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Facile Synthesis of Textile-based Filter for Industrial Wastewater Treatment

Heba Gamal[1] and Nour F. Attia[2*]
[1]*Home Economy Department, Faculty of Specific Education, Alexandria University, Alexandria, Egypt.*
[2]*Fire Protection Laboratory, Chemistry Division, National Institute for Standards, 136, Giza 12211, Egypt.*

IN THIS study, cotton and polyester textile fabrics have been treated with polyaniline layer to use as smart filter for industrial wastewater treatment. The developed filters were effective to anchor the dissolved dye wastewater molecules. The polymerization of polyaniline chains on textile fabrics was assured by microscopic techniques. Also, the electrical resistance of treated samples was significantly reduced recording 20 and 40 kΩ for cotton and polyester-PANI filter respectively. The textile-based filter was tuned to be selective to negative dye molecules dissolved in water. The mass ratio of dissolved dyes was varied with developed filter and achieved 45% removal efficiency. The developed textile-based filter was characterized using various spectroscopic and microscopic techniques. The concentration of waste dyes molecules before and after treatments was determined and efficiency of filter was evaluated.

Keywords: Wastewater, Textile fabrics, Polyaniline, Filter, Textile filters.

Introduction

Fresh water is critical factor for all life aspects on earth. However, the rapid growth of industry, fresh water exposed to various pollutions stemmed from using chemicals on industry process of pesticides, medicines and dyes. Textile industry contributed to pollution of fresh water through various pollutants during dying process of textiles. This process consumes huge amount of fresh water [1,2] and in turn resulted in discharge of dyeing effluents [3-5]. Interestingly, this dyeing effluents contain high concentrations of organic and inorganic toxic substances of high temperature and high pH value. Among the dyes, the azo dyes are commonly used and cause drastic change of color in wastewater at very low concentrations [6]. Furthermore, azo dyes cause occurrence of allergy, dermatitis, skin irritation, cancer and a toxic effect on human health [7,8]. Recently, the treatment of wastewater containing azo dyes has received a lot of interest in different forms such as biological degradation, chemical coagulation, and chemical. Due to the ineffective biological and chemical treatment processes, so that the membrane filtration processes have been used as suitable and effective dyeing wastewater treatment methods [9]. On the other hand, conducting polymers have been commonly used in various applications due to their interesting properties [10]. Polyaniline (PANI) is one of the most essential conducting polymers uses widely in applications due to its unique properties such as, facile synthesis, good environmental stability, low cost, and exceptional electrical, catalytic, and electrochemical properties [11-15]. Our group has long been involved in the synthesis of smart textiles fabrics for various applications [16-18]. In this study, polyaniline was polymerized on the surface of different textile fabrics fibers forming

*Corresponding author e-mail: drnour2005@yahoo.com
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interesting textile-based filter for removing charged dyes from wastewater. The developed textile fabrics based filter has been used for removal of azo dyes. The morphological and structural properties of the developed filters were investigated. Also, the efficiency of filter for removal of toxic dyes was studied.

Experimental Section

Materials

Cotton/polyester blend of 80/20 respectively (C) and polyester/cotton blend of 80/20 respectively (PS) were supplied by Stia - El Nasr Wool & Selected Textiles Co., Alexandria, Egypt. Aniline $C_6H_5NH_2$ (AN), ammonium persulphate $(NH_4)_2S_2O_8$ (APS), Hydrochloric acid (HCl), were purchased from El-Gomhouria for Trading Chemicals and Medical Appliances Co., Alexandria, Egypt. Commercial Acid red 18 dye (AR18) as described in Table 1 was obtained from Misr Spinning, Weaving & Beida Dyers Co., Kafr El Dawar, Behera. Distilled water used throughout the experimental work.

Synthesis of developed textile fabric based filter

The textile samples of dimension 10 cm × 10 cm were immersed in a beaker containing 250 ml of 1 M HCl and 0.9ml of Aniline (ANI) then mixture was stirred at 300 rpm for 30 minutes. Subsequently, a solution contains 4.5 g of APS dissolved in 50 ml of 1 M HCl was dropwise to the first solution. Afterward, the final mixture was magnetically stirred at 300 rpm for 1 hour. Finally, the samples were washed with distilled water followed by methanol and dried in air followed by curing in oven at 100^{o}C for 3 min. Final samples coded as C-PANI-40 where C refers to cotton blend, PANI refers to PANI and the number refers to the concentration of the dye.

Treatment of dye with developed textile fabric based filter

The dye solutions were prepared without additional treatment at a concentration of 40,60 mg/L respectively by dissolving appropriate amounts of the dye salts in distilled water. The textile sample of dimension 5 cm × 5 cm of developed textile fabric based filter was placed above beaker mouth. Then, the dye solutions of 100 ml of a concentration of 20,40 and 60 mg/L respectively were pour drop wise above developed filter as indicated later. Afterward, this process repeated for two times and the concentration of dyes in each time was determined using UV-Vis spectroscopy.

Characterization

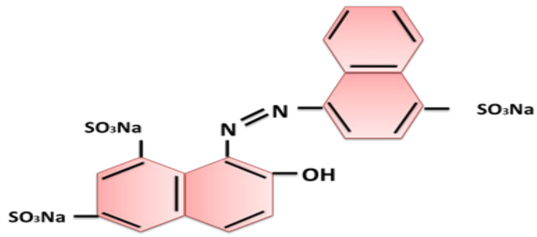
The scanning electron microscope (SEM) images were taken using a scanning electron micro-scope (Quanta FEG-250, with operating at a voltage of 20 kV).UV–vis spectra were measured using a UV–vis Spectrophotometer − Shimadzu UV 3101PC in the wavelength range 300-700 in absorbance mode. The tensile strength (maximum Force) and elongation were tested using tensile testing machine model H1-5KT/S using standard test method EN ISO 13934-1:1999 and results were the average of three replicate samples [19], PH measurements were done with a HACH Sension + PH3 Basic laboratory pH & ORP Meter. The electrical resistance was measured using the Digital Multimeter Fluke 8846A.

Results and Discussion

Morphological and structural properties of developed textile fabrics filter

The new textile fabric based filter was prepared as indicated in schematic diagram represented in Fig. 1. As, two different textile fabrics of different composition from cotton and polyester were used as main fabrics for the filter. The PANI chains were polymerized on the surface of textile fabrics fibers. This polymer chains formed active network on surface of fabrics fibers creating smart filter for negative surface charge dyes. The morphology of untreated and treated fabric surface was investigated using microscopic techniques. Figure 2a,b represents SEM image of blank C with low and high magnification respectively, representing clear smooth surface of fabric fiber as indicated in arrows. However, when PANI chains were polymerized and wrapped on fabrics fiber surface, then the fabric fiber surface was become rough as indicated in Fig. 2c-d. This was clearly observed at high magnification of SEM image (Fig. e,f) as indicated in arrows. Adhering to the same behavior, when the PANI chains polymerized on PS fabrics fiber surface the roughness of fiber surface was clearly observed compared to uncoated PS as indicated in Fig. 3a-f and as indicated in arrows. Furthermore, to prove the polymerization of PANI chain on the textile fabrics fibers, the electrical resistance was measured which indicated the enhanced of electrical conductivity of the treated samples. As, the electrical resistance of C-PANI and PS-PANI was found to be 20 and 40 kΩ, respectively, compared to over 5000 kΩ for blank samples.

TABLE 1. Characteristic properties of Acid Red 18.

Parameter	Value
Molecular formula	$C_{20}H_{11}N_2Na_3O_{10}S_3$
Molecular weight	604.5 (g/mol)
Chemical structure	

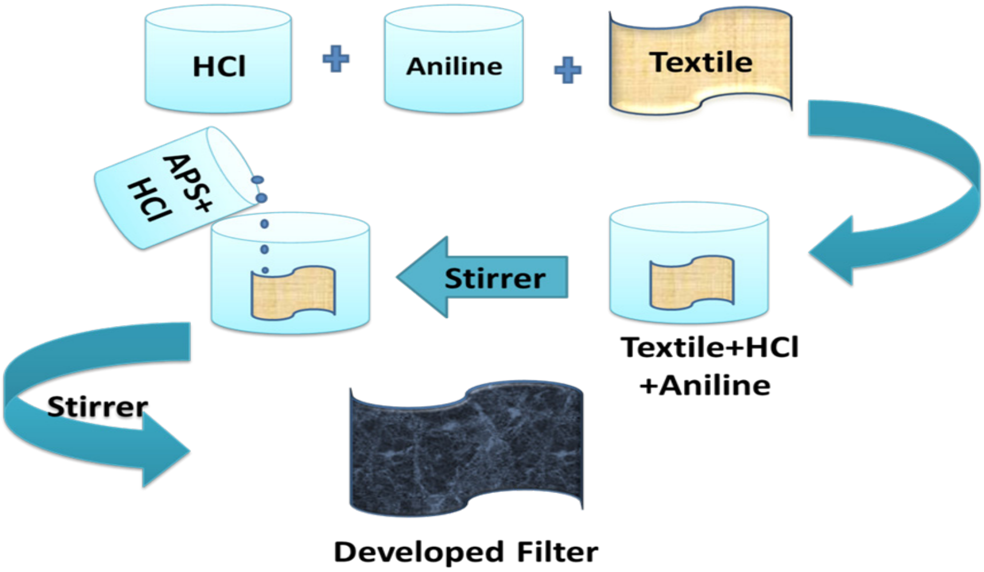


Fig. 1. Schematic diagram showing the Synthesis of developed textile based filter.

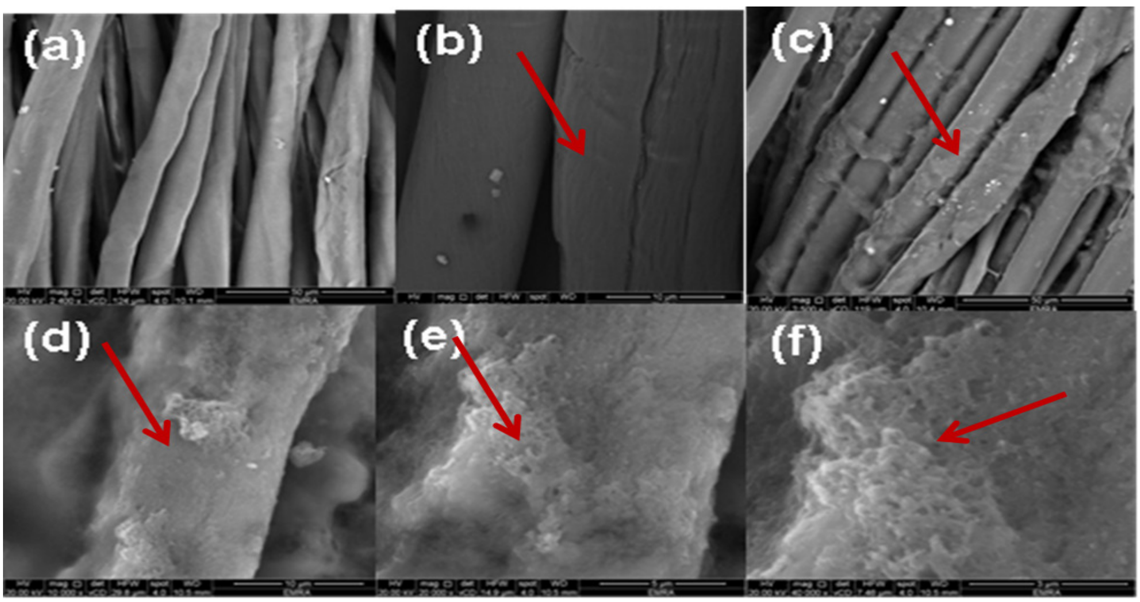


Fig. 2. SEM images of Blank C (a) and at high magnification (b), SEM images of C-PANI (c) and C-PANI at high magnification (d-f).

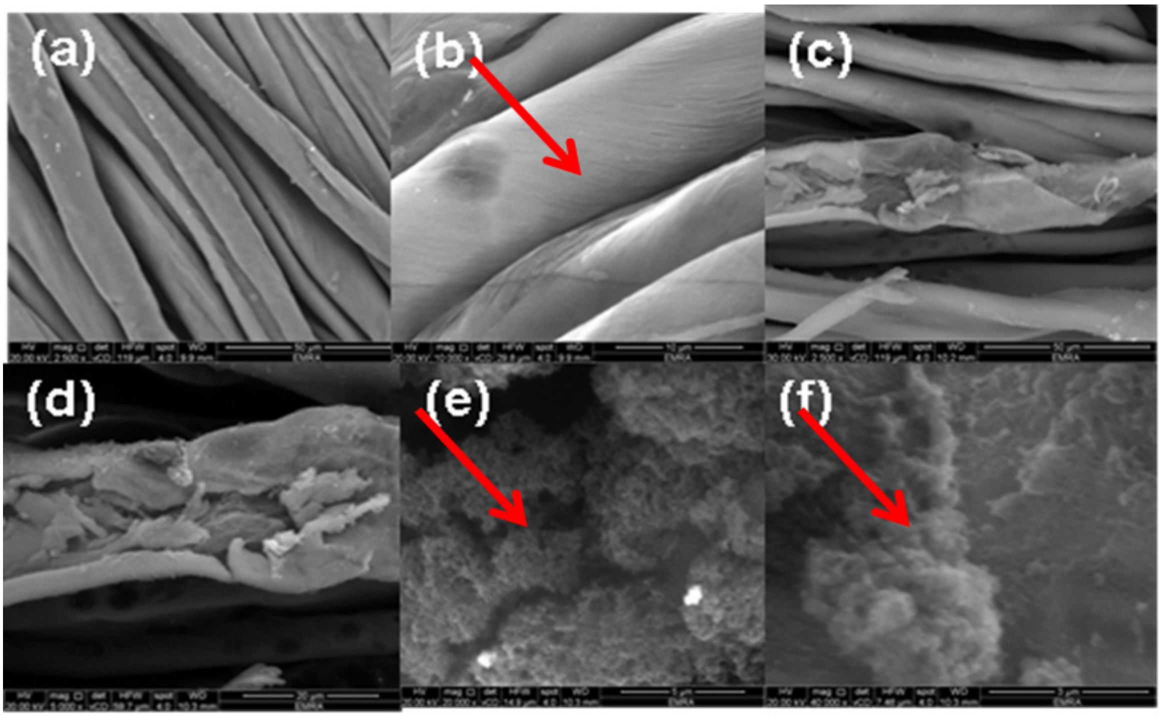


Fig. 3. SEM images of Blank PS (a) and at high magnification (b), SEM images of PS-PANI (c) and PS-PANI at high magnification (d-f).

Tensile properties

The effect of PANI coating network on the tensile strength properties of the developed C-PANI and PS-PANI was investigated by testing tensile strength and elongation properties compared to untreated samples. The tensile strength of blank C and PS was 495 and 441 N respectively. However, when the PANI network coating was coated on fabrics surfaces the tensile strength properties of C-PANI and PS-PANI was almost same without significant change as indicated in Table 2. Also, the elongation properties were behaving same trend without significant change (Table 2). However, the little decrease in tensile strength of the treated textile fabrics could be attributed to the effect of acidic medium (1 M HCl) during the synthesis of PANI layer on textile fabrics strength.

Dyes removal properties of developed textile fabrics based filters

The efficiency of removal of acid red 18 dye (AR18) using developed fabric based filters was performed using decreasing its concentration by recording its UV-Vis absorption band. As, three different concentration of acid red 18 dye (AR18) was prepared by spiking 20,40 and 60 mg/L. Fig.5 represent UV-Vis absorption of C-PANI for wastewater contains 20mg/L dye. It is clear from the drastic reduction in dye concentration as absorbance before treatment with filer was 0.575 reach to 0.317 after treated with C-PANI filter recording 45% AR18 removal. This efficiency of removal of AR18 was attributed to the fact that the C-PANI is emeraldine salt which containing positive centers along PANI-backbone chain and in turn on surface of C-PANI. This positive center anchor the negative surface charge of AR18 as indicated in schematic diagram represented in Fig. 4.

However, when concentration of dye (40 mg/L) increased the removal efficiency of filter to AR18 decreased as seen in Fig.6. This trend was not observed when concentration further increased to 60 mg/L which achieved 25 % removal efficiency (Fig.7), but lower compared to 20 mg/L concentration. This might be due to the capacity of active center responsible for anchoring AR18 molecules.

On the contrast, the efficiency of PS-PANI for dye removal was unexpected as it is recording only 4% removal of AR18 (Fig.8). This could be attributed to the textile fabrics structural and composition played a significant role on the final performance of the fiber prepared at the same treatment conditions. Therefore, the presence of high charge percentage on PS surface compared to C attributed to the low removal efficiency in case of PS-PANI.

TABLE 2. Tensile strength properties results of untreated and treated textile samples.

Sample code	Tensile strength (N)	Elongation (%)
C	495 ± 1	23 ± 0.9
C-PANI	490 ± 0.8	25 ± 1.2
PS	441 ±0.6	16 ± 0.8
PS-PANI	434 ±1.1	13 ± 0.6

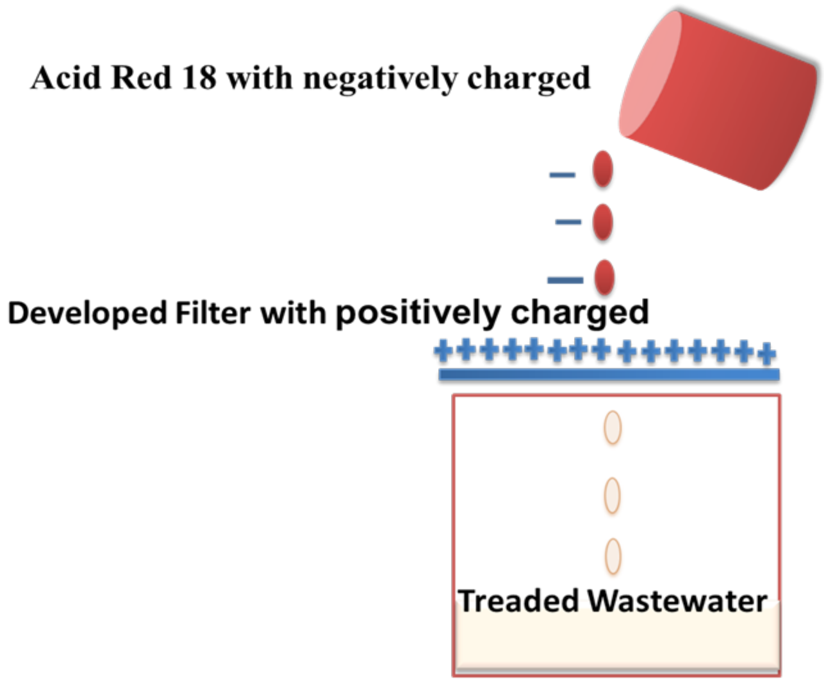


Fig.4. Schematic diagram of treatment of dye with textile fabric based filter.

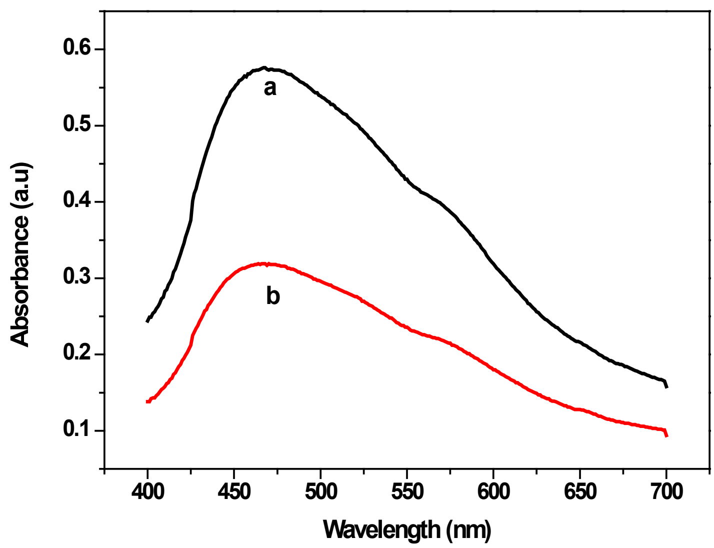


Fig. 5. UV-Vis spectra of wastewater of AR18 before treatment with C-PANI (a) and after treatment with C-PANI (b) of concentration 20mg/L of AR18.

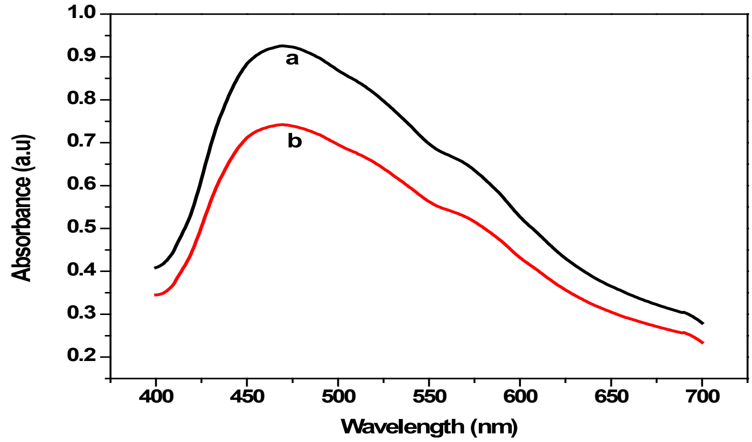


Fig. 6. UV-Vis spectra of wastewater of AR18 before treatment with C-PANI (a) and after treatment with C-PANI (b) of concentration 40mg/L of AR18.

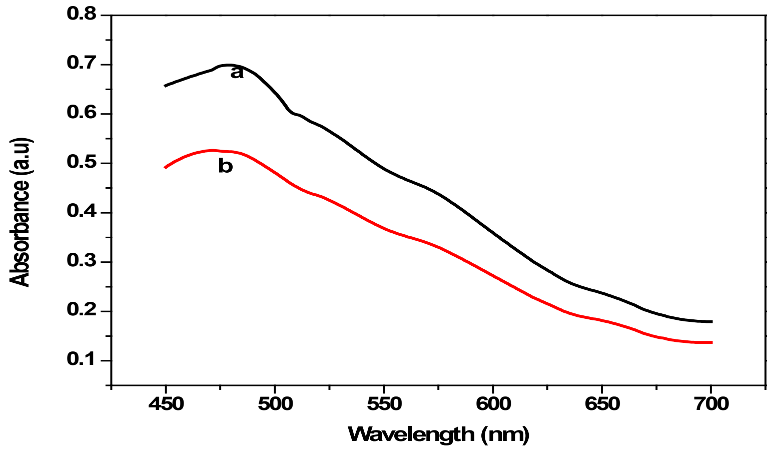


Fig. 7. UV-Vis spectra of wastewater of AR18 before treatment with C-PANI (a) and after treatment with C-PANI (b) of concentration 60mg/L of AR18.

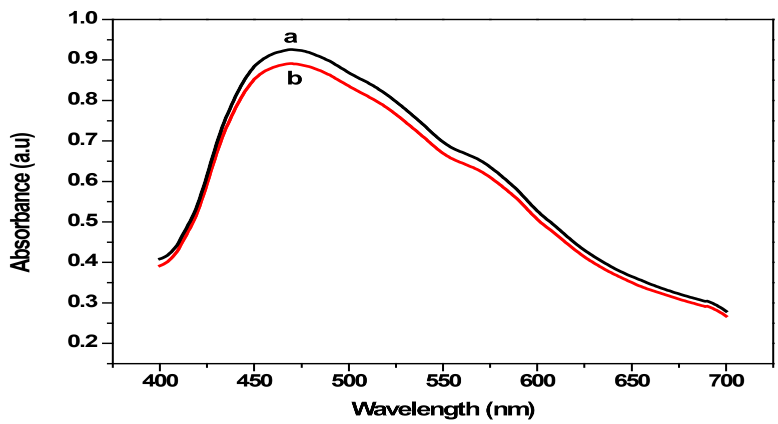


Fig. 8. UV-Vis spectra of wastewater of AR18 before treatment with PS-PANI (a) and after treatment with PSC-PANI (b) of concentration 40mg/L of AR18.

Conclusion

Facile and innovative textile fabric based filer has been developed for toxic negative dyes removal. Polyaniline was synthesized on the fabric surface and coated the fiber surface forming network. The polynailine layer prepared on fabric surface has no negative impact on the mechanical properties of developed filter. The efficiency of developed filter for acid dye removal was very good achieving 45%. The cotton main textile fabric based filter has superior dye removal efficiency than polyester one for the same dye concentration 20 % for C-PANI compared 4% for PS-PANI. The textural and composition of textile fabrics used for filter preparation played a vital role on the performance of developed filter for dye removal.

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تحضير سهل لفلتر مبنى على النسيج لمعالجه المياه الملوثه الصناعيه

نور فتحى عطيه[١] و هبه جمال[٢]
[١]كليه التربيه النوعيه - جامعه الاسكندريه - الأسكندرية - مصر.
[٢]معمل الوقايه من الحريق - شعبه الكيمياء - المعهد القومى للقياس و المعايرة - الجيزة - مصر.

فى هذه الدراسه منسوجات القطن والبولى استر تم معالجتها بطبقه بولى انلين لاستخدامها كفلتر ذكى لمعالجه المياه الملوثه الصناعيه الفلاتر المطورة ذات كفاءه لازاله جزئيات الصبغه الذائبه فى المياه الملوثه. تم التاكد من بلمرة البولى انلين باستخدام الميكروسكوب الماسح وايضا تم قياس المقاومه الكهربيه للعينات المعالجه و التى وجدت ٢٠ و ٤٠ كيلو اوم لكلا من فلتر البولى انلين- قطن و البولى انلين- بولى استر بالترتيب. الفلاتر المطورة تم ظبطه لازاله الصبغه ذات الشحنات السالبه. تم تغير نسب وزن الصبغه المذابه فى المياه مع الفلاتر الجديده والتى حققت كفاءه ازاله بنسبه ٤٥٪.

تم توصيف الفلاتر المطورة باستخدام اجهزه الميكروسكوب و الطيف وايضا تم تعين تركيز الصبغات قبل وبعد استخدام الفلتر.