision Making and Water Treatment," "Fuzzy MCDM and Water Treatment," "Hybrid MCDM and Water Treatment," "Multi-criteria Decision Making and Water Pollution," "Multi-criteria Decision Making and Waste Water Treatment." As a result of data extraction and filtering from the mentioned sources, a total of 119 publications were found to be suitable for systematic literature review out of a total of 183 publications. The period taken for the literature review is 2015-2023. Impact factors and Journal citation reports are considered while collecting the research papers.

A. INCLUSION AND EXCLUSION METHODOLOGY

Table 2 displays the entire inclusion and exclusion parameter set. As a result, the relevant research publications for the review were identified and assessed using "inclusion and exclusion criteria." The following factors were taken into consideration: 1) Exclusion of non-English publications; 2) Exclusion of sustainable treatments other than Table 2: Inclusion and exclusion considered parameters water treatment; and 3) Implementation of at least one single MCDM, fuzzy MCDM, and Hybrid/coupled MCDM framework. Finally, 119 papers met the requirements and are included in this evaluation.

B. OVERVIEW OF REVIEWED RESEARCH PUBLICATIONS

An analysis of the reviewed studies has revealed that the utilization of MCDM techniques in water treatment systems can be categorized into four distinct groups. The first category involves the application of MCDM methods for the selection of water treatment technologies. In this category, MCDM methods initially assess the significance of decision criteria, such as accessibility, reuse potential, adsorption capacity, environmental safety, human safety, material cost, and equipment cost, before prioritizing various water treatment technologies. Commonly employed water treatment methods include nanofiltration membranes, ion exchange, adsorption processes, electrodialysis, and reverse osmosis.

TABLE 2. Inclusion and exclusion criteria.

Information	Including	Excluding	justification
Fuzzy MCDM, single approach MCDM And coupled MCDM	Only Multi-criteria decision-making methods	Not clearly stated MCDM techniques	Review theme
Time period	2015-2023	Before 2015	Not much work has been done on MCDM-based water treatments before 2015
Applications	Surface water and wastewater treatment, water treatment, and nanotechnology	-	According to the review theme.
Type of database	Scopus, WOS, Science Direct		Due to authenticity
Decision Support System	The article has a section on MCDM	Different DSS other than MCDM	Review theme

Secondly, MCDM methods are employed to select a suitable site for both surface water treatment and wastewater treatment technologies from a range of alternatives. In this category, MCDM techniques are applied to assess geographical (territorial) and sustainability criteria, facilitating the ranking of potential location options. In particular research studies, MCDM methods are coupled with Geographic Information Systems (GIS) to enhance the precision and reliability of the location selection process. Thirdly, the MCDM framework has been used to choose the optimal adsorbent material from the available material alternatives for specific water or wastewater treatment. Finally, the remaining publications have utilized MCDM for technologies related to reduced water consumption, water quality index, water supply alternatives, etc.

The literature review primarily concentrated on three types of multi-criteria decision frameworks, as depicted in Figure 3. Meanwhile, Figure 4 illustrates the categories in which MCDM was employed. A brief review of single MCDM approaches, fuzzy MCDM, and hybrid MCDM is provided in the following sections, followed by discussions of the applications of MCDM, findings, and, lastly, conclusions and future directions. Therefore, 121 publications were comprehensively analyzed and selected from research publications.

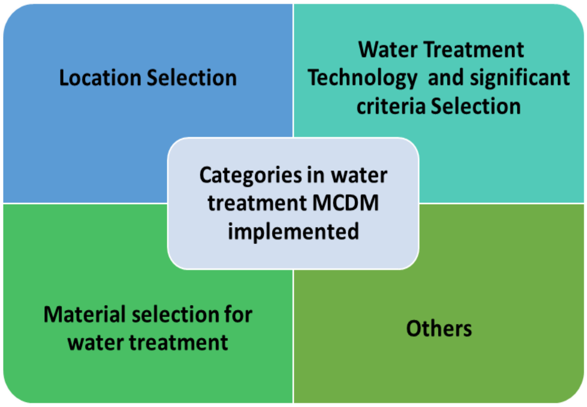

FIGURE 4. Categories in which MCDM was utilized.

III. SINGLE APPROACHES/MCDM FOR THE TREATMENT OF WATER POLLUTANTS

MCDM is a concept that enables the selection of the best alternative from a set of choices by weighing them against various criteria [21]. To address problems involving multiple criteria, a plethora of MCDM methods have been developed, such as AHP, TOPSIS, PROMETHEE, VIKOR, and ELECTRE. MCDM methods are systematic and can be applied depending on the criteria considered, types of alternatives, decision-makers, and ordering preferences [22]. Decision-making techniques are extensively used to determine appropriate solutions to various environmental problems, identify the optimal renewable energy sources, evaluate wastewater treatment system performance, and identify significant criteria for optimizing system efficiency [23]. Among the variety of MCDM techniques, AHP is often employed in environmental and sustainability issues and consists of weighting and ranking procedures [24], [25].

AHP was implemented to calculate the frequency of water quality sampling, marking the first instance in which Do et al. [26] applied MCDM to calculate water quality sampling frequency. They calculated the weights of five variables at each monitoring station and used these weights to determine the sampling frequency. Ultimately, a system for determining the frequency of river water quality sampling for numerous stations and variables was developed using AHP [26].

Ozturk and Cinperi [27] combined AHP with weight sum (WSM), criteria weighting (CWM), and a simple ranking method (SRM) to select the best alternatives from 82 minimization techniques for reducing water consumption, wastewater generation, and water pollutants in woolen textile mills. After evaluating these techniques based on AHP, only nine minimization techniques were considered and implemented. Anaokar et al. [28] implemented TOPSIS for the performance evaluation of municipal wastewater treatment plants.

AHP is widely used in sustainability development and employs a hierarchy process in which alternatives are considered at the top level, followed by criteria and sub-criteria. AHP is a practical method for organizing and analyzing multi-criteria decisions by quantifying the weight of various indices through relative comparisons [29]. AHP creates a hierarchical framework that facilitates a comprehensive understanding of the overarching goal to be achieved [24]. This model is characterized by its simplicity and well-defined structure, comprising goal layers, criteria layers, and alternative solutions. AHP finds applications in a wide array of judgment scenarios, as demonstrated by studies such as those conducted by Rajak and Shaw [30] and Arif et al. [31].

To rank biological treatments for coke wastewater (CW) from the available alternatives, Wei et al. [32] applied AHP. Technical, economic, administrative, and environmental criteria, including eighteen sub-criteria, were considered. The results revealed that the technical factor was the most significant in the criteria layers, and a sensitivity and variability analysis of AHP was presented. Skoczko and Oszczapińska [33] and Shafaghat et al. [34] used conventional AHP techniques to evaluate and select the most suitable wastewater treatment (WWT) technology for diverse urban and industrial wastewater scenarios. The integration of AHP with other software, such as GIS-AHP and SWOT-AHP, is also prevalent in water treatment systems [34]. Given the variations in capacity and operating processes among different STTs, traditional methods often struggle to address such multi-scenario problems. AHP enables descriptive and analytical assessments by representing criteria in terms of weights and conducting consistency checks to eliminate biased decision-making [35], [36].

On the other hand, for WWT/STT and water contamination removal, MCDM-based methods are frequently employed. Decision-makers must consider ecological friendliness, affordability, carbon neutrality, and reliability in addition to functionality. Munasinghe-Arachchige et al. [37] used the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE) to evaluate five different sewage treatment systems against fifteen criteria. It was also employed to identify system drawbacks and gain insights into alternative sewage systems. Gichamo et al. [38] proposed the VIKOR method to rank natural wastewater treatment techniques from best to worst. Similarly, Chaisar and Garg [39] used AHP to select the appropriate STT for Delhi, India, considering thirteen sustainability criteria, including social, economic, and horticultural suitability.

IV. FUZZY MCDM FOR WASTEWATER TREATMENT

Methods of MCDM are also categorized as either traditional/conventional or fuzzy [40]. When dealing with linguistic uncertainty, MCDM techniques are often considered insufficient. Fuzzy MCDM methods were proposed to address complex scenarios with uncertain factors. Fuzzy sets are an appropriate method to overcome vagueness [41]. Using MCDM approaches in conjunction with fuzzy theory allows for more concrete outcomes. In fuzzy set theory, membership functions and fuzzy numbers are effective in handling vagueness, such as trapezoidal, sigmoid, triangular, and Gaussian [17]. These functions are utilized in decision-making to obtain realistic results.

Some authors have worked on the degradation of specific toxins by selecting the best treatment technique, as seen in the case of Debnath et al. [42], who aimed to remove cyanobacteria. They applied the fuzzy-ELECTRE decision methodology to select an effective treatment technique from the considered alternatives. Kamali and Persson [43] considered sustainability criteria to assess nanomaterials for the treatment of industrial effluents, incorporating the fuzzy-delphi method. They considered general technical, economic, social, and environmental criteria, as well as criteria related to nanotechnology. Using the fuzzy-Delphi method, the authors also identified and ranked the sustainability criteria significant for selecting industrial wastewater treatment. Similarly, Kamali and Costa [44] utilized the MCDM-based fuzzy-Delphi method to rank nine wastewater treatment technologies categorized into two processes: physicochemical and biological. According to the fuzzy-Delphi technique, technical criteria, especially treatment efficiency and health and safety issues in the WWT plant, were the most relevant.

To evaluate and analyze the optimal wastewater treatment technology for removing toxic elements from wastewater before releasing it into the environment, Yahya et al. [45] proposed the Fuzzy PROMETHEE decision-making method based on certain factors. The study showed that nanofiltration is more reliable than other treatment techniques. A substantial amount of work has been conducted in sustainable development to select the best WWT technology, considering multiple criteria. Some authors consider or eliminate specific criteria to analyze the treatment plant's performance, efficiency, risk assessment, and cost-effectiveness [46], [47], [48], [49].

To identify significant criteria and remove pollutants (pharmaceutical-activated compounds - PhAC), Fernández-López et al. [50] utilized the fuzzy TOPSIS decision approach in different WWT plants to assess MBR and CAS technologies. Mahammad and Islam [51] used FAHP to calculate the groundwater quality index (GWQI) of the Damodar Fan Delta, West Bengal. Twelve physiochemical parameters were examined and assigned weights through pairwise comparison using the fuzzy triangular number scale. Singh et al. [52] demonstrated the analysis of water quality data (2011-2016) for five upper Ganga river stations, namely Kanpur, Prayagraj, Varanasi, Haridwar, and Bareilly, based on the Fuzzy AHP approach, considering physical, biological, and chemical parameters.

V. HYBRID MCDM APPROACHES IN WWT

Hybrid methods have been introduced to address randomness in assigning weights to criteria associated with various decision-making problems. Hybrid methods offer high flexibility due to integrating multiple methods, increasing their applicability. For instance, [53], [54], [55], and [56].

Borza and Petrescu [57] identified the least and most polluted sites on the Olt River in Romania using data from multiple sample stations. They employed AHP and TOPSIS approaches along with GIS software. Much research has been conducted to identify the most critical parameters to assist decision-makers in developing efficient water treatment technologies/plants. For example, Saha et al. [58] proposed a non-structural fuzzy decision support system (NSFDSS) and ANN to determine the significant parameters. Choudhury and Saha [59] identified the optimum location for installing surface water treatment plants and found that the water quality index (WQI) was the crucial factor. Various literature is available related to site selection and identifying significant criteria/alternatives, such as [59], [60], [61], [62], [63], [64], [65], and [66].

Azari et al. [67] proposed the fuzzy AHP-TOPSIS methodology to evaluate the optimal color treatment process using carbon-based adsorbent materials. The key decision-making criteria discovered were cost safety, accessibility, reusability, and adsorption capacity. Comparative research was conducted between nano-zero-valent iron (nZVI) and activated carbon (AC) adsorbents to evaluate the advantages of using these materials for textile treatment technology based on technical and sustainable criteria using TOPSIS, AHP, and SAW MCDM methods. The study indicated that AC is superior to nZVI based on the defined parameters and weights. Two approaches were prepared: one with equal weight for all criteria and another with weighted criteria using a pairwise comparison method [11].

Majumdar et al. [68] proposed an amalgamation of two MCDM methods named intuitionistic fuzzy BWAH used to identify the most critical alternative for a water treatment plant's efficiency. They also performed sensitivity analysis and compared this new MCDM method with seven other decision-making methods.

GIS utilizes spatial location to combine a wide range of geographical data. In the realm of water treatment technologies, MCDM with GIS software is used to determine optimal site selection. For instance, Zolfaghary et al. [69] examined the viability of using urban treated wastewater as irrigation water using geographic information software (GIS) and (MCDM). Technical, economic, and environmental criteria were assessed. GIS software was used to construct maps associated with the criteria. The analytical hierarchy technique (AHP) was used to calculate the weight of the criteria. Similarly, (Dolui and Sarkar [70], Fernandes et al. [71], Brahim et al. [72], Bilgilioğlu [73], and Mukherjee et al. [74] employed multi-criteria decision-making with GIS (GIS-MCDM) for water treatment.

Several hybrid analyses have been performed to explore the influence of criterion weights and for the selection of treatment technology, such as combined TOPSIS and adaptive AHP [75], Integrated AHP, OWA, ELECTRE, and TOPSIS [76], Internal VIKOR and Internal AHP, FMOORA, fuzzy objective optimization by ratio analysis, and FSWARA, fuzzy stepwise weighted assessment ratio [3], TOPSIS and SAW with the Aquatic environment index (AEI) [77], and also Grey correlation analysis and TOPSIS [78], best-worst method and BTOPSIS [79]. Ayyildiz and Özçelik [80] utilized SAW, TOPSIS, and MOORA for the prioritization of municipal WWT.

Agarwal and Singh [62] applied an integrated MCDM framework, Fuzzy Delphi, and hybrid fuzzy AHP to select appropriate treatment technology. Fuzzy Delphi methods analyzed the sustainability factors, and fuzzy AHP assessed the alternatives and ranked them. The results demonstrated that, in addition to technical, economic, social, and environmental criteria, other factors like color removal efficiency, construction cost, effluent suitability for reuse, and space requirements play a significant role in the selection of Textile Wastewater Treatment Techniques (TWWTT). These technologies were compared using sustainability indices.

VI. FEW MORE APPLICATIONS OF MCDM METHODS IN WWT

MCDM encompasses both quantitative and qualitative techniques. It assesses data using quantitative and qualitative data; however, some approaches solely use quantitative data, while others exclusively use qualitative data [81]. MCDM has been widely used in various fields, taking technical, economic, environmental, social, and sustainability criteria into account. Several studies have employed AHP as a single approach or as part of an integrated MCDM approach to weigh decision criteria and evaluate alternative water treatment technologies. This could be attributed to the simplicity and applicability of the AHP method. Apart from AHP, other prevalent techniques include TOPSIS, ELECTRE, PROMETHEE, and VIKOR, as demonstrated in Table 3. It also encompasses fuzzy and coupled/hybrid multi-criteria techniques.

Sometimes, the trade-off between criteria makes it challenging to achieve the best results. In addition to being ideal for handling multi-criteria, MCDM has the added benefit of being able to account for ambiguity and vagueness in expert assessments and complex problems with parameter variations, as seen in Fuzzy MCDM. Fuzzy MCDM is advantageous when dealing with complex, uncertain problems.

In the case of sustainable water treatment development, when sustainability criteria such as economic and social criteria are included in sustainability assessments of water treatment, decision-making becomes more challenging. In such cases, the decision-making process becomes a complex multi-criteria problem with multiple objectives and increased conflicts. To achieve an environmentally friendly water treatment system, a multi-analysis approach like MCDM can simultaneously address problems involving environmental, economic, and social criteria. Moreover, many publications have also conducted a sensitivity analysis to check the robustness of the results obtained through multi-criteria decision-making, whether a single, fuzzy, or hybrid approach.

TABLE 3. There are a few more applications of MCDM in wastewater treatment.

S. No	Reference	The main purpose of the study	Criteria considered	Techniques used
1.	Hadipour et al. [82], 2015	In this case study of Iran, an AHP-based MCDM model was used to determine the optimal choice for utilizing wastewater to reduce water pollution.	TECH (5 scr), ENV (3 scr), SOCIAL (4 scr), ECO (4 scr)	AHP
2.	Ravi et al. [83], 2015	Calculation of sewage water quality index and Pollution potential of sewage treatment plants using fuzzy MCDM approach	Ph, SS, Temp, Oil & Grease, TDS, BOD, Chlorides, Sulphates, COD, Ammonical Nitrogen, Phenolic Compounds, Total Residual chlorine	Fuzzy MCDM
3.	Dange and Lad [47], 2015	The fuzzy MCDM approach is applied to govern SWQI for a sewage treatment system	13 criteria related to water contaminants	Fuzzy MCDM
4.	Chauhan and Singh [84], 2016	Choosing a sustainable site for a medical waste disposal facility	Distance, Land, sensitivity towards the environment, area covered by healthcare waste, waste disposable site, cost, road condition, quantity of healthcare waste	Fuzzy AHP, Fuzzy TOPSIS
5.	Dursun [85], 2016	Water treatment evaluation using fuzzy multi-criteria analysis	Reliability, Manpower requirement, land requirement, Eutrophication potential,	Fuzzy VIKOR

TABLE 3. *(Continued.)* There are a few more applications of MCDM in wastewater treatment.

			Global warming, Cost, Flexibility and Sustainability	
6.	Voudrias [86], 2016	This research analyzes five various technologies for infectious medical waste treatment, which is a major source of water pollution, and chooses the best one using a multi-criteria analysis.	ENV, Social, ECO, TECH	AHP
7.	Liquete et al. [87], 2016	An integrated assessment of a natural-based water pollution management technology.	Social (2 scr), ECO (2 scr), ENV (2 scr)	AHP
8.	Li et al. [88], 2016	This study describes a method for calculating indices of groundwater pollution intensity (GPI)Zhan	Concentration, mobility, toxicity, degradability, soil stratum, permeability coefficient, emission load, mode and location, impacted area ratio, existence time, topographic slope, groundwater depth, vadose zone rating media, the thickness of the aquifer, preventative measure.	AHP, TOPSIS
9.	Garrido - Baserba et al.	To select optimum wastewater treatment.	Environmental and economic criteria, life-	Environmental decision

TABLE 3. *(Continued.)* There are a few more applications of MCDM in wastewater treatment.

	[89], 2016		cycle analysis, population size, reuse, technical criteria, cost-benefit, sensitivity area discharge.	support system
10.	Zahedi [90], 2017	MCDM strategy was applied to reduce the effects of conflicting criteria arising during the prioritization of water wells using IWAQI and DWQI.		OWA, CP, TOPSIS
11.	Karahalios [91], 2017	The proposed MCDM framework was used to select a Ballast Water Treatment System from the considered alternatives.	Power, system capacity, use of chemicals, Manufacturer longevity, System capacity, treatment time, and Installation dimensions.	AHP, TOPSIS
12.	Hossain [92], 2017	Selection of Municipal Drinking Water Treatment Approach Using Multiple Criteria	Efficiency, Colour removal, Technology availability, Cost, Cancer risk, Ease of operation and maintenance, Odour removal	AHP
13.	An et al. [93], 2017	For sustainability assessment of groundwater treatment/ remediation, MCDM methodology implemented	3 economic, 1 environmental, 2 technological, 1 social, and 1 political	AHP ELECTRE
14.	Kamble et al.	A fuzzy MCDM methodology is proposed in this	12 criteria	Fuzzy AHP

TABLE 3. *(Continued.)* **There are a few more applications of MCDM in wastewater treatment.**

	[94], 2017	study for the assessment and choice of optimal municipal wastewater treatment alternatives (WTT)		Fuzzy Delphi Fuzzy TOPSIS
15.	Anaokar et al. [28], 2018	In this study, six large treatment plants in India are evaluated for the performance of municipal wastewater treatment.	Temperature, Suspended solids (SS), Ph, Total Dissolved Solids (TDS), Biological and chemical Oxygen demand (BOD) & (COD), chlorides	Fuzzy-TOPSIS
16.	Sapkota et al. [95], 2018	An integrated approach Is proposed to choose among several alternatives for hybrid water supply.	6 Evaluation criteria	PROMETHEE-GAIA
17.	Sun et al. [96], 2019	Regulating agricultural non-point-source pollution by optimizing the pollutant reduction system.	Total Nitrogen & phosphorous, Ammonium-Nitrogen, COD, Construction & Operational Cost	AHP
18.	dekan Abbasl and Jassima [97], 2019	This study used an integrated method for the selection of an appropriate wastewater sewage plant.	Sewage areas, land use, roads, green areas, surface water, the slope of the ground, and historical areas.	GIS-AHP
19.	Aung et al. [98], 2019	Study of Myanmar's healthcare waste management systems.	Segregation system(5 scr), waste transportation (2 scr),	AHP, ANP

TABLE 3. *(Continued.)* **There are a few more applications of MCDM in wastewater treatment.**

			safety (2 scr), waste collection (2 scr), treatment & disposal (2 scr), capacity (3 scr)	
20.	Kanwal et al. [99], 2020	To determine the appropriateness of a natural wastewater treatment system on-site in an urban and industrial context	Soil; LULC; Depth to water table; slope; distance from roads, railway, rivers & drains; Groundwater EC	WLC, AHP, Heuristic approach
21.	Narayanamoorthy et al. [100], 2020	Using an integrated weighing approach and hesitant fuzzy logic, a unique assessment of bio-medical waste disposal strategies has been conducted.	Social acceptance, ENV production, Noise, Technical and operation, Cost, Health risk	Hesitant Fuzzy Subjective and Objective Weight Integrated Approach (HF-SOWIA) Hesitant Fuzzy Multi-Objective Optimization on the basis of Simple Ratio Analysis (HF-MOOSRA).
22.	Sadr et al. [101], 2020	Applied MCDM technique to find feasible and appropriate drinking water treatment technology.	9 economic, 8 technical, 7 socio-economic, and 6 environmental	AHP, NSGA-II
23.	Mooselu et al. [102], 2020	Multi-criteria analysis was utilized for the purpose of treating wastewater		NSGA-II ELECTRE

TABLE 3. *(Continued.)* **There are a few more applications of MCDM in wastewater treatment.**

		allocation in Tehran, Iran.		
24.	Liu et al. [103], 2020	In a case study of China, the MCDM method was employed to enhance sewage treatment systems in urban areas of the Liao River basin.	3 criteria: economic affordability, social acceptability, and environmental sustainability 10 sub-criteria/Indicators	AHP, Fuzzy TOPSIS
25.	Savun-Hekimoğlu et al. [104], 2020	In this article, the MCDM framework is implemented to evaluate five different water management alternatives.	1 economic, 3 environmental, 1 technological, 1 technical, and 1 social-political	TOPSIS PROMETHEE
26.	Kujlu et al. [105], 2020	Research study of seven oil-contaminated soils that have been treated with various stabilization/solidification (S/S) procedures, as well as the selection of the best-treated site treatment method.	_	BWM
27.	Özdemir et al. [106], 2020	To prioritize four different leachate treatment alternatives.	For ANP: benefit, risk, and cost For PROMETHEE: 4 environmental, 3 technical, and 3 economic	ANP PROMETHEE
28.	Zhou et al. [107], 2020	To choose the most suitable disposal (sewage sludge) system	Environmental criteria: global warming potential (GWP), human toxicity	AHP, VIKOR, TOPSIS

TABLE 3. *(Continued.)* **There are a few more applications of MCDM in wastewater treatment.**

			potential (HTP), Acidification potential, abiotic depletion, eutrophication potential, photochemical ozone potential. Economic criteria: Investment cost, benefits, operating expenses. Social criteria: society, value chain actors, employees, consumers, and local communities.	
29.	Becker et al. [108], 2021	MCDM approaches have been used to assess risk for rating surface water micro-contaminants.	Biowin, Mobility, PBT, Half-life	ToxPi, TOPSIS
30.	Nasiri et al. [109], 2021	Reduce seawater intrusion in the Caspian Sea's Tajan coastal aquifer (Iran) using an MCDM method combined with numerical modeling.	ENV, Socio-culture, ECO	SAW, VIKOR, AHP, TOPSIS
31.	Torkayesh et al. [110], 2022	To reduce harmful pollution, choose a sustainable waste disposal system.	Operation & Investment cost; Energy recovery rate; Emission; Social acceptance; Efficiency; Qualified person;	Stratified Best Worst Method (SBWM)

TABLE 3. *(Continued.)* **There are a few more applications of MCDM in wastewater treatment.**

			Technology Accessibility; Employment potential.	
32.	Sulthonuddin et al. [111], 2021	This study attempted to determine wastewater management priorities for the Batik industrial center, considering various factors in the local community and institutional aspects.	ENV, INSTITUTIONAL, SOCIAL, ECO, COST	AHP
33.	Akhtar et al. [112], 2021	WQI approach for water quality evaluation based on two MCDM methods is discussed.	Drinking, Irrigation, Domestic, Industry	MACBETH, AHP
34.	Mascarenhas et al. [113], 2021	A multi-criteria study of waste disposal treatment technology was conducted to aid decision-making.	Cost, GHG emission, Air quality, Recycling, Soil & water contamination, Electricity, Land	Multi-Criteria Analysis (MCA)
35.	Todaro et al. [114], 2021	The article discusses a novel approach to selecting the optimum reactive capping alternatives for rehabilitating contaminated seafloor sediments.	Remediation Index, Cost, Ecological Damage	MCDA, AHP
36.	Saha and Paul [115], 2021	This research aims to identify potential water-use sites based on water quality and to develop a plan for city planning.	Drinking, Irrigation, Industry, and Fishery	GIS-AHP
37.	Fetanat et al. [116], 2021	Prioritize wastewater treatment methods that recapture energy.	Water security principle (3 cr), energy security principle (6 cr), food security principle (4 cr)	Intuitionistic fuzzy environment, Linear assignment method
38.	Zhang et al. [117], 2022	An environmental and ecological risk assessment model has been developed in this work to estimate the dangers of microplastics in the Yangtze River Estuary and nearby marine areas.	Pressure Index (7 scr), State Index (5 scr), Response Index (3 scr)	AHP
39.	Senathirajah et al. [118], 2022	This research aims to assess the harmful characteristics of common polymers.	21 criteria's Land use, consumption, litter, production, monomer, recycling, crystallinity, plasticizers, metals, biofilm, POPs & ECs, etc.	MCA, semi-quantitative approach
40.	Alkan and Kahraman [119], 2022	This study investigates the evaluation of garbage disposal sites where the assessment is vulnerable to temporal change.	ENV (6 scr), ECO(2 scr), SOCIAL (5 scr)	IFS, CRITIC method

VII. BIBLIOMETRIC ANALYSIS

The bibliometric study indicates developments in research. For 2015-2023, the bibliometric study utilized the "SCOPUS/WoS" database. For the analysis, the keyword used is "Multi Criteria Decision Making AND Water Treatment" in the SCOPUS/WoS database. The year of publication, research area, country-wise distribution, journal statistics, publication source, document type distribution of publications, and subject-wise publication analysis are shown in the figures depicted below (Figure 5 - Figure 10)."

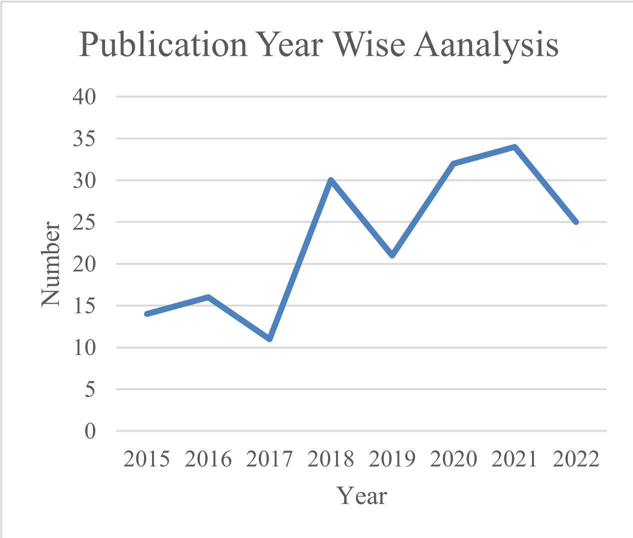

FIGURE 5. Year-wise publications of 'Multi-criteria decision making AND water treatment.'

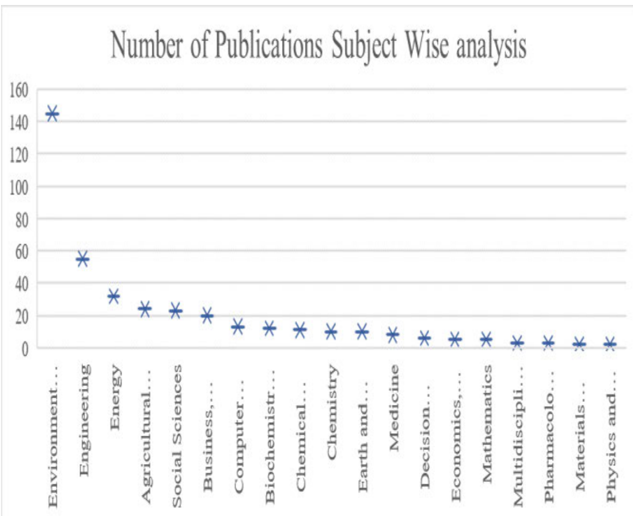

FIGURE 6. Publications quantitative analysis based on subject area.

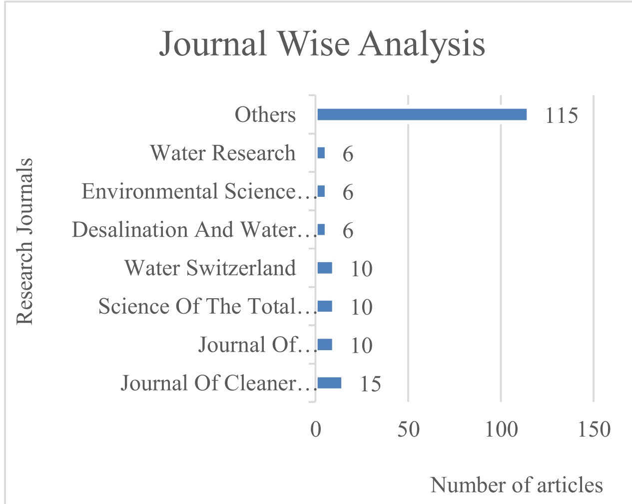

FIGURE 7. Journal wise publications.

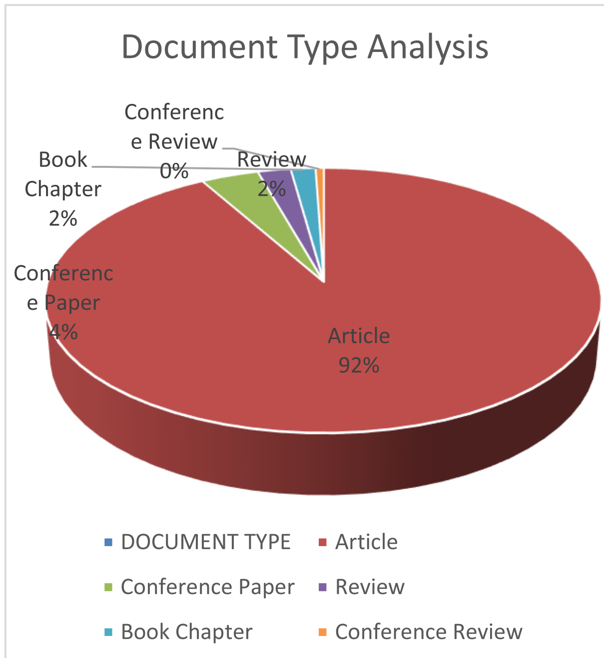

FIGURE 8. Quantitative analysis of the articles based on article type.

VIII. FINDINGS, LIMITATIONS AND FUTURE DIRECTIONS

• To apply multi-criteria methodologies in real life, it must be technically and economically feasible. As a result, AHP is the most utilized MCDM method, even when integrated with other methods in water treatment technologies. AHP offers the advantage of combining multiple weights and parameters to calculate final weights and variables.

• The limitations inherent in a literature review of this nature lie in its exclusive dependence on previously published research and the accessibility of these studies through the methodology outlined in the search process.

• The majority of research has been conducted on wastewater treatment, followed by surface/groundwater technology.

• In water treatment and wastewater technology, not only broad criteria such as economic and technical significance but also sustainable measures, social and political factors, and risk assessment are critical for cost-effective, ecologically friendly WTT.

• Nanotechnology in surface or wastewater treatment is popular as it is effective and safe. Not much work has been done on the evaluation and effectiveness of water treatment technologies based on nanotechnology using MCDM methods. Future research on finding the best adsorbents, selecting WWT based on nanotechnology, and exploring adsorbents' sustainability measures with MCDM can be beneficial.

• Some researchers have employed integrated MOO and MCDM to identify the best water remediation solutions;

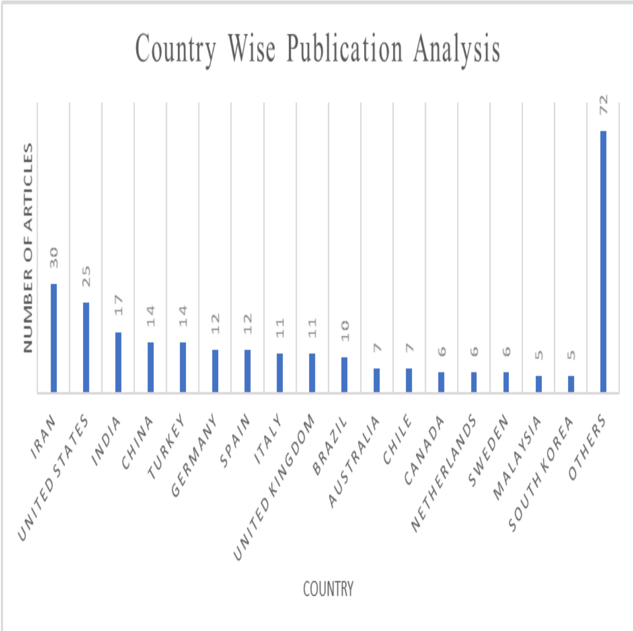

FIGURE 9. **Country-wise publication analysis.**

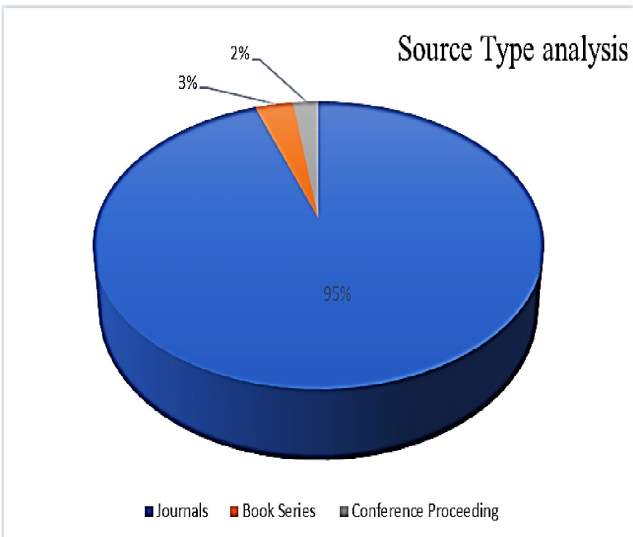

FIGURE 10. **Analysis based on source of publications.**

further research studies on combined approaches to address environmental concerns are essential.

- Fuzzy MCDM applications in sustainability decisions offer several advantages, including the ability to incorporate numerous disparate and conflicting criteria, as well as making the procedure for assigning criteria weights flexible and simple.
- There are several MCDM techniques available, each with its unique set of outcomes. While most approaches provide a definite result, finding the appropriate approach is far from simple, especially in challenges involving sustainable technology.

IX. CONCLUSION

Conflicting criteria, affordability, applicability, and sustainability measures together create a complex multi-criteria analysis task in the field of water treatment, which directly impacts technology performance. Sustainability, in addition to general criteria such as technical, economic, and social aspects, plays a significant role in the challenging task of selecting the most appropriate water treatment technology from a range of predefined alternatives. In this context, Multi-Criteria decision-making (MCDM) methods emerge as suitable tools to address the complexities of establishing sustainable technology solutions.

Through this literature analysis, it becomes evident that a multitude of MCDM methods are being applied within the realm of sustainable development. Many of these methods have proven effective in achieving objectives related to environmental concerns. These include the prioritization of Wastewater Treatment (WWT) alternatives, the evaluation of crucial criteria influencing treatment technology efficiency, and the comparison of various WWT approaches. Furthermore, integrated MCDM methods offer decision-makers more detailed and definitive solutions, enabling them to make well-informed and scientifically based decisions.

In the future, continued research may lead to the development of a more consistent decision-making model for technology assessment that accounts for uncertain criteria. The current study also offers recommendations for multi-criteria analysis aimed at obtaining reliable and robust outcomes.

REFERENCES

[1] *UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) 2017 Report: Financing Universal Water, Sanitation and Hygiene Under the Sustainable Development Goals*, World Health Organization, Geneva, Switzerland, 2017.

[2] P. Bhawan and E. A. Nagar, "Central pollution control board," Central Pollut. Control Board, New Delhi, India, Tech. Rep. 20-21, 2020.

[3] S. D. Attri, S. Singh, A. Dhar, and S. Powar, "Multi-attribute sustainability assessment of wastewater treatment technologies using combined fuzzy multi-criteria decision-making techniques," *J. Cleaner Prod.*, vol. 357, Jul. 2022, Art. no. 131849, doi: 10.1016/j.jclepro.2022.131849.

[4] M. Roy and R. Saha, "Dyes and their removal technologies from wastewater: A critical review," in *Intelligent Environmental Data Monitoring for Pollution Management*. Cambridge, MA, USA: Academic, 2021, pp. 127–160.

[5] R. Kuhn, I. M. Bryant, R. Jensch, and J. Böllmann, "Applications of environmental nanotechnologies in remediation, wastewater treatment, drinking water treatment, and agriculture," *Appl. Nano*, vol. 3, no. 1, pp. 54–90, Mar. 2022.

[6] A. S. Adeleye, J. R. Conway, K. Garner, Y. Huang, Y. Su, and A. A. Keller, "Engineered nanomaterials for water treatment and remediation: Costs, benefits, and applicability," *Chem. Eng. J.*, vol. 286, pp. 640–662, Feb. 2016.

[7] A. Ullah, S. Hussain, A. Wasim, and M. Jahanzaib, "Development of a decision support system for the selection of wastewater treatment technologies," *Sci. Total Environ.*, vol. 731, Aug. 2020, Art. no. 139158.

[8] S. Sharma, P. Dhingra, and S. Jain, "Advancements & challenges of nanotechnology in wastewater treatment," *Mater. Today, Proc.*, vol. 80, pp. 18–23, Jan. 2023.

[9] D. Gola, A. Adhikary, R. K. Bharti, P. Dey, S. Gola, N. Chauhan, and R. Mehrotra, "Advances in nanotechnologies of wastewater treatment: Strategies and emerging opportunities," in *Development in Wastewater Treatment Research and Processes*. Amsterdam, The Netherlands: Elsevier, 2022, pp. 123–138.

[10] A. P. Tom, "Nanotechnology for sustainable water treatment—A review," *Mater. Today, Proc.*, vol. 10, pp. 16–78, Jan. 2021.

[11] A. K. Badawi, E. S. Bakhoum, and K. Zaher, "Sustainable evaluation of using nano zero-valent iron and activated carbon for real textile effluent remediation," *Arabian J. Sci. Eng.*, vol. 46, no. 11, pp. 10365–10380, Jan. 2021, doi: 10.1007/s13369-021-05349-5.

[12] S. Yu, H. Pang, S. Huang, H. Tang, S. Wang, M. Qiu, Z. Chen, H. Yang, G. Song, D. Fu, B. Hu, and X. Wang, "Recent advances in metal-organic framework membranes for water treatment: A review," *Sci. Total Environ.*, vol. 800, Dec. 2021, Art. no. 149662, doi: 10.1016/j.scitotenv.2021.149662.

[13] G. Mannina, T. F. Rebouças, A. Cosenza, M. Sànchez-Marrè, and K. Gibert, "Decision support systems (DSS) for wastewater treatment plants—A review of the state of the art," *Bioresource Technol.*, vol. 290, Oct. 2019, Art. no. 121814, doi: 10.1016/j.biortech.2019.121814.

[14] H.-C. Lee and C.-T. Chang, "Comparative analysis of MCDM methods for ranking renewable energy sources in Taiwan," *Renew. Sustain. Energy Rev.*, vol. 92, pp. 883–896, Sep. 2018, doi: 10.1016/j.rser.2018.05.007.

[15] Z. Wen, H. Liao, E. K. Zavadskas, and J. Antuchevičienė, "Applications of fuzzy multiple criteria decision making methods in civil engineering: A state-of-the-art survey," *J. Civil Eng. Manage.*, vol. 27, no. 6, pp. 358–371, Jul. 2021.

[16] A. Mardani, E. K. Zavadskas, Z. Khalifah, N. Zakuan, A. Jusoh, K. M. Nor, and M. Khoshnoudi, "A review of multi-criteria decision-making applications to solve energy management problems: Two decades from 1995 to 2015," *Renew. Sustain. Energy Rev.*, vol. 71, pp. 216–256, May 2017, doi: 10.1016/j.rser.2016.12.053.

[17] I. Kaya, M. Çolak, and F. Terzi, "A comprehensive review of fuzzy multi criteria decision making methodologies for energy policy making," *Energy Strategy Rev.*, vol. 24, pp. 207–228, Apr. 2019, doi: 10.1016/j.esr.2019.03.003.

[18] A. E. Torkayesh, B. Malmir, and M. R. Asadabadi, "Sustainable waste disposal technology selection: The stratified best-worst multi-criteria decision-making method," *Waste Manage.*, vol. 122, pp. 100–112, Mar. 2021, doi: 10.1016/j.wasman.2020.12.040.

[19] A. Rakshit, S. Chatterjee, and S. K. Naskar, "Multi-criteria decision making methods applied in waste water treatment: A review," *Int. J. Res. Publication Rev.*, vol. 2582, p. 7421, 2021.

[20] G. Mannina, H. Gulhan, and B.-J. Ni, "Water reuse from wastewater treatment: The transition towards circular economy in the water sector," *Bioresource Technol.*, vol. 363, Nov. 2022, Art. no. 127951.

[21] S. Sriram, M. Ramachandran, S. Chinnasamy, and G. Mathivanan, "A review of multi-criteria decision-making and its application," *REST J. Emerg. Trends Model. Manuf.*, vol. 7, no. 4, pp. 101–107, 2022.

[22] A. Kumar, "Multi-criteria decision-making techniques for complex decision making problems," *Math. Eng., Sci. Aerosp. (MESA)*, vol. 13, no. 2, pp. 791–803, 2022.

[23] S. S. Rawat, S. Pant, A. Kumar, M. Ram, H. K. Sharma, and A. Kumar, "A state-of-the-art survey on analytical hierarchy process applications in sustainable development," *Int. J. Math., Eng. Manage. Sci.*, vol. 7, no. 6, pp. 883–917, Dec. 2022.

[24] S. Pant, A. Kumar, M. Ram, Y. Klochkov, and H. K. Sharma, "Consistency indices in analytic hierarchy process: A review," *Mathematics*, vol. 10, no. 8, p. 1206, Apr. 2022, doi: 10.3390/math10081206.

[25] A. Kumar and S. Pant, "Analytical hierarchy process for sustainable agriculture: An overview," *MethodsX*, vol. 10, Jan. 2023, Art. no. 101954, doi: 10.1016/j.mex.2022.101954.

[26] H. T. Do, S.-L. Lo, and L. A. P. Thi, "Calculating of river water quality sampling frequency by the analytic hierarchy process (AHP)," *Environ. Monitor. Assessment*, vol. 185, no. 1, pp. 909–916, Mar. 2012, doi: 10.1007/s10661-012-2600-6.

[27] E. Ozturk and N. C. Cinperi, "Water efficiency and wastewater reduction in an integrated woolen textile mill," *J. Cleaner Prod.*, vol. 201, pp. 686–696, Nov. 2018, doi: 10.1016/j.jclepro.2018.08.021.

[28] G. Anaokar, A. Khambete, and R. Christian, "Evaluation of a performance index for municipal wastewater treatment plants using MCDM—TOPSIS," *Int. J. Technol.*, vol. 9, no. 4, p. 715, Jul. 2018, doi: 10.14716/ijtech.v9i4.102.

[29] R. D. F. S. M. Russo and R. Camanho, "Criteria in AHP: A systematic review of literature," *Proc. Comput. Sci.*, vol. 55, pp. 1123–1132, Jan. 2015, doi: 10.1016/j.procs.2015.07.081.

[30] M. Rajak and K. Shaw, "Evaluation and selection of mobile health (mHealth) applications using AHP and fuzzy TOPSIS," *Technol. Soc.*, vol. 59, Nov. 2019, Art. no. 101186, doi: 10.1016/j.techsoc.2019.101186.

[31] J. M. Arif, M. F. A. Razak, S. R. T. Mat, S. Awang, N. S. N. Ismail, and A. Firdaus, "Android mobile malware detection using fuzzy AHP," *J. Inf. Secur. Appl.*, vol. 61, Sep. 2021, Art. no. 102929, doi: 10.1016/j.jisa.2021.102929.

[32] C. Wei, J. Wei, Q. Kong, D. Fan, G. Qiu, C. Feng, F. Li, S. Preis, and C. Wei, "Selection of optimum biological treatment for coking wastewater using analytic hierarchy process," *Sci. Total Environ.*, vol. 742, Nov. 2020, Art. no. 140400, doi: 10.1016/j.scitotenv.2020.140400.

[33] I. Skoczko and K. Oszczapińska, "The choice of location for a community water treatment plant using the AHP method," *Econ. Environ.*, vol. 68, no. 1, pp. 1–11, 2019.

[34] A. Shafaghat, "A treatment wetland park assessment model for evaluating urban ecosystem stability using analytical hierarchy process (AHP)," *J. Environ. Treatment Techn.*, vol. 7, no. 1, pp. 81–91, 2019.

[35] J. Gyani, A. Ahmed, and M. A. Haq, "MCDM and various prioritization methods in AHP for CSS: A comprehensive review," *IEEE Access*, vol. 10, pp. 33492–33511, 2022, doi: 10.1109/access.2022.3161742.

[36] M. R. Asadabadi, E. Chang, and M. Saberi, "Are MCDM methods useful? A critical review of analytic hierarchy process (AHP) and analytic network process (ANP)," *Cogent Eng.*, vol. 6, no. 1, May 2019, Art. no. 1623153, doi: 10.1080/23311916.2019.1623153.

[37] S. P. Munasinghe-Arachchige, I. S. A. Abeysiriwardana-Arachchige, H. M. K. Delanka-Pedige, and N. Nirmalakhandan, "Sewage treatment process refinement and intensification using multi-criteria decision making approach: A case study," *J. Water Process Eng.*, vol. 37, Oct. 2020, Art. no. 101485, doi: 10.1016/j.jwpe.2020.101485.

[38] T. Gichamo, "Ranking of natural wastewater treatment techniques by multi-criteria decision making (MCDM) methods," in *Application of Multi-Criteria Decision Analysis in Environmental and Civil Engineering*.New York, NY, USA: Springer, 2021, pp. 87–100.

[39] M. Chaisar and S. K. Garg, "Selection of sewage treatment technology using analytic hierarchy process," *Mater. Today, Proc.*, vol. 56, pp. 3433–3440, Dec. 2022, doi: 10.1016/j.matpr.2021.10.486.

[40] M. L. Kamari, H. Isvand, and M. A. Nazari, "Applications of multi-criteria decision-making (MCDM) methods in renewable energy development: A review," *Renew. Energy Res. Appl.*, vol. 1, no. 1, pp. 47–54, 2020.

[41] A. Budak, I. Kaya, A. Karaşan, and M. Erdoğan, "Real-time location systems selection by using a fuzzy MCDM approach: An application in humanitarian relief logistics," *Appl. Soft Comput.*, vol. 92, Jul. 2020, Art. no. 106322, doi: 10.1016/j.asoc.2020.106322.

[42] A. Debnath, M. Majumder, and M. Pal, "Potential of fuzzy-ELECTRE MCDM in evaluation of cyanobacterial toxins removal methods," *Arabian J. Sci. Eng.*, vol. 41, no. 10, pp. 3931–3944, Feb. 2016, doi: 10.1007/s13369-016-2032-7.

[43] M. Kamali, K. M. Persson, M. E. Costa, and I. Capela, "Sustainability criteria for assessing nanotechnology applicability in industrial wastewater treatment: Current status and future outlook," *Environ. Int.*, vol. 125, pp. 261–276, Apr. 2019, doi: 10.1016/j.envint.2019.01.055.

[44] M. Kamali, M. E. Costa, T. M. Aminabhavi, and I. Capela, "Sustainability of treatment technologies for industrial biowastes effluents," *Chem. Eng. J.*, vol. 370, pp. 1511–1521, Aug. 2019, doi: 10.1016/j.cej.2019.04.010.

[45] N. M. Yahya, H. Gökçekuş, and D. U. Ozsahin, "Comparative analysis of wastewater treatment technologies," *Jurnal Kejuruteraan*, vol. 32, no. 2, pp. 221–230, 2020, doi: 10.17576/jkukm-2020-32(2)-06.

[46] G. Danesh, S. M. Monavari, G. A. Omrani, A. Karbasi, and F. Farsad, "Compilation of a model for hazardous waste disposal site selection using GIS-based multi-purpose decision-making models," *Environ. Monitor. Assessment*, vol. 191, no. 2, pp. 1–14, Jan. 2019, doi: 10.1007/s10661-019-7243-4.

[47] P.S. Dange and R. K. Lad, "Sewage water quality index of sewage treatment plant using fuzzy MCDM approach," in *Proc. 5th Int. Conf. Fuzzy Neuro Comput. (FANCCO)*. Cham, Switzerland: Springer, 2015, pp. 241–253.

[48] Y. Ali, H. Pervez, and J. Khan, "Selection of the most feasible wastewater treatment technology in Pakistan using multi-criteria decision-making (MCDM)," *Water Conservation Sci. Eng.*, vol. 5, nos. 3–4, pp. 199–213, Sep. 2020, doi: 10.1007/s41101-020-00094-6.

[49] M. Ghandi and A. Roozbahani, "Risk management of drinking water supply in critical conditions using fuzzy PROMETHEE V technique," *Water Resour. Manage.*, vol. 34, no. 2, pp. 595–615, Jan. 2020, doi: 10.1007/s11269-019-02460-z.

[50] C. Fernández-López, M. G. García, and J. M. Sánchez-Lozano, "Analysis of WWTPs technologies based on the removal efficiency of pharmaceutical activated compounds for water reuse purposes. A fuzzy multi-criteria decision making approach," *J. Water Process Eng.*, vol. 42, Aug. 2021, Art. no. 102098, doi: 10.1016/j.jwpe.2021.102098.

[51] S. Mahammad and A. Islam, "Evaluating the groundwater quality of damodar fan delta (India) using fuzzy-AHP MCDM technique," *Appl. Water Sci.*, vol. 11, no. 7, pp. 1–17, Jun. 2021, doi: 10.1007/s13201-021-01408-2.

[52] V. K. Singh, D. Kumar, S. K. Singh, Q. B. Pham, N. T. T. Linh, S. Mohammed, and D. T. Anh, "Development of fuzzy analytic hierarchy process based water quality model of upper Ganga River Basin, India," *J. Environ. Manage.*, vol. 284, Apr. 2021, Art. no. 111985, doi: 10.1016/j.jenvman.2021.111985.

[53] K. Govindan, K. Madan Shankar, and D. Kannan, "Sustainable material selection for construction industry—A hybrid multi criteria decision making approach," *Renew. Sustain. Energy Rev.*, vol. 55, pp. 1274–1288, Mar. 2016, doi: 10.1016/j.rser.2015.07.100.

[54] A. Kumar, B. Sah, A. R. Singh, Y. Deng, X. He, P. Kumar, and R. C. Bansal, "A review of multi criteria decision making (MCDM) towards sustainable renewable energy development," *Renew. Sustain. Energy Rev.*, vol. 69, pp. 596–609, Mar. 2017, doi: 10.1016/j.rser.2016.11.191.

[55] P. Golfam, P.-S. Ashofteh, T. Rajaee, and X. Chu, "Prioritization of water allocation for adaptation to climate change using multi-criteria decision making (MCDM)," *Water Resour. Manage.*, vol. 33, no. 10, pp. 3401–3416, Jul. 2019, doi: 10.1007/s11269-019-02307-7.

[56] A. Paul, N. Shukla, S. K. Paul, and A. Trianni, "Sustainable supply chain management and multi-criteria decision-making methods: A systematic review," *Sustainability*, vol. 13, no. 13, p. 7104, Jun. 2021, doi: 10.3390/su13137104.

[57] S. Borza and V. Petrescu, "The olt river pollution monitoring, using spatial analysis, analityc hierarchy process and technique for order preference by similarity methods," *Process Saf. Environ. Protection*, vol. 101, pp. 9–18, May 2016, doi: 10.1016/j.psep.2016.01.002.

[58] A. K. Saha, S. Choudhury, and M. Majumder, "Performance efficiency analysis of water treatment plants by using MCDM and neural network model," *Matter, Int. J. Sci. Technol.*, vol. 3, no. 1, pp. 27–35, May 2017, doi: 10.20319/mijst.2017.31.2735.

[59] S. Choudhury and A. K. Saha, "Location selection for installation of surface water treatment plant by applying a new sinusoidal analytical hierarchy process," *Int. J. Energy Optim. Eng.*, vol. 8, no. 3, pp. 20–42, Jul. 2019, doi: 10.4018/ijeoe.2019070102.

[60] M. G. Kharat, S. Murthy, S. J. Kamble, R. D. Raut, S. S. Kamble, and M. G. Kharat, "Fuzzy multi-criteria decision analysis for environmentally conscious solid waste treatment and disposal technology selection," *Technol. Soc.*, vol. 57, pp. 20–29, May 2019, doi: 10.1016/j.techsoc.2018.12.005.

[61] A. Shahnazari, M. Rafiee, A. Rohani, B. B. Nagar, M. A. Ebrahiminik, and M. H. Aghkhani, "Identification of effective factors to select energy recovery technologies from municipal solid waste using multi-criteria decision making (MCDM): A review of thermochemical technologies," *Sustain. Energy Technol. Assessments*, vol. 40, Aug. 2020, Art. no. 100737, doi: 10.1016/j.seta.2020.100737.

[62] S. Agarwal and A. P. Singh, "Performance evaluation of textile wastewater treatment techniques using sustainability index: An integrated fuzzy approach of assessment," *J. Cleaner Prod.*, vol. 337, Feb. 2022, Art. no. 130384, doi: 10.1016/j.jclepro.2022.130384.

[63] P. Liu, P. Rani, and A. R. Mishra, "A novel Pythagorean fuzzy combined compromise solution framework for the assessment of medical waste treatment technology," *J. Cleaner Prod.*, vol. 292, Apr. 2021, Art. no. 126047, doi: 10.1016/j.jclepro.2021.126047.

[64] L. Yao, Z. Xu, C. Lv, and M. Hashim, "Incomplete interval type-2 fuzzy preference relations based on a multi-criteria group decision-making model for the evaluation of wastewater treatment technologies," *Measurement*, vol. 151, Feb. 2020, Art. no. 107137, doi: 10.1016/j.measurement.2019.107137.

[65] D. V. Thakur, "Locating temporary waste treatment facilities in the cities to handle the explosive growth of HCWs during pandemics: A novel Grey-AHP-OCRA hybrid approach," *Sustain. Cities Soc.*, vol. 82, Jul. 2022, Art. no. 103907, doi: 10.1016/j.scs.2022.103907.

[66] E. Vaseghi, M. R. Z. Mehrjerdi, A. Nikouei, and H. M. Boshrabadi, "Prioritizing potential use of urban treated wastewater using expert-oriented and multi-criteria decision-making approaches: A case study in Iran," *Water Sci. Technol.*, vol. 82, no. 1, pp. 81–96, Jul. 2020, doi: 10.2166/wst.2020.330.

[67] A. Azari, R. Nabizadeh, A. H. Mahvi, and S. Nasseri, "Integrated fuzzy AHP-TOPSIS for selecting the best color removal process using carbon-based adsorbent materials: Multi-criteria decision making vs. Systematic review approaches and modeling of textile wastewater treatment in real conditions," *Int. J. Environ. Anal. Chem.*, vol. 102, no. 18, pp. 7329–7344, Dec. 2022.

[68] P. Majumder, D. Baidya, and M. Majumder, "Application of novel intuitionistic fuzzy BWAHP process for analysing the efficiency of water treatment plant," *Neural Comput. Appl.*, vol. 33, no. 24, pp. 17389–17405, Aug. 2021, doi: 10.1007/s00521-021-06326-7.

[69] P. Zolfaghary, M. Zakerinia, and H. Kazemi, "A model for the use of urban treated wastewater in agriculture using multiple criteria decision making (MCDM) and geographic information system (GIS)," *Agricult. Water Manage.*, vol. 243, Jan. 2021, Art. no. 106490, doi: 10.1016/j.agwat.2020.106490.

[70] S. Dolui and S. Sarkar, "Identifying potential landfill sites using multicriteria evaluation modeling and GIS techniques for Kharagpur city of West Bengal, India," *Environ. Challenges*, vol. 5, Dec. 2021, Art. no. 100243, doi: 10.1016/j.envc.2021.100243.

[71] A. C. P. Fernandes, D. P. S. Terêncio, F. A. L. Pacheco, and L. F. S. Fernandes, "A combined GIS-MCDA approach to prioritize stream water quality interventions, based on the contamination risk and intervention complexity," *Sci. Total Environ.*, vol. 798, Dec. 2021, Art. no. 149322, doi: 10.1016/j.scitotenv.2021.149322.

[72] F. B. Brahim, E. Boughariou, and S. Bouri, "Multicriteria-analysis of deep groundwater quality using WQI and fuzzy logic tool in GIS: A case study of Kebilli Region, SW Tunisia," *J. Afr. Earth Sci.*, vol. 180, Aug. 2021, Art. no. 104224, doi: 10.1016/j.jafrearsci.2021.104224.

[73] S. S. Bilgilioğlu, "Site selection for radioactive waste disposal facility by GIS based multi criteria decision making," *Ann. Nucl. Energy*, vol. 165, Jan. 2022, Art. no. 108795, doi: 10.1016/j.anucene.2021.108795.

[74] I. Mukherjee, U. K. Singh, and S. Chakma, "Evaluation of groundwater quality for irrigation water supply using multi-criteria decision-making techniques and GIS in an agroeconomic tract of lower Ganga Basin, India," *J. Environ. Manage.*, vol. 309, May 2022, Art. no. 114691, doi: 10.1016/j.jenvman.2022.114691.

[75] Y. T. Birgani and F. Yazdandoost, "An integrated framework to evaluate resilient-sustainable urban drainage management plans using a combined-adaptive MCDM technique," *Water Resour. Manage.*, vol. 32, no. 8, pp. 2817–2835, Mar. 2018, doi: 10.1007/s11269-018-1960-2.

[76] M. M. Shahsavar, M. Akrami, Z. Kian, M. Gheibi, A. M. Fathollahi-Fard, M. Hajiaghaei-Keshteli, and K. Behzadian, "Bio-recovery of municipal plastic waste management based on an integrated decision-making framework," *J. Ind. Eng. Chem.*, vol. 108, pp. 215–234, Apr. 2022, doi: 10.1016/j.jiec.2022.01.002.

[77] R. Rizk, M. Alameraw, M. A. Rawash, T. Juzsakova, E. Domokos, A. Hedfi, M. Almalki, F. Boufahja, P. Gabriel, H. M. Shafik, and Á. Rédey, "Does lake Balaton affected by pollution? Assessment through surface water quality monitoring by using different assessment methods," *Saudi J. Biol. Sci.*, vol. 28, no. 9, pp. 5250–5260, Sep. 2021, doi: 10.1016/j.sjbs.2021.05.039.

[78] Z. Yang and Y. Wang, "The cloud model based stochastic multi-criteria decision making technology for river health assessment under multiple uncertainties," *J. Hydrol.*, vol. 581, Feb. 2020, Art. no. 124437, doi: 10.1016/j.jhydrol.2019.124437.

[79] A. Salamirad, S. Kheybari, A. Ishizaka, and H. Farazmand, "Wastewater treatment technology selection using a hybrid multicriteria decision-making method," *Int. Trans. Oper. Res.*, vol. 30, no. 3, pp. 1479–1504, May 2023, doi: 10.1111/itor.12979.

[80] E. Ayyildiz and G. Özçelik, "Evaluation of wastewater treatment performances for municipalities by using MCDM methods: Case study in Turkey," *Erzincan Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, vol. 11, no. 2, pp. 243–254, Aug. 2018, doi: 10.18185/erzifbed.390010.

[81] G. P. Bhole and T. Deshmukh, "Multi-criteria decision making (MCDM) methods and its applications," *Int. J. Res. Appl. Sci. Eng. Technol. (IJRASET)*, vol. 6, no. 5, pp. 899–915, 2018.

[82] A. Hadipour, T. Rajaee, V. Hadipour, and S. Seidirad, "Multi-criteria decision-making model for wastewater reuse application: A case study from Iran," *Desalination Water Treatment*, vol. 57, no. 30, pp. 13857–13864, Jun. 2015, doi: 10.1080/19443994.2015.1060905.

[83] V. Ravi, B. K. Panigrahi, S. Das, and P. N. Suganthan, "Advances in intelligent systems and computing," in *Proc. 5th Int. Conf. Fuzzy Neuro Comput. (FANCCO)*, 2015, pp. 1–16, doi: 10.1007/978-3-319-27212-2.

[84] A. Chauhan and A. Singh, "A hybrid multi-criteria decision-making method approach for selecting a sustainable location of healthcare waste disposal facility," *J. Cleaner Prod.*, vol. 139, pp. 1001–1010, Dec. 2016, doi: 10.1016/j.jclepro.2016.08.098.

[85] M. Dursun, "Evaluation of wastewater treatment alternatives using fuzzy VIKOR method," *J. Adv. Manage. Sci.*, vol. 4, no. 4, pp. 333–336, 2016, doi: 10.12720/joams.4.4.333-336.

[86] E. A. Voudrias, "Technology selection for infectious medical waste treatment using the analytic hierarchy process," *J. Air Waste Manage. Assoc.*, vol. 66, no. 7, pp. 663–672, Mar. 2016, doi: 10.1080/10962247.2016.1162226.

[87] C. Liquete, A. Udias, G. Conte, B. Grizzetti, and F. Masi, "Integrated valuation of a nature-based solution for water pollution control. Highlighting hidden benefits," *Ecosyst. Services*, vol. 22, pp. 392–401, Dec. 2016, doi: 10.1016/j.ecoser.2016.09.011.

[88] J. Li, Y. Yang, H. Huan, M. Li, B. Xi, N. Lv, Y. Wu, Y. Xie, X. Li, and J. Yang, "Method for screening prevention and control measures and technologies based on groundwater pollution intensity assessment," *Sci. Total Environ.*, vols. 551–552, pp. 143–154, May 2016, doi: 10.1016/j.scitotenv.2015.12.152.

[89] M. Garrido-Baserba, R. Reif, M. Molinos-Senante, L. Larrea, A. Castillo, M. Verdaguer, and M. Poch, "Application of a multi-criteria decision model to select of design choices for WWTPs," *Clean Technol. Environ. Policy*, vol. 18, no. 4, pp. 1097–1109, Jan. 2016, doi: 10.1007/s10098-016-1099-x.

[90] S. Zahedi, "Modification of expected conflicts between drinking water quality index and irrigation water quality index in water quality ranking of shared extraction wells using multi criteria decision making techniques," *Ecolog. Indicators*, vol. 83, pp. 368–379, Dec. 2017, doi: 10.1016/j.ecolind.2017.08.017.

[91] H. Karahalios, "The application of the AHP-TOPSIS for evaluating ballast water treatment systems by ship operators," *Transp. Res. D, Transp. Environ.*, vol. 52, pp. 172–184, May 2017, doi: 10.1016/j.trd.2017.03.001.

[92] M. Hossain, "Selection of municipal drinking water treatment approach using multiple criteria," in *Encyclopedia of Sustainable Technologies*. Amsterdam, The Netherlands: Elsevier, 2017, pp. 115–124.

[93] D. An, B. Xi, J. Ren, Y. Wang, X. Jia, C. He, and Z. Li, "Sustainability assessment of groundwater remediation technologies based on multi-criteria decision making method," *Resour., Conservation Recycling*, vol. 119, pp. 36–46, Apr. 2017, doi: 10.1016/j.resconrec.2016.08.002.

[94] S. J. Kamble, A. Singh, and M. G. Kharat, "A hybrid life cycle assessment based fuzzy multi-criteria decision making approach for evaluation and selection of an appropriate municipal wastewater treatment technology," *Euro-Medit. J. Environ. Integr.*, vol. 2, no. 1, pp. 1–17, Mar. 2017, doi: 10.1007/s41207-017-0019-8.

[95] M. Sapkota, M. Arora, H. Malano, A. Sharma, and M. Moglia, "Integrated evaluation of hybrid water supply systems using a PROMETHEE–GAIA approach," *Water*, vol. 10, no. 5, p. 610, May 2018, doi: 10.3390/w10050610.

[96] X. Sun, Z. Hu, M. Li, L. Liu, Z. Xie, S. Li, G. Wang, and F. Liu, "Optimization of pollutant reduction system for controlling agricultural non-point-source pollution based on grey relational analysis combined with analytic hierarchy process," *J. Environ. Manage.*, vol. 243, pp. 370–380, Aug. 2019, doi: 10.1016/j.jenvman.2019.04.089.

[97] O. Jassima and Z. D. Abbasl, "Application of GIS and AHP technologies to support of selecting a suitable site for wastewater sewage plant in al kufa city," *Al-Qadisiyah J. Eng. Sci.*, vol. 12, no. 1, pp. 31–37, Mar. 2019, doi: 10.30772/qjes.v12i1.586.

[98] T. S. Aung, S. Luan, and Q. Xu, "Application of multi-criteria-decision approach for the analysis of medical waste management systems in Myanmar," *J. Cleaner Prod.*, vol. 222, pp. 733–745, Jun. 2019, doi: 10.1016/j.jclepro.2020.121987.

[99] S. Kanwal, M. Sajjad, H. F. Gabriel, and E. Hussain, "Towards sustainable wastewater management: A spatial multi-criteria framework to site the land-FILTER system in a complex urban environment," *J. Cleaner Prod.*, vol. 266, Sep. 2020, Art. no. 121987, doi: 10.1016/j.jclepro.2020.12198.

[100] S. Narayanamoorthy, V. Annapoorani, S. Kalaiselvan, and D. Kang, "Hybrid hesitant fuzzy multi-criteria decision making method: A symmetric analysis of the selection of the best water distribution system," *Symmetry*, vol. 12, no. 12, p. 2096, Dec. 2020, doi: 10.3390/sym12122096.

[101] S. M. K. Sadr, M. B. Johns, F. A. Memon, A. P. Duncan, J. Gordon, R. Gibson, H. J. F. Chang, M. S. Morley, D. Savic, and D. Butler, "Development and application of a multi-objective-optimization and multi-criteria-based decision support tool for selecting optimal water treatment technologies in India," *Water*, vol. 12, no. 10, p. 2836, Oct. 2020.

[102] M. G. Mooselu, M. R. Nikoo, M. Latifi, M. Sadegh, M. Al-Wardy, and G. A. Al-Rawas, "A multi-objective optimal allocation of treated wastewater in urban areas using leader-follower game," *J. Cleaner Prod.*, vol. 267, Sep. 2020, Art. no. 122189, doi: 10.1016/j.jclepro.2020.122189.

[103] B. Liu, J. Tang, Z. Li, Y. Yan, and J. Chen, "Optimal selection of sewage treatment technologies in town areas: A coupled multi-criteria decision-making model," *Environ. Manage.*, vol. 66, no. 4, pp. 709–721, Jul. 2020, doi: 10.1007/s00267-020-01338-w.

[104] B. Savun-Hekimoğlu, B. Erbay, M. Hekimoğlu, and S. Burak, "Evaluation of water supply alternatives for Istanbul using forecasting and multi-criteria decision making methods," *J. Cleaner Prod.*, vol. 287, Mar. 2021, Art. no. 125080, doi: 10.1016/j.jclepro.2020.125080.

[105] R. Kujlu, M. Moslemzadeh, S. Rahimi, E. Aghayani, F. Ghanbari, and M. Mahdavianpour, "Selecting the best stabilization/solidification method for the treatment of oil-contaminated soils using simple and applied best-worst multi-criteria decision-making method," *Environ. Pollut.*, vol. 263, Aug. 2020, Art. no. 114447, doi: 10.1016/j.envpol.2020.114447.

[106] A. Özdemir, A. Özkan, Z. Günkaya, and M. Banar, "Decision-making for the selection of different leachate treatment/management methods: The ANP and PROMETHEE approaches," *Environ. Sci. Pollut. Res.*, vol. 27, no. 16, pp. 19798–19809, Mar. 2020, doi: 10.1007/s11356-020-08524-7.

[107] G. Zhou, Y. Gu, H. Yuan, Y. Gong, and Y. Wu, "Selecting sustainable technologies for disposal of municipal sewage sludge using a multi-criterion decision-making method: A case study from China," *Resour., Conservation Recycling*, vol. 161, Oct. 2020, Art. no. 104881, doi: 10.1016/j.resconrec.2020.104881.

[108] R. W. Becker, L. A. Jachstet, A. Dallegrave, A. Ruiz-Padillo, R. Zanella, and C. Sirtori, "Multi-criteria decision-making techniques associated with (Q)SAR risk assessment for ranking surface water microcontaminants identified using LC-QTOF MS," *Sci. Total Environ.*, vol. 797, Nov. 2021, Art. no. 149002, doi: 10.1016/j.scitotenv.2021.149002.

[109] M. Nasiri, H. K. Moghaddam, and M. Hamidi, "Development of multi-criteria decision making methods for reduction of seawater intrusion in coastal aquifers using SEAWAT code," *J. Contaminant Hydrol.*, vol. 242, Oct. 2021, Art. no. 103848.

[110] A. E. Torkayesh, M. A. Rajaeifar, M. Rostom, B. Malmir, M. Yazdani, S. Suh, and O. Heidrich, "Integrating life cycle assessment and multi criteria decision making for sustainable waste management: Key issues and recommendations for future studies," *Renew. Sustain. Energy Rev.*, vol. 168, Oct. 2022, Art. no. 112819, doi: 10.1016/j.rser.2022.112819.

[111] I. Sulthonuddin and H. Herdiansyah, "Sustainability of batik wastewater quality management strategies: Analytical hierarchy process," *Appl. Water Sci.*, vol. 11, no. 2, pp. 1–12, Jan. 2021, doi: 10.1007/s13201-021-01360-1.

[112] N. Akhtar, M. I. S. Ishak, M. I. Ahmad, K. Umar, M. S. Md Yusuff, M. T. Anees, A. Qadir, and Y. K. Ali Almanasir, "Modification of the water quality index (WQI) process for simple calculation using the multi-criteria decision-making (MCDM) method: A review," *Water*, vol. 13, no. 7, p. 905, Mar. 2021.

[113] L. C. Mascarenhas, B. Ness, M. Oloko, and F. O. Awuor, "Multi-criteria analysis of municipal solid waste treatment technologies to support decision-making in Kisumu, Kenya," *Environ. Challenges*, vol. 4, Aug. 2021, Art. no. 100189, doi: 10.1016/j.envc.2021.100189.

[114] F. Todaro, G. Barjoveanu, S. De Gisi, C. Teodosiu, and M. Notarnicola, "Sustainability assessment of reactive capping alternatives for the remediation of contaminated marine sediments," *J. Cleaner Prod.*, vol. 286, Mar. 2021, Art. no. 124946, doi: 10.1016/j.jclepro.2020.124946.

[115] P. Saha and B. Paul, "Identification of potential strategic sites for city planning based on water quality through GIS-AHP-integrated model," *Environ. Sci. Pollut. Res.*, vol. 28, no. 18, pp. 23073–23086, Jan. 2021, doi: 10.1007/s11356-020-12292-9.

[116] A. Fetanat, M. Tayebi, and H. Mofid, "Water-energy-food security Nexus based selection of energy recovery from wastewater treatment technologies: An extended decision making framework under intuitionistic fuzzy environment," *Sustain. Energy Technol. Assessments*, vol. 43, Feb. 2021, Art. no. 100937, doi: 10.1016/j.seta.2020.100937.

[117] F. Zhang, G. Peng, P. Xu, L. Zhu, C. Li, N. Wei, and D. Li, "Ecological risk assessment of marine microplastics using the analytic hierarchy process: A case study in the Yangtze River Estuary and adjacent marine areas," *J. Hazardous Mater.*, vol. 425, Mar. 2022, Art. no. 127960, doi: 10.1016/j.jhazmat.2021.127960.

[118] K. Senathirajah, A. Kemp, M. Saaristo, S. Ishizuka, and T. Palanisami, "Polymer prioritization framework: A novel multi-criteria framework for source mapping and characterizing the environmental risk of plastic polymers," *J. Hazardous Mater.*, vol. 429, May 2022, Art. no. 128330, doi: 10.1016/j.jhazmat.2022.128330.

[119] N. Alkan and C. Kahraman, "An intuitionistic fuzzy multi-distance based evaluation for aggregated dynamic decision analysis (IF-DEVADA): Its application to waste disposal location selection," *Eng. Appl. Artif. Intell.*, vol. 111, May 2022, Art. no. 104809, doi: 10.1016/j.engappai.2022.104809.

TINA SHARMA received the master's degree in mathematics from D.B.S (P.G) College, Dehradun, India. She is currently pursuing the Ph.D. degree in mathematics with the University of Petroleum and Energy Studies, Dehradun. Her current research interests include multi-criteria decision-making techniques and metaheuristics.

ANUJ KUMAR received the master's and Ph.D. degrees in mathematics from the G. B. Pant University of Agriculture and Technology, Pantnagar, India. He is currently a Professor with D. Y. Patil International University, Pune, India. Before this position, he was associated with the University of Petroleum and Energy Studies (UPES), Dehradun, India, as an Associate Professor. He was an Assistant Professor in mathematics with ICFAI University, Dehradun. He has published more than 70 research articles in journals of national and international repute. His research interests include MCDM, reliability analysis, optimization, and artificial intelligence. He is also an Associate Editor of the *International Journal of Mathematical, Engineering, and Management Sciences*. He is a regular reviewer for various reputable journals from, Elsevier, IEEE, Springer, Taylor & Francis, and Emerald.

SANGEETA PANT received the Ph.D. degree from the G. B. Pant University of Agriculture and Technology, Pantnagar, India. She is currently an Associate Professor with Symbiosis International (Deemed University), Pune, India. Before this, she was associated with the Department of Mathematics, School of Engineering and Computing, Dev Bhoomi Uttarakhand University, Dehradun, as an Associate Professor. She was also an Assistant Professor (SG) with the University of Petroleum and Energy Studies (UPES), Dehradun, India. She has published around 65 research articles in journals/books of national and international repute in her area of interest. She has been actively involved in various other research-related activities, such as editing/reviewing for various reputable journals and organizing/participating in conferences. Her research interests include numerical optimization, artificial intelligence, nature-inspired algorithms, and multi-criteria decision-making.

KETAN KOTECHA is currently an Administrator and a Professor with the Symbiosis Centre for Applied Artificial Intelligence, Symbiosis International (Deemed University), Pune, India. His research interests include artificial intelligence, computer algorithms, machine learning, and deep learning. With expertise and experience in cutting-edge research and projects in AI for the last 25 years, he has published more than 300 articles in several excellent peer-reviewed journals covering various topics, such as cutting-edge AI, education policies, teaching-learning practices, and AI for all. He received two SPARC projects worth INR 166 lakhs from the MHRD Government of India in AI, in collaboration with Arizona State University, USA, and The University of Queensland, Australia. Additionally, he has received numerous prestigious awards, including the Erasmus and Faculty Mobility Grant to Poland, the DUO-India Professors Fellowship for research in responsible AI in collaboration with Brunel University, U.K., the LEAP Grant with Cambridge University, U.K., the UKIERI Grant with Aston University, U.K., and a Grant from the Royal Academy of Engineering, U.K., under the Newton Bhabha Fund. He holds three patents and has delivered keynote speeches at various national and international forums, including the Machine Intelligence Laboratory, USA, IIT Bombay under the World Bank Project, and the International Indian Science Festival organized by the Department of Science and Technology, Government of India. He serves as an Associate Editor for IEEE Access journal.