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Comparative Analysis of Wastewater Treatment Technologies

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ABSTRACT

The aim of this study is to apply the principle of multi-criteria decision-making (MCDM) theories on different types of wastewater treatment technologies. An increase in the production and discharge of wastewater is increasing; therefore wastewater treatment alternatives are needed. With increase in population growth, urbanization and industrialization increasing the amount of pollutants in our environments that leads to more wastewater discharge from both domestic and industries. These wastewaters are produced in large volumes and must be absolutely treated before discharge. Therefore, there is need for wastewater treatment technologies that are cost effective, easy to maintain, low energy use etc. This study will use some criteria on Fuzzy PROMETHEE to analyze the wastewater treatment technologies based on these criteria. The outcome of the decision-making theories in these wastewater technologies will help the concern parties in chosen the best among these technologies and will give an insight to these concerned parties such as engineers, town planners and other government personnel's in making decisions. The common and most commonly used wastewater treatment technologies were evaluated and are compared based on certain criteria using fuzzy PROMETHEE decision-making theory and Nano-filtration Method is recommended the best followed by Activated Sludge (AS) Method based on this research.

Keywords: Wastewater Treatment Technologies; Fuzzy PROMETHEE; multi-criteria decision-making

INTRODUCTION

Wastewater treatment are associated with the removal of pollutants and the protection of our natural water resources (US EPA, 2000). An increase in the production and discharge of wastewater is increasing, therefore wastewater treatment alternatives are needed (Marzec, 2017). At present, the two (2) major global issues or stress are environmental pollution and energy crises. Due to rapid industrialization and exponential growth in population, a massive or huge amount of wastewater is being discharged on daily basis into our environment. A lot of toxic heavy metals, organic and inorganic chemicals find their ways into our water bodies from domestic, industrial and commercial activities through anthropogenic activities (Dixie et al., 2011). Most of these wastewater effluents are untreated or inadequately treated before being discharged, which has become a worrisome phenomenon due to its impact on environmental health and safety (Okereke et al., 2016). Therefore, it is necessary to treat wastewater before discharging into fresh water bodies or directly to the environment. To avoid this entire act, an alternative wastewater treatment measure is needed. Though conclusion made by (Von Sperling, 2005) conclude that there is no ideal system or technology applicable to all treatment conditions and another research shows difficulty associated in identifying a best overall option as some factors are not applied to some technologies or processes (Muga, H.E.; Mihelcic, 2008).

Therefore, there is need for a research to evaluate all or some of the wastewater treatment technologies, so as to choose the best process among all the various wastewater treatment technologies.

These include: Activated sludge (AS), Trickling Filtration (TF), Membrane Filtration (MF), Nano-filtration (NF), Membrane Bioreactor (MBR), Waste Stabilization Ponds (WSPs), and Constructed Wetlands (CWs). Factors or criteria to be considered for this study include; Pore size of membrane, Water flux, and pressure, BOD removal efficiency, space requirement, investment cost, energy required, etc. will be used to evaluate or analyze the above mention treatment technologies and Fuzzy PROMETHEE Method will be used.

The basic steps of the PROMETHEE Method to be used for these study will be same used in (D U Ozsahin, Isa, Uzun, & Ozsahin, 2018; Dilber Uzun Ozsahin, 2018; Dilber Uzun Ozsahin et al., 2017; Uzun et al., 2017; Uzun, Uzun, Sani, & Ozsahin, 2018). Which are all based on mutual comparison. PROMETHEE being one of the most efficient and easiest methods in conception and application compared to other MCDM methods.

In this study, we propose the Fuzzy PROMETHEE. One of the most important multi-criteria decision-making techniques, to analyze the wastewater treatment technologies based on the criteria mentioned above.

Wastewater Treatment Methods

Activated Sludge method

The term Activated Sludge refers to a system consisting of flocs of active bacteria that take in and remove aerobically biodegradable organic matters wastewater that undergo conventional primary treatment. This sludge is produced as a result of growth of this organism in aeration tanks. the system is called “activated” because the particles are crowded with bacteria and protozoa and fungi (Wee Seow et al., 2016).

All contaminants treated by this process are usually biodegradable being it black water, grey water, brown water, faecal sludge or effluent wastewater from industries.

Developed in the UK around 1990’s, widely used process adopted by large cities and communities for wastewater treatment around the world. A very economical wastewater treatment technology that treat a huge amount of wastewater both from industrial and domestic sources and an excellent choice for isolated facilities such as hospitals or hotels, cluster situations, and subdivisions. In this type of treatment; different types of microorganisms use the pollutants found in the wastewater as food source. Being it a process where organisms are suspended in the wastewater not as the case of a trickling or in biological contactor processes filter where they are attached to the media (Jr. Mark J Hammer and Mark J Hammer, 2006).

This process relies on the activities of million different species of microorganisms, mostly aerobic and facultative heterotrophic bacteria that are usually found suspended in wastewaters which passes through the aeration tank. The basic processes that took place in any activated sludge are; the aeration tank where the biological reactions occur, the aeration source which is either through air diffusers, surfaces aerators or jet mixers for easy mixing of suspended organic matter and microorganisms and also function as source of oxygen to the system for the organisms to grow. The clarifier for easy settlement of solid waste and for its separation from treated wastewater, and a settling compartment where the solid sludge are collected for disposal as Waste Activated Sludge (WAS) or returned to the system as Return Activated Sludge (RAS) (L. Ho et al., 2018).

The system being a low cost-effective technology, having a good quality effluent, low land requirement and is free from flies and odour nuisance compared to WSPs and CWs which are more natural system and appear to be more viable option than the AS system. Moreover, Activated Sludge system has the limitation of not being a flexible method, with more operation cost, with system being sensitive to some certain industrial waste making it not feasible for these industries. Another disadvantage is the issue of sludge disposal which is generally in large scale, and the checks required and amount of sludge to be return requiring a skilled supervision and expert in wastewater treatment.

Nano-filtration method

Nano-filtration is one of the recent developed pressure-driven liquid-phase separations membrane process which substituted reverse osmosis in most applications due to higher flux rate and lower energy consumption (Gozálvez-Zafrilla, Sanz-Escribano, Lora-García, & León Hidalgo, 2008). The NF membrane is the relatively recent introduced technology in wastewater treatment system which describe the characteristics of membrane that falls between ultra-filtration (UF) and Reverse Osmosis

(RO) (Eriksson, 1988). Having a membrane pore size of less than 1nm shows how it can reject small solutes while the surface electrostatic properties allow monovalent ions to be reasonably well transmitted with multivalent ions mostly retained. With NF technology development, many industries such as textile, pharmaceuticals, and dairy use this technology in the treatment of their pulp bleaching effluents, separation of pharmaceutical wastes from fermentation broths, and demineralization respectively. Another characteristic of NF technology that increases its application in a number of industries is its ability to recover metals from wastewater and its virus removal efficiency (Bowen et al., 2002). In surface water treatment, NF is considered as one of the promising technologies that can be used in both organic matter and inorganic pollutants removal, since surface water is having a low osmotic pressure, a low-pressure operation of NF can be used in its treatment. In surface water treatment using NF technology the organic matters are removed by sieving mechanism since they are bigger in terms of size than the pore size of the membrane, while the inorganic pollutants are removed by the charge effect of the membranes and ions (Thanuttamavong, Yamamoto, Ik Oh, Ho Choo, & June Choi, 2002).

Advantages of Nano-filtration technology

1. Low operating pressure compared to reverse osmosis
2. Low energy requirement
3. High rejection of organic compared to ultra-filtration.
4. Another advantage of NF is that it can remove hardness up to 50%, colour using substance up to 90% and almost all turbidity in wastewater.

Limitations:

1. Its ability towards fouling and low performance at high temperature is a great disadvantage of NF technology especially in countries with high temperatures.
2. Large amount of wastewater is produced during drinking water production using membrane processes.
3. NF discharges a lot of concentrated effluents into the environment that leads to environmental pollution and even affects ground water quality.

Membrane Bioreactor method

Recently, membrane technology is becoming more popular compared to other water treatment technologies in the water industry in increasing fresh water production for both domestic and industrial purposes (Yeit Haan et al., 2017). MBR treatment is quite similar to the conventional activated sludge (CAS) treatment techniques in which biodegradation separation takes place simultaneously, with the only difference of membrane modules and aeration steps present in CAS (Dharupaneedi et al., 2019).

Membrane separation is brought about by either of the two-membrane vacuum-driven membrane immersed into a bioreactor which functions in dead-end mode in submerged MBRs or pressure-driven filtration in side-stream MBRs. But the most common one use in most wastewater treatment is former, with immersed membranes where wastewater is pumped through the membrane module and then return to the bioreactor.

To keep away solids in the waste streams which enter the membrane tank, fine screening is a basic pre-treatment step. This limits the amassing of solids and shields the membrane from dangerous debris and particles, increases the membrane life time, decreases the operational cost and ensures a higher sludge quality and also makes operations smooth.

Most MBRs are cleaned chemically on a weekly basis, the process lasts between half to an hour, and a recovery cleaning is conducted once or twice a year when filtration is no longer durable. A deposit that is impossible to be expelled by the available methods of cleaning is called “irrecoverable fouling”. This type of fouling accumulates over the years of functioning and this serve as a measure of the membrane life-time. All these operations and maintenance are done by skilled workers (O. T. Iorhemen, R. A. Hamza, 2016).

One of the advantages of this process is the reduction in plant footprint, as secondary and tertiary filtration processes are eliminated, thus having higher efficiencies. Lower sludge production and system designed to delay sludge age is also associated with

MBRs. In addition to all the above mention advantages of membrane treatment technology is gaining more attention from a lot of researchers in the field of water and wastewater engineering. Some of the limitations associated with these systems are high energy cost, membrane complexity and fouling and high operation and capital costs of the membranes (Djun Lee, Dayou, & Karunakaran, 2018; Yeit Haan et al., 2017)

Trickling technology

This is the process where microorganisms are attached to an inert filter material and are responsible for the digestion taken place in the system. This type of wastewater treatment process is an attached process in which wastewater is distributed continuously. Rocks, gravels sands, synthetic materials and a wide range of plastics are usually used as the parking materials in this type of treatment. Absorption and adsorption of organic materials by the layer of microbial bio-film are the two main processes that are used in pollutant removal from wastewater in trickling filter technology. The use of parking media is to provide a very high surface area to volume for the proper functioning of this system. Other names given to this process are trickling bio-filter, trickle filter, bio-filter, or biological filter.

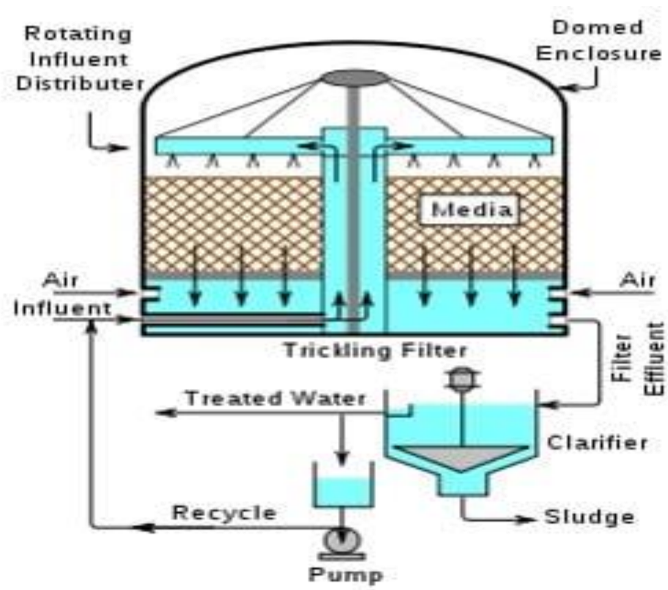

FIGURE 1: biological trickling filter diagram.

In this system of wastewater treatment, solid media of either rocks or plastics are filled in the tank, and then bacteria are allowed to grow on the surface of the media. The wastewater is distributed from the top of the filter penetrating through the openings of the film-covered medium either through a rotating influent distributer or a stationary distribution mechanism (Peavy, H. S., Rowe, D. R., Tchobanoglous, 1985). For organic degradation, required oxygen is supplied by air circulating through the filter brought by natural draft or aeration which is supplied through the nozzles or openings. As the wastewater moves through the filter, the organic matter is then adsorbed onto the film which helps in mixing the degraded organic matter with aerobic microorganisms. These microorganisms near the surface may lose their ability to stick to the medium as more biological films grow, which makes some portion of it to fall off the layer adding more biological activities in the system. The above-mentioned process is called sloughing. The final stage being the passage of the collected to the settled tank, which is used for the liquid-solid separation with some portion of the taken back to the system filter as recycled in order to keep the system moist and active (Adams , C. E ., Aulenbach , D. B. L., Bollyky, J., Burns , D. E ., Canter , L. W., Crits, G. J., Dahlstrom, D. Lee, K. David, H. F., Liptak, 1997).

High surface area per unit volume of the range 50-65m^2/m^3, high void, light weight, biological inertness, chemical resisting, mechanical durability, low cost, enough porosity of up to 40-50% to minimize clogging of the filter, and good air circulation are some of the advantages of the system. Other characteristics of the medium include a size of 50-100mm of medium, and a hydraulic head of 1.0m. Another advantage of the system is having high CO_2, H_2S, N_2, and other gases removal due to their large air-water interface. improves the treatment efficiency, suitable for shock loads, low running cost and low power requirement (US EPA, 2000).

Waste Stabilization Ponds (WSPs)

Waste Stabilization Ponds (WSPs) are natural processes that took place in a large, shallow basins containing algae and bacteria in which raw wastewater from different sewage are treated. Among the different biological wastewater treatment technologies in general, a WSP is a very suitable technology for wastewater treatment in developing countries due to its flexibility especially those in the tropics (Senzia, M. A., Mayo, A.W., Mbwette, T. S. A., Katima & & Jorgensen, 2002). (WSPs) are the most common methods of choice for municipal sewage treatment by many communities around the world, because the system requires a relatively modest investment, easy and cheap to operate and maintain by locally available personnel and not requiring too much technical knowledge of operation. These types of treatments are also called “sewage lagoons” or “Facultative Lagoons”(Recio-Garrido, Kleiner, Colombo, & Tartakovsky, 2018). Moreover, possibility of reusing the effluent water for irrigation as it contains nutrients like nitrogen and phosphorus is one of the advantages of WSP that makes it feasible to be used as an integrated process (L. T. Ho, Van Echelpoel, & Goethals, 2017)(Shilton, A. N., & Mara, 2005).

Conventional WSPs consist of a string of three different ponds namely; anaerobic (AP), facultative (FP), and maturation ponds (MP). The three ponds (AP, FP and MP) differ from each other geometrically, in terms of hydraulic flows, biochemical processes taken place in each pond and in the removal of carbon, nutrient and pathogens. Pathogen removal makes the reason for the system use (Mara D. and Pearson, 1998). Anaerobic pond is the first stage in WSPs and is designed to improve settling activities and the subsequent removal of organic load through the anaerobic digestion of particulate organic solids. Biological degradation and sedimentation are the two combined effect that helps in BOD removal in an anaerobic pond via hydrolysis, acetogenesis, acidogenesis and methanogenesis. Depending on the composition and influent sulphate concentration reduction and denitrification might also occur in the first stage. The main focus of second stage in WSP system is to reduce the amount of BOD and nutrients, but can also remove pathogens. In facultative Ponds a symbiosis occurs between heterotrophic bacteria and photosynthetic algae/cyanobacteria present in the water. Process takes more time, more land area, and possibly 2 -3 weeks water retention time, rather than 2 -3 days in the anaerobic pond. The third stage of treatment in conventional WSP which took place in the maturation pond (MP), is a shallow basin in which an aerobic condition is maintained over the entire depth of the pond. With the main purpose to remove pathogen (Sah, Rousseau, & Hooijmans, 2012). This removal of pathogens is as the result of the interaction of many factors such as high dissolved oxygen, high pH, predation, starvation UV radiation etc. while that of organic matter and nutrients presents in the MP is accomplished by aerobic bacteria (Von Sperling, 2005).

Constructed Wetlands (CWs)

Constructed wetlands (CWs) are planned, designed and constructed natural wetlands that assist in the treatment of wastewater in order to control a polluted environment. Hammer (1990) defines CWs as an artificial designed system consisting of vegetation, animal life, and water that stimulate wetlands for the benefit of human beings. CWs sometimes also serve as the alternatives for municipal and industrial wastewater treatment due to their ability to remove some pollutants in wastewater with ease. The pollutants removed by this process include suspended solids, heavy metals, pathogens, organic materials, nutrients and other toxic and hazardous pollutants. Constructed wetland being a friendly process should not be used for the treatment of sewage raw water, and for industrial effluents pre-treatment is needed for the proper functioning of the biological element with the effluent (Muga, H.E.; Mihelcic, 2008; Von Sperling, 2005).

CWs for wastewater treatment can be classified either as Free Water Surface (FWS) or Subsurface Flow (SSF) systems. In the FWS system the water is supplied from above and plant rooted at the base of the water column called the sediment layer while the SSF system water is supplied from beneath through a porous media comprising of gravels and aggregates (Yang, Gao, Wu, Liang, & Liu, 2018).

Constructed wetlands are an easy to operate and inexpensive, easy to maintain, reliable and effective process of wastewater treatment, and provide an aesthetic view. Some of the limitations according to study shows how CWs can only treat domestic wastewater mainly consisting of oxygen-consuming organic pollutants, and problem of clogging experienced after a period of operation which leads to decrease in treatment effect (Yang et al., 2018).

METHODOLOGY

The PROMETHEE

PROMETHEE procedure for decision making where various alternatives do exist was developed by Brans et al. this procedure was based on comparing different alternatives to be used with respect to the selected criteria. Among different multi-criteria decision-making tools, PROMETHEE is one of the less complicated in terms of application and conception (Uzun et al., 2018).

Two type of information are needed in the PROMETHEE method, which are those on the weight of the criteria considered and the decision-maker's preference function when comparing the contribution of the alternatives in terms of each separate criterion. In PROMETHEE method, in order to define different criteria, different preference functions are available. The preference functions (Pj) denotes the difference between the evaluations obtained with two alternatives (a and a_t') with regards to a particular criterion, within a preference degree ranging from 0 to 1. Six (6) different types of preference functions do exist and can be used to implement PROMETHEE method which include; U-shape function, usual function, V-shape function, linear function, level function and Gaussian function.

The basic steps to be followed for the PROMETHEE method are;

Step1: Determine a specific preference function Pj(d) for each criterion j.

Step 2: Assign weights to each criterion w_T= (w_1,w_2,…,w_k). At the discrete of the decision makers, each weights of criterion can be taken equally if only their importance is equal. And they can be normalized; $\sum_{i=1}^{k} w_k = 1$

Step 3: For all alternatives $a_{t,}a_{t'}, \in A$ define the outranking relation π;

$$\pi(a_t, a_{t'}) = \sum_{i=1}^{k} w_k \,.\, [pk(f_k(a_t) - f_k(a_{t'}))],$$

$$AXA \rightarrow [0,1]$$

Here π (a,b) denotes the preference index which is a measure for the intensity of preference of the decision maker for an alternative a_t in comparison with an alternative $a_{t'}$ while considering all criterion simultaneously.

Step 4: Determine the leaving and entering outranking flows as follows;

- Leaving (or positive) flow for the alternative a_t:

$$\phi^+ (a_t) = \frac{1}{n-1} \sum_{\substack{t'=1 \\ t' \neq t}}^{n} \pi((a_t, a_{t'})$$

- Entering (or negative) flow for the alternative a_t:

$$\phi^- (a_t) = \frac{1}{n-1} \sum_{\substack{t'=1 \\ t' \neq t}}^{n} \pi(a_{t'}, a_t)$$

where, n is the number of alternatives. With each alternative compared with (n-1) number of other alternatives. Having leaving flow of $\phi^+ (a_t)$ and entering flow $\phi^- (a_t)$, with the former expressing the strength of alternative $a_{t,} \in A$ and the later denoting the weakness of alternative $a_{t,} \in A$.

Through these outranking flows, the PROMETHEE I gives the partial pre-order of the alternatives, while the PROMETHEE II method provide the complete pre-order based on net flow.

Step 5: Determine the partial pre-order on the alternatives of A according to the following principle;

In PROMETHEE I alternative a_t is preferred to alternative $a_{t'}(a_t\, Pa_{t'})$ if it satisfies one of the following conditions.

$(a_t\, Pa_{t'})$ if;

$$\begin{Bmatrix} \phi^+(a_t) > \phi^+(a_{t'}) and\ \phi^-(a_t) < \phi^-(a_{t'}) \\ \phi^+(a_t) > \phi^+(a_{t'}) and\ \ \phi^-(a_t) = \phi^-(a_{t'}) \\ \phi^+(a_t) = \phi^+(a_{t'}) and\ \phi^-(a_t) < \phi^-(a_t, a_{t'}) \end{Bmatrix}$$

When the two alternatives a_t and $a_{t'}$ have the same leaving and entering flows a_t is in different to $a_{t'}(a_t\, Ia_{t'})$:

$(a_t\, Ia_{t'})$
if:$\phi^+(a_t) = \phi^+(a_{t'})\ and \phi^-(a_t)\ \phi^-(a_{t'})$

a_t Is incomparable to $a_{t'}(a_t\, Ra_{t'})$ if;

$$\begin{Bmatrix} \phi^+(a_t) > \phi^+(a_{t'}) and\ \phi^-(a_t) > \phi^-(a_{t'}) \\ \phi^+(a_t) < \phi^+(a_{t'}) and\ \phi^-(a_t) < \phi^-(a_t, a_{t'}) \end{Bmatrix}$$

Step 6: Determine the net outranking flow for each alternative.

$$\phi^{net}(a_t) = \phi^+(a_t) - \phi^-(a_t)$$

Through PROMETHEE II, the complete pre-order can be obtained by the net flow and is defined by;

a_t is preferred to $a_{t'}$ $(a_t\, Pa_{t'})$ if $\phi^{net}(a_t) > \phi^{net}(a_{t'})$

a is indifferent to $a_{t'}$ $(a_t\, Ia_{t'})$ if $\phi^{net}(a_t) = \phi^{net}(a_{t'})$

For better alternative the higher $\phi^{net}(a_t)$ value is more preferred.

Fuzzy PROMETHEE (F- PROMETHEE)

The F-PROMETHEE being a combination of PROMETHEE and Fuzzy logic is used in many decision-making application scenarios. As collecting satisfactory data to examine is becoming a problem and appropriate decision making becoming difficult in real life scenarios. But with fuzzy sets, which is a decision-making tool used to examine the concept of partial truth, which is practically not very clear. Ozsahin et al., gives detailed discussion of the F-PROMETHEE method that is used in this paper (Dilber Uzun Ozsahin, 2018; Uzun et al., 2017).

Fuzzy scale in table 1 was used to compare the defined criteria of the wastewater treatment methods effectively in order to get significance of each criterion. Yager index was employed to defuzzify the triangular fuzzy numbers to forecast the weight of each criterion.

TABLE 1. Linguistic Fuzzy Scale

Linguistic Scale for Evaluation	Triangular Fuzzy Scale	Priority Ratings of Criteria
Very high (VH)	0.75, 1, 1	HRT, Water flux, sludge generation, energy usage, efficiency, BOD removal, space requirement.
Important (H)	0.5, 0.75, 1	Aesthetics
Medium (M)	0.25, 0.50, 0.75	
Low (L)	0, 0.25, 0.5	
Very low (VL)	0, 0, 0.25	

After gathering the parameters for the comparison of the waste water treatment technologies, Gaussian preference function was utilized for each criterion as presented in Table 2. Visual PROMETHEE decision lab program was then applied.

TABLE 2. Visual PROMETHEE for selection of best wastewater treatment method

Design Method	Hydraulic ret. time (Hour)	Aesthetics	Typical water flow (LMH)	Sludge Generation	Energy consumption	Efficiency (%)	BOD Removal (%)	Space Requirement
				Preference				
Min/Max	Max	Max	Max	Max	Max	Max	Min	Max
Weight	**0.75**	**0.50**	**0.75**	**0.92**	**0.92**	**0.92**	**0.92**	**0.50**
Act sludge	**240**	**4**	**2**	**2**	**3**	**80**	**90**	**3**
MBR	**22**	**5**	**50**	**5**	**5**	**95**	**85**	**1**
NF	**30**	**5**	**200**	**5**	**5**	**98**	**90**	**1**
CWs	**168**	**5**	**0.6**	**3**	**3**	**80**	**90**	**4**
Trickling	**4**	**4**	**4.6**	**4**	**4**	**75**	**75**	**4**
WSPs	**26**	**5**	**0.6**	**3**	**3**	**80**	**80**	**5**

RESULT AND DISCUSSION

Table 3 and Figure 2 provides the ranking of wastewater treatment methods with NF been the best method to be used after considering all the criteria used for the study, though not good for developing countries where power is expensive, followed by Activated Sludge (AS) treatment which is good and can be used in developing countries, though requiring more space than NF, less in energy consumption. Moreover, AS Method requires more supervision and experts for its operation. The least method been Trickling Filtration, this is due to the fact that the method requires more energy, more land space, more supervision, more installment cost, and less in BOD removal compared to both the latter methods.

Figure 2 shows the pictorial positive and negative side of the treatment methodologies for each criterion. This is obtained using Decision Lab visual PROMRTHEE program, and can be used to easily change the criteria and also the weight for each criteria.

TABLE 3. Complete ranking of wastewater treatment methods

Ranking	Methods	Net flow	Positive outflow ranking	Negative outflow Ranking
1	NF	0,2698	0,3438	0,0740
2	ACT SLUD	0,1468	0,2122	0,0654
3	CWs	0,0848	0,2182	0,1334
4	MBR	0,0287	0,2242	0,1955
5	WSPs	-0,1718	0,1107	0,2824
6	TRICKLING	-0,3584	0,0302	0,3886

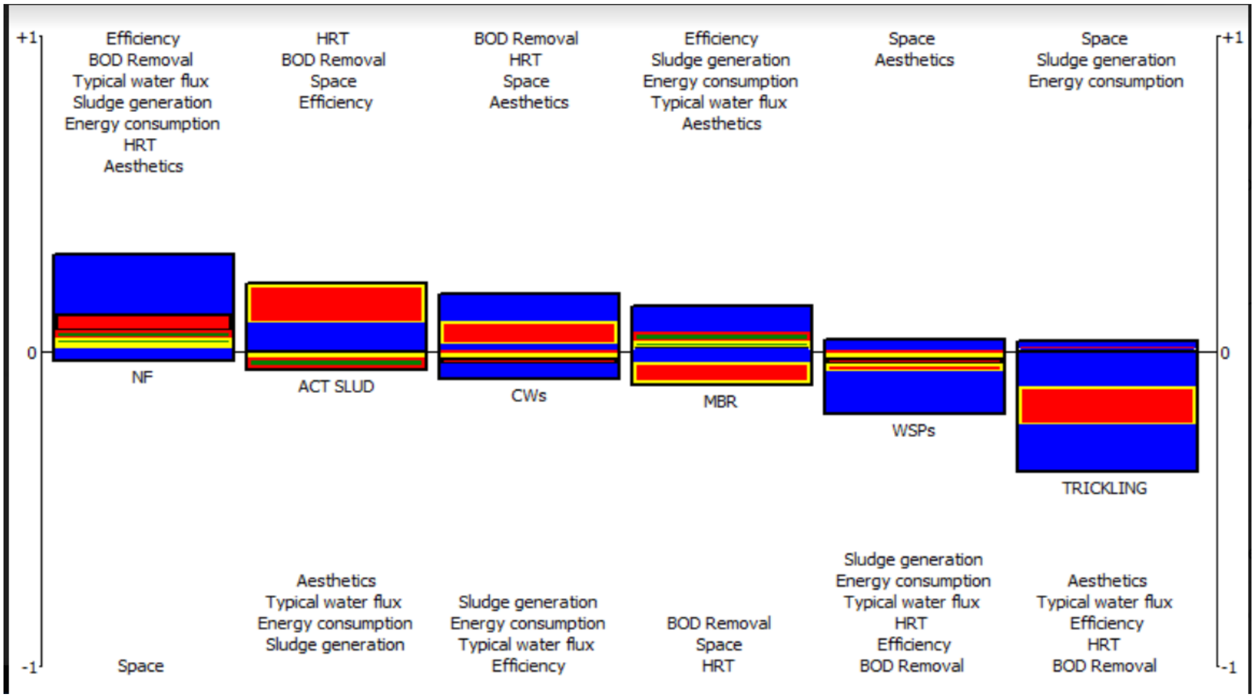

FIGURE 2. Evaluation of wastewater treatment methods

CONCLUSION

In conclusion, the fuzzy PROMETHEE decision making tool proven to be an effective instrument that can be used for selecting most preferred method among different wastewater treatment technologies. The results show NF as the best method with Activated Sludge (AS) been the second most preferred method for wastewater treatment, though may not be feasible for developing where power supply is a problem. Further understanding of the PROMETHEE method and comparing it with other decision-making methods will be beneficial and will make decision makers and other governmental and non-governmental organizations in making necessary decisions, not only in the field of engineering but also in other fields of study. For further research, it will be recommended that more criteria to be added as the more the criteria, the more the reliability of the outcome and vice versa.

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