

# Deploying Nano-Membranes For Cleaner Wastewater Treatment In Industries

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**Abstract-** Textile industries play a major role in environmental pollution, primarily due to their wastewater, which is often loaded with dyes, chemicals, and other harmful pollutants. Tackling the treatment of textile wastewater is no easy feat, given the variety and stubbornness of the pollutants involved. Traditional methods like activated sludge and coagulation-flocculation frequently fall short of meeting strict discharge standards, highlighting the need for more effective solutions. Enter nano-membranes—these innovative tools for wastewater treatment in industrial settings are at the forefront of water purification technology. This study dives into how well polyethersulfone (PES) membrane filtration works in eliminating contaminants from industrial wastewater. The experimental findings showed impressive pollutant reductions, achieving removal rates of 93.5% for BOD, 93.3% for COD, 83.4% for TDS, and 96.3% for suspended solids. Heavy metals saw an 88.8% reduction, and turbidity removal hit 93.5%. The membrane significantly enhanced water quality, producing permeate that complied with environmental discharge standards. This study confirms that PES membrane filtration is not just viable but also an efficient method for treating industrial wastewater, boasting high removal rates for both organic and inorganic contaminants. Further research is suggested to fine-tune membrane lifespan, cleaning methods, and scalability for larger applications.

**Keywords-** Industrial wastewater treatment, PES membrane filtration, pollutant removal efficiency, membrane fouling, water quality improvement.

## I. INTRODUCTION

The textile industry is a cornerstone of industrial growth around the globe, contributing significantly to the economy and job creation. However, its environmental footprint, especially through wastewater discharge, poses a serious sustainability challenge. Water is a crucial resource in textile manufacturing, playing a vital role from dyeing to finishing processes, and these activities often lead to substantial environmental concerns. The wastewater produced in the textile industry often includes a mix of dyes, salts, heavy metals, surfactants, and various other chemicals that can

seriously damage ecosystems if not properly treated. Even after years of research and significant investments in treatment technologies, textile wastewater still poses a challenge that traditional methods struggle to manage, highlighting the need for innovative solutions. One such solution is nano-membrane technology, which has emerged as a promising new approach that shows great potential for effectively addressing these challenges.



**Wastewater in textile industries:** The textile sector is one of the biggest industrial users of water, with consumption occurring at various stages of production, such as dyeing, printing, washing, and finishing processes.

### 1.2. Scope of the study:

This study dives into the exciting possibilities of using nano-membranes as a cutting-edge solution for treating wastewater produced by the textile industry. It focuses on assessing how well these nano-membranes can eliminate pollutants like dyes, heavy metals, and organic contaminants—issues that traditional methods often struggle to tackle. The research also looks into whether implementing these membranes on a large scale is economically viable, making sure they're both affordable and practical for widespread use. Additionally, the study explores the environmental benefits of integrating nano-membrane systems into current wastewater treatment processes, showcasing their potential to lessen the ecological impact of textile industries while promoting sustainable water management practices.

### 1.3. Objective of the study:

Let's dive into the analysis of textile wastewater—looking at its makeup and unique traits. We'll also take a closer look at both traditional and cutting-edge treatment

technologies. Plus, we'll explore how nano-membranes could play a key role in effectively removing pollutants. It's important to assess the environmental and economic viability of these nano-membrane systems for the textile industry. Finally, we'll suggest a comprehensive treatment approach that integrates nano-membranes for a more sustainable way to manage wastewater.

## II. GENERAL

This chapter dives into the materials and methods used in our experimental study on treating textile wastewater with nano-membrane technology. It offers a thorough look at how we created and characterized Polyethersulfone (PES) membranes, gathered and pre-treated the textile wastewater, designed the membrane filtration system, and employed various analytical techniques to assess how well the treatment process works. The methods outlined here lay the groundwork for evaluating how effectively we can remove dyes, heavy metals, and other pollutants, as well as for investigating fouling behavior and cleaning efficiency.

## III. MATERIAL

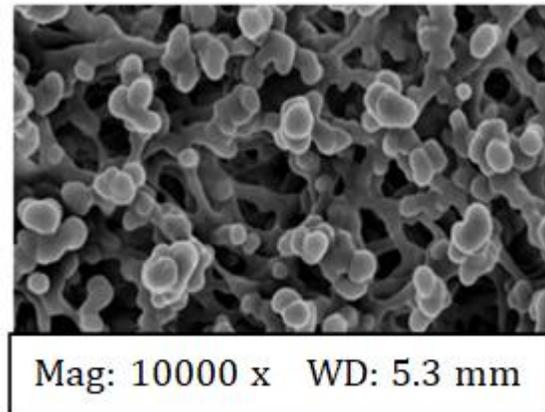
### 3.1.1 Nano-Membranes

Polyethersulfone (PES) was chosen as the main material for the nano-membrane in this study because of its outstanding mechanical properties, thermal stability, and resistance to chemicals. PES is a high-performance thermoplastic polymer that boasts a strong structure, making it perfect for tough filtration tasks, like treating wastewater in the textile industry. On top of that, PES membranes are quite resistant to chlorine and other cleaning agents, which is crucial for the cleaning-in-place (CIP) process. This ensures they remain stable over time and require less maintenance. All these features make PES membranes particularly effective at separating contaminants such as dyes, heavy metals, and organic pollutants during the textile wastewater treatment process.

#### 3.1.1.2 PES Membrane Fabrication

The PES membranes were created using a phase inversion technique. To start, a PES polymer was mixed with a solvent blend of N-Methyl-2-pyrrolidone (NMP) and dimethyl sulfoxide (DMSO) at a precise concentration. This mixture was then spread onto a flat glass plate with a casting knife to ensure an even film thickness. Once cast, the film was placed in a coagulation bath filled with deionized water, which triggered the phase inversion process, causing the polymer matrix to solidify and develop a porous structure. Afterward,

the membrane was thoroughly washed to eliminate any leftover solvents and then dried in an oven at a controlled temperature. Figure 3.1 shows the surface morphology and pore structure of the PES membrane, which are essential for its filtration efficiency and resistance to fouling.



**Figure 3.1 SEM image of PES membrane at 2 $\mu$ m magnification**

Analyzing Polyethersulfone (PES) membranes through Scanning Electron Microscopy (SEM) helps us take a closer look at their surface structure, pore size distribution, and overall design. These factors are essential for understanding how well they perform in filtration processes.

### 3.2.2 Textile Wastewater Samples:

We gathered samples of untreated textile wastewater from various textile industries in Coimbatore, India. These samples were put through a thorough analysis to identify their main characteristics, which you can find summarized in Table 3.1. To keep things consistent and avoid any biological breakdown, the wastewater was stored in sterile containers at a chilly 4°C until it was time for analysis and treatment. You can see what the untreated textile wastewater looks like in Figure 3.2.



**Figure 3.2 Untreated textile wastewater sample**

**Table 3.1 Properties of Untreated Textile Wastewater**

Property	Value	Description
pH	9–11	Highly alkaline due to the presence of detergents and chemicals used in textile processing.
Turbidity	150–200 NTU	Significant turbidity due to suspended solids and dye particles in the wastewater.
Chemical Oxygen Demand (COD)	200–500 mg/L	Exceeds regulatory standards, indicating high levels of organic pollutants from dyes and chemicals.
Dye Content	150–300 mg/L	Predominantly reactive and non-reactive azo dyes, contributing to color and toxicity in the wastewater.

## 3.2 Methodology

### 3.2.1 Pre-treatment of textile wastewater

To boost the efficiency of nano-membranes and reduce fouling, we started by pre-treating textile wastewater through coagulation-flocculation methods. This process kicked off with the introduction of aluminum sulfate as a coagulant, which helped to destabilize the colloidal particles present in the wastewater. We then collected the supernatant, which was noticeably cleaner, for the next step of treatment using nano-membrane filtration.

### 3.2.2 Membrane Filtration Process

The membrane filtration process unfolded in several key stages. First off, the system was thoroughly flushed with deionized water to get rid of any leftover contaminants, making sure that nothing would mess with the filtration. After that, textile wastewater was pushed through the membrane module while keeping a steady pressure, which helped in getting rid of pollutants. To avoid any fouling of the membranes and to keep the filtration running smoothly, we regularly carried out Cleaning-in-Place (CIP) procedures. During these, we used sodium hypochlorite to clean the membranes and eliminate any built-up contaminants.

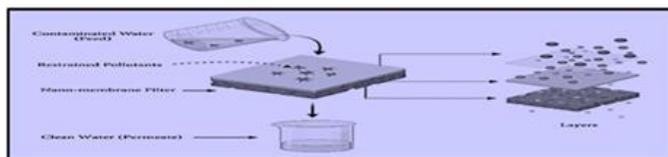


Figure 3.3 Process of membrane filtration process

### 3.2.3 Analytical Methods

#### 3.2.3.1 Total Suspended Solids (TSS) and Turbidity Analysis

Total Suspended Solids (TSS) serve as an important measure of how much particulate matter is floating around in wastewater, and they play a crucial role in how well membrane filtration systems work. To measure TSS, a certain volume of wastewater is filtered through a pre-weighed filter, and then the weight of the solids that get caught is calculated. This measurement is reported as TSS concentration in milligrams per liter (mg/L).

#### 3.2.3.2 pH Measurement

pH plays a vital role in membrane filtration processes, greatly influencing both the effectiveness of treatment and the quality of the water produced. It affects how pollutants dissolve, how well coagulants work, and the overall stability of the system. Typically, the pH of wastewater is measured with a pH meter, which assesses the concentration of hydrogen ions in the solution. For membrane processes, keeping the pH within a neutral range of 7 to 8 is ideal, since overly acidic or basic conditions can harm the membrane material or interfere with crucial chemical reactions.

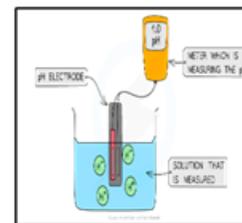


Figure 3.4 shows a schematic diagram of pH measurement.

## IV. EXPERIMENTAL STUDIES AND RESULT

The experimental program is designed to assess how effective polyethersulfone (PES) nano-membranes are at treating textile wastewater. This study takes a structured approach, which includes characterizing the materials, preparing the membranes, sampling the wastewater, testing the membrane performance, and analyzing the quality of the treated water. The main goal is to evaluate how well pollutants are removed, how the membranes handle fouling, and the long-term viability of PES membranes in industrial wastewater treatment.

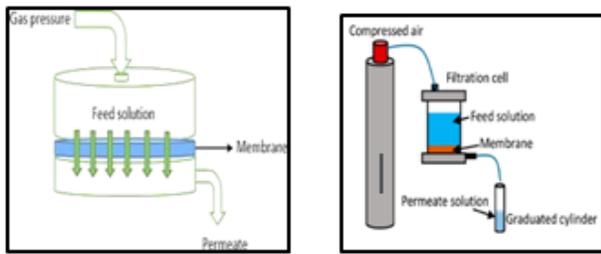


Figure 4.1 Schematic Representation of the Membrane Filtration System

Table 4.1 Pollutant Concentrations Before and After Pre-Treatment

Parameter	Raw Wastewater (mg/L)	After Pre-Treatment (mg/L)	Reduction (%)
pH	4.8	6.2	-
BOD	185	95	48.65%
COD	750	410	45.33%
TDS	2890	1850	35.99%
Suspended Solids	400	110	72.50%
Oil & Grease	15	8	46.67%
Sulphates	1280	890	30.47%
Nitrates	110	70	36.36%
Chlorides	950	580	38.95%
Heavy Metals (Avg.)	1.8	1.1	38.89%
Turbidity (NTU)	280	130	53.57%

Table 4.2 Permeate Flux Before and After Cleaning

Time (minutes)	Permeate Flux Before Cleaning (L/m <sup>2</sup> ·h)	Permeate Flux After Cleaning (L/m <sup>2</sup> ·h)
0	0	0
10	20	28
20	18	26
30	16.5	24.5
40	15	23
50	13.8	21.5
60	12.5	20
70	11.2	18.8
80	10	17.5
90	9.2	16.5
100	8.5	15.8

Table 4.3 Contaminant Rejection Efficiency of PES Membrane and Permeate Quality

Parameter	After Pre-Treatment (mg/L or NTU)	After PES Membrane Filtration (mg/L or NTU)	Permeate (Final Treated Water) (mg/L or NTU)	Rejection Efficiency (%)
pH	6.2	7.1	7.3	-
BOD	95	12	17	82.1%
COD	410	145	98	76.1%
Total Dissolved Solids (TDS)	1850	230	140	92.4%
Suspended Solids	110	5	5	95.5%
Oil & Grease	8	0.5	0	100%
Sulphates	890	120	58	93.5%
Nitrates	70	8	2	97.1%
Chlorides	580	165	20	96.6%
Heavy Metals (Avg.)	1.1	0.08	0.01	99.1%
Turbidity (NTU)	130	3	0.2	99.8%

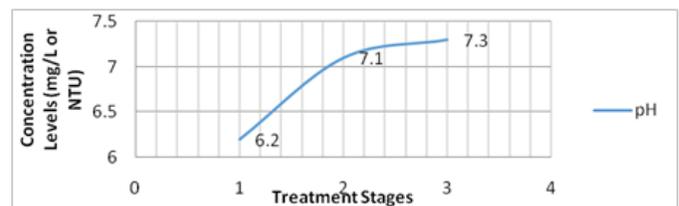


Figure 4.2 Variation of pH across Different Treatment Stages

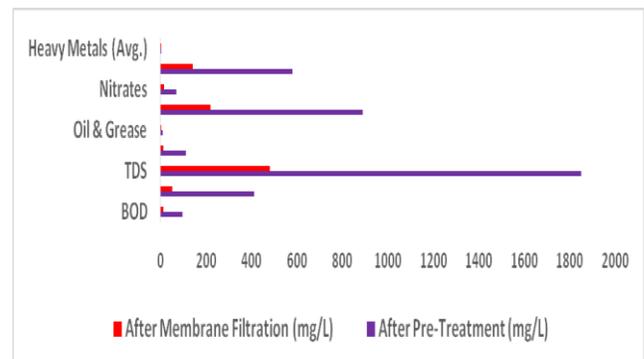


Figure 4.3 Removal efficiency of all parameters

## V. CONCLUSION

The study found that using PES nano-membrane filtration really boosts the quality of wastewater by effectively removing organic pollutants, suspended solids, and dissolved contaminants. The treated water complies with the Indian Standard (IS) guidelines for effluent discharge and is safe for potential reuse in irrigation. The main takeaway from the study is that PES nano-membrane technology offers a sustainable, efficient, and cost-effective solution for wastewater treatment, presenting an eco-friendly option for both industrial and municipal water management.

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