Analysis of Membrane Methods Application for Treatment of Textile Wastewater

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Abstract. Wastewater of textile enterprises may be significantly different in concentration of main pollutants and thus implemented methods of treatment. The technological solutions have to meet the requirements of wastewater disposal and discharge of treated water into fishery water bodies. The choice of the wastewater treatment technique for textile enterprises depends on many factors: capacity (flow of wastewater), the possibility and feasibility of extracting impurities from wastewater, the requirements for the quality of treated water when it is reused or discharged. Dimensions of membrane bioreactors afford installation of them in conditions of limited space. Operation of membrane bioreactors may be easily provided by filtered wastewater even at wastewater treatment plants of low capacity, so pure water use is not required. The combined Fenton oxidation and the process of membrane sludge separation as an advanced wastewater treatment with integrated dyeing wastewater treatment plant to reduce total organic carbon and coloration. The system has three steps of treatment: the Fenton oxidation unit, which is an aerated continuous reactor with a mixer, a neutralization tank that equalizes the pH value of the influent and MBR.

1. Introduction
Wastewater of textile enterprises may be significantly different in concentration of main pollutants and thus implemented methods of treatment. The technological solutions have to meet the requirements of wastewater disposal and discharge of treated water into fishery water bodies. Wastewater treatment of textile enterprises is carried out with the use of basic technological operations - mechanical, physical and chemical, biological treatment. Modern membrane and electrochemical methods can also be used. These may be an alternative to conventional wastewater treatment facilities for textile industries, as well as food, petrochemical, machine-building industries industries [1].

According to the volume of natural water consumption and wastewater discharge, one of the leading places in textile enterprises is occupied by dyeing and finishing workshops. The specific consumption of natural water and, accordingly, wastewater in them is about 70-400 m³ per ton of products. It was found that more than 50 types of organic and mineral compounds are present in the wastewater of paint and finishing shops [2,3].

Depending on the class of dye, the type of material to be dyed and other parameters, 5-50% of the initial amount of dye passes into the wastewater [4]. The maximum permissible concentrations of dyes in water are relatively low and range from 0.1-0.0025 mg/L. In this regard, research is being conducted in many countries of the world to improve existing and develop new methods of wastewater treatment [5]. It was found that membrane processes lead to a decrease of more than 90% in color,
turbidity and suspended particles, as well as to a decrease in COD. In addition, it was found that the formation of sediment occurs already at the initial stage of filtration, but during the microfiltration and ultrafiltration processes, its amount is small, while during the nanofiltration process, its amount progressively increases. It was revealed that various methods of wastewater treatment in the silk and knitting industry, including flotation, flotation in combination with oxidation and adsorption, biological treatment electrodialysis, ultrafiltration. Preference is given to the use of sorption and membrane methods [6].

The most priority task in wastewater treatment of industrial enterprises is the creation of zero-liquid discharge technological processes based on modern equipment [7-9]. The choice of the wastewater treatment technique for textile enterprises depends on many factors: capacity (flow of wastewater), the possibility and feasibility of extracting impurities from wastewater, the requirements for the quality of treated water when it is reused or discharged.

Within last decade, the scope of membranes’ application for water purification and treatment of wastewater was broaden intensively worldwide. If to focus on membrane bioreactors (MBR, fig.1) for wastewater treatment, they have the most solid outlooks as a technology fitted for various type of objects with variable flow capacity – treatment of urban sewage (no matter how big the town is), industrial wastewater systems, or even treatment of wastewater of single object. As the previous research showed, MBRs require 1.5-2 times less square and volume for their placing if to compare with conventional technologies, so their installation can even be possible in conditions of limited space. Operation of membrane bioreactors may be easily provided by filtered wastewater even at wastewater treatment plants of low capacity, so pure water use is not required.

![Figure 1. Typical membrane treatment processes.](image)

2. Materials and methods
In this research, wastewater of dye baths was taken into investigation. In the dye bath, the fabrics are printed with colored stamps or patterns. The usual way is by using roller machines [10-12]. The color is transferred to the fabric of the drums containing the printed media. This media is a combination of dye, thickening and hygroscopic substances, coloring, and water itself. The dye baths pollution is mainly occurred during the washing process when the equipment has to be cleaned and a fabric has to be rinsed. The pollution concentration of biological oxygen demand (BOD) is relatively low [13-15]. During printing and dyeing processes, the BOD estimates 17% of total pollution load, that is mainly caused by chemical agents in use.
Table 1. Type of compounds used dying process.

| Type of dyes | Chemical compounds |
|--------------|--------------------|
| Black aniline| Aniline hydrochloride, sodium ferrocyanide, sodium chloride, pigment, soap |
| Diversed     | Dye, penetrant, sodium chloride, sodium nitrate, hydrochloric acid or sulfuric acid, developer (beta-naphthol), soap or sulfated soap or fatty alcohol. |
| Direct       | Dye, sodium carbonate, sodium chloride and wetting agent or soluble oil or sodium sulfate |
| Naphtol      | Dye, caustic soda, soluble oil, alcohol, soap, soda ash, sodium chloride, base, sodium nitrate, sodium nitrite, sodium acetate |
| Sulphur      | Dye, sodium sulfide, sodium carbonate, sodium chloride |
| Cube dye     | Dye, caustic soda, sodium hydrosulfite, soluble oil, gelatin, perborate and hydrogen peroxide |

Table 2. Properties of wastewater specific for various processes.

| Process          | Major pollutants                          |
|------------------|------------------------------------------|
| Desizing         | High BOD, neutral pH, high TSS           |
| Scraping         | High BOD, high alkalinity, high TSS, high temperature |
| Whitening        | High BOD, alkaline pH, high TSS, high temperature |
| Mercerization    | Low BOD, alkaline pH, low TSS            |
| Dying and printing| High BOD, high TSS, neutral to alkaline pH |

A combination of membrane bioreactor and Fenton oxidation is an advanced wastewater treatment with integrated dyeing wastewater treatment plant to reduce total organic carbon and coloration of 38% and 70% respectively after the reaction of 35 minutes in optimum conditions of Fenton's oxidation (initial value pH 5, H₂O₂ dosage 17 mmol/l and Fe²⁺ 1.7 mmol/l). Additional purification by membrane bioreactors shows the efficiency of COD and TOC (total organic carbon) removal at the level of 86% at different hydraulic retention time. The final flow of the MBR meets the criteria for the reuse of urban water recycling standards, but still it showed less stability than it was expected.

The system has three steps of treatment: the Fenton oxidation unit, which is an aerated continuous reactor with a mixer, a neutralization tank that equalizes the pH value of the influent and MBR.

Figure 2 shows the system, in which Fenton oxidation must go under optimum operating conditions, determined using the “test with the banks”. The Fenton oxidation effluent goes to accumulation tank, after which it is pumped to membrane bioreactor in continuous mode. After the adaptation of for further purification using a continuous MBR processing system. Performance features can be estimated after a certain period of adaptation. After acclimatization, various parameters and performance characteristics are evaluated during the long-term operation.

![Figure 2. Pilot plant scheme.](image-url)
3. Results
The flow capacity of bench-scale wastewater treatment plant is 50 L per day. The immersed (or submerged) membrane bioreactor has dimensions of 40x40x30 cm (that gives the entire volume of 47 litres), and is equipped by the ultrafiltration membrane cassettes allows the COD by 88%. The hollow-fiber membrane cassettes are connected to the supply and vacuum pump for simultaneous operation. The membrane bioreactor is also equipped with coarse bubble aeration system and compressor to withstand fouling. Performance control is maintained by means of sensors for operation parameters (level, pressure, airflow) and for technological parameters (dissolved oxygen, pH, temperature, conductivity etc.)

The reverse osmosis was used after MBR treatment to provide stable treatment process of dye bath wastewater. The reverse osmosis process uses polymer membranes (normally produced from cellulose acetate or nylon), to provide water (and wastewater) purification at high speed (and high pressure, respectively) and to separate salts. The operation pressure should be quite high to surpass the osmotic pressure and provide a downforce to supply water from the reject compartment through the membrane to the clean water compartment.

![Graph showing reduction of pollutants](image)

**Figure 3.** Research results.

RO membranes can be exposed to fouling due to organic substances, colloids and microorganisms. Reverse osmosis process normally needs that wastewater should be pre-treated in order to remove pollutants such as suspended particles or ions of iron and magnesium. Only after pre-treatment, the efficient treatment can be provided at reverse osmosis cassette. The pore size reverse osmosis membranes provides the retention of all soluble compounds, while ultrafiltration membranes can retain only macromolecules and suspended solids. The table 3 and figure 3 shows the reduction of pollution at bench-scale model. As it can be seen reverse osmosis process provides an extra-high quality of treatment for main parameters.
Table 3. Parameters of treatment process.

| Parameters | Raw sewage | MBR | RO-1 Permeate | Discharge | RO-2 Permeate | Discharge |
|------------|------------|-----|---------------|-----------|---------------|-----------|
| pH         | 9,88       | 6,92 | 6,03          | 6,72      | 5,76          | 7,04      |
| TSS [mg\text{L}^{-1}] | 167        | 19   | 6             | 70        | 6             | 124       |
| COD [mg\text{L}^{-1}] | 586        | 70   | 26            | 327       | 17            | 754       |
| BOD [mg\text{L}^{-1}] | 190        | 41   | 1             | 16        | 0,2           | 208       |

4. Conclusions
1. Membrane methods proved to be among the most efficient for the treatment of wastewater of textile industry allowing obtaining necessary quality.
2. Treatment by means of single MBR showed relatively good results however they required more stability.
3. According to the results of bench-scale research combination of MBR and reverse osmosis showed great potential for the further implementation.

5. References
[1] Makisha N, Kulakov A 2018 MATEC Web of Conferences 178 09018
[2] Andrianov A, Govorova Z 2019 E3S Web of Conferences 100 00001
[3] Gulshin I 2017 IOP: Earth and Env. Sci. 90 012198
[4] Pervov A, Tikhonov K, Dabrowski W 2018 Desalination and Water Treatment 110 1-9
[5] Kang X, Cheng Y, Wen Y, Qi J, Li X 2020 J. of Hazardous Mat. 4005 123121
[6] Teow Y H, Amirudin S N, Ho K C 2020 J. of Water Process Eng. 34 101182
[7] Saeid Hosseini S, Nazif A, Shahmirzadi M, Ortiz I 2017 Separation and Purification Technology 187 46-59
[8] Zou D, Chen X, Qiu M, Drioli E, Fan Y 2019 Separation and Purification Tech. 21515 143-154
[9] Peydayesh M, Mohammadi T, Bakhtiar O 2018 Separation and Purification Tech. 1943 488-502
[10] Pervov A G 2017 Petroleum Chemistry 57 (6) 532-535
[11] Zhang W, Liu F, Wang D, Jin Y 2018 Bioresource Tech. 269 269-275
[12] Galkina E, Vasyutina O 2018 IOP: Materials Sci. and Eng. 365 (2) 022047
[13] Sathya U, Keerthi M, Nithya N 2019 Balasubramanian J. of Environ. Manag. 246 768-775
[14] Cinperi N C, Ozturk E, Yigit N O, Kittis M 2019 J. of Cleaner Production 223 837-848
[15] De Jager D, Sheldon M S, Edwards W 2014 Separation and Purification Technology 135 135-144

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