ANSF APPLIED AND NATURAL SCIENCE FOUNDATION

Journal of Applied and Natural Science
15(1), 57 - 68 (2023)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Review Article

A proposed Fuzzy logic model for Electrospun nanofiber pressurised membranes for water treatment- A review

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Article Info
https://doi.org/10.31018/jans.v15i1.4190
Received: November 5, 2022
Revised: January 19, 2023
Accepted: January 25, 2023

How to Cite
Rao, A. G. *et al.* (2023). A proposed Fuzzy logic model for Electrospun nanofiber pressurised membranes for water treatment- A review. *Journal of Applied and Natural Science*, 15(1), 57 - 68. https://doi.org/10.31018/jans.v15i1.4190

Abstract
Electrospun nanofiber membranes and nanocomposites for water treatment is an emerging concept growing faster in science, gaining more prominence among various scientists, and creating attention to improve water quality. The familiarity with fabricating these materials is increased, and researchers worldwide target more nanomaterial manufacturing and synthesis for several applications. The electrospinning process for nanofibers' preparation allows polymers to incorporate various functionalized materials. Scientists have recently proposed electrospun membranes using fluorinated compounds and polymers with hydrocarbons. The membranes prepared by the electrospun nanofiber to purify water created a primary research axis, and various laboratory experiments proved efficient. In recent years, the usage of fuzzy analysis in industries has increased, and these logics are applied in every unit process of the water industry. The present review primarily discusses the recent pressurized electrospun membrane technologies utilized in the water industries and machine learning methods that can be applied in the water industries. Further, it suggests a new novel way of integrating options to connect the fuzzy with water treatment to enhance the electrospun nanofiber prospects in the water industry. Implementing these fuzzy models in future by water industries might reduce maintenance costs and help in understanding the characteristics of the effluent quality in detail.

Keywords: Desalination, Electrospun nanofiber, Fuzzy analysis, Water treatment

INTRODUCTION

Modernization, industrialization, and the increase in population worldwide create significant water scarcity, one of the century's most critical challenges. (Drioli *et al*., 2021; Konni *et al*., 2022). As stated by the world trade organization, by 2025, the universal population will suffer from water scarcity. It will worsen in developing nations and is estimated to increase by fifty per cent. In addition, the disposal of manufacturing waste without treatment into fresh waters is becoming a common concern (Chen *et al*., 2020). They deteriorate the quality of the water, causing environmental pollution and resulting in adverse effects on human health due to the consumption of this unhealthy water (Sikder et al., 2019). Thus, there is a need for alternative low-cost sustainable methods for recycling and treating the water (Rodríguez-Chueca et al., 2019). Due to this situation, many technologies are currently utilized to eliminate the pollutants from water shown in Fig. 1. Nevertheless, numerous techniques have emerged rapidly to enhance these aspects, reduce costs, and improve sustainable methods. Several researchers are exploring to produce potable water using eco-friendly and economically viable techniques to address these challenges.

Membrane separation technologies have gained much prominence amongst other techniques owing to their efficiencies, safety and selectivity of water resources (Fane *et al*., 2015). These techniques are classified based on particle removal into reverse osmosis, membrane filtration, membrane reactor, gas separation, nanofiltration, ultrafiltration, membrane distillation etc. (Vara *et al*., 2020). Membrane distillation is a thermally driven process to treat water to eliminate the non-volatile substance. The fabrication of the membranes was done using several techniques. Many researchers explored electrospinning, wet spinning, and phase inversion to the separation membrane and found electrospinning techniques are more efficient and gained much prominence. Electrospun membranes produced by the electrospinning technique have a lesser thickness, exhibit uniform dispersion, and have a high surface area, enhancing hydrophobicity and reducing resistance (Konni e*t al.,* 2022; Bölgen and Vaseashta, 2021; Vara *et al.,* 2020) . Moreover, based on the methods and synthesis for fabricating these membranes, these can be polymeric composites; the membranes' preparation procedures and compositions determine their properties (Ismail *et al*., 2020). The membranes prepared with the polymeric substances gained much prominence in the research due to their low cost, performance and selectivity. The electrospinning process for the fabrication of the nanofibers provided an entirely new direction to the research in energy, environmental and biomedical fields. These methods are versatile, and fabricated fibres range from micro to nanometres. Electrospinning methods naturally incorporate polymers with various functional materials like enzymes, drugs, and semiconductor nanoparticles to produce nanofibers. Boudriot *et al.,* (2006) stated that nanofiber structures and morphology are controlled by significant parameters like the solution's concentration and viscosity; the nanofibers' thickness tends to increase with attention; however, it can be avoided by adjusting the redox potentials (Boudriot *et al*., 2006). Fig. 2 depicts the electrospinning process along with its components. Nanofibers fabricated by this method produce high surface areas with small pore sizes compared to the other materials. The electrospun nanofiber quality enables its usage more efficiently towards seniors (Yang *et al*., 2020), biomedical applications (Lin *et al*., 2019), water and air quality (Konni *et al*., 2021), sensors (Bölgen and Vaseashta, 2021).

Table 1 shows the significant parameters that affect the electrospun nanofiber membranes. Moreover, nanofiber dimensions depend on the polymer properties, polymeric solution and environmental conditions. Nanofibers produced by the electrospun technique exhibit significantly enhanced properties due to their surface/mass ratio. Many researchers have proposed fluoropolymers and hydrocarbons for the fabrication of membranes by using electrospun techniques as they exhibit higher stability, entrapments of ions, minor pore blockage, and lower operational costs (Konni e*t al.,* 2022; Bölgen and Vaseashta, 2021; Vara *et al.,* 2020). Many researchers have researched polypropylene, polyvinylidene difluoride, Creslan 61, polystyrene etc., in water applications (Elmarghany *et al*., 2020; Konni *et al.,* 2022). Recent investigations proved that incorporating nano additives enhances the filtration performance in removing the impurities as these additives strengthen the size of the pores, surface roughness and stabilities. The researchers have used Metal-organic frameworks (MOFs) to fabricate the membranes as they have greater separation and adsorption properties (Li *et al*., 2020). In addition, these nanofiber membranes support thin-film composites for forwarding osmosis and gained much prominence in water application. They show higher strengths and greater porosity with interconnect-

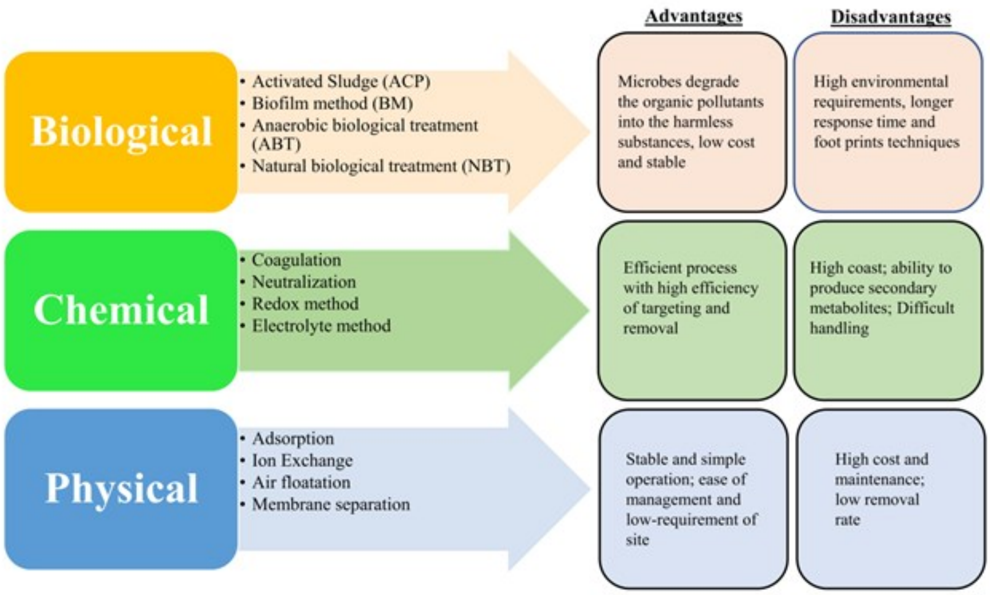

Fig. 1. *Widely used techniques for the recycling and treatment of water*

Table 1. Significant properties affecting the nanofiber membranes fabricated by the electrospun technique

S. No	Limitations	Variables	Effects	References
	Polymer solution properties	Molar mass enhancement. Surface tension and viscosity of the solution enhancement. Conductivity of the solution was enhanced. Solvent selection.	Membrane stable performance. Enhancement of nanofiber diameter and pore size. A rise in membrane flux and a decrease in diameter. Nanofibre diameter affected.	Liu *et al*., 2020
	Spinneret and collector design	Bicomponent tri/co-axial spinneret Copper rings with polymer droplets on spinneret. Liquid collector with a rectangular shape.	Nanofibers with significant physical and chemical properties. Applicability in sensors. Fabrication of tubular membranes.	Gao *et al*., 2019
	Practical reasons	Voltage enhancement. A rise in flow rate. Distance enhancement between collector and spinneret.	A rise in voltage decrease the diameter of the nanofiber. Nanofiber diameter size enhances pore size.	Hu *et al*., 2011
	Environmental conditions	Increasing humidity. Increasing temperature.	Nanofiber diameter decreases with a decrease in membrane flux.	Yang *et al*., 2017

ed structures with minor blockage. Polymers with hydrophilicity have been utilized in some studies, and it found that these polymers outperform forward osmosis. Doping nanomaterial to these materials, like titanium dioxide, graphene oxide and zeolites, supported and enhanced the membrane's performances (Xiao *et al*., 2020; Donato *et al*., 2020).

Nanoscience and nanotechnology result in a distinctive and inventive medium for water desalination. Nanomaterials like carbon nanotubes, zeolites, nanofibers etc., have been used to improve the desalination process, which includes distillation, adsorption and ion exchange owing to their higher stabilities and sieving abilities of the molecules in the saline solutions. The present review discussed nanofiber's usage in various water treatment applications, specifically desalination. Electrospun nanofiber applications in the separation of membranes are also critically discussed. The study proposed machine learning models and described their importance in water treatment. Further it is suggested that integration of the fuzzy logic methods along with the membrane technology in the future might be the best solution for water treatment.

Electrospun membranes for the treatment of water

Pressure-driven membrane in filtration

This technology applies force to the fed waters and is the leading force for separating infused solution and filtrate. In recent years rapid advancements in technologies helped the usage of nanofibers in these technologies like micro-filtration, ultra-filtration, nano-filtration, and reverse osmosis; characteristics of these mem-

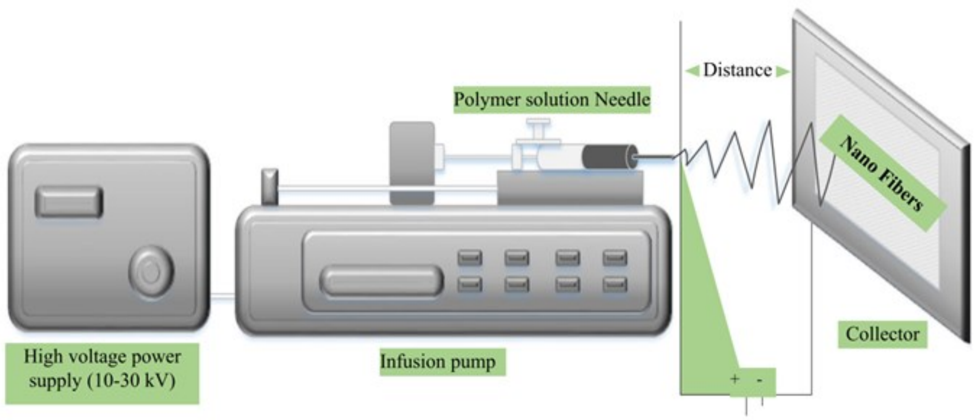

Fig. 2. *Electrospun process for the nanofibers production (Konni et al., 2022)*

Table 2. Membrane properties used in the pressure-driven membranes to separate impurities from water.

S.no	Membrane Type	Electrospun polymers used	Properties	Limitations	References
1.	Micro-Filtration	Poly ether, Polyvinylidene difluoride, Poly Ethelene, Poly propylene etc.	Greater pore size and connectivity	Highly prone to blockage of the pore	Chen *et al*., 2020
2.	Ultrafiltration	Polyether ether ketone, Poly propylene, Poly ethylene etc.	Asymmetric pore structure high permeate flux	Sensitive to pressure and strenuous process for cleaning	Dobosz *et al*., 2017
3.	Nanofiltration	Polyhydroxyalkanoate, Polysulfones etc.	Higher retention time enhances the desalination process	Higher production cost, lower stability	Shen *et al*., 2019
4.	Reverse Osmosis	Creslan 61, Polyether sulfone etc.	High efficiencies in separation	Pressure-sensitive and fouls faster	Zhou *et al*., 2019

branes are given in Table 2. In general, the filtrate represents decontaminated water; concentrate means both solutes/suspended water which must be treated before its disposal according to Indian government norms. The suitability mainly depends on the pollutant type that must be eliminated from the feed. The efficacy of filtration, dropping of pressure, and adsorption efficiencies of the electrospun membranes play a significant role in water purification in pressure-driven technologies. In addition, the operating procedures and combination of the techniques also depend on the particle size, emulsions, microbes, organic/inorganic compounds etc. Another widely used membrane technology includes forward osmosis, categorized under the osmotically driven methods.

Microfiltration

These membranes are sieve based and remove the particles with the size of 0.1-10 μm along with the bacteria and suspended particles (Hu *et al*., 2015). The membranes with the supra-micron size are used to prefiltrate the particles with larger sizes. Due to low energy consumption and higher production rates. Electrospun membranes showed higher performance than innate microfiltration membranes due to their uniformity in polymer dispersion (Aslan *et al*., 2016). In addition, a significant disadvantage of the microfiltration membranes is organic content removal; as this content is more minor than membrane pore sizes, it is harder to remove and results in fouling, leading to higher losses of permeate; to avoid these drawbacks modification of the membranes are much needed and in the current section modification of the membranes with the electrospun techniques for the water treatment are discussed (Konni e*t al.,* 2022; Bölgen and Vaseashta, 2021; Vara *et al.,* 2020).

Highly used electrospun nanofibers for the treatment of water are:

Gopal *et al*. (2006) used poly (vinylidene fluoride) for microfiltration removed the polystyrene particles with 90 % efficiency.

Barhate *et al*. (2006) synthesized electrospun nanofibers of acrylonitrile homopolymer/polyethylene terephthalate for microfiltration with high flux.

Aussawasathien *et al*. (2008) Fabricated nylon nanofiber filters separate micron/sub-micron particles from the aqueous medium.

Ultrafiltration

Ultrafiltration is vital in filtering bacteria, viruses and biological cells (Shi et al., 2014; Konni et al., 2022). Ultrafiltration is also a pressure-driven filtration technique that removes the particulate matter from 10-3 to 10-1μm. In this technique, membrane size is the factor liable for higher performance. In this method, solutes with smaller sizes pass over the membrane, and larger particles are eliminated. The primary applications of this technique are for pre-treatment before the reverse osmosis, reclamation and bioreactors. Nevertheless, the significant disadvantages of the ultrafiltration membranes are lower output and sensitivity of the pollutants in the infiltration process, and the large closed pores do not conduct the diffusion of water, reducing their efficiencies (Goh *et al*., 2015). Thus, there is a need to develop novel membranes with porous supports in ultrafiltration membranes (Dobosz *et al*., 2017; Okoji *et al.,* 2022). The conventional polymeric ultrafiltration membranes are fabricated using the phase inversion method and have limitations like the lower flux and high fouling rate. An additional problem with this method for membrane fabrication is the more significant pore size discussed in, the earlier section, resulting in fouling and incomplete retention of the suspended particulate matter (Sagle and Freeman, 2007). Concurrently, there is a need for scaffolds of electrospun nanofibers with features like highly porous and hydrophilic. It is to be overserved that all three layers should be laminated to maintain stability and porosity. This electrospun ultrafiltration membrane is proven more efficient than conventional membranes by gaining higher flux and rejection rates (Yoon *et al*., 2006). Further research is needed to optimize the layers' thickness to enhance water permeability.

Nanofiltration

This process includes the lower portion of ultrafiltration and the upper part of reverse osmosis with a range of 10^2-10^3 nm. Low *et al*. (2018) used the nanofiltration process is known for disinfection, removing dyes, softening water, and removing the organic content and divalent metal ions. The nanofiltration process has high trans membranes with more tremendous pressures and

Table 3. Electrospun membranes for the adsorption of impurities from water

Membrane application	Electrospun Polymer	Contaminants removed	References
Desalination and removal of heavy metals.	Aminated polyacrylonitrile nanofibers coated with carbon	Lead, copper, cadmium and chromium	Sun *et al*., 2016
	Carboxylic functionalized polyacrylonitrile nanofibers	Lead and methylene blue	Zhao *et al*., 2018
	Chitosan nanofibers doped with titanium dioxide nanoparticles	Copper and lead	Razzaz *et al*., 2016
	Oxidized polyacrylonitrile nanofibers	Lead and cadmium	Lee *et al*., 2017
	Double layer MOF-88 doped with polyacrylonitrile at the top and polyvinylidene difluoride at bottom	Lead	Efome *et al*., 2018
	Polyacrylonitrile functionalized with the ethylene and ethylenediamine	Zinc lead and copper	Martín *et al*., 2018
	Cellulose modified with montmorillonite	Chromium	Cai *et al*., 2017
	Chitosan doped with the titanium dioxide	Congo red and methyl orange	Habiba *et al*., 2019
	Chitosan grafted by glycidyl methacrylate/ polyaziridine.	Cobalt, chromium and copper	Yang *et al*., 2019
	Iron oxide/ multi-walled carbon nanotubes/ polyamide hybrid nanofibers	Lead	Bassyouni *et al*., 2019
	polyacrylonitrile modified with ethylenediamine	Chromium	Li *et al*., 2018
	polyacrylonitrile doped with thiol loaded with silver nanoparticles	Rhodamine B and methylene blue	Li *et al*., 2020
	Melanin extracted from Armillaria cepistipes	Lead, nickel, cadmium and chromium,	Tran-Ly *et al*., 2020
Oil separated from water	Polylactide membranes	Oil/ water	Zhang *et al*., 2020
	Polyvinylidene difluoride doped with polystyrene and iron oxide.	Sunflower/diesel/motor oils	Jiang *et al*., 2015
	Poly Methyl Methacrylate	Oil/water separation with greater flux after passing CO_2	Che *et al*., 2015
	Polysulfone fibres	Hexane and soybean oil	Obaid *et al*., 2018
	Poly (vinylene fluoride) tree-like membrane	Oil/water separation and pH-responsive	Cheng et al., 2017
	Carbon nanofiber/polyvinyl alcohol/ graphene oxide nanofiber	Engine/pump/soybean oil	Xu *et al*., 2018
	Polylactic/chitosan mats	Rhodamine B/oil/water separation	Wang *et al*., 2018
	Bacterial-derived cellulose and polyhemiaminal	Oil/ water	Li *et al*., 2018
	Nylon/cellulose acetate/ polyacrylonitrile	Oil in water	Bae *et al*., 2018
	Janus nanofibers	Oil/ water	Jiang *et al*., 2017
	Polyacrylonitrile doped with titanium dioxide nanoparticles	Oil/water separation/ photocatalysis	Saleem and Zaidi, 2020
	Polyamic acid	Oil/ water separation by using a gravity separator	Zhang *et al*., 2020
	Polyallylamine hydrochloride	Oil/ water	Guo *et al*., 2020

exhibits electrostatic effects. They showed the difference between the nanofiltration process and the reverse osmosis process is that a Nanofiltration process removes the monovalent atoms and rejects the divalent or trivalent atoms during the operation be attributed to the steric hindrance and Donnan repulsions. The nanofibrous ultrathin membranes must have high porosity for moderate pressure and the forces applied during the operation. Thin-film nanofiber composites exhibited higher performance in pollutant removal; Shen *et al*. (2016) identified that these membranes are used for commercial operations and made up of polyamide materials doped with the polyacrylonitrile thin-film nanofibers, and these membranes exhibited two times higher flux retention with higher rejection rates (Shen *et al*., 2016). Decisively, electrospun techniques are one of the most favourable techniques for uniform membrane fabrication with interconnected pore structures for water and wastewater treatment.

Nevertheless, owing to its fragile nature, a substrate is necessary. These nanofiber membranes were used for pressure-driven application in water/oil separation, heavy metal adsorption, filtration of microbes and desalination. The widely modified electrospun nanofibers for removing the contaminants are tabulated in Table 3.

Desalination

The desalination technique is potent and reliable for potable water production for the people residing in the coastal areas by treating the seawater. Among these processes, reverse osmosis, nanofiltration, ultrafiltration, electrodialysis, reverse osmosis and membrane distillation are efficient in terms of thermal and electrical energy usage (Konni *et al.,* 2022). Nanofiltration and ultrafiltration are widely used pressure-driven techniques consisting of hallo and sheet-like nanofibers. Many researchers have much-researched cellulose acetate and polymeric materials and their combinations (Konni *et al.,* 2022; Vara *et al.,* 2020). Electrolysis and reversal electrodialysis techniques utilize DC currents bypassing the ions via membranes with oppositely charged materials and found that the ions' rate of flow and concentrations is a deciding factor for filtration efficiencies. Forward osmosis techniques are new and have the potential for commercialization for the process of desalination of saltwater. The higher osmotic pressures of the membranes draw the clean water from the feed and don't require external forces. Membrane desalination techniques have limitations in commercial applications in the desalination process, and this process is a hybrid of desalination and reverse osmosis techniques. The membrane desalination process has synthetic membranes, exhibits hydrophobicity, and allows water vapour to pass through. The pressure acts as a powerful force for the flow of liquid in the membrane distillation process (Basile and Curcio, 2018). The most potential application of this membrane is tested with the membranes distillation procedure for extracting the potable water from the feed water. These membranes showed stable performance in the desalination process continuously for eight hours. Conclusively the desalination process's future application has been tabulated in Table 4.

Machine Learning for the Prediction of the Wastewater Quality

The concept of thinking of machines on the convergence concepts gained prominence in the early 1950s. During recent neurology studies, the brain discovered an electrical network of neurons for conducting pulses (Srivastava and Handa, 2022; Hameed *et al.,* 2021). Alan Turing's computational theories revealed that any form of computation could be expressed digitally. There is a close interrelationship between computational concepts and the electronic pulses of the brain. These concepts have become a pioneer study for the Machine Learning (MLS) we use today. Even though several machine learning and computational works are related, they only generate predictions, and not all the machine learning works might be applicable in real-time applications. Mathematical modelling studies for optimizing the process parameters might be the best domain for machine learning. Thus, implementing the MLS can mimic the human brain operations that the data combination with neural networks can operate, termed predictive analytics, used for commercial purposes. The term fuzzy represents ambiguity; in the current world, for real-time applications to face situations using the senses, it is impossible to tell whether a decision is true or false. In these situations, fuzzy logic provides a suitable solution with high probability and greater flexibility for good results (Srivastava and Handa, 2022). Thus, in recent

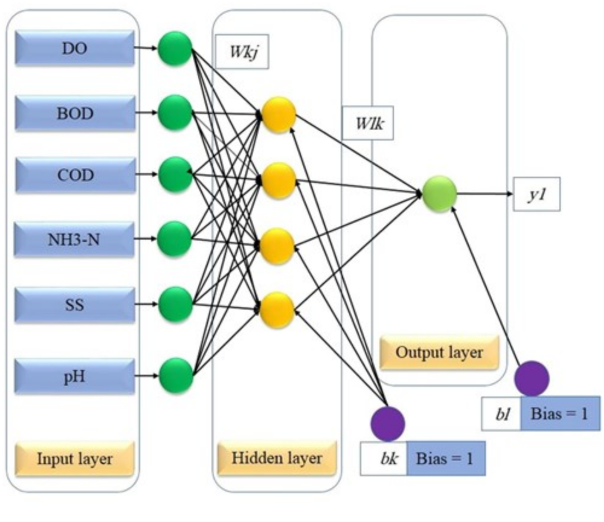

Fig. 3. *Three-layer ALN back propagation age for water treatment (Hameed et al., 2021)*

Table 4. Future possibility of membranes in treating water and wastewater (Konni *et al.*, 2022)

Methods	Short time frame (< 10 years)	Extended time frame (< 20 years)
Microfiltration/ Ultrafiltration	Reduction in cost An increase in the usage of a membrane made up of ceramic Development in instrument modules Pretreatment enhancements in reaverse osmosis Developments in vibratory and responsive membrane systems Enhancement in telemetric Availability of technologies in the remote areas	Availability of the isoporous membranes Uniformity in system modules Microfiltration/ultrafiltration as standard pretreatment reverse osmosis Worldwide utilization
Reverse osmosis/ Nanofiltration	Enhancement of permeability Reduction of cost Robust membrane production at a larger scale Development of spiral modules Development of closed-circuit desalination Introduction of fouling sensor system Increase of hybrid system combinations like nanofiltration/reverse osmosis, forward osmosis/reverse osmosis	Switching to hallow membranes Switching of hollo membranes to ultra-permeable membranes Negligible biofouling Potable equipment Integration of reverse osmosis plant with the reclamation plant

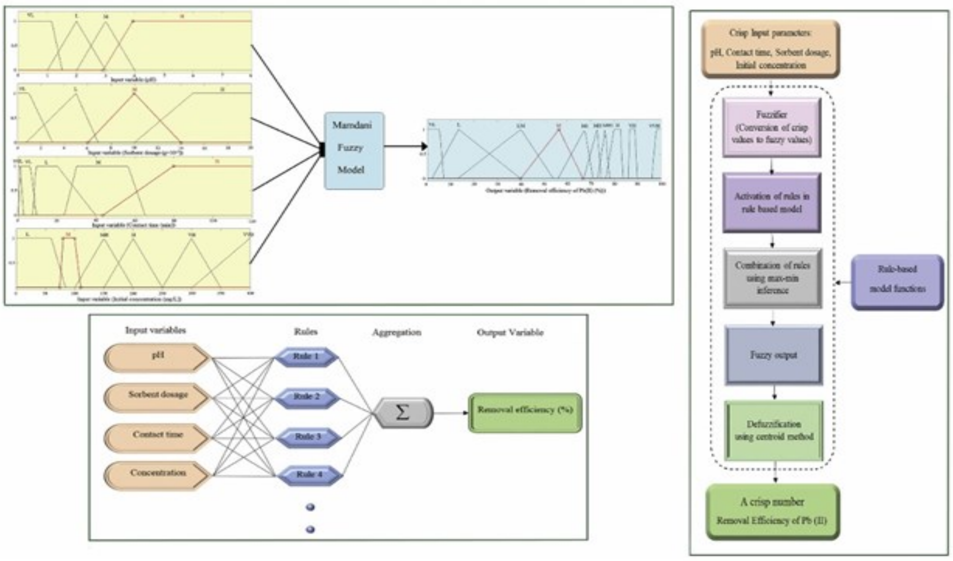

Fig. 4. *Fuzzy system (FS) for water treatment (Javadian et al., 2018).*

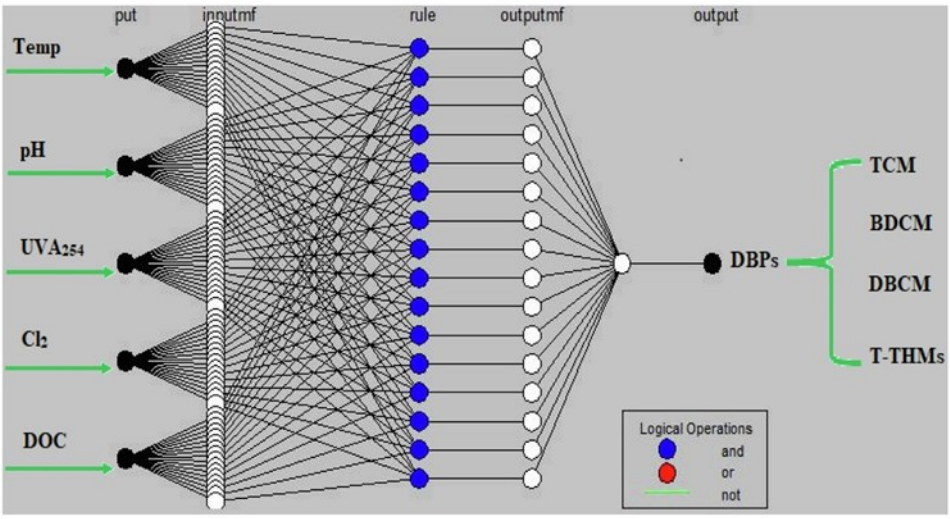

Fig. 5. *ANLN and FS integrated model for water treatment (Okoji et al., 2022)*

years many researchers (Srivastava and Handa, 2022; Hameed *et al.,* 2021; Javadian *et al*., 2018) considered MLS to avoid the uncertainties that might occur during accounting in any situation. Artificial neural networks (ANLN) are one of the MLS acting as a foundation for deep learning approaches (DLPs). The ANLN designs are inspired by the brain of humans relating to the neurons and how they communicate with each other. Node layers (NL) are generally used for the ANLN Construction, and there are three levels NLs, i.e., input, hidden and output layers. Each node has a specific weight and maximum value for linking the networks. These models help determine the production parameters of each processing unit. Thus, these predictions can help analyze the treatment required for the effluent that comes out from each unit which prevents the membranes of the units. For instance, if the projection shows that the effluent is becoming more acidic, then the water industries can apply the neutralization techniques and vice versa. These methods might be the best solution for the future as they reduce the damage costs of the equipment. MLS has a wide variety of applications in the water industry, gaining prominence in the past few years in treating wastewater. Even though many MLS are available, the ANLN, Fuzzy interface systems, and Adaptive-Neuro Fuzzy (ANF) gained much prominence in predicting the effluent parameters based on the influents in the treatment plants using historical data sets.

ANLN

The current design methods motivate the human brain network connected with neurons. ANLNS are computational models consisting of different mechanisms that accept the inputs and provide results based on the beginning functions. Every element in this MLS is analogous to the brain system and consists of algorithms and mathematical modelling that mimic the brain's functions. The influent physicochemical parameters are generally used for analyzing the network of the influent and effluent quality of the treatment plants. The NL hidden layers are defined according to the dataset, and the accuracy of the water was determined using an array for analyzing the model with the results obtained (Fig. 3). However, these methods have certain limitations and can't be considered accurate for treating water and wastewater (Srivastava and Handa, 2022).

Fuzzy analysis

This analysis is used to implement the knowledge to gain control over the analytical instruments used in the treatment units. Like other MLS that is binary true or false, the current methods use the degree of truth that can be accurate and considered a subset of the multiple-valued logic. The present analysis has high precision and accuracy and is widely employed in the water industry (Srivastava and Handa, 2022). The functional models (membership) used in the water industries are shown in Fig. 4. The fuzzy consists of if-then statements with defined variables in the data set. Javadian *et al*. (2018) predicted the characteristics of the influent and out fluent using the Fuzzy analysis and proved to be significant with less variance than the laboratory results. Further, they proposed that using these techniques in predicting water quality is accurate. Even though these methods are proper, these methods are replaced by the adaptive neuro-fuzzy systems, which are more accurate. Javadian *et al*. (2018) predicted the characteristics of the influent and out fluent using the Fuzzy analysis and proved to be significant with less variance than the laboratory results. Further, they proposed that using these techniques in predicting water quality is accurate. Even though these methods are proper, these methods are replaced by the adaptive neuro-fuzzy systems, which are more accurate.

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ANLN-FS

This method is a combination of ANLN and FS (Fig. 5). This system can analyze even nonlinear applications, and in recent years, this stent has acted as a universal estimator. The data input was accepted by the primary layers of the network and associated with the other functions. The secondary layer is used for locating the base rules, the third is for converting data, and the fourth is for accepting the processed values. Finally, the fifth layer is used for the defuzzied of the data to provide accurate output. The current method is highly reliable for the identification of the characteristics of effluent. Okoji *et al*. (2022) used this model for the prediction and the removal of the trihalomethanes and removed successfully from the influent. Mullai *et al*. (2022) used similar methods for modelling the sludge blanket reactor to treat the industrial effluents. Srivastava and Handa (2022) proposed this method for treating industrial wastewater and stated that the current process is efficient compared to the other methods. More research on fuzzy analysis integrating the ANLN and FS is required for the membrane techniques for removing the pollutant by using electro-spun nanofibers as the current methods are not entirely implemented in this sector, which might enhance the performance of the water treatment.

Conclusion

The availability of potable water is becoming a significant concern worldwide. Novel methods are developed to meet the needs of the increasing population and essential drinking water standards. Nanofibers are proven efficient and potent in these lines by providing a new dimension in the water industry for water purification. These membranes consist of beneficial features like larger surface areas and pore sizes. Electrospinning techniques are convenient in fabricating the nanofibers by providing a viable method for tuning the nanofiber's aperture size. Utilization of these membranes in the water treatment gives good results. Machine learning languages and statistical procedures like fuzzy logic integration with these new technologies might be helpful for the water industries as they help to predict the effluent and influent qualities. These predictions will reduce the costs associated with the treatments and prevent membrane blockages and fouling. Even though very few studies are available in water treatment using fuzzy, the proposed methods in the review and their application in electrospun nanofibers pressurized membrane technologies are gaining prominence recently. Applying these integrated methods in the future might help the water industry's prospects. Several challenges should be overcome and possible only by collaborating with institutional and industrial research. Researchers must concentrate on the current areas as it is entirely new, and this helps to develop affordable engineering-scale units and highly effectual electrospun membranes for water treatment.

Conflict of interest

The authors declare that they have no conflict of interest.

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