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WASTEWATER TREATMENT OF PIGMENT PRODUCTION PLANTS IN TWO STAGES: PREPARED ACTIVATED CARBON AND ELECTRODIALYSIS PROCESS

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Abstract. *One of the most important factors limiting the development of industrial processes is the consumption of large amounts of clean water and the generation of large amounts of wastewater. Pigments are available in a wide range of colors, consisting of small molecules practically insoluble in the medium and known to be unique compounds for many industries. They are widely used in dyestuff, cosmetics, food products, pharmaceuticals, manufacturing processes, etc. This study focuses on the removal of pigments and other components from wastewater discharged from pigment plants. The separation process was carried out in two stages: the first was to use prepared activated carbon as an adsorbent to separate the pigment, and then the separation process by electrodialysis to remove other components such as salts, acids, and others. This study considers prepared activated carbon (AC) as an effective separating adsorbent. The preparation process mainly included two-stage pyrolysis and activation using potassium hydroxide (KOH) and sodium hydroxide (NaOH).*

Keywords: *Activated carbon, Adsorption, Electrodialysis, Ion exchange membrane, Current efficiency.*

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Origin article

ОЧИСТКА СТОЧНЫХ ВОД ЗАВОДОВ ПО ПРОИЗВОДСТВУ ПИГМЕНТОВ В ДВА ЭТАПА: ПРИГОТОВЛЕНИЕ АКТИВИРОВАННОГО УГЛЯ И ПРОЦЕСС ЭЛЕКТРОДИАЛИЗА

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Аннотация. *Одним из наиболее важных факторов, ограничивающих развитие промышленных процессов, является потребление большого количества чистой воды и образование большого количества сточных вод. Пигменты доступны в широком диапазоне цветов, со-*

стоят из небольших молекул, практически нерастворимых в среде, и известны как уникальные соединения для многих отраслей промышленности. Они широко используются в красителях, косметике, пищевых продуктах, фармацевтике, производственных процессах и т.д. Это исследование сосредоточено на удалении пигментов и других компонентов из сточных вод, сбрасываемых с пигментных заводов. Процесс разделения проводился в два этапа: первый заключался в использовании подготовленного активированного угля в качестве адсорбента для отделения пигмента, а затем в процессе разделения электродиализом для удаления других компонентов, таких как соли, кислоты и другие. В данном исследовании рассматривается готовый активированный уголь (АС) в качестве эффективного разделяющего адсорбента. Процесс приготовления в основном включал двухступенчатый пиролиз и активацию с использованием гидроксида калия (KOH) и гидроксида натрия (NaOH).

Ключевые слова: *активированный уголь, адсорбция, электродиализ, ионообменная мембрана, выход по току.*

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INTRODUCTION

The lack of fresh water is currently a global problem [1]. Less than 5% of the waters covering the surface of the planet are suitable for drinking [2]. If at the beginning of the 20th century, about 15% of the world's population lived in areas with a shortage of fresh water, then after 100 years, almost 60% of the population falls on the share of such a population. Another problem is the quality of fresh water. According to the World Health Organization (WHO) [3], more than 2.1 billion people now live in conditions of lack clean drinking water.

Wastewater from textiles, cosmetics, printing, dying, food processing, and paper-making industries is polluted by dyes. Discharge of these colored effluents presents a major environmental problem for developing countries because of their toxic and carcinogenic effects on living beings [4]. Therefore, many methods such as activated carbon sorption, chemical coagulation, ion exchange, electrolysis, and biological treatments [5, 6], have been developed for removing dye pollution from wastewater before being discharged into the environment. Of these methods, activated carbon sorption is highly effective for the removal of dyes and pigments as well as other organic and inorganic pollution [7, 8].

There are two basic processes to activate carbon materials, physical and chemical. The temperatures used in chemical activation are lower than that used in the physical activationprocess. As a result, the development of a porous structure is better in the case of the chemical activation method. Chemical activation can be accomplished in a single step by carrying out the thermal decomposition of raw material with chemical reagents. Chemical activation processes have been carried out with acidic reagents, that is, $ZnCl_2$ [9], H_3PO_4 [10], HCl [11], and H_2SO_4 [12], or with basic reagents KOH [12], K_2CO_3 [13], NaOH [10], and Na_2CO_3 [14].

Porosity, penetration, surface area, adsorption capacity, and regeneration processing are important properties of eco-friendly adsorption materials such as activated carbon prepared from different waste sources. These low cost-environmental materials can be produced through various methods. One of these is chemical activation that its base is human, agricultural, or food waste companies by thermal decomposition and chemical reagents [15, 16]. Activated carbon prepared from consumed black tea and characterized by following different steps besides the adsorption steps of different chemicals [17, 18].

Previous work [19] concluded that ED processes are suitable for treating pigment industrial wastewater. Therefore, this study aimed to improve the removal efficiency by investigating the effect of the prepared activated carbon as pretreatment for pigment industrial wastewater followed by the electrodialysis process.

1. Activated carbon

1.1. Preparation of Activated Carbon

Eco-friendly adsorption material was prepared from waste-cooked tea and characterized by spectroscopic techniques. This work aimed to use activated carbon as an effective adsorbent for removing dyes and pigment pollution and then filter it with microfilter paper. All stages of preparation of activated carbon from waste black tea are shown in Figure 1.

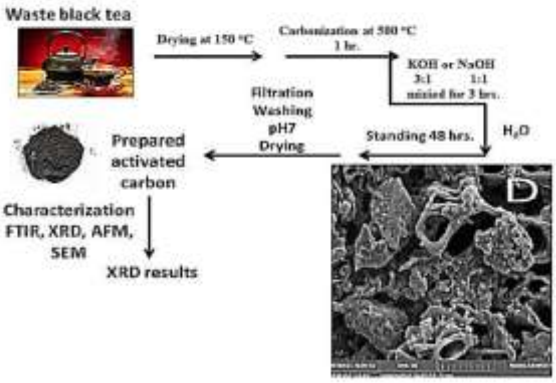

Figure 1 – Activated carbon preparation steps

Рисунок 1 – Этапы приготовления активированного угля

1.2. Characterization methods

In this study, the methods including N_2 adsorption/desorption, SEM, XRD, and XPS were used to determine the main physicochemical properties related to the adsorption characteristics of AC samples.

1.3. Adsorption Experiments

Adsorption equilibrium and kinetics were determined by the batch method. The action of the multi-adsorption was evaluated through the UV-Vis measurements for various adsorbed organics. This activated carbon is prepared from waste-cooked tea with KOH or NaOH. The removal percentage (R%) and adsorption capacities (Q) values will be calculated for all repeated times using the following equation:

$$Removal\ \% = [(C_0 - C_t)/Co] \times 100\,, \qquad (1)$$

where C_o: initial concentration (ppm) and C_t: concentration after adsorption (after a specific time).

$$Q(\ Adsorption\ capacity\ ) = \left[\frac{(C_0 - C_t)}{m}\right] \times v\,, \qquad (2)$$

where C_o: initial concentration (ppm) of adsorbate, C_t: concentration of adsorbate after adsorption (after a specific time) (ppm or mg/L), *m*: weight of adsorbent (g); v: volume of solution (L), Q: Adsorption capacity of adsorbent after a specific time (mg/g).

Actually, the adsorption of any material especially dye is affected by the presented micropores and the functional chemical groups in the activated carbon surface. The particle size of the prepared material in its nanoscale is an excellent indicator of its quality, especially, in the adsorption process.

2. Electrodialysis process

Electrodialysis is widely used for the desalination of natural waters, saline solutions, and the separation of organic acids and their salts [20]. In experiments related to the study of the processes of wastewater desalination by electrodialysis, an experimental electrodialysis unit (EDU) was used [21]. Electrodialysis (ED) is an electrical process. Typically, an ED stack consists of an alternating arrangement of anion exchange membranes (AEM) and cation exchange membranes (CEM). Polymer gaskets inside between them. In the complex of membranes filled with electrolytes, the cells of desalination and concentration alternate successively. Electrodes of different polarities are connected to the opposite sides of the complex, to which a constant voltage is applied (see Figure 2). The general view is shown in Figure 3.

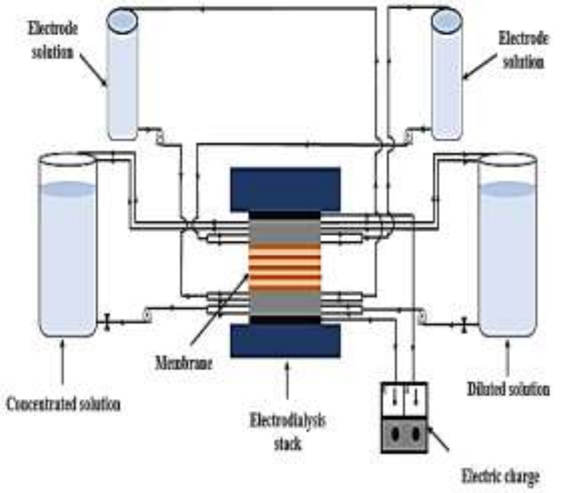

Figure 2 – Schematic flow diagram of the electrodialysis process

Рисунок 2 – Принципиальная технологическая схема процесса электродиализа

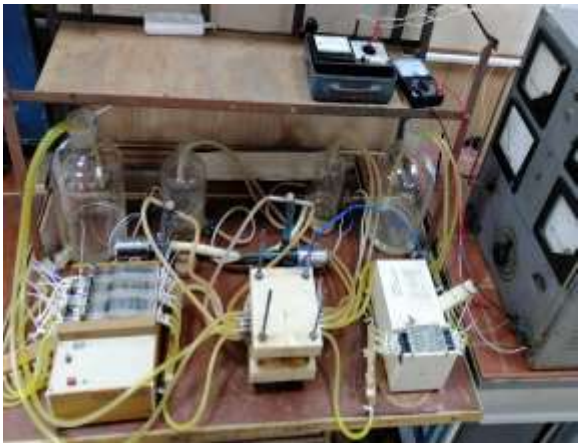

Figure 3 – General view of the electrodialysis unit

Рисунок 3 – Общий вид электродиализной установки

The anions contained in the purified water move to the positively charged anode, and the cations to the negatively charged cathode. Anion exchange membranes allow anions to pass through but cations to pass through. Cation-exchange membranes have the opposite effect - they allow cations to pass through, but prevent the movement of anions. Thus, during the operation of the EDU, the concentration of ions in the desalting cells decreases, and in the concentration cells, it increases. To achieve maximum selectivity, cell size, membrane chemistry, and operating conditions must be optimized for the properties of the treated water and the ions to be separated.

2.1. Current Efficiency in Electrodialysis process

The efficiency of the separation process was determined by the actual utilization factor - the current output η, which was found as the ratio of the actual amount of the component transferred under the action of electric current to the theoretical one.

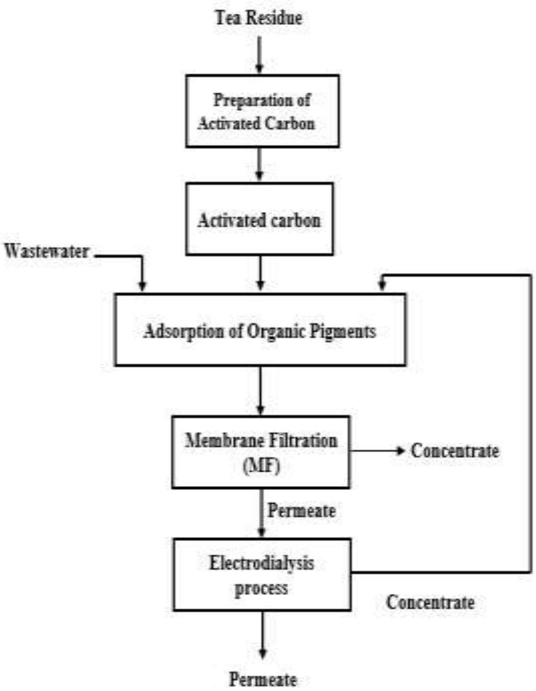

Figure 4 – Schematic diagram of the two-stage separation process

Рисунок 4 – Принципиальная схема двухступенчатого процесса разделения

The current output for each component was calculated using Equation 3.

$$\eta = \frac{(c_0 \cdot V_0 - V \cdot c) \cdot F}{i \cdot S \cdot n \cdot t} \quad , \qquad (3)$$

Where: C_o (M) and V_o (L) are the concentration of the electrolyte and its volume at time 0, respectively; C(M) and V (L) are the concentration of the electrolyte and its volume at time t (s), respectively; F is the faraday constant (96485 C.mol^{-1}); I (A) is the applied current; $n$is electrons transferred per ion; and t (s) is a time of electrolysis.

However, parameters that can improve selectivity in ED can also have an adverse effect on overall performance. Carrying out the electrodialysis process of separation of solutions containing ions of different valence, an increase in the separation efficiency for ions with a higher valence and a decrease in the overall efficiency of ion removal are observed [22].

The efficiency of electrodialysisis affected by the concentration of ions in the initial solution, the volume of the treated solution, current density, membrane properties, and section geometry [23, 24].

Figure 4 presents a methodical diagram of a two-stage process for the separation of wastewater from the production of pigments containing various impurities.

CONCLUSIONS

This study showed the modernization of a two-stage process for the treatment of wastewater from pigment industrial plants. The first is an adsorption process using prepared activated carbon, and the second is an electrodialysis process. It is proposed to prepare activated carbon from tea residues by adding chemical reagents such as KOH and NaOH. Activated carbon is usually effective in removing pigments. On the other hand, Electrodialysis mainly used to desalinate saline solutions as well as organic acids. The removal efficiency and adsorption capacity of ED membranes for various solutions were studied.

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