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Evaluation of different natural wastewater treatment alternatives by fuzzy PROMETHEE method

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ABSTRACT

Wastewater treatment is the procedure of removing contaminants from wastewater to convert it into wastewater that has a negligible effect on the environment or can be reintroduced into the water cycle for direct reuse. Today, the world is searching for wastewater treatment techniques that have less cost, low energy input, and are ecologically friendly, such as natural treatment methods and a combination of conventional and natural in different treatment methods. In the present study, the effectiveness of different natural wastewater treatment methods such as stabilization pond (SP), constructed wasteland, use of aquatic plants (AP), soil filters (SF) and reuse of wastewater for irrigation (RWI) was evaluated by using the fuzzy-preference ranking organization method for enrichment evaluation (fuzzy PROMETHEE) method. The comparison was performed by using different criteria such as pollutant removal efficiency, land requirement, capital cost, maintenance cost, health risk, hydrogeological risk, ecological benefit and subject to seasonal effects. The results indicate that the SP is the most appropriate and reusing wastewater for irrigated agriculture is the least appropriate technique for wastewater treatment. SP with 0.2293 net flow was ranked first, constructed wetland with 0.0830 net flow was ranked second, use of AP was the third with 0.0243 net flow, while SF and reuse of wastewater were ranked as the fourth and fifth alternatives with net flows of –0.0143 and –0.3223, respectively. Similar data were cross-validated by technique for order of preference by similarity to ideal solution and the result was closely similar to the fuzzy PROMETHEE result except for soil filter and RWI which interchanged their position of the rank.

Keywords: Natural; Wastewater treatment; Fuzzy PROMETHEE

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1. Introduction

The global population is predicted to increase to more than 9 billion by 2050 and as a result, water demand and wastewater generation will rise accordingly [1]. Wastewater causes a direct effect on life diversity in aquatic environments if it is not well managed.

In the 21st century, the rapid industrial developments have led to critical complications in natural ecological systems. Discharge from numerous manufacturing activities such as paint, metallic plating, food complexes, pharmacological factories, and battery engineering, which contain heavy metal ions, dyes, and organic ingredients, are released directly into aquatic ecology [2].

The increased quantity of wastewater has forced the world to control and increase the quality of wastewater treatment methods to reduce the environmental effects and to safeguard aquatic ecological environments [3]. In recent years, quality standards for treating wastewater effluents have been increased, which has subsequently increased the costs for constructing, operating and maintaining treatment structures, power requirements and technological advancements [4]. Energy usage in wastewater treatment (WWT) structures and the associated greenhouse gas emissions are also progressively increasing because of strong treatment objectives [5]. A particularly important aspect in WWT is the handling of sewerage sludge, which is a product of sewer treatment and may contain toxic components such as pathogenic microorganisms, organic contaminants, and heavy metals that can cause severe ecological contamination.

Today, the world is searching for wastewater treatment techniques that offer less cost, low energy input, and are ecologically friendly such as natural treatment methods and a combination of conventional and natural methods in different treatment methods. Natural WWT systems primarily depend on natural processes to achieve the intended purpose; while they may need pumping and pipes for wastewater conveyance, they do not depend on external energy sources for major processing [6]. Stabilization ponds (SP), the use of aquatic plants (AP), and constructed wetlands (CW) is the integrated WWT choices, which are ecologically friendly and are engaged to reduce water contamination and to ensure ecological and environmental sustainability [7].

The treatment costs associated with the natural method are significantly lower than conventional methods. According to [4], the treatment cost for one gallon of wastewater by conventional methods is 6.5 USD, while the treatment cost by the natural method for an equal amount of wastewater is 0.6 USD. The removal efficiency of pollutants and pathogens using natural methods is very high when effluents are treated at secondary levels through natural treatment systems. Natural WWT methods are applied in high income and lower-income nations because of the reduced operation and maintenance costs (MC), lower carbon emissions, and low energy utilization and are therefore an attractive solution for climate change adaptation [6]. The optimum WWT methods should achieve the goals of less treatment cost, minimum discharge of water pollutants, high maintenance performance and the provision of water for reuse [8].

Natural WWT technologies such as soil filters (SF), constructed treatment wetlands, aquatic plants, waste SP, and the reuse of wastewater for irrigated agriculture are focused on safeguarding the wellbeing of the environment. The natural WWT methods broadly deal with ecological sustainability, managing specific components of wastewater while treating wastewater [9]. The waste is cleaned through vegetation and soil to maintain microorganisms, which consume pollutants in sewage. Operational and MC are lower for cities or industries that use natural wastewater treatment because it uses less mechanical apparatus [8]. Natural WWTs need more land for operational processes and this method is most effective for small cities and villages with limited population size. However, when using the method in high-density industrialized and cities with large populations, decentralized and more localized distribution is more effective.

The fuzzy-preference ranking organization method for enrichment evaluations (fuzzy PROMETHEE) is a multiple-criteria decision-making technique [10]. The method is used to rank activities, to choose the most suitable method, or to sort activities into diverse clusters [11]. The PROMETHEE techniques need only two types of data, which are valuable data about the weights of the defined criteria and the preferred functions used for comparing individual criterion [12].

Natural wastewater treatment methods give high-quality effluents with less chemical oxygen demand, biochemical oxygen demand (BOD_5), suspended solid (SS), total nitrogen (TN), and total phosphorus and it is efficient in avoiding harmful organic compounds and heavy metals [13]. Even though they offer high pollutant removal efficiency (PRE), the capability is significantly influenced by seasonal climate variations.

Natural wastewater treatment technologies are climate-resilient, which means they release zero carbon emissions to the atmosphere and are cost-effective. The methods comply with environmental standards, are low cost, offer easy operations, and provide excellent resilience capacity despite the increased land requirements (LR) [14]. However, the treatment efficiency of various natural wastewater treatment technologies can be highly variable and it is not easily quantifiable. The fuzzy PROMETHEE is a powerful ranking tool and to the best of the authors' knowledge, this model has not been applied for ranking the effectiveness of natural wastewater treatment technologies. Hence, the main objective of the present study is to propose fuzzy PROMETHEE as an approach for identifying the most effective natural wastewater treatment technologies.

2. Natural wastewater treatment methods

2.1. Stabilization pond

A waste SP is a shallow pond of wastewater in an earthen basin in which a series of aerobic, anaerobic and facultative ponds exist. SP are ponds in which the required treatment is attained by physical, chemical and biological processes, which can be undertaken in the hydro-ecology in the presence of water and wetland microorganisms (bacteria, phytoplankton, and zooplankton), large plants and other life forms [9]. They control and maintain the physical, chemical and biological characteristics of wastewater effluents.

2.2. Constructed wetland

CW are man-made marshlands constructed by moving earth and grading that have filtration structures vegetated with wetland plants such as reeds, cattail and canary grass, which have definite filtering structures and a path of wastewater movement. As sewage is allowed to pass over the media, the treatment takes place, where complex biological, chemical and physical treatments are achieved [9]. The use of CW does not need exceptional requirements to improve discharge quality, but more attention is given to controlling hydraulic regimes, which gives higher efficiency than natural marshes [6]. CW treatment systems are categorized into three subgroups, namely free surface water, sub-surface flow, and vertical flow wetlands. Subsurface flow wetlands use a permeable medium to filter and the water stage is kept lower than the top of the bed, whereas in vertical flow wetlands, gravel and sand are used for filtration and wastewater is distributed on the media and allowed to move vertically. Wastewater is applied over sand or gravel then gradually filtered through the filtration substrate, which has good nutrient removal capacity [15]; however, changing temperatures affect its efficiency.

In CW wastewater treatment, the removal of pollutants occurs through plant and microorganism activities at the root zone of plants. Vegetation provides oxygen for microorganisms, which is very important for their metabolic activities in the root zone [16] and improves the absorption of essential nutrients and the break-down of pollutants. In the CW wastewater treatment method, the interaction of plant roots and microorganisms treats wastewater through the uptaking of inorganic or organic compounds, and the release of carbon by plants and decomposition of pollutants. CW in association with water hyacinth can effectively remove total suspended solids, BOD, phosphorus (P), nitrogen (N), sulfur and heavy metals [17].

2.3. Uses of aquatic plants

In aquatic plant wastewater treatment, certain types of either floatation or submerged plant species such as mangrove, water hyacinth, pondweed, duckweed, and reed, are used as natural wastewater treatment options. They absorb and remediate organic pollutants and heavy metals, thus increasing the treatment efficiency of the system [13].

2.4. Soil filters

SFs are a type of natural wastewater treatment system in which the soil plays a natural purification role [9], which is applied as a primary treatment unit or secondary treatment facility designed with a perpendicular upward flow or downward and horizontal lateral flow. SFs are a cylinder or prismatic shaped plastic or concrete mixture tanks and excavations with waterproof materials, which are positioned on the ground so that the treatment processes cannot be differentiated from the trench.

Soil aquifer wastewater treatment is operated by infiltrating the wastewater through the soil profile and it is very effective in removing biological oxygen demand, bacteria and organic carbon from pre-treated wastewater [18]. Moreover, this treatment method incurs less cost and produces high-quality water.

2.5. Reuse of wastewater for irrigation

The use of pre-treated or raw wastewater for irrigated farming utilizes water and nutrients from sewage and at the same time exposes the wastewater to the soil environment, which has a high treatment capacity as either a primary or final treatment process. Wastewater reuse for irrigation is beneficial for farmers in conserving freshwater resources, increasing soil fertility, and reducing ground and surface water contamination because it is filtered through the soil when irrigated. Untreated wastewater is applied for informal irrigation in uncontrolled sectors, but it can benefit farmers who do not have access to or cannot afford fresh water. Many farmers choose to use wastewater because of the cost savings generated by not purchasing fertilizer [1] as the nutrient composition for essential nutrients is good in wastewater, for instance, 50 mg/L of nitrogen, 10 mg/L phosphorus and 30 mg/L of potassium.

3. Methodology

This study uses the fuzzy PROMETHEE method, which is applied in a wide variety of multi-criteria decision settings. This technique is a hybrid of the PROMETHEE and fuzzy logic techniques. This approach is suggested to investigate options where the parameters are not numerical [19]. PROMETHEE has been developed to give a comprehensive ranking of a finite set of choices according to the order of the best to the worst. In this study, the effectiveness of natural wastewater treatments will be compared by the fuzzy PROMETHEE method based on predefined comparison criteria [20].

In PROMETHEE techniques, various preference functions are presented to describe numerous principles [21]. The preferring function (P_j) represents the variation among the valuations acquired and two alternatives (a and a_t') with respect to a specific criterion, with a preference degree range of 0–1 [10]. The most frequently applied preference functions for PROMETHEE are common function, V-shaped function, level function, Gaussian function, U-shaped function, and a linear function.

For the determination of the best wastewater treatment options, the three most common steps in the investigation should be taken into consideration [22], namely the desired sewage quality, factors that affect the management and application of a number of processes such as economic, environmental, land availability, climatic, operational simplicity [23] and cost fairness evaluation as the selecting criteria, to determine the best economically and environmentally viable option.

The study conducted by [24] provides further details about the fuzzy PROMETHEE method and we applied the same methodology to study the effectiveness of natural wastewater treatment methods. Moreover, fuzzy logic and fuzzy PROMETHEE have been used by different researchers for evaluation purposes [24–27].

The suitability of natural wastewater treatment methods can predominately be prioritized by high system efficiency, low specific footprint to reduce land area, low energy, maintenance, and operation costs, and low subjectivity to seasonal and climate variability [13,28]. The study that compared sequencing batch reactor, triple oxidation ditch and anaerobic single oxidation ditch by hierarchy gray relational analysis applied the comparison criteria namely: cost (capital, operational and maintenance), removal of nitrogenous and phosphorus pollutants, land area, the stability of plant stability and sludge disposal effects [29]. Similarly, environmental aspects, economic costs, and technological factors were applied as comparison criteria to select the most sustainable wastewater treatment technology among anaerobic digestion, composting and phytoremediation [30]. Ouyang et al. [8] compared five different natural wastewater treatment techniques, such as rapid infiltration land treatment, slow rate land treatment, overland flow treatment, CW, and SP by using the comparison criteria of capital and MC, PRE, seasonal effects, hydrogeological risk (HGR) and land availability.

For this study, we compared five natural treatment methods, namely SP, CW, use of AP, SF, and reuse of wastewater for irrigation (RWI). The selected comparison criteria are PRE, the LR, capital cost (CC), MC, health risk (HR), HGR, ecological benefit (EB) and subject to seasonal effects (SSE).

These criteria have been specifically selected to measure the treatment efficiency of natural treatment techniques based on environmental sustainability, health, and economic efficiency. Economic efficiency is measured in terms of operation maintenance and treatment cost. Since the technologies are operated by nature-based systems, the overall treatment cost is low [31,32]. Moreover, the land area required for the construction of the treatment structure is also considered as an economic factor. Health factors refer to potential HR emanating from the existence of toxic waste in the treatment site for people living around and working on the site. The environmental issue deals with the possible effects of wastewater treatment processes on ecology, hydrogeology, and atmosphere. The natural technologies utilize little to no energy, there are no carbon emissions and they are considered to facilitate climate-smart treatments. For a treatment technique to be regarded as the best, it should offer the lowest cost, ensure ecological sustainability through promoting minimum or zero carbon emission and reduce or avoid pollutants in an acceptable range. The PRE varies from one natural wastewater treatment method to another and it differs for different pollutants. However, recent studies have indicated that PRE for most pollutants is in the high range.

The fundamental scales of comparison weight are given in Table 1.

The triangular fuzzy numbers given for each alternative are de-fuzzified by the Yager index and applied to fuzzy PROMETHEE [33]. Then, the Gaussian preference function is used for contrasting with the allocated linguistic fuzzy scale to define the weight for every criterion.

In the present study, all of the alternatives selected have been allocated three values from the given parameters, which are limits corresponding to the low, medium and upper bounds. These values were changed to the triangular fuzzy figures, and then de-fuzzified using the Yager index. Then it was fed into the PROMETHEE and the Gaussian preference function was selected to make a comparison using the defined fuzzy linguistic scale and to determine the weight of every criterion.

Table 1
Linguistic scales of comparison

Scales of comparison	Triangular fuzzy scale	Criteria rating importance
Very high	(0.75, 1, 1)	PRE, LR, CC, MC, HR, HGR, EB
Important	(0.5, 0.75, 1)	SSE
Medium	(0.25, 0.5, 0.75)	
Low	(0, 0.25, 0.5)	
Very low	(0, 0, 0.25)	

The most commonly applied steps of the PROMETHEE technique are described as follows [24,34].

- Specific preference function P_j (d) is defined for every criterion j.
- Weights of every criterion are pre-defined, $W_T = (w_1, w_2, \ldots, w_k)$. In the decision, the weight of each criterion should be considered as equal if they are exactly equally important and all the weights should be normalized as.

$$\sum_{i=1}^{k} w_k = 1 \tag{1}$$

- For all the alternatives a_t, $a_t' \in A$ define the outranking relation π:

$$\pi\left(a_t, a_t'\right) = \sum_{k=1}^{k} w_k \left[p_k \left(f_k\left(a_t\right) - f_k\left(a_t'\right) \right) \right], \mathrm{AXA} \to \left[0,1\right] \tag{2}$$

where π (a, b) represents the preference indices, which is a measure for the intensity of the preference of the decision-maker for an alternative a_t in comparison to an alternative a_t' while considering all criteria at the same time.

- The entering and leaving outranking flows are defined as follows:

A positive value (leaving) flow parameter for the alternative a_t:

$$\Phi^+\left(a_t\right) = \frac{1}{n-1} \sum_{t'=1}^{n} \pi\left(a_t, a'_t\right) \tag{3}$$

where $t' \neq t$.

A negative value (entering) flow parameter for the alternative a_t:

$$\Phi^-\left(a_t\right) = \frac{1}{n-1} \sum_{t'=1}^{n} \pi\left(a'_t, a_t\right) \tag{4}$$

where n stands for the number of alternatives. In this step, every alternative is evaluated with a total of (n–1) other alternatives. The leaving (positive) flow $\Phi^+(a_t)$ describes the strength of given alternatives $a_t \in A$, while the entering (negative) flow $\Phi^{+}(a_t)$ indicates the weakness of given alternatives $a_t \in A$.

Next, to the outranking flows, PROMETHEE I techniques are applied to determine the partial pre-order of the alternatives and PROMETHEE II techniques are applied to determine the complete pre-order based on net flow. Nevertheless, it does not provide comprehensive information about the preference relations.

- The partial pre-order for the alternatives should be determined based on the following condition:

PROMETHEE I alternative a_t is selected to the alternative $a_t'(a_tPa_t')$ if it fulfills either of the conditions listed below.

(a_tPa_t') if;

$$\left\{\Phi^{+}\left(a_t\right) > \Phi^{+}\left(a_{t'}\right)\text{and}\Phi^{=}\left(a_t\right) < \Phi^{=}\left(a_{t'}\right)\right. \quad (5)$$

$$\left\{\Phi^{+}\left(a_t\right) > \Phi^{+}\left(a_{t'}\right)\text{and}\Phi^{=}\left(a_t\right) = \Phi^{=}\left(a_{t'}\right)\right. \quad (6)$$

$$\left\{\Phi^{+}\left(a_t\right) = \Phi^{+}\left(a_{t'}\right)\text{and}\Phi^{=}\left(a_t\right) < \Phi^{=}\left(a_{t'}a_{t'}\right)\right. \quad (7)$$

If we have two alternatives, a_t and a_t', with comparable negative and positive flows, the a_t is different to a_t' (a_tIa_t'):

$$\left(a_tIa_{t'}\right)if:\Phi^{+}\left(a_t\right) = \Phi^{+}\left(a_{t'}\right)\text{and}\Phi^{=}\left(a_t\right) = \Phi^{-}\left(a_t\right) \quad (8)$$

a_t is incomparable to $a_t'(a_tRa_t')$ if:

$$\left\{\Phi^{+}\left(a_t\right) > \Phi^{+}\left(a_{t'}\right)\text{and}\,\Phi^{=}\left(a_t\right) > \Phi^{=}\left(a_{t'}\right)\right. \quad (9)$$

$$\left\{\Phi^{+}\left(a_t\right) < \Phi^{+}\left(a_{t'}\right)\text{and}\,\Phi^{=}\left(a_t\right) < \Phi^{=}\left(a_{t'}\right)\right. \quad (10)$$

- The net (resultant) outranking flow can be estimated for every alternative by applying the following equation.

$$\Phi^{\text{net}}\left(a_t\right) = \Phi^{+}\left(a_t\right) - \Phi^{-}\left(a_t\right) \quad (11)$$

Through PROMETHEE II, the complete pre-order for net flow can be found and defined as:

a_t is preferred to a_t' (a_tPa_t') if $\Phi^{\text{net}}(a_t) > \Phi^{\text{net}}(a_t')$
a_t is indifferent to a_t' (a_tIa_t') If $\Phi^{\text{net}}(a_t) = \Phi^{\text{net}}(a_t')$

Usually, the better alternative is the one with the higher $\Phi^{\text{net}}(a_t)$ value.

For this study, linguistic scales of comparison (Table 1) and the weight of each criterion (Table 2) are used for evaluating the effectiveness of natural wastewater treatment techniques.

4. Result and discussion

Table 3 indicates the complete ranking of natural wastewater treatment methods, where the techniques are compared based on selected comparison criteria and the weights of the selected criteria (Section 3). The various alternatives with different evaluation criteria indicate variable suitability for wastewater treatment. When setting criteria, economic, environmental and health parameters are primarily considered. The ranking was determined for the overall effects of criterions accordingly; all the other alternatives fluctuated between positive and negative for the specified criteria except the SP (Fig. 1).

The positive outranking flow shows the strength of the alternatives, the negative outranking flow shows the weakness of the alternatives and the net flow is the difference between the positive and negative outranking flows, which gives the net ranking results. The better alternative has a higher net flow. The ranking reveals that the SP has the highest positive outranking flow and lowest negative outranking flow, while the CW has the next highest positive outranking flow and lower negative outranking flow value. With maximum net flow, the SP is the most efficient natural wastewater treatment method among the compared methods. This finding is in agreement with [8]. Moreover, recent studies have indicated that the removal efficiency of natural wastewater treatment methods for most pollutants is in the high range. For instance, a study on SP revealed that overland flow and wetland systems can reduce BOD_5 up to 90%, suspended solid removal was removed up to 93.3%, ammonia nitrogen removed up to 90.7% and phosphorus was removed up to 84% [35]. This study ranks the SP in the first place compared with other methods. SP removes up to 94% of TN, 93% of nitrate nitrogen and 96% of ammonia nitrogen [36].

Table 2
Visual PROMETHEE application

Criteria	PRE	LR	CC	MC	HR	HGR	EB	SSE
Preferences								
Maximum/Minimum	Maximum	Minimum	Minimum	Minimum	Minimum	Minimum	Maximum	Minimum
Weight	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.75
Evaluations								
SP	0.9	0.5	0.4	0.3	0.2	0.3	0.8	0.3
CW	0.8	0.6	0.6	0.4	0.3	0.3	0.8	0.6
AP	0.9	0.6	0.6	0.6	0.4	0.2	0.7	0.7
SF	0.5	0.6	0.4	0.2	0.3	0.5	0.4	0.4
RWI	0.6	0.9	0.5	0.4	0.7	0.7	0.4	0.8

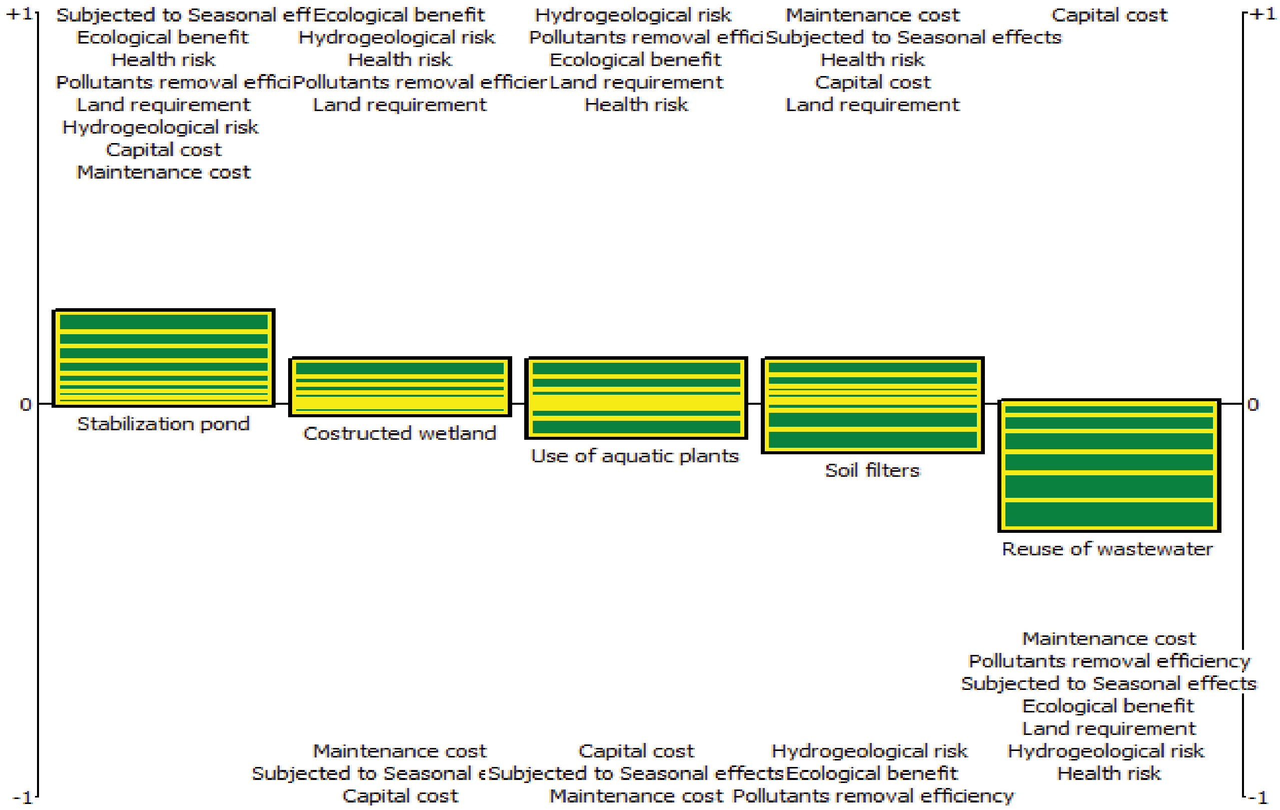

Fig. 1. PROMETHEE evaluation result.

SP gives good results for all evaluation criteria (Fig. 1); for instance, the treatment efficiency of the system is not dependent on seasonal variations and consequent climatic variability, health effects for workers and people living in the area are low and maintenance and CC are fair compared to the other methods. This result indicates that CW is the second natural wastewater treatment alternative with positive EB, low HGR, low HR, high PRE, although cost and seasonal variation in treatment efficiency was observed as the drawbacks.

The application of aquatic plants for wastewater treatment is acceptable despite high seasonal variability of efficiency and high MC for harvesting and clearing dead plant parts. According to the ranking, the RWI is the least relevant wastewater treatment technique because of its negative environmental and health impacts and high seasonal variation of treatment efficiency; however, the installment costs are relatively low. Moreover, the reuse of raw wastewater for irrigation may cause serious environmental pollution such as groundwater contamination. This problem is most significant if the wastewater is from industrial sources that may contain heavy metals and other pollutants.

The possible merits and drawbacks of each technique were thoroughly evaluated based on environmental and ecological health, costs and seasonal variability of the treatment performance. The decision lab PROMETHEE output (Fig. 1) presented corresponding advantages and disadvantages for each natural wastewater treatment method. This has importance for decision-making processes for municipalities, environmentalists or any stakeholders related to the sector.

To validate the fuzzy PROMETHEE output, another commonly used multi-criteria decision-making technique, which is called the technique for order of preference by similarity to ideal solution (TOPSIS), has been applied. This technique was first applied by Yoon and Hwang [37] and widely applied for the comparison of wastewater treatment methods [28,38] in several fields. For the evaluation of the different natural wastewater treatment alternatives with TOPSIS, the same weights of the criteria which has been used in the fuzzy PROMETHEE technique was normalized and applied (Table 4).

Positive ideal solution set:
(0.068, 0.044, 0.045, 0.028, 0.027, 0.026, 0.071, 0.024)

Negative ideal solution set:
(0.038, 0.079, 0.068, 0.085, 0.096, 0.091, 0.035, 0.063)

Relative closeness to the positive ideal solution (R_i) indicates the ranks of wastewater treatment methods and an alternative with the higher R_i is more preferable technique. The ranking results of the natural wastewater treatment alternatives presented below (Table 5). The ordering indicated that the SP is the best option with 0.86 relative closeness to the ideal solution (R_i), the CW is the second-best option with 0.66 R_i with 0.54 R_i, the use of AP is the third-best option between the alternatives, and the reuse of wastewater and SF were the least effective options.

These results are quite reliable and consistent with the outputs of the fuzzy PROMETHEE technique. However, the fourth-ranked alternative (SF) in fuzzy PROMETHEE output became fifth-ranked in TOPSIS and fifth-ranked alternative

Table 3
Complete ranking of natural wastewater treatment methods

Complete ranking	Natural wastewater treatment methods	Positive outranking flow (ϕ^+)	Negative outranking flow (ϕ^-)	Net flow (ϕ_{net})
1	Stabilization pond	0.2328	0.0035	0.2293
2	Constructed wetland	0.1297	0.0467	0.0830
3	Use of aquatic plants	0.1250	0.1007	0.0243
4	Soil filters	0.1181	0.1325	–0.0143
5	Reuse of wastewater for irrigation	0.0116	0.3338	–0.3223

Table 4
Weighted normalized natural wastewater treatment alternatives

Maximum/ Minimum	Maximum	Minimum	Minimum	Minimum	Minimum	Minimum	Maximum	Minimum
Evaluations	PRE	LR	CC	MC	HR	HGR	EB	SSE
SP	0.068	0.044	0.045	0.043	0.027	0.039	0.071	0.024
CW	0.060	0.052	0.068	0.057	0.041	0.039	0.071	0.047
AP	0.068	0.052	0.068	0.085	0.055	0.026	0.062	0.055
SF	0.038	0.052	0.045	0.028	0.041	0.065	0.035	0.032
RWI	0.045	0.079	0.056	0.057	0.096	0.091	0.035	0.063

Table 5
Relative closeness to a positive ideal solution

Ranking	Alternatives	R_i
1	SP	0.863
2	CW	0.664
3	AP	0.548
4	RWI	0.208
5	SF	0.131

(RWI) in fuzzy PROMETHEE technique output became fourth-ranked in TOPSIS. Despite the slight difference of rank for the least option alternatives, the outcomes from both models are fairly similar. Hence, this closed similarity of the results from both models could give evidence about the precision of the ranks of wastewater treatment options compared.

5. Conclusions

Population increase, industrialization and the related high demand for raw material consumption have increased wastewater generation rates. Rising wastewater affects environmental and ecological pollution, increases social crises and causes economic losses. To reduce the pressure of wastewater, it should be treated before being released into the environment. Conventional wastewater treatment techniques are very expensive and unaffordable both economically and technically. The natural wastewater treatment methods have more advantages over conventional techniques because they are low cost and environmentally friendly. The present study evaluated the effectiveness of five different natural wastewater treatment methods, namely SP, constructed wasteland, use of AP, SF and RWI by using the fuzzy PROMETHEE evaluation method. The complete ranking results indicated that the SP was ranked first, CW was ranked second, and the use of AP was the third, while SF and reuse of wastewater were ranked as the fourth and fifth alternatives respectively.

Hence, the SP is the most appropriate method with the highest positive net flow, which indicates that this is the best option in terms of the evaluated criteria. Conversely, the RWI is the least preferred alternative with the highest negative net flow except for appropriate primary treatment. This is because of its environmental, ecological and health impacts. For cross-validation, similar data was simulated by TOPSIS and a similar rank was obtained SP, CW, and AP but SF and RWI are interchanged their rank position.

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