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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

Performance of Chitosan/Carbon Nanotube-Coated Ultrafiltration Membranes for Natural Organic Matter Removal from Drinking Water

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Abstract: The objective of this study is to improve the filtration efficiency of commercially available polyethersulfone (PES) ultrafiltration (UF) membranes, with a specific focus on removing natural organic matter (NOM) and preventing membrane fouling. The modification of UF membranes was accomplished by utilizing chitosan/multi-walled carbon nanotubes (CS/MWCNT-OH) and employing both dip and spin coating techniques. The membrane surface morphologies were evaluated using the Attenuated Total Reflectance Fourier Transform Infrared Spectroscopy (ATR-FTIR), Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), and Energy-Dispersive X-ray Spectroscopy (EDX) techniques. Tests were carried out to assess the effectiveness of the membranes in a laboratory-scale system using two primary water sources from Istanbul, specifically the Melen River and Terkos Lake. Total organic carbon (TOC), UV_{254} absorbance, turbidity, and trihalomethane formation potential (THMFP) were all measured as part of a thorough analysis. The surface morphology investigations verified the effective deposition of MWCNT-OH nanoparticles onto the membrane surface. This was corroborated by the reduction in the water contact angle, showing an improvement in the hydrophilicity of the membrane. The modified membranes demonstrated much higher TOC removal rates compared to the original membranes. Specifically, the removal efficiencies for Melen River and Terkos Lake were 37.14% and 56.86%, respectively. Nevertheless, the alteration of the surface led to a decline in membrane flux as a result of the concurrent drop in pore size. To summarize, the results of this work highlights the considerable capability of surface modification using CS/MWCNT-OH to improve the performance and antifouling characteristics of commercial PES UF membranes.

Keywords: MWCNT, membrane coating, filtration, natural organic matter, THMFP.

İçme Suyundan Doğal Organik Madde Gideriminde Kitosan/Karbon Nanotüp Kaplı Ultrafiltrasyon Membranlarının Performansı

Öz: Bu çalışmanın amacı, doğal organik maddenin (NOM) giderilmesine ve membran kirlenmesinin önlenmesine özel olarak odaklanarak, ticari olarak temin edilebilen polietersülfon (PES) ultrafiltrasyon (UF) membranlarının filtrasyon verimliliğini arttırmaktır. UF membranlarının modifikasyonu, kitosan/çok duvarlı karbon nanotüp (CS/MWCNT-OH) kullanılarak ve hem daldırma hem de döndürerek kaplama teknikleri kullanılarak gerçekleştirildi. Membran yüzeyi morfolojileri, Zayıflatılmış Toplam Yansıma Fourier Dönüşümü Kızılötesi Spektroskopisi (ATR-FTIR), Taramalı Elektron Mikroskobu (SEM), Atomik Kuvvet Mikroskobu (AFM) ve Enerji Dağıtıcı X-ışını Spektroskopisi (EDX) teknikleri kullanılarak değerlendirildi. Membranların etkinliğini değerlendirmek için laboratuvar ölçekli bir sistemde İstanbul'un iki ana su kaynağı, özellikle Melen Nehri ve Terkos Gölü kullanılarak testler gerçekleştirildi. Toplam organik karbon (TOC), UV254 absorbansı, bulanıklık ve trihalometan oluşum potansiyeli (THMFP) kapsamlı bir analizin parçası olarak ölçüldü. Yüzey morfolojisi araştırmaları, MWCNT-OH nanopartiküllerinin membran yüzeyine etkili bir şekilde çökeldiğini doğruladı. Bu, membranın hidrofilikliğinde bir iyileşme gösteren su temas açısındaki azalma ile desteklendi. Modifiye edilmiş membranlar, orijinal membranlarla karşılaştırıldığında çok daha yüksek TOC giderim oranları gösterdi. Spesifik olarak Melen Nehri ve Terkos Gölü'nün temizleme verimliliği sırasıyla %37,14 ve %56,86 idi. Bununla birlikte, yüzeydeki değişiklik, gözenek boyutunda eş zamanlı düşüşün bir sonucu olarak membran akışında bir düşüşe yol açtı. Özetlemek gerekirse, bu çalışmanın sonuçları, ticari PES UF membranlarının performansını ve kirlenme önleyici özelliklerini geliştirmek için CS/MWCNT-OH kullanılarak yüzey modifikasyonunun önemli kapasitesini vurgulamaktadır.

Anahtar kelimeler: Doğal organik madde, filtreleme, membran kaplama, MWCNT, THMFP.

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INTRODUCTION

Complex combinations of organic compounds found in both surface and groundwater sources are known as NOM (Adusei-Gyamfi et al., 2019; Levchuk et al., 2018a). NOMs are complex mixtures of organic chemicals that are formed as a result of natural processes, such as the breakdown of organic materials in water and metabolic responses in algae. (Pan et al., 2016). Approximately 50% of the NOMs present in drinking water sources are made up of humic and fulvic acid compounds. The other half consists of proteins, amino acids, carbohydrates, and carboxylic acids. (Adusei-Gyamfi et al., 2019; Levchuk et al., 2018b).

NOMs present in water sources can cause aesthetic issues, including alterations in color, smell, and flavor. (Pan et al., 2016; Song et al., 2022). Furthermore, NOMs have the ability to promote the proliferation of bacteria in water distribution networks, which could result in the development of waterborne illnesses. (Cabral, 2010). NOMs not only impairs the efficacy of drinking water treatment processes, but also combine with disinfectants like chlorine to produce a combination of disinfection byproducts (DBPs) that exhibit genotoxic, mutagenic, and carcinogenic qualities. (Levchuk et al., 2018b; Pan et al., 2016). NOMs are considered the primary precursors of DBPs in drinking water (Pan et al., 2016; Shao et al., 2023). Among the 700 documented disinfection byproducts (DBPs), trihalomethanes (THMs) are particularly noteworthy as a significant category. THMs are produced when water is disinfected with chlorine. (Pérez-Lucas et al., 2022). THMs, which have been associated with potential health hazards, are subject to maximum concentration limits (MCL) regulations in several countries. As an illustration, the European Union has set a MCL of 100 µg/L for total THMs. (Villanueva et al., 2023). A significant proportion of hydrophobic NOMs with high molecular weights can be eliminated in a standard drinking water treatment procedure that includes coagulation, flocculation, sedimentation, and filtering. Nevertheless, the hydrophilic portion of NOMs with low molecular weights continues to be unyielding to traditional treatment techniques, resulting in their enduring presence as residual organic matter.

While conventional methods like coagulation/filtration can partially remove NOM from drinking water, advanced techniques such as granular activated carbon (GAC) and membrane processes like UF and nanofiltration (NF) have shown higher effectiveness in terms of removal efficiency. (Mallya et al., 2023; Marais et al., 2018; Peters et al., 2021). UF membranes, as opposed to NF membranes, may operate at lower pressures and effectively remove suspended organic particles. Nevertheless, UF membranes cannot effectively remove dissolved organic matter (DOM), such as humic compounds, which make up to 50% of NOM, due to their very broad pore size range (0.01-0.1 µm). (Zhang et al., 2018). Additionally, membrane-based technologies encounter difficulties with membrane fouling caused by the presence of NOM, which is a significant disadvantage. (Mallya et al., 2023). The accumulation of NOM on the membrane surface over time leads to increased operational costs and reduced filtration efficiency. (Zhang et al., 2018).

In recent years, there has been a growing interest in surface modification as a means to improve membrane properties, with the goal of mitigating fouling. (Anis et al., 2022; Hu et al., 2021; Zhao et al., 2012). Applying hydrophilic polymers or nanoparticles to the membrane's surface enhances its ability to transport hydrophobic organic foulants, effectively aiding in the avoidance of fouling. Carbon nanotubes (CNTs) are a promising choice for surface coating materials because of their unique one-dimensional tubular structure and high surface area-to-volume ratios. They offer effective control over membrane fouling (Cheng et al., 2019). CNTs, carbon-based nanomaterials, have gained significant attention due to their exceptional physical and chemical properties since their initial successful synthesis. CNTs possess notable characteristics such as a substantial surface area, significant porosity, and exceptional mechanical, thermal, and chemical stability. Carbon nanotubes have shown great potential as materials for a wide range of membrane applications (Han et al., 2021).

PES is extensively utilized in UF due to its remarkable mechanical and hydrolytic robustness, as well as its resistance to oxidation, elevated temperatures, and chemicals. (Kallem et al., 2021; Susanto et al., 2020). Nevertheless, the inherent hydrophobicity of PES membranes renders them susceptible to fouling, compromising treatment efficacy, diminishing membrane durability, and escalating energy usage. (Kallem et al., 2021; Zhao et al., 2012). Extensive research has been carried out to investigate surface alterations aimed at tackling the issue of membrane fouling and minimizing its negative effects.

The main goal of this project is to improve the performance of commercial PES membranes, which are commonly used in UF applications. This will be achieved by applying MWCNT nanoparticles to the membranes using dip and spin coating processes. Consequently, the study's objective is to assess the efficacy of these altered membranes by examining their ability to filter two important sources of drinking water in Istanbul. Previous studies have mostly focused on analyzing the effectiveness of membranes using artificial solutions. However, there is a lack of information regarding the performance of modified membranes when filtering real drinking water sources. This study aims to close this gap by assessing the effectiveness of coated membranes in treating the two primary sources of drinking water in Istanbul, which have unique properties. This research is expected to offer novel perspectives on the functioning of membranes in real-world situations and enhance our comprehension of their practical usefulness.

MATERIAL AND METHOD

Surface coating: PES UF membranes with molecular weights of 5 kDa, 10 kDa, and 20 kDa (designated as UP005, UP010, and UP020) were purchased from Microdyn-Nadir. The modification of membrane surfaces was accomplished using a mixture of chitosan and MWCNT nanoparticles through dip and spin coating methods. MWCNT-OH with an outer diameter of 10-20 nm, a 30 µm length, and 95% purity, functionalized with OH groups, was obtained from the Timesnano Company. A solution of chitosan (Sigma Aldrich) was prepared by mixing chitosan with 2 mL of acetic acid, which was then diluted to various concentrations and stirred using a WiseStir SMHS-6 magnetic stirrer at 1500 RPM for 4 hours at room temperature. Coating experiments were conducted using a (w/v) ratio of 0.8%. Then, 0.08 g of MWCNT-OH was added to the chitosan solution. The prepared solution was initially treated with a Bandelin Sonopuls HD 2200 ultrasonic homogenizer for 15 minutes, followed by stirring for a day at 1500 rpm and room temperature using a WiseStir SMHS-6 magnetic stirrer. Before the coating process, the solution underwent an additional 15 minutes of homogenization.

The KSV NIMA and Laurell WS-650MZ-23 instruments were used to employ two coating methods: dip coating and spin coating. Flat membranes with a square shape, measuring 10 cm in size, were immersed in a solution containing 400 mL of CS/MWCNT-OH. Aluminum foil served as a barrier between the membranes' support layer and the coating solution. The coating technique involved immersing the membrane in the solution at a speed of 100 mm/min for a duration of 1 minute, followed by withdrawing the membrane from the solution at the same speed, which took around 1 minute.

During the spin coating procedure, a volume of 8 mL of the coating solution was applied onto the membranes using a syringe, and they were subjected to a rotational speed of 2500 rpm for a duration of 1 minute. The covered membranes were subsequently cured through 15 seconds of UV irradiation and subsequently dried in an oven at room temperature for 24 hours.

Filtration experiments: Experiments were carried out utilizing a small-scale membrane system in the laboratory (Fig. 1). Experimental investigations were carried out utilizing both unaltered and treated PES UF membranes, which were subjected to distilled, Terkos Lake, and Melen River waters. Prior to conducting the filtration tests, any chemical remnants present in the membrane pores were removed by immersing the membranes in distilled water for a duration of 1 hour, followed by filtration with 1 liter of distilled water. Distilled water was generated using the double distillation method employing Meck Millipore Direct-Q Ultrapure Water Systems. Filtration tests were conducted under a pressure of 4 bar, and the surface of each membrane was cleaned after every test. Following filtration, the membranes were dried in an oven for 2 days before undergoing morphology analyses.

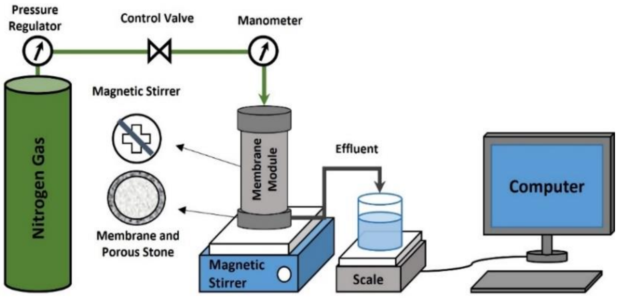


Fig 1. Shematic diagram of the lab scale membrane filtration unit.

Analyses: Samples of water from the Melen River and Terkos Lake were stored at +4 °C until they were ready for analysis.

Chemical analyses were conducted according to the guidelines outlined in the Standard Methods (Table 1).

Table 1. Water quality analysis conducted in the study.

Parameter	Method	Equipment
TOC	SM 5310 B	Sievers 5310C TOC analyzer
UV254	SM 5910	Shimadzu UV-1800
THMFP	SM 5710 B	Shimadzu GC-2010 Plus
pH	SM 4500 H	Thermo Orion 5 star
Conductivity	SM 2510	Thermo Orion 5 star

The membranes' hydrophilicity was assessed by quantifying the contact angle with the utilization of an optical tensiometer (Theta Lite). The surface and structural properties of the membranes were examined by the use of advanced techniques including AFM, SEM, EDX, and ATR-FTIR. SEM analysis was conducted using a scanning electron microscope (JEOL JSM-7001F) to observe alterations in the micro morphology of the membrane. An Oxford Instruments INCA x-act EDX system was utilized to conduct EDX tests in order to ascertain the elemental composition of the membranes. The surface roughness of clean, coated, and utilized membranes was quantified using atomic force microscopy (AFM, Park Systems XE-100). AFM scans were performed across a 100 µm × 100 µm area, with a vertical probing depth of 25 µm. Attenuated total reflectance mode is a method of spectroscopy that involves measuring the reflection of light on the surface of a sample. The membranes' ATR-IR spectra were obtained using a Bruker Tensor 27 FTIR spectrophotometer. The spectra were collected in the range of 4000–200 cm^{-1} with a resolution of 2 cm^{-1}. A Perkin Elmer BX FTIR spectrophotometer, equipped with a ZnSe attenuated total reflectance (ATR) crystal was utilized.

RESULTS AND DISCUSSION

***Characteristics of water sources*:** The Melen River and Terkos Lake play a crucial role as reservoirs for the city of Istanbul. Istanbul, one of the most densely populated cities in the world, fulfills its water requirements, which exceed 2.5 million cubic meters, using conventional techniques that depend on eight surface water reservoirs. Terkos Lake is noteworthy for its biggest freshwater capacity among these reservoirs. It serves as the main supply for the Kağıthane treatment plant, which produces 700,000 cubic meters of drinking water every day. Furthermore, the Melen River has been acknowledged as a prospective future drinking water reservoir for Istanbul, intended to mitigate the issue of water scarcity. Table 2 displays the fundamental statistical information for various water sources.

Upon comparing multiple metrics, it is apparent that Terkos Lake exhibited higher amounts of pollution in comparison to the Melen River. Both water sources displayed a slightly alkaline pH, with a measured temperature of 22°C. Terkos Lake exhibited a dissolved organic carbon (DOC) concentration of 4.9 mg/L, which was approximately twice as high as that of Melen River. The UV_{254} values in the water sources were consistent with the levels of DOC, with low UV_{254} values indicating a negligible presence of aromatic carbons.

The $SUVA_{254}$ values for both sources were similar, with Terkos Lake having a value of 3.95 L/mg·m and Melen River having a value of 3.52 L/mg·m. THMFP in the Melen River was measured at 296.98 µg/L, while the turbidity level was recorded at 11.1 NTU. Contrasting Terkos Lake, it displayed decreased cloudiness but a greater level of THMFP. With the exception of Fe^{+2} and Mn^{+2}, all other metrics exhibited an estimated 1.5-fold increase in Terkos Lake compared to the Melen River.

Table 2. Characteristics of Terkos Lake and Melen River water sources.

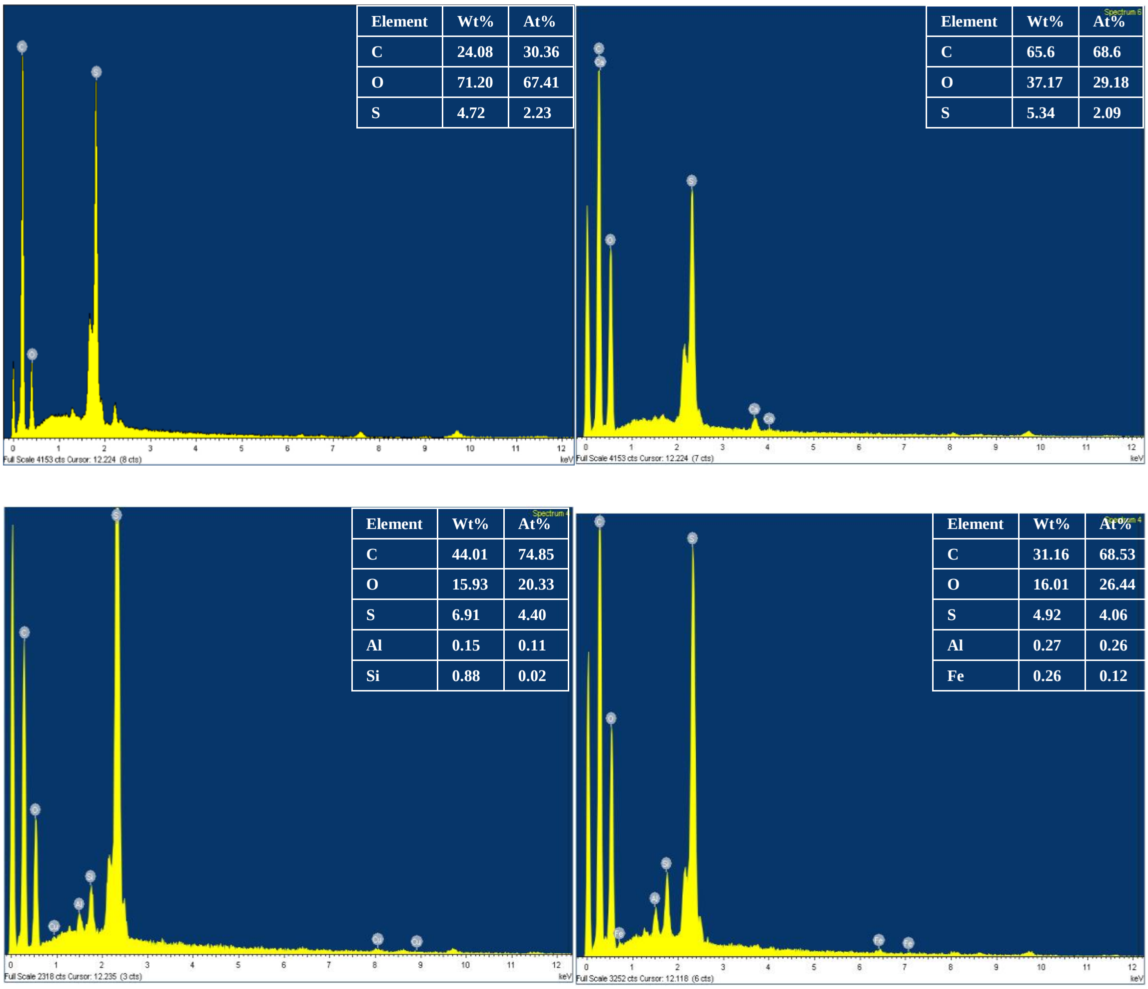
Parameter	Unit	Terkos Lake	Melen River
pH		8.04	7.73
Temperature	°C	22	22
TOC	mg/L	4.9	2.55
UV_{254}	cm^{-1}	0.17	0.09
$SUVA_{254}$	L/mg.m	3.95	3.52
THMFP	µg/L	320.53	296.98
Turbidity	NTU	8.8	11.1
Conductivity	µS/cm	323	460
Alkalinity	mg $CaCO_3$/L	120	90
Total hardness	mg $CaCO_3$/L	154	106
Fe^{2+}	mg/L	< 0.02	< 0.02
Mn^{2+}	mg/L	< 0.02	< 0.02
Br^-	µg/L	180	70

Effects of coating on the membrane morphology: Figure 2 exhibits the EDX spectra of the original and CS/MWCNT-coated UF membranes. The immaculate membrane displayed essential constituents such as carbon, oxygen, and sulfur, which are important ingredients of polymeric membranes. The carbon content on the coated membrane surface increased significantly compared to the original membrane due to the predominance of carbon in the MWCNT composition (Savi et al., 2019). In Figures 2C and D, EDX analysis of the coated membrane reveals detection of Fe(II) from the Melen River on its surface post-filtration, while the uncoated membrane does not exhibit such detection. Modifying the membrane can decrease pore size due to the accumulation of coating material on the membrane surface, enhancing its ability to remove pollutants. The presence of chitosan/MWCNT-OH particles on the membrane surface serves as a partial obstruction to water, resulting in a reduction in the average pore size of the membrane (Bin Darwish et al., 2019).

As seen in Fig. 3 it is evident that MWCNT particles are clearly visible on the surface of the membrane. The distribution of MWCNT particles is more homogeneous when spin coating is used. The surface variances revealed in Fig. 3C and D are a result of the use of different coating processes. During the process of dip coating, nanoparticles have a tendency to form clusters in certain areas. In contrast, during the spin coating process, the coating solution is evenly applied to the surface due to the centrifugal force, which helps to evenly distribute particles over the membrane surface. The observed increase in thickness post-filtration may be attributed to the retention of NOM and other foulants on the membrane surface.

Figure 4 exhibits the surface images of the two membranes that have been coated with CS/MWCNT. SEM images of the membranes clearly demonstrate the successful application of CS/MWCNT nanoparticles to the membrane surface. (Mousavi et al., 2020). The coated membranes display a smoother surface compared to the pristine membrane, indicating the presence of chitosan, with MWCNT particles dispersed throughout. After filtration, the membrane surface shows evidence of fouling caused by NOM. However, the presence of MWCNT particles suggests that the coating is still intact.

The ATR-FTIR spectra of the pristine and coated membranes were presented in Figure 5, encompassing the 500-4000 cm^{-1} range. The spectra displayed distinct peaks that are linked to the PES membrane material. The peaks observed between 3000 and 3600 cm^{-1} are specifically associated with the stretching vibrations of hydroxyl (OH) groups present in sulfonic or water molecules. The peaks observed between 1000 and 1100 cm^{-1} were identified as the result of stretching vibrations of sulfonic groups. The peaks seen at 579 cm^{-1}, 1485 cm^{-1}, and 1240 cm^{-1} matched specific features, namely benzene rings, C-C stretching bands, and aromatic ether bands, respectively. (Ren et al., 2022). After the application of the coating, no additional peaks were observed, although there were alterations in the intensities of certain peaks. Significantly, the intensity of the stretched OH peaks dropped. This drop was attributed to the evaporation of water molecules caused by the heat released during the curing process.



Element	Wt%	At%
C	24.08	30.36
O	71.20	67.41
S	4.72	2.23

Element	Wt%	At%
C	65.6	68.6
O	37.17	29.18
S	5.34	2.09

Element	Wt%	At%
C	44.01	74.85
O	15.93	20.33
S	6.91	4.40
Al	0.15	0.11
Si	0.88	0.02

Element	Wt%	At%
C	31.16	68.53
O	16.01	26.44
S	4.92	4.06
Al	0.27	0.26
Fe	0.26	0.12

Fig 2. EDX spectra of (a) pristine UP005 membrane, (b) CS/MWTCNT-OH coated (dip) UP005 membrane, (c) After filtration of Melen River water from pristine UP005 membrane, (d) after filtration of Melen River water from CS/MWTCNT coated (dip) UP005 membrane.

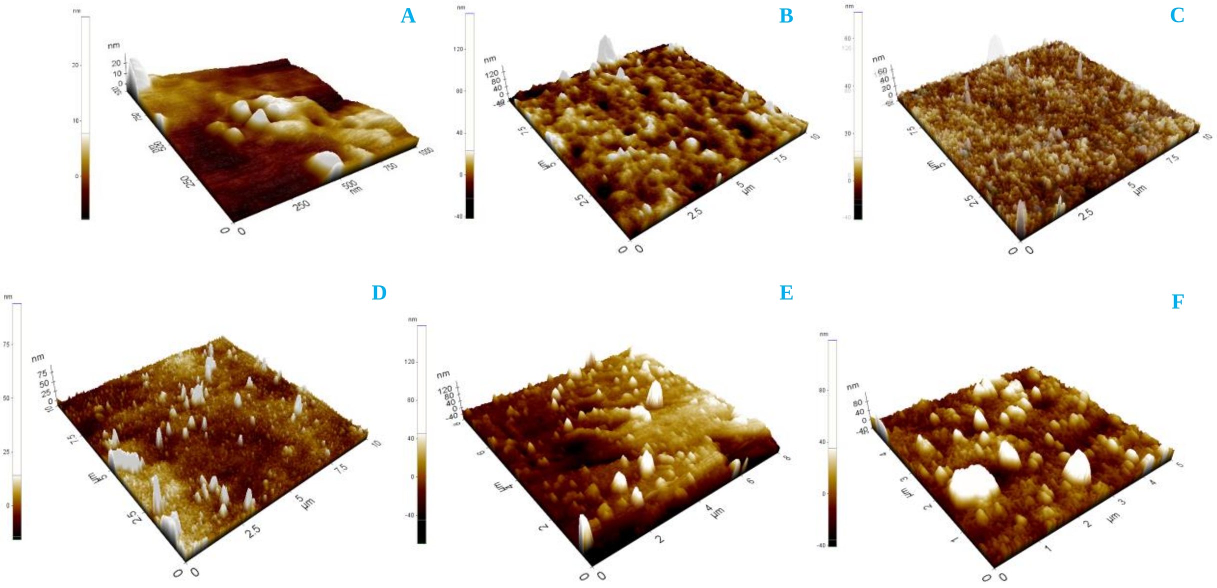


Fig 3. Upon comparison, AFM spectra of (a) pristine UP005 membrane, (b) pristine UP020 membrane (c) CS/MWTCNT coated (spin) UP005 membrane, (d) CS/MWTCNT coated (dip) UP020 membrane, (e) after filtration of Melen Lake water from CS/MWTCNT coated (spin) UP005 membrane, (f) after filtration of Terkos Lake water from CS/MWTCNT coated (dip) UP020 membrane.

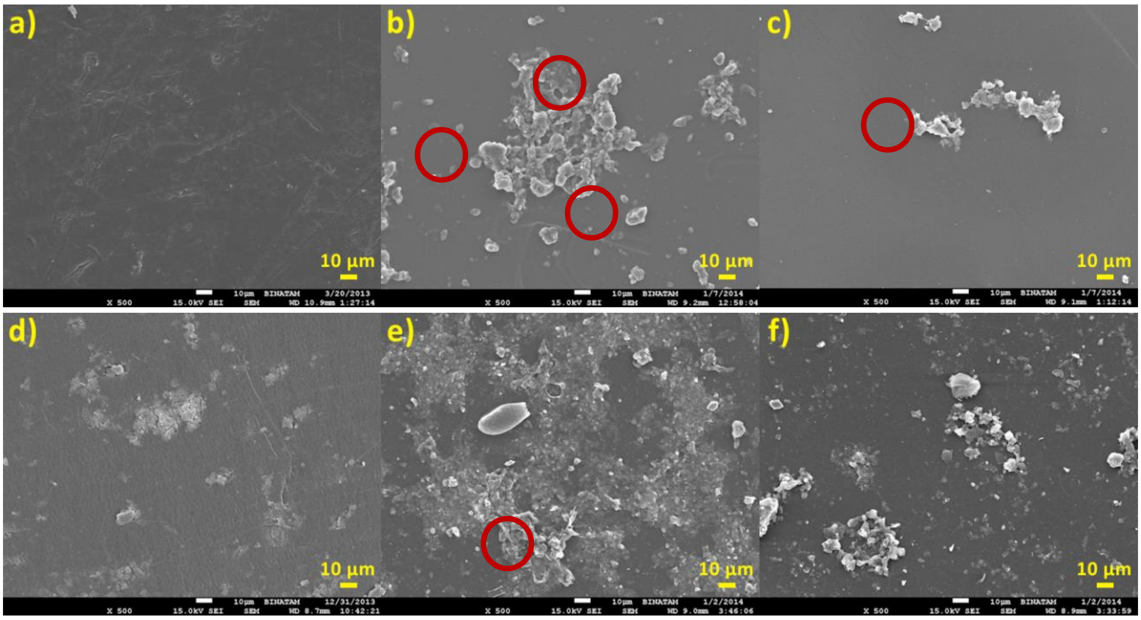


Fig 4. SEM spectra include (a) pristine UP020 membrane, (b) CS/MWTCNT-OH coated (dip) UP020 membrane, (c) CS/MWTCNT-OH coated (spin) UP020 membrane, (d) after filtration of Melen Lake water from pristine UP020 membrane, (e) after filtration of Melen Lake water from CS/MWTCNT-OH coated (spin) UP020 membrane, (f) after filtration of Melen Lake water from CS/MWTCNT-OH coated (dip) UP020 membrane.

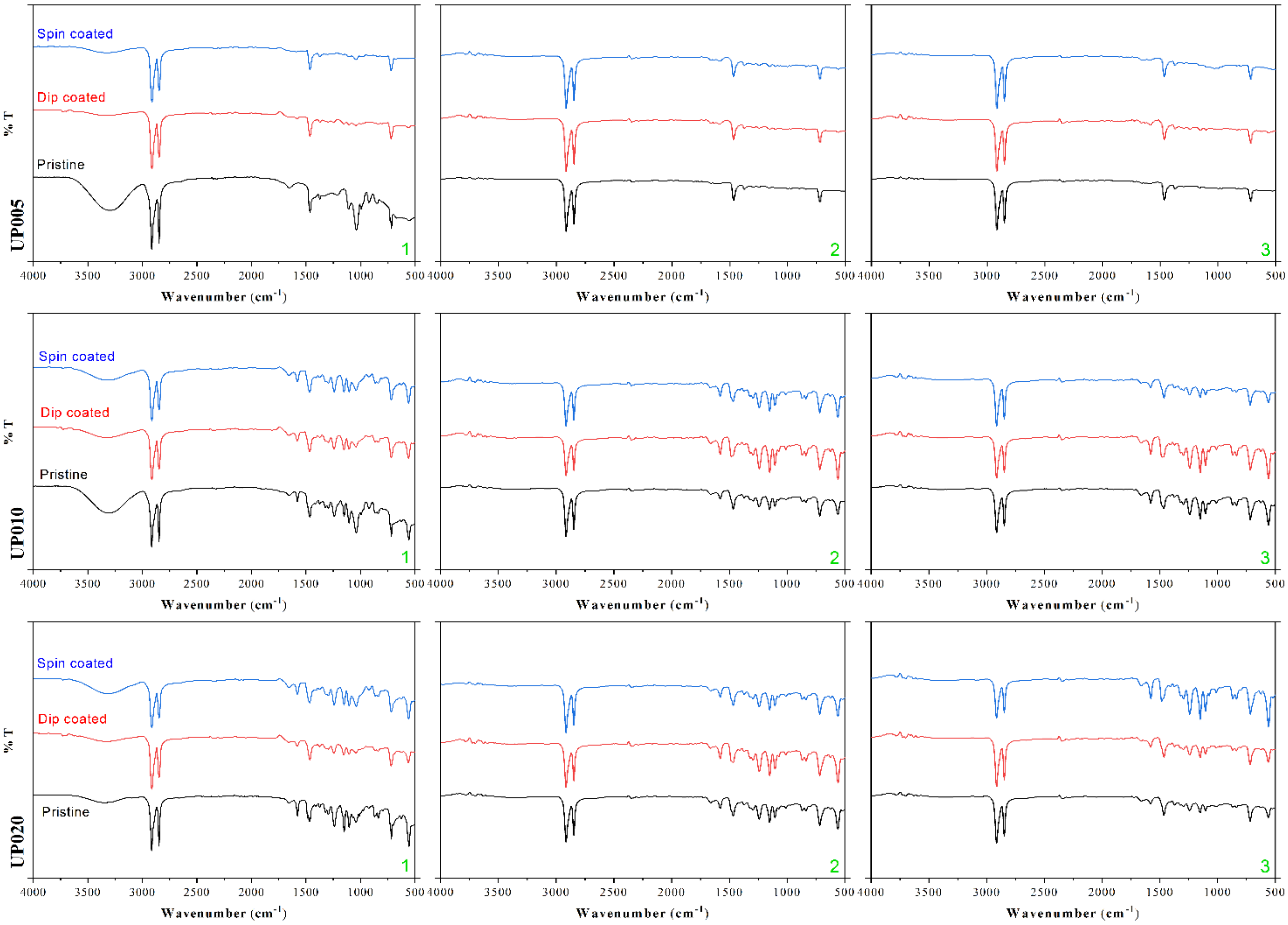


Fig 5. (1) ATR-FTIR spectra of (1) Clean UP005, UP010 and UP020 membranes; (2) fouled UP005, UP010 and UP020 membranes after filtration of Terkos Lake water; (3) fouled UP005, UP010 and UP020 membranes after filtration of Melen River water.

Changes in contact angle and flux: The water contact angle was employed as a metric to evaluate the hydrophilicity of the membrane surface. The contact angle values and fluxes of the pristine and coated membranes, as well as the values following filtering with water samples, are shown in Figures 6 and 7. The findings clearly demonstrated that the CS/MWCNT coating had a substantial impact on reducing the contact angle of the membrane. The inclusion of coated CS/MWCNT nanoparticles on the membrane surface led to an increased hydrophilicity of the membrane. Similar results were obtained in a study conducted by Masoumi et al. (2018), where the surface modification of PVC UF membranes with MWCNT resulted in a decrease in contact angle. The study noted that membranes modified with MWCNT exhibited higher hydrophilicity due to the hydrophilic nature of MWCNTs (Masoumi et al., 2018). Another study conducted by Hudaib et al. (2022) similarly observed a decrease in the contact angle of a PVDF membrane following modification with MWCNTs (Hudaib et al., 2022). Although the contact angle increases slightly after filtration with modified membranes due to foulant accumulation, they still demonstrate superior hydrophilicity compared to pristine membranes.

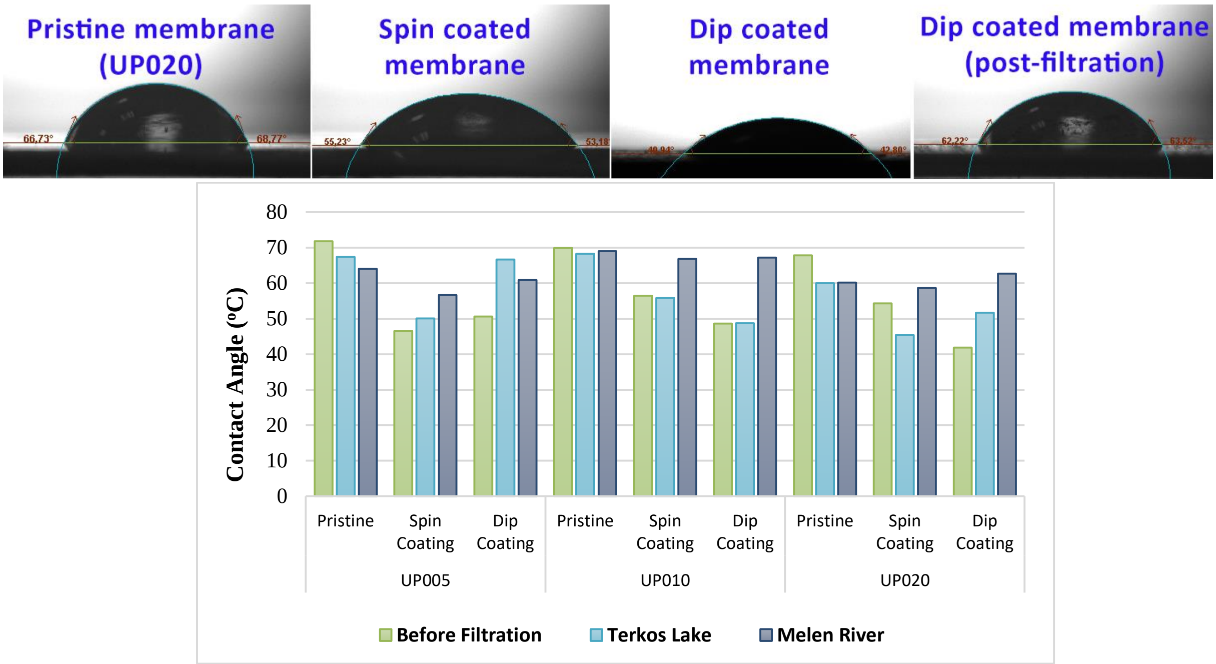


Fig 6. Contact angles of pristine and coated membranes.

The data depicted in Figure 7 clearly indicate that the pace at which substances pass through a membrane is greatly affected by the techniques used to apply a protective layer, the specific chemicals used in the coating, and the properties of the water being filtered. The flux of the pristine UP005 membrane, initially measured at 231.48 LMH, fell to a range of 174.6-152.11 LMH after being coated with CS/MWCNT. The decrease in flux can be attributed to the buildup of coating chemicals inside the pores of the membrane and on its surface during the coating process, which subsequently impedes the rate of flow.

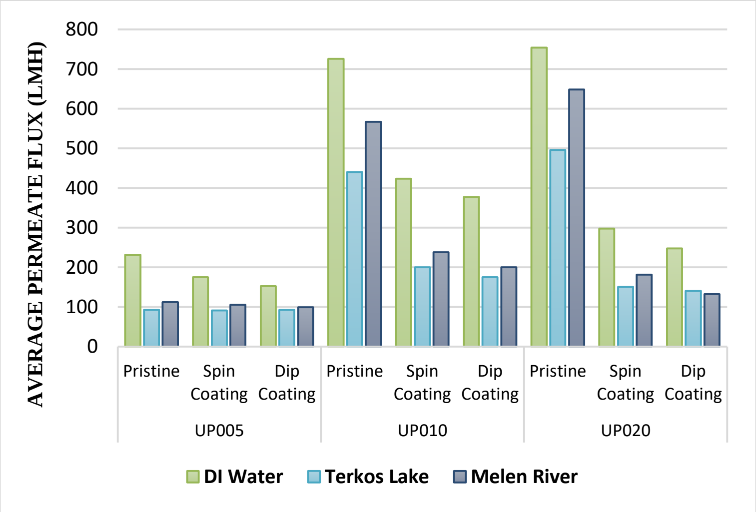
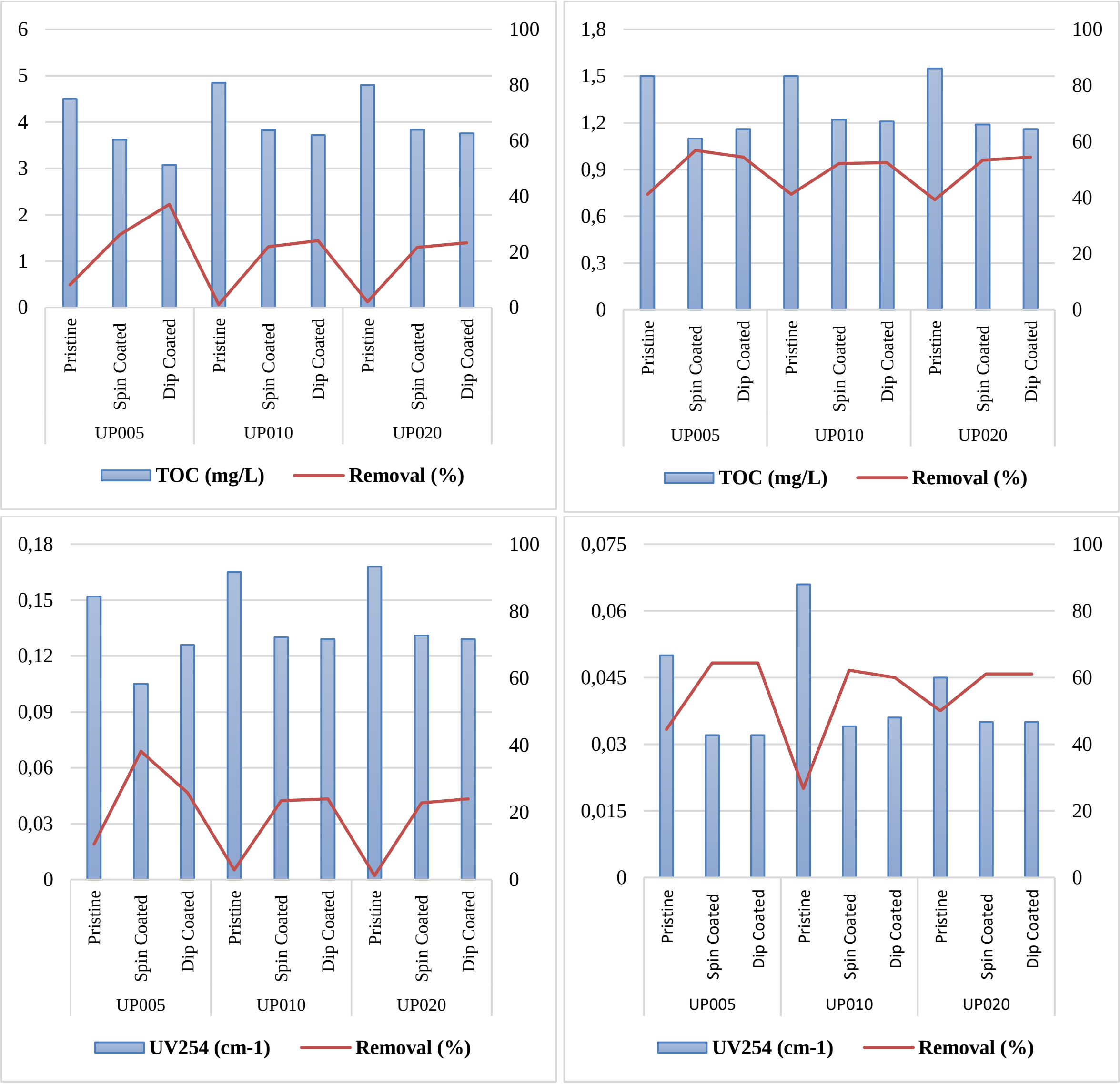


Fig 7. Changes in fluxes of pristine and coated membranes.

Dip coating is particularly noteworthy for its capacity to efficiently cover both the pores and surface, resulting in lower flux values compared to spin coating. Moreover, when comparing the filtration of lake and river waters to distilled water, a significant decrease in flow values is seen. The decrease in flux can be attributed to the blockage of membrane pores and surfaces due to the existence of organic and inorganic molecules.

Figure 8 offers valuable insights into the filtration efficiencies of both unmodified and treated membranes during the filtration of lake and river waters. The pristine membrane demonstrated only 8.6% efficiency in removing TOC from Terkos Lake water, and 41.17% efficiency in removing TOC from Melen River water. Nevertheless, the application of a coating to the membranes resulted in heightened efficiency in the removal of TOC. The membranes that were coated showed enhancements, achieving a TOC removal effectiveness of 37.14% for Terkos Lake and exceeding 56.86% for Melen River. Comparable trends were noted for additional variables, such as UV_{254}, THMOP, conductivity, and turbidity. Both pristine and coated membranes demonstrated similar rejection performances, reflecting the findings obtained for TOC elimination. Ultraviolet absorbance at a wavelength of 254 nm (UV_{254}) is used to measure the amount of aromatic compounds present in organic matter. Although the virgin membrane had a negligible effect on UV_{254} rejection, the coated membranes showed significantly enhanced performance, especially in the instance of Melen River.

The $SUVA_{254}$ values, ranging from 2 to 4, indicate that the organic matter has a moderate level of hydrophobicity. The virgin membrane displayed around 4% conductivity rejection for both water sources. Conversely, membranes that were coated exhibited greater levels of rejection, reaching roughly 20%. After conducting a comparison between the two coating processes, it was found that dip coating exhibited marginally better filtration performance than spin coating in all aspects.



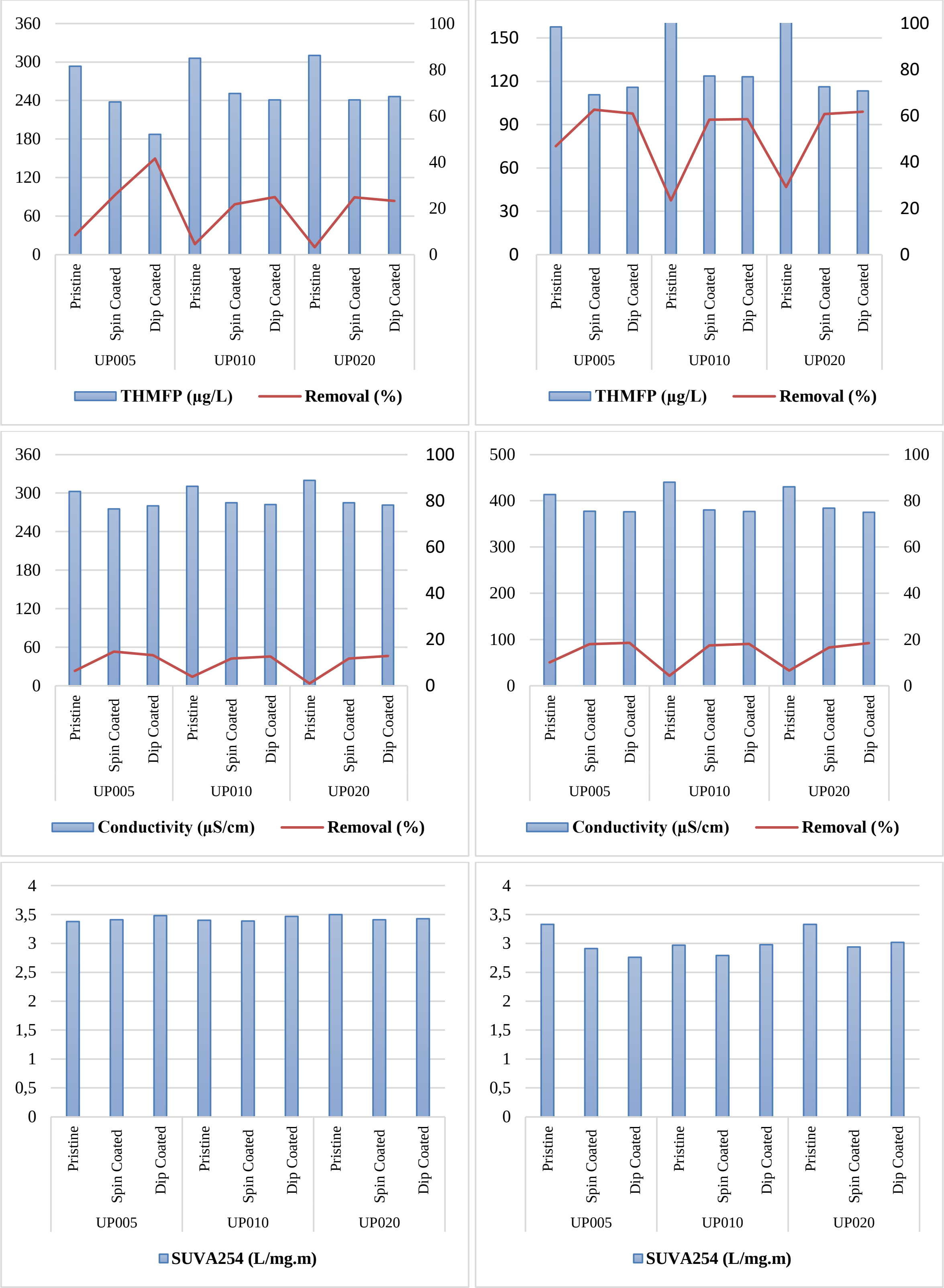


Fig 8. Filtration performance of pristine and CS/MWTCNT coated UF membranes for (a) Terkos Lake, (b) Melen River surface water.

CONCLUSION

This study investigates the impact of the CS/MWCNT coating on the filtration effectiveness of commercial UF membranes, employing two different sources of drinking water: Terkos Lake and Melen River. Surface morphology experiments demonstrated that the application of the CS/MWCNT coating caused changes in the membrane surface, resulting in an improvement in its hydrophilicity. As a result, this modification led to a higher level of resistance against fouling. The pristine membranes exhibited insufficient efficacy in removing TOC, UV_{254}, and THMOP. Nevertheless, the effectiveness of eliminating TOC significantly increased when a coating was applied, achieving a clearance rate of 37.14% for Terkos Lake and 56.86% for Melen River. Crucially, it was clear that the effectiveness of removing TOC from membranes coated with MWCNT was affected by the unique properties of the water source. The membrane fluxes showed variations that correlated with the size of the pores, and spin coating often led to greater flux values. The occurrence of this phenomenon can be attributed to the obstruction of both pores and the surface by CS/MWCNT nanoparticles while undergoing the dip coating procedure. The observed flow values were lower than the pure water flux value, mainly because of the accumulation of pollutants found in the filtered fluids, including both natural and manmade organic matter. The presence of these pollutants leads to their accumulation either on the surface of the membrane or within its pores, resulting in a decrease in the rate of flow. The application of surface coating resulted in an improvement in the filtration efficiency for the elimination of NOM. Nevertheless, this enhancement was accompanied by a decrease in membrane flow rate as a result of the reduction in pore diameter.

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