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Planning decentralized wastewater treatment systems by comparing through TOPSIS

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ABSTRACT

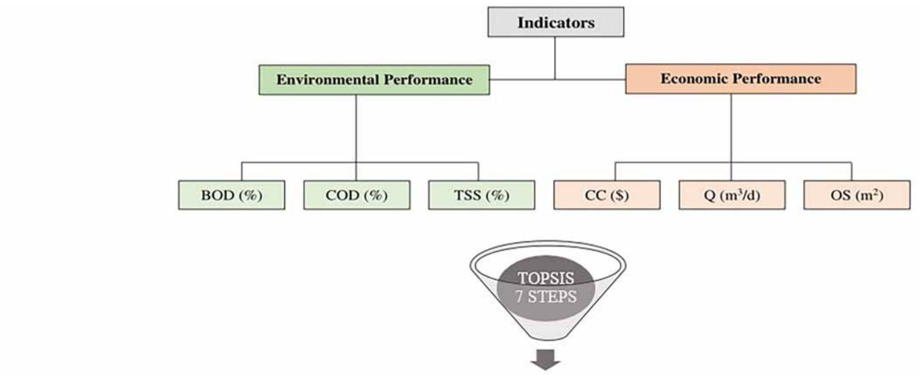
This study evaluates 10 case studies of decentralized wastewater treatment systems (DEWATS) and compares them based on their environmental and economic performance. The aim is to identify the best treatment system composed of specific treatment processes that can be used in the future for hospitals, universities/colleges, and small communities. The comparison was conducted using the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) method of multiple criteria decision-making. According to the TOPSIS method, systems are ranked from 1 to 10 by normalizing and weighting the decision matrix criteria, measuring the alternative's distance from the ideal best to worst value, and then calculating the performance score of each system. The study found that the H4 system, which includes a septic tank, anaerobic baffled reactor, anaerobic filter, horizontal filter, and pond, achieved the highest performance score. Therefore, the processes of the H4 system are recommended as the best alternative for DEWATS. This study may therefore assist stakeholders on their decision to implement DEWATS in similar facilities.

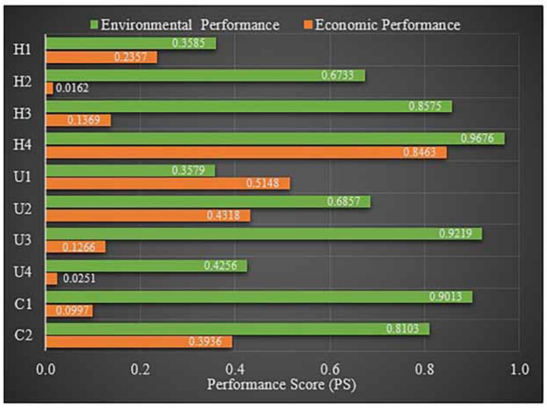
Key words: DEWATS, TOPSIS, wastewater treatment process, wastewater treatment system

HIGHLIGHTS

- The TOPSIS method is used to select appropriate DEWATS.
- A comprehensive assessment using six criteria of two indicators: environmental performance and economic performance of DEWATS.
- Determination of the performance score, separately for each indicator.
- Ranking of systems based on the summarized performance scores for each system.
- The evaluation of the best alternative for DEWATS, which comprises a set of DEWATS processes.

GRAPHICAL ABSTRACT





Systems	Treatment processes				Rank
	I	II	III	IV	
H1	ST+ABR	2HF	2VF		9
H2	ST	HF	2VF		8
H3	ST+ABR	AF	HF		6
H4	ST+ABR	AF	HF	APP	1
U1	ST+ABR	AF	2VF		7
U2	ST	BCH	2AF	BF	3
U3	ST	HF	2VF		4
U4	ST+ABR	2AF	HF		10
C1	2BCH	6 HF			5
C2	BCH	ABR	2HF	2VF	2

1. INTRODUCTION

Wastewater treatment contributes directly and indirectly to all Sustainable Development Goals (SDGs). Regarding the 17 SDGs, SDG 6 is directly related to wastewater treatment, 'ensuring availability and sustainable management of water and sanitation for all' (Obaideen *et al.* 2022). Globally, an estimated 80% of industrial and municipal wastewater is discharged into the environment without any prior treatment, with adverse effects on human health and ecosystems (Lin *et al.* 2022). A sustainable solution for the treatment of wastewater is a decentralized wastewater treatment system (DEWATS), and over the last two decades, large numbers of decentralized wastewater treatment plants of different technologies have been installed all over the world (Singh *et al.* 2015). Massoud *et al.* (2009) stated that the most appropriate technology is the technology that is economically affordable, environmentally sustainable, and socially acceptable.

DEWATS are designed to operate on a small scale (EPA 2004; Massoud *et al.* 2009). They have a comprehensive approach to managing wastewater that involves collecting, treating, and disposing/reusing wastewater close to where it is generated. This approach can be applied to individual dwellings, clusters of homes, entire communities, institutional buildings, schools, or hospitals (Gutterer *et al.* 2009; Ali 2018). Capodaglio *et al.* (2017) highlighted that DEWATS not only reduces the negative effects of wastewater disposal on the environment and public health but may also increase the possibility of reusing wastewater. The extent of reuse depends on the community type, technical options, and local settings. According to Geetha Varma *et al.* (2022) and Sasse (1998), the following technical treatment technologies (processes) are typically seen in DEWATS. The primary treatment consists of sedimentation ponds, settlers, septic tanks, or biodigesters. The secondary treatment consists of anaerobic baffled reactors, anaerobic filters, or anaerobic and facultative pond systems. The secondary aerobic/facultative treatment consists of horizontal filters (HFs), and the post-treatment consists of aerobic polishing ponds. These processes efficiently treat wastewater from commercial and institutional facilities, including hotels, restaurants, office buildings, schools, hospitals, laboratories, and government and military institutions (EPA 2012; Gautam & Singh 2016; Ergas *et al.* 2021).

In this paper, DEWATS composed of different treatment technologies used in a variety of facilities is analyzed, including hospitals (ENPHO 2010a, 2010d; BORDA 2015; CDD 2019a), schools and universities (Gutterer *et al.*

2009; Riccardo Bresciani 2014; Bartaula 2016; CDD 2019b), and small communities (ENPHO 2010b, c). The main purpose of this study is to find the most appropriate system with suitable treatment processes within DEWATS for these types of facilities in the context of economic and environmental indicators.

Multiple criteria decision-making (MCDM) is one of the most accurate methods for decision-makers to choose acceptable alternatives concerning suitable criteria (Taherdoost & Madanchian 2023). MCDM includes different methods (Hajduk 2022). One of them is the Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS), which is the most popular and commonly used in MCDM across different fields (Çelikbilek & Tüysüz 2020). The TOPSIS method is a practical (Yahya *et al.* 2020) and useful technique for ranking and selecting alternatives (Roszkowska 2011). TOPSIS is applied for comparison in many areas: supply chain management and logistics, design, engineering and manufacturing systems, business and marketing management, health, safety and environment management, human resources management, energy management, chemical engineering, and water resources management (Behzadian *et al.* 2012; Yahya *et al.* 2020).

1.1. TOPSIS – comparative method for wastewater treatment systems

In this paper, TOPSIS is used as a comparative method in the selection of appropriate DEWATS treatment alternatives. Several works have highlighted the potential of using TOPSIS in the field of wastewater treatment (Table 1). The aim for implementing TOPSIS among other MCDM tools is outlined in the table, including the main application area in a given study. The set of papers does not have a particular order.

The information presented in Table 1 highlights the various practical uses where the TOPSIS was applied among other MCDM methods. These cases range from selecting a proper wastewater treatment technology for either domestic or industrial use, identifying the best site of the wastewater treatment plant and the best disinfection technique, determining rehabilitation priority, and selecting the best ordering of technologies in wetland segmentation (Table 1). There are cases related to the selection of treatment systems that vary

Table 1 | TOPSIS in wastewater treatment

References	Aim	MCDM used
Dang *et al.* (2023)	Select a wastewater treatment technology – for a factory	TOPSIS, AHP
Attri *et al.* (2022)	Multi-attribute sustainability assessment of wastewater treatment technologies – secondary treatment technologies	Fuzzy SWARA, Fuzzy MOORA, Fuzzy TOPSIS
Orhan *et al.* (2022)	Determining rehabilitation priority in wastewater systems	ENTROPY, ELECTRE, TOPSIS
Yahya *et al.* (2020)	Evaluation of wastewater treatment technologies – for municipal and industrial wastewater	TOPSIS
Yu *et al.* (2020)	Evaluation and selection of industrial sewage treatment projects – for industrial sewage treatment projects (technologies)	Entropy, TOPSIS
Zhou *et al.* (2018)	Selection of wastewater treatment plans – for the wastewater treatment plants selection problem	IFS-TOPSIS
Srdjevic *et al.* (2017)	Selection of best ordering of treatment technologies in wetland segmentation	TOPSIS, AHP, ANP
Mehtap (2015)	Integrated approach for the evaluation of wastewater treatment alternatives – for a case study conducted in Istanbul (four WWT technologies)	DEMATEL, Fuzzy TOPSIS
Jinxiang *et al.* (2013)	Finding out the best wastewater pollution control technology of high efficiency and low energy consumption – in the municipal wastewater treatment plants	ENTROPY WEIGHT TOPSIS
Mansouri *et al.* (2013)	Most suitable site for wastewater treatment plant	TOPSIS, AHP
Karimi *et al.* (2011)	Selection of anaerobic wastewater treatment processes – for an industry	TOPSIS, FUZZY AHP
Gómez-López *et al.* (2009)	Finding the best disinfection technique – for treated urban wastewater	TOPSIS

according to the treatment technologies used in the particular system. In this paper, the focus is on selecting the best DEWATS served for an individual facility. The selection of an appropriate system through TOPSIS also reflects the environmental and economic performance of the DEWATS as the main indicators used in this paper.

2. MATERIAL AND METHODS

2.1. Case studies

Four of the systems analyzed in this paper are for hospitals, four for universities/colleges, and two for small communities. These cases are chosen for comparison as they represent the most common facilities where DEWATS are applied. The systems are referred to as H1, H2, H3, and H4 for hospitals; U1, U2, U3, and U4 for universities/colleges; and C1 and C2 for small communities. Table 2 presents all case studies, and their abbreviated names as systems, that have to be evaluated for comparison analysis in this paper. The table also includes references for each case study in case there is detailed interest in the project for the given case study.

Table 2 | Case studies used for system comparison with TOPSIS

Case studies	Systems	References
Hospitals	H1	ENPHO (2010a)
	H2	ENPHO (2010d)
	H3	BORDA (2015)
	H4	CDD (2019a)
Universities/colleges	U1	Riccardo Bresciani (2014)
	U2	Gutterer *et al.* (2009)
	U3	Bartaula (2016)
	U4	CDD (2019b)
Small communities	C1	ENPHO (2010b)
	C2	ENPHO (2010c)

The systems are compared based on two indicators: environmental performance and economic performance. The indicator of environmental performance refers to the treatment performance of any system. It includes three criteria: biological oxygen demand (BOD), chemical oxygen demand (COD), and total dissolved solids (TSS). The cost of construction (CC), the treated flow (Q), and the occupied space (OS) are criteria for economic performance as a second indicator (Figure 1).

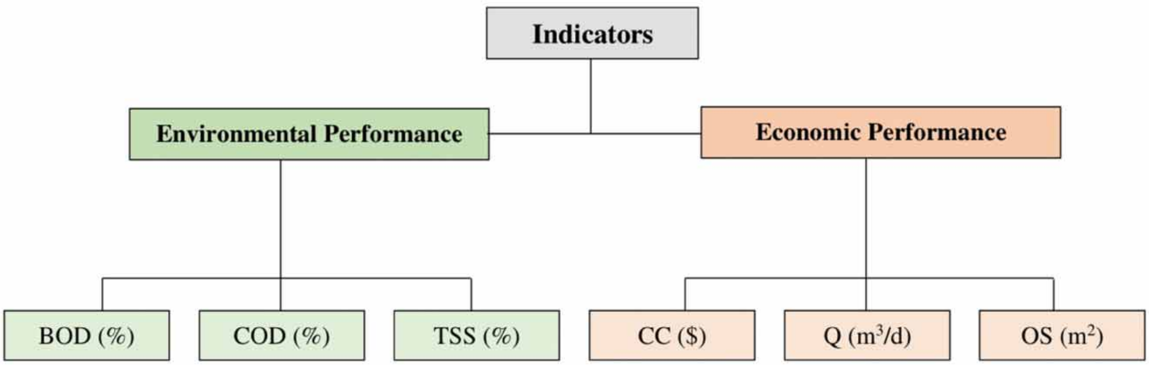


Figure 1 | Indicators/criteria of systems to be compared with TOPSIS.

The processes that are used frequently in the systems of case studies are settling and septic tank (ST), anaerobic baffled reactor (ABR), biogas chamber (BCH) anaerobic filter (AF), horizontal filter (HF), vertical filter (VF), biofilter (BF), and aerobic polishing pond (APP). It is important to mention that the study is based on original data (Table 3) gathered from the literature (case studies).

Table 3 | Data of indicators/criteria and treatment processes of the systems

Systems	Environmental Performance			Economic Performance			Treatment Processes			
	BOD	COD	TSS	CC	Q	OS	I	II	III	IV
H1	90%	48%	91%	39,683 $	90 m^3/d	800 m^2	ST+ABR	2HF	2VF	
H2	84%	81%	97%	14,103 $	20 m^3/d	200 m^2	ST	HF	2VF	
H3	90%	97%	92%	42,713 $	60 m^3/d	357.24 m^2	ST+ABR	AF	HF	
H4	97%	98%	96%	110,000 $	307 m^3/d	2690 m^2	ST+ABR	AF	HF	APP
U1	72.2%	73%	67.7%	160,000 $	180 m^3/d	679 m^2	ST+ABR	AF	2VF	
U2	92.8%	89%	77.5%	115,942 $	146 m^3/d	777.5 m^2	ST	BCH	2AF	BF
U3	98%	93.3%	96.3%	23,000 $	30 m^3/d	628 m^2	ST	HF	2VF	
U4	70.4%	65.8%	95%	21,000 $	25 m^3/d	135.4 m^2	ST+ABR	2AF	HF	
C1	94%	93%	98%	28,188 $	50 m^3/d	385 m^2	2BCH	6 HF		
C2	88%	90%	98%	81,602 $	103 m^3/d	1240 m^2	BCH	ABR	2HF	2VF

Table 3 presents the data related to the environmental and economic performance criteria, used for comparing systems through the TOPSIS method. The table distinguishes each system based on specific treatment processes. The colored boxes in the table indicate similarities or differences between the systems in terms of the processes used.

2.2. TOPSIS method for case studies

The purpose of TOPSIS is to arrange the issues of comprehensive evaluation into a matrix, determine the ideal solution and negative ideal solution after normalization, and then calculate the distance between each evaluation alternative and the ideal solution or negative ideal solution (Tu *et al.* 2020). The paper by Khan & Sahabuddin (2022) outlines a five-step procedure for TOPSIS calculation. This paper divides the same five steps into seven steps to perform the TOPSIS calculation. The seven steps include: constructing the decision matrix, normalizing the decision matrix, weighting the normalized decision matrix, determining the ideal best (IB) and ideal worst (IW) solution, calculating the separation measure, determining the performance score (PS), and finally ranking the alternatives based on the PS.

2.2.1. Step 1: Construct decision matrix

In this step (Table 4), a decision matrix is formed using the following equation:

$$X = (x_{ij}) \tag{1}$$

Table 4 | Decision matrix

	Criteria			
Systems	C_1	C_2	…	C_j
S_1	X_{11}	X_{12}	…	X_{1j}
S_2	X_{21}	X_{22}	…	X_{2j}
⋮	⋮	⋮	⋰	⋮
S_i	X_{i1}	X_{i2}	…	X_{ij}

where X_{ij} is the value of S_i related to C_j, S is the system, C is the criteria, i is the number of systems, and j is the number of criteria.

2.2.2. Step 2: Normalized decision matrix

In this step, the normalized decision matrix is obtained using the following equation:

$$n_{ij} = \frac{Xij}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}} \tag{2}$$

2.2.3. Step 3: Weighted normalized decision matrix

To find the weighted normalized decision matrix, the following equation is used.

$$d_{ij} = n_{ij} \times w_{ij},\ \ i = 1,\ 2,\ \ldots, m;\ j = 1,\ 2 \tag{3}$$

where w_{ij} is the weight of the jth criterion.

2.2.4. Step 4: Determine IB and IW solution

In this step, the IB and the IW alternatives are identified:

$$\text{ideal best},\ \ p_j = \max jd_{ij} \tag{4}$$

$$\text{ideal best},\ \ p_j = \min jd_{ij} \tag{5}$$

$$\text{ideal worst},\ \ q_j = \min jd_{ij} \tag{6}$$

$$\text{ideal worst},\ \ q_j = \min jD_{ij} \tag{7}$$

2.2.5. Step 5: Separate each alternative from the IB solution and the IW solution

The separation measure of each alternative from the IB solution is as follows:

$$d_i^+ = \sqrt{\sum_{j=1}^{n} (d_{ij} - p_j)^2} \tag{8}$$

The separation measure of each alternative from the IW solution is as follows:

$$d_i^- = \sqrt{\sum_{j=1}^{n} (d_{ij} - q_j)^2} \tag{9}$$

2.2.6. Step 6: Calculate performance score

PS is calculated as the relative closeness of the ith alternative A_i, concerning A^+, and is defined as

$$\text{PS}_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{10}$$

where $0 \leq \text{PS}_i \leq 1$, $i = 1, 2, \ldots, m$.

2.2.7. Step 7: Rank the alternatives

Alternatives are ranked according to PS.

The alternatives with the highest $\sum$PS are given first rank and successively the others.

3. RESULTS AND DISCUSSION

The evaluation and the selection of wastewater treatment systems in general can be a complex procedure, as numerous evaluation indicators exist, differing by a lot of criteria. In this paper, the TOPSIS method is used to rank and select the most appropriate wastewater treatment system from 10 case studies of DEWATS in the context of 6 criteria. The evaluated criteria are defined under environmental performance and economic performance. Through TOPSIS, the weights and rating of each criterion are determined (Tables 5 and 6), after initial construction and normalization of the decision matrix (Tables 7 and 8). The main TOPSIS concept is to measure the distance of the alternatives from the positive ideal solution and the negative ideal solution (Table 9), to calculate the PS of each alternative. The most preferred alternative is the one that is closer to the positive ideal solution and also further from the negative ideal solution simultaneously in terms of distance measured. Considering all these steps, the ranking alternatives of DEWATS from 1 as the best to 10 as the worst is finally obtained and it is presented in Table 9 as well. Table 10 shows the same rank values considering the respective systems.

Table 5 | Weighted normalized decision matrix

Systems	BOD (%)	COD (%)	TSS (%)	Cost ($)	Q (m^3/d)	Area (m^2)
H1	0.1016	0.0569	0.0997	0.0526	0.0718	0.0797
H2	0.0948	0.0959	0.1063	0.0187	0.0160	0.0199
H3	0.1016	0.1149	0.1008	0.0567	0.0479	0.0356
H4	0.1095	0.1161	0.1052	0.1459	0.2448	0.2678
U1	0.0815	0.0865	0.0742	0.2122	0.1436	0.0676
U2	0.1047	0.1054	0.0849	0.1538	0.1164	0.0774
U3	0.1106	0.1105	0.1055	0.0305	0.0239	0.0625
U4	0.0795	0.0779	0.1041	0.0279	0.0199	0.0135
C1	0.1061	0.1102	0.1074	0.0374	0.0399	0.0383
C2	0.0993	0.1066	0.1074	0.1082	0.0821	0.1235

Table 6 | Ideal best (IB) and ideal worst (IW) values

Type	BOD (%)	COD (%)	TSS (%)	CC ($)	Q (m^3/d)	OS (m^2)
IB	0.1106	0.1161	0.1074	0.2122	0.2448	0.2678
IW	0.0795	0.0569	0.0742	0.0187	0.0160	0.0135

3.1. Formation of decision matrix

A decision matrix is formed from the data collected for each compared system parameter.

Table 9 represents the measurement of the distances from the ideal values (IB and IW). PS is calculated separately for each indicator and it is presented in Figure 2 as well. The table summarizes the performance scores (∑PS) for each system and ranks them accordingly in the column named (labeled) rank.

Table 10 shows the same ranking values as Table 9, but with the processes for each respective system included.

The TOPSIS analysis provided a structured and objective approach for evaluating wastewater treatment systems. The results show that each ranking represents a particular system with a set of DEWATS processes. The H4 system used for the treatment of wastewater discharged by a hospital is ranked as the best alternative. The H4 system has the highest performance score (∑PS) of 1.8138, and it is given the first rank. It is a more preferred alternative, being closer to the positive ideal solution (value) and also far from the negative ideal solution (value) simultaneously in terms of distance measured. The H4 system is composed of the ST+ABR, AF, HF, and APP. The system H4, incorporating the APP unit as the last polishing one, makes the system provide the best treatment performance, as well as economic parameters, if compared to the level of contaminant removal and water flow treated.

Compared with the H4 system as ranked number 1, the other systems that use more treatment processes are also ranked with the order values of 2, 3, and 4, and they are the H1, C2, and U2 systems. This indicates that incorporating multiple treatment processes typically leads to more effective outcomes. System U4 is evaluated as the worst alternative and ranked as the last since it is far from the IB value and closer to the IW value in comparison to other systems.

Table 7 | Decision matrix – from collected data of case studies

Systems	BOD (%)	COD (%)	TSS (%)	CC ($)	Q (m^3/d)	OS (m^2)
H1	90	48	91	39,683	90	800
H2	84	81	97	14,103	20	200
H3	90	97	92	42,713	60	357.24
H4	97	98	96	110,000	307	2690
U1	72.2	73	67.7	160,000	180	679
U2	92.8	89	77.5	115,942	146	777.5
U3	98	93.3	96.3	23,000	30	628
U4	70.4	65.8	95	21,000	25	135.4
C1	94	93	98	28,188	50	385
C2	88	90	98	81,602	103	1240

Table 8 | Normalized decision matrix

Systems	BOD (%)	COD (%)	TSS (%)	CC ($)	Q (m^3/d)	OS (m^2)
H1	0.3047	0.1706	0.2992	0.1579	0.2153	0.2390
H2	0.2844	0.2878	0.3189	0.0561	0.0479	0.0597
H3	0.3047	0.3447	0.3025	0.1700	0.1436	0.1067
H4	0.3284	0.3482	0.3157	0.4377	0.7345	0.8035
U1	0.2445	0.2594	0.2226	0.6366	0.4307	0.2028
U2	0.3142	0.3163	0.2548	0.4613	0.3493	0.2322
U3	0.3318	0.3315	0.3166	0.0915	0.0718	0.1876
U4	0.2384	0.2338	0.3124	0.0836	0.0598	0.0404
C1	0.3183	0.3305	0.3222	0.1122	0.1196	0.1150
C2	0.2979	0.3198	0.3222	0.3247	0.2464	0.3704

Table 9 | Distance (d) from ideal best (IB) and ideal worst (IW), and performance score (PS)

Systems	dIB	dIW	PS	dIB	dIW	PS	∑PS	Rank
H1	0.0604	0.0338	0.3585	0.3013	0.0929	0.2357	0.5942	9
H2	0.0256	0.0528	0.6733	0.3889	0.0064	0.0162	0.6895	8
H3	0.0112	0.0675	0.8575	0.3419	0.0542	0.1369	0.9944	6
H4	0.0025	0.0732	0.9676	0.0663	0.3650	0.8463	1.8138	1
U1	0.0532	0.0296	0.3579	0.2243	0.2380	0.5148	0.8726	7
U2	0.0255	0.0557	0.6857	0.2369	0.1800	0.4318	1.1175	3
U3	0.0059	0.0695	0.9219	0.3520	0.0510	0.1266	1.0485	4
U4	0.0494	0.0366	0.4256	0.3863	0.0100	0.0251	0.4508	10
C1	0.0075	0.0682	0.9013	0.3538	0.0392	0.0997	1.0011	5
C2	0.0147	0.0630	0.8103	0.2410	0.1565	0.3936	1.2039	2

According to the ranking presented in Table 10, it is possible to determine the most appropriate processes for a specific DEWATS system. This can serve as an initial point to identify which processes are the most favorable and suitable for other DEWATS projects serving similar facilities as discussed in this paper. It should be emphasized

Table 10 | Rank of systems

Systems	Treatment processes				Rank
	I	II	III	IV	
H1	ST+ABR	2HF	2VF		9
H2	ST	HF	2VF		8
H3	ST+ABR	AF	HF		6
H4	ST+ABR	AF	HF	APP	1
U1	ST+ABR	AF	2VF		7
U2	ST	BCH	2AF	BF	3
U3	ST	HF	2VF		4
U4	ST+ABR	2AF	HF		10
C1	2BCH	6 HF			5
C2	BCH	ABR	2HF	2VF	2

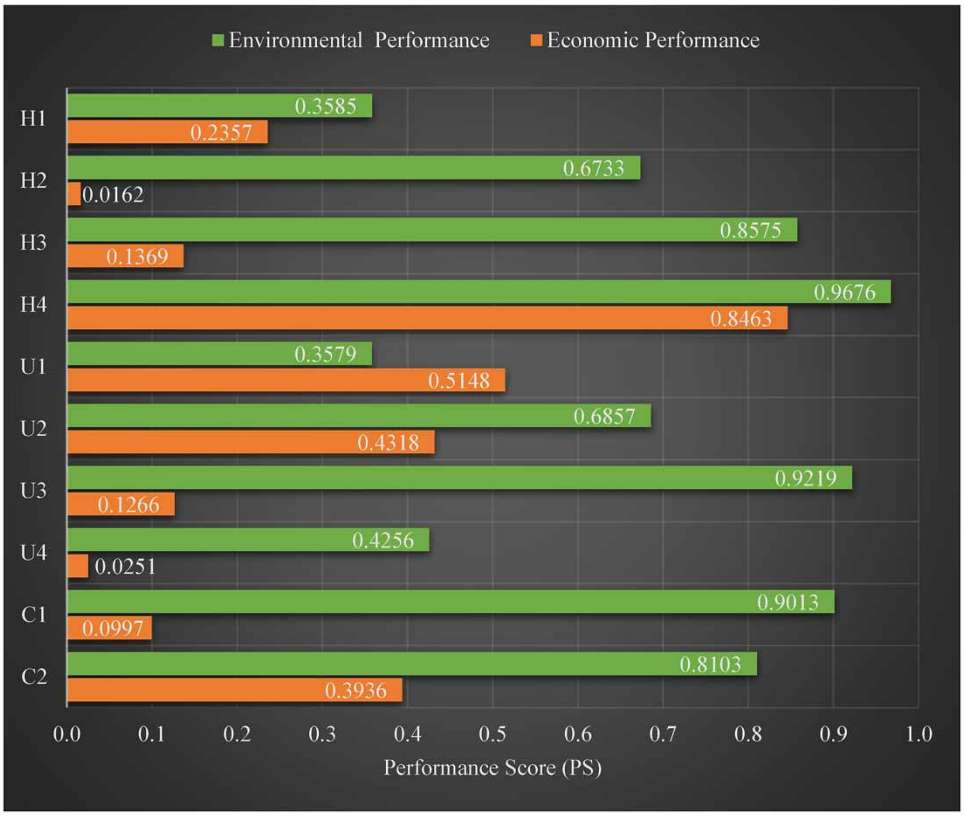


Figure 2 | Environmental and economic PS of systems.

that when analyzing alternatives using such methods, the evaluation is based on the model and weights assigned by the analyst. It is worth mentioning that even if two systems have similar processes, changes in the determination of criteria values or weights may result in changes in the final ranking.

Ranking of systems with similar processes, like H2 and U3 systems, can differ based on specific criteria. To comprehend the reasons for these differences, the discussion of the important criteria for both H2 and U3 systems with reference to the data presented in Table 7 is given below:

1. BOD, COD, and TSS (%) – If the treatment performance of a system was better concerning the parameters specified in Table 7, which were set as criteria in the TOPSIS analysis, and then it could be a possible explanation for the changes in the ranking of the systems H2 and U3.
2. CC ($) – If there are differences in capital costs between the two systems being considered, this could impact the final ranking of the systems. The CC is influenced by the amount of flow that needs to be treated and the occupied surface. Additionally, the type of substrate used for the treatment unit, such as for AF and HF, for both systems H2 and U3, and the dimensions of the treatment unit can also affect the CC. These criteria are interrelated and can influence each other, ultimately affecting the CC.
3. Q (m^3/d) – Systems that have higher treatment capacity can be considered more effective in some cases.
4. OS (m^2) – Depending on the treatment capacity, various systems can occupy different surfaces.

These systems even they use the same processes, but their weight is not the same. They may have differences in some criteria. Therefore, if a system is closer to the IB value for a particular criterion, that system will have a higher PS. This principle applies to other similar systems as well.

4. CONCLUSIONS

Effective wastewater treatment is crucial for achieving sustainable water management and sanitation goals. Selecting the appropriate wastewater treatment system can be a challenging and significant task for study. The TOPSIS method has been proven to be an effective decision-making tool for selecting the most preferred alternative among different wastewater treatment technologies (processes). The potential of using TOPSIS in the field of wastewater treatment has been highlighted several times, especially in selecting the best technology within wastewater treatment plants. This paper demonstrates the TOPSIS methodology for selecting appropriate systems within 10 case studies of DEWATS used in hospitals, universities/colleges, and small communities. The evaluation through TOPSIS is developed using six criteria of two indicators, namely environmental performance and economic performance. The criteria evaluated are BOD, COD, TSS, CC, Q, and the OS. The results show that the H4 system is top-ranked (first) and therefore the best system, which includes the APP as a follow-up process after HF, AF, and ST+ABR. The second most preferred system is the C2 system. These systems (H4 and C2) can be used for the treatment of wastewater discharged from facilities similar to those assessed in this paper. This paper shows that ranking systems through TOPSIS indicate that if there are systems consisting of the same processes, the rank value difference may be affected by other data, e.g. the amount of flow to be treated. Therefore, it should be noted that the results obtained from this paper might vary if more criteria are considered, which would provide a more sustainable assessment. The utilization of the TOPSIS method for the selection of appropriate DEWATS will be beneficial for decision-makers not only in the field of wastewater treatment but also in other fields of water management in general. By following this structured approach, stakeholders can ensure that their decisions are in line with sustainability goals, effectively balancing environmental and economic considerations.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Ali, O. (2018) *Decentralised Wastewater Treatment Systems (DEWATS) in Peri-Urban and Urban Areas in Tajikistan*. WASH Learning Reports.

Attri, S. D., Singh, S., Dhar, A. & Powar, S. (2022) Multi-attribute sustainability assessment of wastewater treatment technologies using combined fuzzy multi-criteria decision-making techniques, *Journal of Cleaner Production*, **357**, 131849. https://doi.org/10.1016/j.jclepro.2022.131849.

Bartaula, R. (2016) Performance Evaluation of Water and Wastewater Treatment Plant in Kathmandu Valley. MASTER of Science in Environment and Natural Resources, Specialization Sustainable Water and Sanitation, Health and Development (M-MINA), Norwegian University of Life Sciences (NMBU).

Behzadian, M., Khanmohammadi Otaghsara, S., Yazdani, M. & Ignatius, J. (2012) A state-of the-art survey of TOPSIS applications. *Expert Systems with Applications*, **39** (17), 13051–13069. https://doi.org/10.1016/j.eswa.2012.05.056.

BORDA (2015) Decentralized Wastewater Treatment Systems Bacnotan District Hospital. Available at: http://bns-phils.webs.com/TDS/2010.PBNS.061.HOS.Bacnotan%20District%20Hospital.pdf.

Capodaglio, A. G., Callegari, A., Cecconet, D. & Molognoni, D. (2017) Sustainability of decentralized wastewater treatment technologies, *Water Practice and Technology*, **12** (2), 463–477. https://doi.org/10.2166/wpt.2017.055.

CDD (2019a) DEWATS for Arvind Eye Hospital, Pondicherry. Available at: https://cddindia.org/wp-content/uploads/2017/10/Factsheet-2020-DEWATS-Arvind-Eye-Hospital.pdf.

CDD (2019b) DEWATS for Harvest International School, Bangalore, Karnataka. Available at: https://cddindia.org/wp-content/uploads/2017/10/Harvest-International-School.pdf.

Çelikbilek, Y. & Tüysüz, F. (2020) An in-depth review of theory of the TOPSIS method: An experimental analysis, *Journal of Management Analytics*, **7** (2), 281–300. https://doi.org/10.1080/23270012.2020.1748528.

Dang, T. H., Nguyen, H. T. & Nguyen, H. A. T. (2023) Application of TOPSIS and AHP methods to select a wastewater treatment technology for Poong In Vina Factory, *Journal of Thu Dau Mot University*, **5** (2), 229–240. https://doi.org/10.37550/tdmu.ejs/2023.02.411.

ENPHO (2010a) DEWATS for Dhulikhel Hospital, Dhulikhel, Nepal. Available at: https://enpho.org/wp-content/uploads/2021/12/DEWATS-for-Dhulikhel-Hospital.pdf.

ENPHO (2010b) DEWATS for Srikhandapur Community, Srikhandapur, Dhulikhel, Nepal. Available at: https://enpho.org/wp-content/uploads/2021/12/DEWATS-for-Srikhandapur-Community.pdf.

ENPHO (2010c) DEWATS for Sunga Community, Sunga, Madhyapur Thimi, Nepal. Available at: https://enpho.org/wp-content/uploads/2021/12/DEWATS-for-Sunga-Community.pdf.

ENPHO (2010d) DEWATS for Sushma Koirala Hospital, Sankhu, Kathmandu, Nepal. Available at: https://www3.epa.gov/npdes/pubs/primer.pdf.

EPA (2004) Primer for Municipal Wastewater Treatment Systems. Available at: https://www.babcockranchliving.com/DocumentCenter/View/2105/Commercial-and-Institutional-Facilities-PDF.

EPA (2012) Best Management Practices for Commercial and Institutional Facilities.

Ergas, S. J., Amador, J., Boyer, T. & Friedler, E. (2021) Onsite and decentralized wastewater management systems, *Journal of Sustainable Water in the Built Environment*, **7** (3). https://doi.org/10.1061/jswbay.0000955.

Gautam, R. K. & Singh, A. (2016) Decentralized low cost wastewater treatment plant based on phytoremediation and bagasse fly ash as natural filtering media, *International Journal of Science and Research (IJSR)*, **5**, 1097–1100. Available at: https://www.researchgate.net/publication/335228318.

Geetha Varma, V., Jha, S., Himesh Karthik Raju, L., Lalith Kishore, R. & Ranjith, V. (2022) A review on decentralized wastewater treatment systems in India, *Chemosphere*, **300**, 134462. https://doi.org/10.1016/j.chemosphere.2022.134462.

Gómez-López, M. D., Bayo, J., García-Cascales, M. S. & Angosto, J. M. (2009) Decision support in disinfection technologies for treated wastewater reuse, *Journal of Cleaner Production*, **17** (16), 1504–1511. https://doi.org/10.1016/j.jclepro.2009.06.008.

Gutterer, B., Ulrich, A., Reuter, S. & Water, E. (2009) *Decentralized Wastewater Treatment Systems (DEWATS) and Sanitation in Developing Countries: A Practical Guide*. Water Engineering and Development Centre (WEDC), Loughborough University, Loughborough, UK.

Hajduk, S. (2022) Multi-criteria analysis in the decision-making approach for the linear ordering of urban transport based on TOPSIS technique, *Energies*, **15** (1), 274. https://doi.org/10.3390/en15010274.

Jinxiang, F., Lingwei, X., Xingguan, M., Jing, T., Rongxin, Z., Yuping, B. & Yunan, G. (2013) Application of entropy weight TOPSIS method for optimization of wastewater treatment technology of municipal wastewater treatment plant. *Nature Environment and Pollution Technology*, **2** (2), 285–287. Available at: www.neptjournal.com.

Karimi, A., Nabi, R., Tavakkoli-Moghaddam, R., Karimi, A. R., Mehrdadi, N., Hashemian, S. J., Nabi-Bidhendi, G. R., Tavakkoli-Moghaddam, R. & Student, P. D. (2011) Using of the fuzzy TOPSIS and fuzzy AHP methods for wastewater treatment process selection, *International Journal of Academic Research*, **3** (1), 737–745. Available at: www.ijar.lit.az.

Khan, I. & Sahabuddin, M. (2022) Sustainability – Concept and its application in the energy sector. In: Imran Khan (ed.) *Renewable Energy and Sustainability: Prospects in the Developing Economies*. Elsevier, pp. 1–22.

Lin, L., Yang, H. & Xu, X. (2022) Effects of water pollution on human health and disease heterogeneity: A review, *Frontiers in Environmental Science*, **10**, 880246. https://doi.org/10.3389/fenvs.2022.880246.

Mansouri, Z., Moghaddas, N. H. & Dahrazma, B. (2013) Wastewater treatment plant site selection using AHP and GIS: A case study in Falavarjan, Esfahan, *JGeope*, **3** (2), 63–72.

Massoud, M. A., Tarhini, A. & Nasr, J. A. (2009) Decentralized approaches to wastewater treatment and management: Applicability in developing countries, *Journal of Environmental Management*, **90** (1), 652–659. https://doi.org/10.1016/j.jenvman.2008.07.001.

Mehtap, D. (2015) An integrated approach for the evaluation of wastewater treatment alternatives. World Congress on Engineering and Computer Science 2015 Vol II WCECS 2015, October 21-23, 2015, San Francisco, USA.

Obaideen, K., Shehata, N., Sayed, E. T., Abdelkareem, M. A., Mahmoud, M. S. & Olabi, A. G. (2022) The role of wastewater treatment in achieving sustainable development goals (SDGs) and sustainability guideline, *Energy Nexus*, **7**, 100112. https://doi.org/10.1016/j.nexus.2022.100112.

Orhan, C., Firat, M. & Yilmaz, S. (2022) Identification of priority areas for rehabilitation in wastewater systems using ENTROPY, ELECTRE and TOPSIS, *Water Practice and Technology*, **17** (4), 835–851. https://doi.org/10.2166/wpt.2022.030.

Riccardo Bresciani (2014) *Case Study of SuSanA Projects Wastewater Reuse in an Urban College Hostel Pune, Maharashtra, India, 2014*.

Roszkowska, E. (2011) Multi-criteria Decision Making Models by Applying the Topsis Method to Crisp and Interval Data, *Mult. Criteria Decis. Mak*. **6**, 200–230.

Sasse, L. (1998) *Decentralised Wastewater Treatment in Developing Countries DEWATS*.

Singh, N. K., Kazmi, A. A. & Starkl, M. (2015) A review on full-scale decentralized wastewater treatment systems: Techno-economical approach, *Water Science and Technology*, **71** (4), 468–478. https://doi.org/10.2166/wst.2014.413.

Srdjevic, B., Srdjevic, Z. & Suvocarev, K. (2017) Multi-criteria evaluation of wastewater treatment technologies in constructed wetlands, *European Water*, **58**, 165–171.

Taherdoost, H. & Madanchian, M. (2023) Multi-criteria decision making (MCDM) methods and concepts, *Encyclopedia*, **3** (1), 77–87. https://doi.org/10.3390/encyclopedia3010006.

Tu, Y., Chen, K., Wang, H. & Li, Z. (2020) Regional water resources security evaluation based on a hybrid fuzzy BWM-TOPSIS method, *International Journal of Environmental Research and Public Health*, **17** (14), 1–24. https://doi.org/10.3390/ijerph17144987.

Yahya, M. N., Gökçekuş, H., Ozsahin, D. U. & Uzun, B. (2020) Evaluation of wastewater treatment technologies using TOPSIS, *Desalination and Water Treatment*, **177**, 416–422. https://doi.org/10.5004/dwt.2020.25172.

Yu, X., Suntrayuth, S. & Su, J. (2020) A comprehensive evaluation method for industrial sewage treatment projects based on the improved entropy-TOPSIS, *Sustainability (Switzerland)*, **12** (17), 6734. https://doi.org/10.3390/SU12176734.

Zhou, Z., Dou, Y., Zhang, X., Zhao, D. & Tan, Y. (2018) A group decision-making model for wastewater treatment plans selection based on intuitionistic fuzzy sets, *Journal of Environmental Engineering and Landscape Management*, **26** (4), 251–260. https://doi.org/10.3846/jeelm.2018.6122.

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