Membrane Treatment of Industrial Effluent

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Abstract :-Ultrafiltration is a viable, environmentally friendly alternative to today's physicochemical-based Industrial Effluent treatment methods. The social component is highlighted in this study as a weapon, a mirror by which the access to clean and reclamation of waste water management may take on new perspectives. It was carried out to determine the viability of using Micellar Enhanced Ultrafiltration as a clean technology for the treatment and reclamation of textile effluent and dye house wastewater.

The water treatment strategy mixing ultrafiltration (UF) and micellar-enhanced ultrafiltration (MEUF) approaches was primarily employed for the removal of water containing a wide variety of contaminants in textile industry water samples. Two distinct pigments, Reactive Red 218 (RR218) and Methylene Blue (MB), were tested for removal experiments. Using a stirred ultrafiltration cell, dye was removed from the aqueous stream using sodium dodecyl sulphate (SDS) and polysulfone membrane (MWCO 50 kDa). When compared to ultrafiltration, MEUF provided improved dye rejection but a lower permeate flow. Not only was the elimination achieved, but the physicochemical parameters were also within the limitations set by the Central Pollution Control Board (CPCB) and the Bureau of Indian Standards (BIS).The maximum removal of dye rejection for RR218 pulled off from 59% to 73% and for MB dyes it was from 67.5% to 87.%.

Keywords: -Industrial Effluent, Magnetic Stirred UF, polysulfone membrane, Micellar Enhanced Ultrafiltration.

INTRODUCTION

A considerable source of energy could be produced from the huge amounts of industrial effluents with high organic content that have been produced as a result of the global trend toward increasing industrialisation. For the generation of electricity, thermal energy, nuclear energy, and the growth of biofuels, water is necessary. For the maintenance of a healthy life and a healthy environment, fresh and safe water is required. Industries typically produce differently and undergo significant changes in product categories, which makes treating industrial wastewater more challenging. The most cost-effective and environmentally benign of these techniques is now biological treatment, which is utilised extensively in the treatment of industrial wastewater. The threat of environmental pollution has increased since the industrial revolution.

In today's world, environmental degradation is one of the biggest worries, and companies have a significant impact on how quickly our natural resources are depleted. Because these effluents typically include harmful substances that can seriously harm human health, they are frequently dumped into the ocean, causing the extinction of aquatic life. The heavy metal concentration, colour, and odour of these discharged effluents are their main physical characteristics. The solids in wastewater might be either insoluble or suspended, depending on their nature. Prior to discharge, businesses are advised to treat wastewater effluent in accordance with government standards. For the formation of wastewater and the release of effluents, there are some general standards. These techniques all have advantages and disadvantages.

Environmental destruction is among the most serious concerns in today's society, and businesses have a massive impact on how rapidly our mineral wealth are exhausted. These effluents are regularly thrown into the sea, triggering the extinction of marine organisms since they generally include hazardous compounds that can gravely impair human health. The principal physical features of such discharged industrial effluent are their heavy metal content, colour, and odour. Depending on their nature, the particles in wastewater may be insoluble or suspended. Businesses are urged to industrial effluents effluent in compliance with regulatory regulations prior to release. There are certain broad rules for the generation of pollution and the discharge of effluents. Each of these strategies has advantages and limitations.

The feeding rate and number of microorganisms can be adjusted by operators using a well-maintained continuous biological treatment system. A facility where wastewater from diverse sources is treated and then goes through posttreatment before being released into the environment is known as an effluent treatment plant (ETP).The sedimentation tank, slurry settler, or thickener is the principal component of the ETP. It should be stressed that the treated water produced by this procedure does not meet the standards for drinking water. The primary treatment goal is the sedimentation and skimming-based removal of organic and non-organic solids. To remove the remaining organics and suspended particles, the effluent is subjected to secondary treatment. When the aforementioned stages are insufficient, the advanced level of waste treatment known as tertiary water treatment is used. Water-borne infections account for approximately 66% of all ailments in India, and 70% of the accessible water is polluted. Water quality indicators such as acidity, alkalinity, pH, nitrogen, turbidity and TDS (total dissolved solids) must be measured both before and after treatment.

There are various toxic chemicals as well as hues in industrial effluents that are difficult to break down using typical treatment processes. Several treatment technologies, including biological, physical, chemical, and hybrid, have been developed to remove pollutants from textile wastewater. The presence of colour indicates that dye is present in the water. This tint hinders with photosynthesis by blocking sunlight from accessing the bodies of water where it is emitted. To remove dyes, several procedures are utilised, including electrocoagulation, adsorption, improved softening, UV-irradiated titania, biosorption, reverse osmosis, polyelectrolyte enhanced ultrafiltration, and nanofiltration. These procedures have previously been approved as efficient methods of separating different contaminants from wastewater. MEUF is a novel separation method that goes one step beyond NF. Toxic dye may be successfully removed from wastewater using MEUF. The concept "membrane tech" refers to a diverse range of various separation processes. Membranes are increasingly being used to transform wastewater, surface water, or groundwater into process water. The concept is simple: the membrane serves as a filter, permitting the passage of water through while trapping suspended particles and certain other items. Either dead-end flow or cross-flow can be used to control membrane filtering systems. There are two primary varieties: plate & frame membrane system and tubular membrane system. Capillary, tubular, and hollow fibre membranes are examples of tubular membranes. Spiral membranes and pillow shaped membranes are two categories of plate and frame membranes. The buildup of feed stream constituents on a membrane's surface, which increases hydraulic resistance, is known as membrane fouling. Fouling may happen in a number of ways and may be reversible or irreversible depending on the type and degree of fouling seen. Numerous emulsion, surfactant, and chelating chemicals are reliably separated via membrane separation. Although less than evaporation, the energy cost is greater than chemical treatment. Because oil emulsions cannot be "chemically separated," recovering secondary oil can be challenging.

Ultrafiltration, a specialised membrane filtration technology, enhances the pressure-mediated suspension of solid and infectious waste in waste mixes. The ultrafiltration technique produces an extremely pure good that is free of pathogenic waste. Ultrafiltration membranes are designed to remove specific pollutants from waste products using a pressure-driven approach. Ultrafiltration (UF) is a method that eliminates virtually all colloidal particles (0.01 to 1.0 microns) from water. Filters containing micellar and surfactant components can be used to extract heavy metals from trash. Certain contaminants can be separated using ultrafiltration membranes. Each UF membrane is classified by its manufacturer as having a certain molecular weight cutoff (MWC), which refers to an estimate of the size of pollutant cleared by a given UF membrane. When water with a molecular weight of around 100,000 Daltons is injected into the UF unit, the 100,000 MWCO UF separation process ensures that almost no material goes through the membrane. Materials with a molecular structure of 100,000 Daltons range in size from 0.05 microns to 0.08 microns. When using UF membranes, most pathogenic organisms and virtually all colloidal particles must be removed; however, most suspended particles can traverse the membrane without causing problems further down the line or in the end product water. Excluding the size of the molecules retained, ultrafiltration is basically similar to reverse osmosis, microfiltration, and nanofiltration.

UF readily removes colloids, proteins, microorganisms, pyrogens, macromolecules and proteins, larger than the membrane pores from water. An ultrafiltration system does not require electricity to function. With this method, water may be processed using natural pressure. To remove particles, water is pushed across a membrane. This method may be used to clean up muddy, dirty water. Ultrafiltration-based cleaners do not require much maintenance and can operate in peak condition for many years.

Even though the ultrafiltration technology is the most effective and powerful technique of water purification, it has a number of drawbacks. Colloidal and suspended particles that build in the pores and on the surface of the membrane restrict water from flowing through. Ultrafiltration cannot remove dissolved salts from water. Surface-water sources that amass biological pollutants over time may cause the system's membrane to fail, halting water flow. Surfactant micelles are employed to solubilize both inorganic and organic pollutants from the effluent stream in a technique called as micellar-enhanced ultrafiltration, or MEUF. MEUF is very efficient in removing isolated components such as ions and organic compounds. This includes the use of MEUF to remove different soluble compounds from water, such as ion, organics, and dyes, as well as the selection of materials and operation conditions (surfactant, filtering mode, membrane, , etc.). Zn2+, Cr3+, Cu2+, Ni2+, Ca2+, Pb2+, Sr2+, Fe2+, Co2+, As3+, Mn2+, and many other metal ions, such as phosphates, ferrocyanide, oxyanions, and organic compounds like -naphthol, phenol, p-nitrophenol, m-nitrophenol,o-chlorophenol, catechol. The bulk of metal ions are toxic and dangerous to the environment. Given the use of elevated permeability membranes and the requirement for a high operating pressure, micellar-enhanced ultrafiltration (MEUF) is a better option. MEUF is extremely effective in the elimination of single components such as Cd2+, Mn2+, Cu2+,Zn2+, and Cr3+. MEUF performance can be affected by the membrane's (MWCO) and material, the surfactant (types, features, dosage, surfactant-to-solute ratio), and the working conditions (UF mode, temperature, transmembrane pressure, pH).

According to studies, MEUF blends membrane-based separation's operational flexibility with the efficacy and simplicity of classic systems. MEUF might be used to eliminate wastewater if the contaminants have a small molecular weight. In comparison to the MEUF-hybrid approach, the traditional MEUF method has greater reagent and electricity expenses. Surfactants are used less in the hybrid technique. MEUF is regarded to offer a superior alternative to the currently available membrane separation technologies. The advantages of this method have been discussed. Other procedures have high removal efficacy, use minimal energy, and are easy to apply. The surfactant used in the removal procedure is selected based on the contaminants.

Surfactants are amphiphilic molecules with a hydrophilic head group and a hydrophobic chain and The kind of surfactant determines which types of solutes, ions, and/or organics may be eliminated in MEUF procedures. Critical micelle concentration (CMC) and micelle size are other important parameters in MEUF filtration. While certain surfactants are good to the environment, others are less efficient at removing ions or small organic molecules from aqueous streams. To validate the generation of micelles at a certain surfactant concentration, the CMC should be evaluated in the vicinity of all species. Given the lack of publications in MEUF that use "bio" surfactants, further research should be done. The current study's goal is to use the micellar-enhanced ultrafiltration (MEUF) membrane technology to address the physicochemical qualities of effluent and dye in an aqueous solution. The efficacy of an anionic surfactant, Sodium Dodecyl Sulfate (SDS), was investigated. A polysulfone membrane with a molecular weight limit of 50 kDa was used in stirred dead-end filtering. The mass transfer coefficient, observed dye rejection, effects of feed surfactant concentration on permeate flow, and variations in physicochemical characteristics have all been examined as a function of operating duration.

MATERIAL AND METHODS

2.1 Industrial Effluents Tested

The membrane was used to treat a real effluent coming from a nearby textile factory in Maharashtra. Then, using various techniques, the physico-chemical characteristics of the permeate and the effluent were determined.

By comparing absorbance to a calibration curve and using the common multiple dilution approach, colour was measured. By regulating the decline of the absorbance peak at the maximum wavelength for the global effluent, the decolorization was accomplished. The open reflux method is used to assess COD. The BOD5 Track Method is used to estimate BOD. The Standard Titration Method was used to analyse additional parameters. Using a pH-meter and Conducti-meter, respectively, the two parameters were measured in accordance with accepted procedures.

2.2 Materials

The surfactant Sodium Dodecyl Sulfate SDS (MW 288.38), Reactive Red218 (MW 852.15) and Methylene Blue (MW 319.85) were purchased from Kolhapur, Maharashtra.

2.3 Membrane

A polymeric membrane of molecular weight cut-off 50kDa was used for the experiments. The permeability of the membrane was 2.5×10^{-3} m/Pa.s. The properties of this membrane are given in Table 1.

Designation	PS 50 kDa
Polymer Type	Polysulfone
Molecular Weight Cut-off	50 kDa
Operating Pressure	<6bar
Operating pH	2 to 13
Maximum Temperature	150 °C

Table 1: -Membrane specifications

2.4 Ultrafiltration Cell

Millipore agitated ultrafiltration cells have a capacity of 100mL and are intended for the fast concentrating or purifying of macromolecular solutions. All types work in tandem with a spinning table. The table is magnetically connected to a stirring bar, which keeps fluid moving throughout operation and so mitigates the harmful effects of concentration polarisation.

The cell has a pressure-relief valve that is pre-set to nominally 75 psi (5.3 kg/cm2). 55 psi (3.9 kg/cm2) is the recommended operating pressure. Until the pressure relief valve is released and the cap is lowered, the cell stays trapped in the retaining stand. The stand has a big base for increased cell stability. Stirred dead-end filtration studies were carried out in an 80 mL stirred cell. The effective membrane area was 11.34cm2 and the membrane diameter was 38 mm. The maximum operating pressure was 10psi (0.69 bar).

2.5 Experimental Design

Filtration tests were performed out in agitated dead-end filtration using (i) the effluent sample, (ii) just dye, (iii) a sample and surfactant mixture, and (iv) a surfactant and dye mixture. Each ultrafiltration experiment took around 90 minutes per effluent sample, sample-surfactant, dye solution, and dye-surfactant combination. The purpose of these studies was to determine the influence of feed concentration of surfactant on permeate flow and dye rejection. For sample filtering, 30 ml of sample was used, and SDS values above the threshold micellar concentration were used (CMC). A feed volume of 0.050 g/L was used for dye filtering. The dye concentration was held constant at 0.050 g/L in the dye and surfactant combination, and CPC concentrations were chosen just above critical micellar concentration (CMC).

2.6 Experimental Procedure

Nitrogen was used to pressurise the cell. For 24 hours, membrane was then compacted using distilled water. Water flux was monitored continually during membrane compaction until a consistent flux was reached. Water flow was determined at a variety of operating pressures, and the permeability of membrane (Lp) was calculated using the slope of the flux vs. pressure curve. At room temperature, the operating pressure was kept constant at 19.61 KPa. All test's dye feed solution was prepared by weighing and dissolving suitable amounts of dye and surfactant in distilled water. Following the filling of the cells with feed solution, a pressure regulator was used to maintain the working pressure. The bottom cell's permeate was collected, and the accumulated volume was continually measured. The concentrations of permeate were determined spectrophotometrically. After each trial, the cell and membrane were thoroughly cleaned with distilled water. Membrane permeability was tested, and it was discovered that it fluctuated within 2.000% of the initial measured value. All studies were carried out at standard room temperature (32±2°C). Figure 1 depicts a schematic of the experimental design.

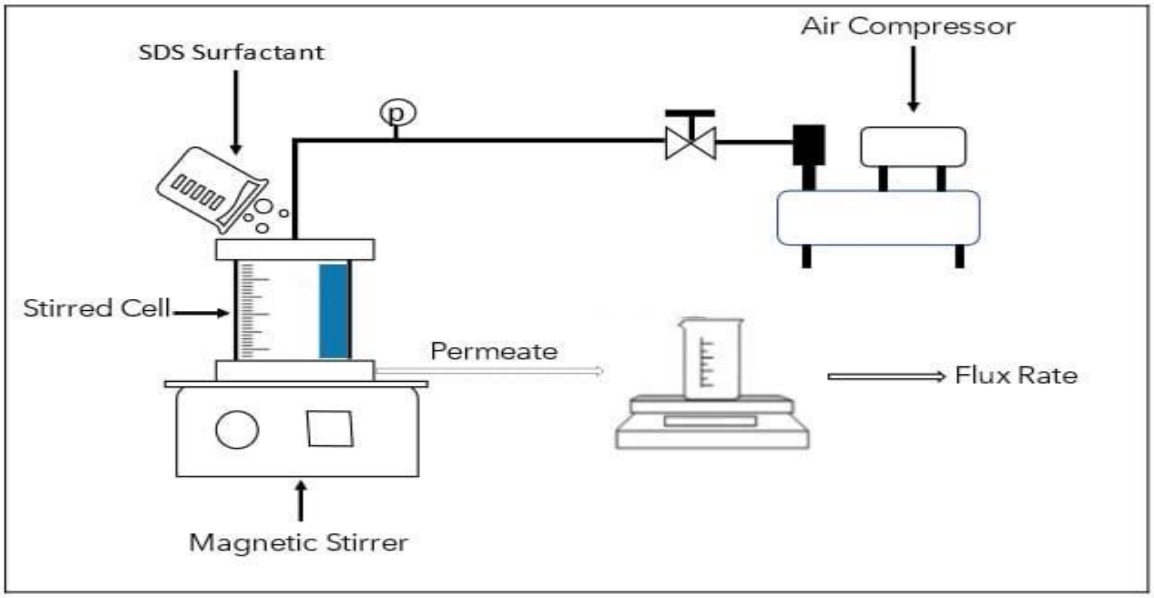


Figure 1: -Experimental Setup

2.7 Analysis

The dye concentrations in the feed and permeate were determined using a UV-Vis Spectrophotometer. The maximal absorption wavelengths for Reactive RED 218 were 629 nm and 447 nm for methylene blue.Observed permeate flux and dye rejection can be calculated using Eq. (1) and Eq. (2) below

$$\mathbf{Jp} = \frac{V}{At} \qquad (1)$$

where *Jp* denotes permeate flux (m^3/m^2hr), *V* indicates permeate volume (m^3), *A* symbolizes the effective membrane area (m^2) and *t* provides the sampling time (hr). Permeate samples will be taken at the same time for water quality examination.

The rejection coefficient R% is calculated as a percentage according to Eq. (2)

$$\mathbf{R\%} = \left(\mathbf{1} - \frac{\mathrm{Cp}}{\mathrm{Cf}}\right) \times \mathbf{100} \qquad (2)$$

where *Cf* represents the concentration in the feed stream (g/L) and *Cp* denotes the concentration in the permeate stream(g/L).

Mass transfer refers to the net movement of mass from one location to another (typically a phase, fraction ,stream,or component). Mass Transfer over an interfacial or along a virtual surface in the majority of a phase is caused by a chemical potential driving force. This driving force is frequently portrayed in terms of species ratios or partial pressures in the instance of gas phases. The rate of transfer of a certain species per unit area adjacent to the surface, known as the species flux, is impacted by certain physical properties of the system in addition to the degree of Turbulence of the process involved. In general, the relationship between flow and these factors is not easily established using mass transfer principles, therefore mass transfer coefficients summing them all have been defined.These definitions are of the following format:

Flux = coefficient. (Concentration difference).

There are numerous flux expressions for species traversing an interface based on different driving factors. According to film theory, the experimental mass transfer coefficient k may be computed as follows:

$$\boldsymbol{Jp = k\ ln\frac{Cp}{C}} \qquad (3)$$

where where *Jp* is the permeate flux (m^3/m^2.sec),*Cp* and *C* are the concentrations of permeate and flux (mg/m^3), and *k* is the mass transfer co efficient (m/sec).

RESULT AND DISCUSSION

3.1 Characteristics of Sample and demonstration of ultrafiltration of sample before and after treatment.

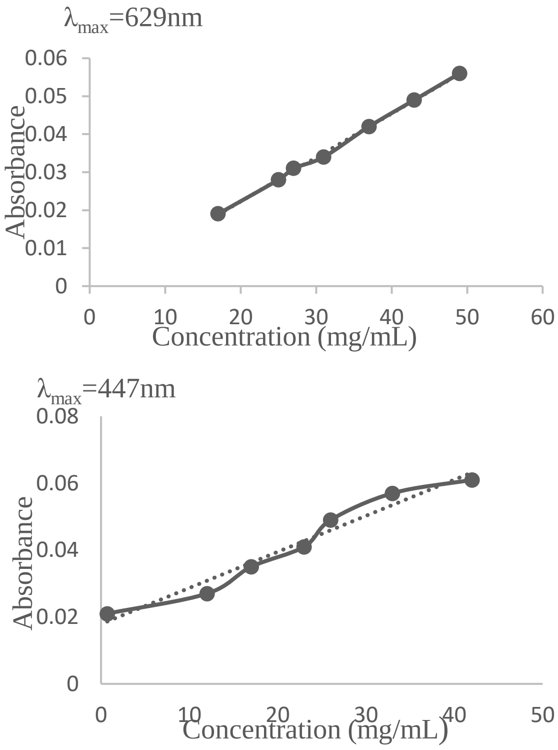
The sample effluent was stored at room temperature. Table 2 summarizes the physico-chemical parameters of the effluent, to verify repeatability, each sample was tested in triplicate, and the round value was taken into account.

Table 2: -Characteristics of Sample before and after treatment.

Effluent Characteristics	Value	Ultrafiltration	M.E.U. F	Max.Limit (Asian Journal of Chemistry Vol 25, No.16,2013)	Tolerance Value Limit of	
					CPCB	BIS
pH	8.1	7.9	7.7	5.5-10.5	6.5-8.5	6.5-8.5
Total Alkalinity(mg/L)	657	616	601	500-800	-	-
Chloride(mg/L)	210.93	117.67	101.89	200-6000	600	600
Oil&Grease(mg/L)	45	39	34	10-50	10	100
TDS (mg/L)	3310	3001	2730	1500-6000	2100	500
COD (mg/L)	1780	1707	1600	150-10000	250	500
BOD (mg/L)	186	169	150	100-5000	30	500
Electrical Conductivity(mS/cm)	38.7	35.09	29.9	20-100	-	-
Colour (P.C.U)	1450-4750	470	164	-	150	100
Total Hardness	209	159	123	-	-	300

3.2 Spectrometric representation.

Using a UV-visible spectrophotometer, it was discovered that the reference wavelengths for the dyes Reactive Red 218 and Methylene Blue were 629 nm and 447 nm, respectively. The absorbance was measured for a range of known dye solution concentrations based on the reference wavelength. Using these values, the calibration curve (Fig. 2) for both dyes was created. We can quickly determine any unknown dye solution concentration using this calibration curve.



(a) (b)

Figure 2:-Absorbance of Reactive Red 218 and methylene blue concentration curve at 629 and 447 nm wavelength respectively

3.3 Variability in permeate flow during dye solution ultrafiltration in the lack and availability of surfactant.

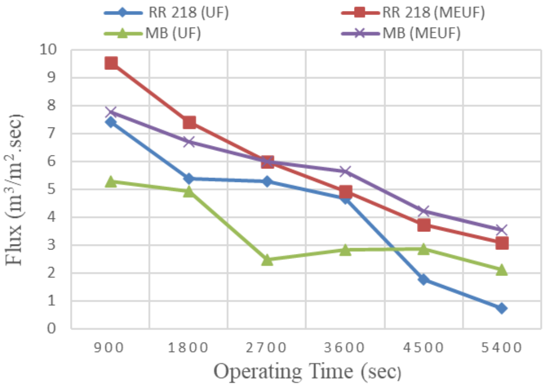


Figure 3: - Variability in permeate flow during dye solution ultrafiltration in the lack and availability of surfactant.

The above graph depicts the variation in permeate flow for MB dye and RR218 dye in the existence and exclusion of surfactants. The graph clearly shows that the permeate flow reduced with time for both the MEUF and UF processes. Because the dye particle could readily flow across the screen in the UF process, there was less cake building because the solvent flux over the membrane was less resistant. However, the preponderance of the micelles were maintained on upper edge of the membrane surface during the MEUF process. When surfactants were applied just above critical micellar concentration, significant aggregates of surfactant micelles were formed (CMC). This resulted in the formation of a layer on the membrane's surface, which increased the membrane's resistance to solvent flow. In contrast to the dye concentration alone, this resulted to a diminution in the permeate flow.

3.4 Variability in observed rejection during dye solution ultrafiltration in the lack and availability of surfactant.

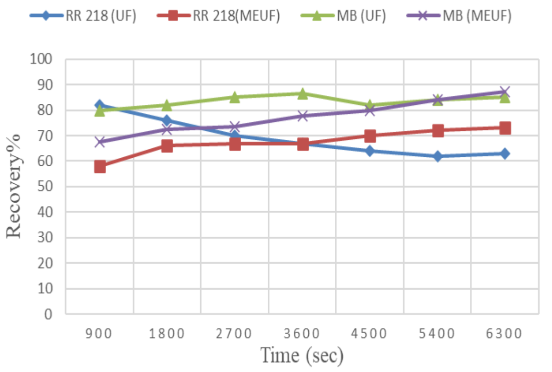
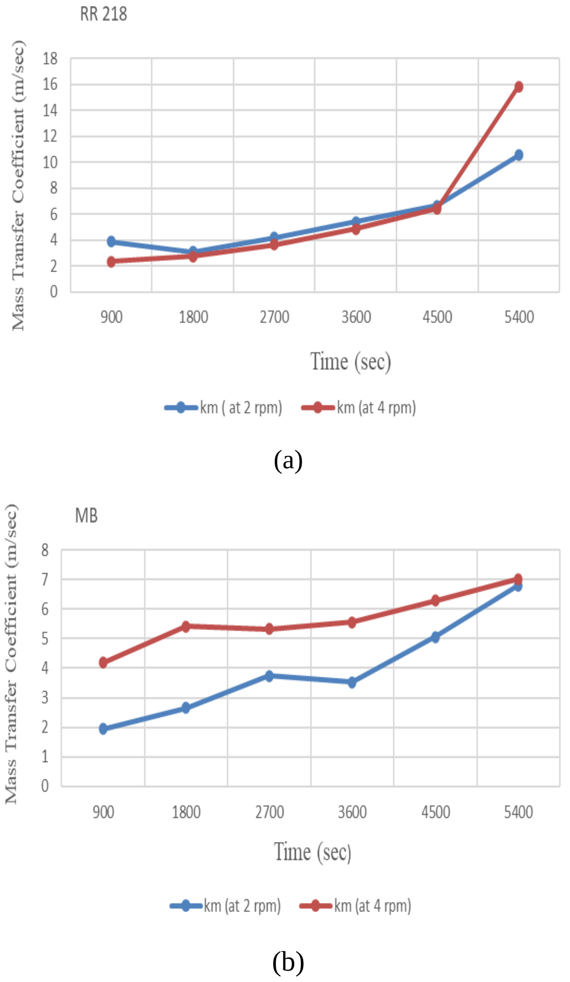


Figure 4: - Variability in observed rejection during dye solution ultrafiltration in the lack and availability of surfactant

The graph above depicts the difference in dye rejection for MB dye and RR 218 dye in the absence and presence of surfactant. It illustrates that dye rejection decreases with time in UF (no surfactant) settings. Interestingly, for both RR 218 and MB dyes, the recorded dye rejection for the UF process was lower than for the MEUF approach. The pigment particle size was too tiny for the membrane pores employed in the investigation (MWCO 50). More dye particles may quickly pass over the membranes to the permeate side, causing an increased permeate concentration and decreased dye rejection. MEUF (in the presence of a surfactant) indicated that dye rejection increased over time.. The estimated dye rejections for RR 218 and MB for UF (without surfactant) were 59% and 67.5%, respectively, as shown in this figure. When surfactant was added, the reported rejection rates of MB and RR218 dyes increased to 73% and 87.3%, respectively. Based on the assessment of the MEUF and UF techniques, the colours were solvated inside the bigger surfactant micelles. The majority of the micelle particles caught on the membrane surfaces were then rejected by the ultrafiltration membrane.

3.5 Variation in Mass Transfer Coefficient for dye solution with surfactant.

We see that the above equation (3) is comparable to the general equation for a straight line with a positive slope crossing the origin (y = mx), thus we should already have a good idea of how this function's graph might look. In this case, the dependent variable is flux, and the independent variable is gradient. The graph seems to be as follows when plotted:



(a)

(b)

Figure 23:- Variation of mass transfer coefficient during ultrafiltration of dye solution with surfactant.

As can be seen, as the rotating speed is raised, the mass transfer coefficient increases for both of the dyes (with surfactant) under investigation. When we are aware, as velocity rises, the mass transfer coefficient rises as more fluid components enter the mass transfer contact. Fresh fluid components will increase the mass transfer driving force and, as a result, the molar flux if they come into contact with the interface.

CONCLUSION

Micellar Enhanced Ultrafiltration is strongly recommended for the removal of all elements that make textile effluent a nuisance. Ultrafiltration membrane treatment is one of the key techniques for the industrial wastewater treatment. MEUF might be an alternate technique with a high potential for pollution rejection from wastewater. The settings of micellar-enhanced ultrafiltration differed significantly. Furthermore, micellar-enhanced ultrafiltration (MEUF) of RR218 and MB dyes in SDS solution was investigated using 50kD attenuated composite membranes at a pressure range of 18-20 kPa and a consistent concentration of dye of 0.050 g/L. In the tests', stirred ultrafiltration was employed. Under various experimental conditions, the reported color rejections and permeation flux characteristics of MB and RR218 dyes are tested and analyzed. In terms of dye rejection, MEUF beat ultrafiltration while producing less permeate flux. At lower working pressure and higher membrane MWCO, the MEUF method easily separated reactive dyes from an aqueous environment. At SDS, the dye rejection rate for RR218 dyes and MB dyes was 67.5% and 87.3%, respectively.

A comprehensive water management plan for the textile industry is presented, which incorporates recycling. The efficiency of this membrane in processing a specimen of commercial textile wastewater in terms of pollutant removal and permeate flow is evaluated. The polysulfone UF membrane was restored using a new process based on acid-basic washing. Recognizing the MEUF process system and surfactant selection is critical for this approach to perform more successfully. Given the promising results of the experimental study, the technique is expected to be technically and economically viable for commercial usage, and it has the potential to decrease freshwater discharge and wastewater outflow in half. This research aims to shift the perception of wastewater from a nuisance that must be rid of to a resource that should not be squandered and may increase the availability of energy, water security, and human and ecological health.

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