

## Decolorization of direct blue dye by electrocoagulation process

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### Abstract:

Electrocoagulation (EC) was tested as an alternative method for satisfactory removal of direct blue dye from aqueous medium. Batch EC studies were performed using Iron electrodes to evaluate the influence of various experimental parameters, i.e., Initial pH: 2-10, current density (CD): 25-250 A/m<sup>2</sup>, electrolysis time (t): 2-10 min, and initial concentration (Co): 25 – 200 mg/L, on the removal of direct blue dye. Additionally, the effects of these parameters on electrical energy consumption were studied under the optimum conditions. The results showed that 98.71 % of direct blue was decolorized and 1.7 KWh/m<sup>3</sup> of energy consumed for initial dye concentration of 100 mg/L with the current density of 200 A/m<sup>2</sup>, solution conductivity of 1.16 mS/cm, at room temperature of approximately 29.8±2 K, interelectrode distance of 1.0 cm, and initial pH of 4 at the end of 7 min of time of electrolysis.

**Key Words:** Electrocoagulation; Direct blue dye; Iron electrode; Decolorization.

إزالة لون الصبغة الزرقاء المباشرة بواسطة عملية التخثير الكهربائي

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الخلاصة:

تم استخدام عملية التخثير الكهربائي كطريقة بديلة ومناسبة لإزالة الصبغة الزرقاء المباشرة من المحاليل المائية الملوثة. حيث تم استخدام الطريقة الدفعية في هذه الدراسة باستخدام أقطاب مصنوعة من مادة الحديد لدراسة

المعاملات التالية على عملية الازالة الصبغة الزرقاء المباشرة وهذه المعاملات هي الرقم الهيدروجيني (2-10), كثافة التيار (25-200) امبير/م<sup>2</sup>, زمن التحليل الكهربائي (2-10) دقيقة, وتركيز بدائي للصبغة الملوثة (25-500) ملغرام/لتر. بالإضافة إلى ذلك تم دراسة تغير هذه المعاملات على قيمة الطاقة الكهربائية المستهلكة في الظروف المثالية. بينت النتائج ان نسبة الازالة بلغت 98,71% للصبغة الزرقاء المباشرة والطاقة المستهلكة 1,7 كيلو واط ساعة/متر مكعب عندما كانت قيمة التركيز الاولي لهذه الصبغة يساوي 100 ملغرام/لتر وقيمة كثافة التيار عند 200 امبير/م<sup>2</sup> وقيمة التوصيل الكهربائي 1,16 ملي سم/سم في درجة حرارة الغرفة 298 ± 2 كلفن والمسافة بين الاقطاب 1,5 سم وقيمة الرقم الهيدروجيني عند 4 وزمن التحليل الكهربائي عند 6 دقائق.

## 1- Introduction

Providing clean water to the majority of population around the world is the most important challenge facing humanity today <sup>[1]</sup>. Billions of liters of industrial wastewater are produced everyday <sup>[1]</sup>.

The pollution induced by dyestuff losses and discharge during dyeing and finishing processes in the textile industry has been a serious environmental problem for years <sup>[2]</sup>. Color is one of the most important water quality parameters. During the dyeing process, about 5 - 20% of the dyes are lost due to its partial adsorption on the fibers <sup>[4]</sup>. Dyestuffs are organic compounds which are in solution or in suspension form to react with objects surfaces in chemical or physico-chemical ways. These reactions then change the surface structure of the objects. Color in water bodies effect aquatic diversity by blocking the passage of sunlight. Further, a color in water bodies has an adverse aesthetic effect. Since many organic dyes are harmful to human beings, the removal of color from process or waste effluents becomes environmentally important. Direct dyes are extensively used in textile industry, fundamentally due to the ability of their reactive groups to bind to textile fibers by covalent bonds formation <sup>[5]</sup>. Various treatment methods including, physical, physico-chemical and chemical processes have been investigated for treating dye bearing effluents. All these methods have different color removal capabilities, capital costs and operating rates.

Electrocoagulation (EC) is an alternative technology for wastewater treatment and recovery of valuable chemicals from wastewater <sup>[1]</sup>. This method involves a sacrificial anode, usually aluminum or iron, where the coagulating metal cations are released in situ as long as an electrical current is applied <sup>[1]</sup>. Treatment of wastewater by EC was practiced for most of the past century with limited success and popularity. However, in the last few years, its usage has been increased as the technology has been improved to minimize electrical power consumption and maximize effluent throughput rates <sup>[6]</sup>. EC compared with traditional flocculation and coagulation, has, in theory, the advantage of removing small colloidal particles; they have a larger probability of being coagulated because of the electric field that sets them in motion. Addition of excessive amount of coagulants can be avoided, due to their in situ generation by electro-oxidation of a sacrificial anode. EC equipment is simple and easy

to operate. Short reaction time and low sludge production are two other advantages of the technique [9].

The most widely used electrode materials in electrocoagulation process are aluminum and iron. The mechanism of removal of pollutants by an EC process with iron electrodes is shown below. Upon oxidation in an electrolytic system iron produces iron hydroxide,  $Fe(OH)_n$  where  $n = 2$  or  $3$ . Two mechanisms have been proposed for the production of  $Fe(OH)_n$  [9,10].

Mechanism 1:

Anode:



Cathode:



Overall:



Mechanism 2:

Anode:



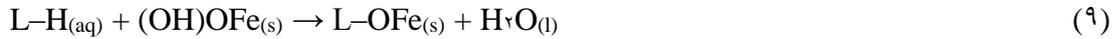
Cathode:



Overall:



The  $\text{Fe}(\text{OH})_n(\text{s})$  remains in the aqueous phase as a gelatinous suspension, which can remove the pollutants from the wastewater by either complexation or electrostatic attraction followed by coagulation. In the surface complexation mode, the pollutant acts as a ligand (L) to chemically bind hydrous iron:



The prehydrolysis of  $\text{Fe}^{+3}$  cations also leads to the formation of reactive clusters for wastewater treatment [11]. Besides the formation of the coagulating agent, the electroflotation (EF) also generates micro gas bubbles that are responsible for the flotation of flocculated particles. When the effluent also contains chloride ions,  $\text{Cl}_2$  will be formed at the anode and could react with water to generate hypochlorite ions. This fact can be considered to be a great advantage for EF, because chlorine generation can be optimized for both the disinfection of the water and the elimination of undesirable odors [1].

The objective of this study to perform the best treatment parameters using iron electrodes for EC process in a batch process by changing various experimental parameters such as initial pH, current density, dye concentration, and time. Dye concentrations were analyzed and energy consumption per  $\text{m}^3$  of wastewater treated was calculated.

## 2- MATERIALS AND METHODS

### 2-1- Materials

Direct blue 86 was used for preparing synthetic dye wastewater. Its chemical structure is shown in Fig. 1. The synthetic wastewater concentration of direct blue was prepared by dissolving amount of the direct dye into distilled water. The pH was adjusted to desired value by using 0.1 N of NaOH or  $\text{H}_2\text{SO}_4$  and the conductivity was adjusted to 1.16 mS/cm with NaCl. Experiments were conducted in a small batch reactor with two iron electrodes with 29,20  $\text{cm}^2$  area (stainless steel 304) anode and cathode connected in parallel Fig. 2. The volume of the reactor cell is about 0.9 L. The current density was maintained constant by means of a precision DC power supply (Farnell L30E). The dimensions of the electrodes are 4 cm  $\times$  4.5 cm, thickness of the plates was 0.3 cm and interelectrodes distance was 1.0 cm. In each run, 0.9 L wastewater is placed into electrolytic cell and at the end of the experiment, the solution is filtered before analysis.

### 2-2- Sampling and Analysis

Samples were taken at the end of each run from the reactor to determining dye concentrations. The samples were filtered and the residual dye concentration was determined. The dye concentration was determined using a UV-Vis spectrophotometer (Thermo Genesys

10 UV) range (190–1100 nm). For these measurements, the maximum adsorption ( $\lambda_{max}$ ) wavelength of dyes was determined as 497 nm by measuring their absorbance at various wavelengths.

The removal efficiency has calculated as;

$$\text{Removal Efficiency (\%)} = \frac{(C_o - C_e)}{C_o} \times 100 \quad (10)$$

Where;

$C_o$ : Initial concentration of dye before electrocoagulation (mg/L);

$C_e$ : Present concentration of dye after electrocoagulation (mg/L)

Energy consumption per  $m^3$  of wastewater treated has calculated as follows [13].

$$E = \frac{U \times I \times t \times 1000}{V} \quad (11)$$

Where:

E: Energy Consumption (kWh/ $m^3$ )

U: Cell voltage (v)

I: Current (A)

t: Time (h)

V: Volume of wastewater ( $m^3$ )

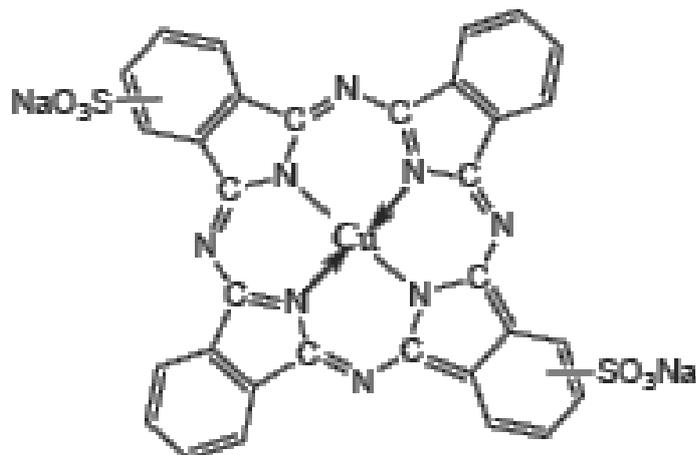
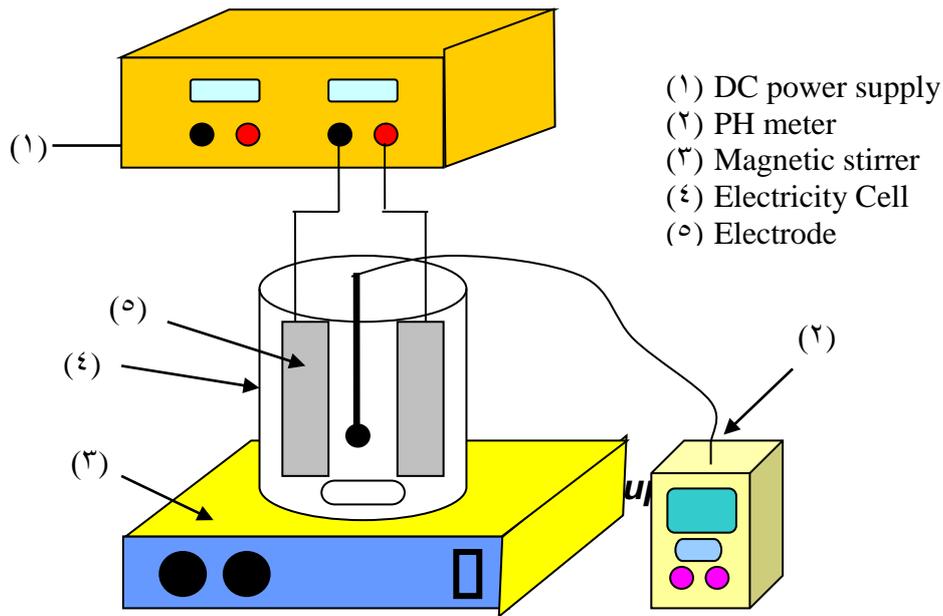


Fig. (1) Direct Blue 19



## 3- Results and discussion

### 3-1- Effect of initial pH

It has been established that PH is an important operating factor influencing the performance of electrocoagulation [11]. To examine its effect, the dye solutions are adjusted to the desired pH for each experiment by adding sodium hydroxide or sulfuric acid solution. The dye removal efficiency, as a function of pH from 3 to 10, is shown in Fig. 3 for the initial dye concentration of 100 mg/L, current density of 200 A/m<sup>2</sup>, conductivity 1,16 mS/cm and at the end of five min of the operation. It can be seen that the initial pH has a significant effect on the dye removal efficiency. From figure it is seen that for 100 mg/L of the dye solution the removal is 97,43 % at a pH of 4. Therefore the desired pH of direct blue dye degradation by EC process should be 4. Fig. 4 shows the change of initial pH of the solution during the process. This change depends on the initial pH. As seen in Fig. 4 the final pH is higher than initial pH > 3. This result suggests that EC exhibits some PH buffering capacity in moderate acid and alkaline medium [12].

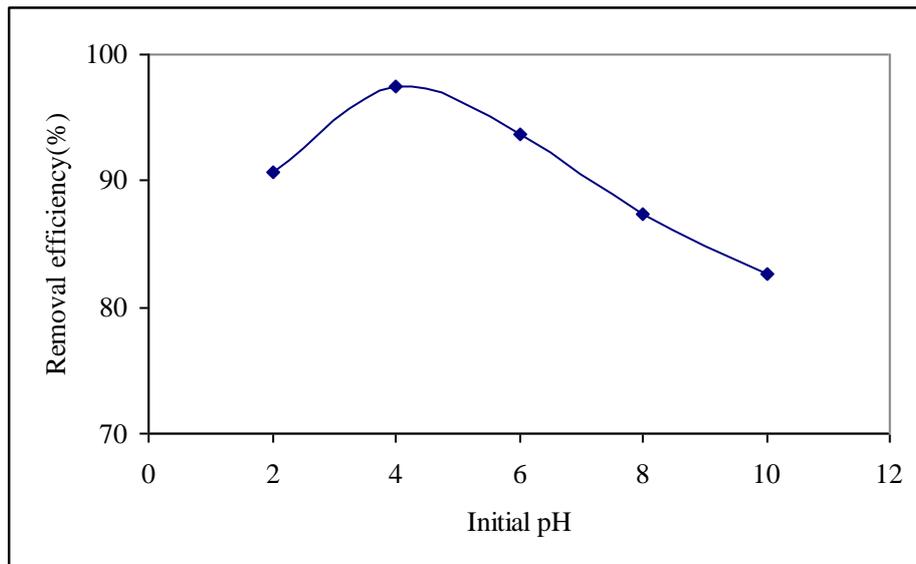


Fig. 3 Effect of initial pH on dye removal

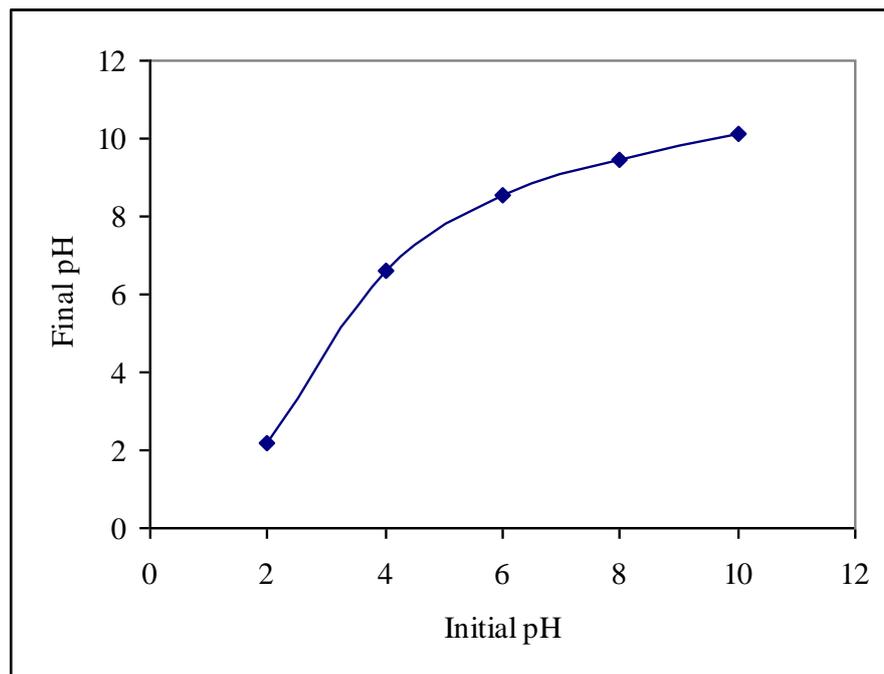


Fig. 4 Relationship of final pH with initial pH

### 3-2- Effect of current density

The current density is the amount of current per area of the electrode. It is expected to exhibit a strong effect on EC, especially on the color removal higher the current, shorter the treatment. The supply of current to the EC system determines the amount of  $Fe^{r+}$  ion released

from the respective electrodes and the amount of resulting coagulant. Thus, more  $Fe^{2+}$  ion get dissolved into the solution and the formation rate of  $Fe(OH)_2$  is increased. To examine its effect, eight current densities were applied. Fig. 6 depicts the effect of current density on the color removal efficiencies. The color removal efficiencies of 16.3, 39.41, 59.43, 70.66, 81.62, 93.6, 98.16, and 98.16% were achieved after 60 min electrocoagulation at 20, 50, 70, 100, 120, 150, 200 and 250  $mA/cm^2$ , respectively. At a high current density, the extent of anodic dissolution of iron increases, resulting in a greater amount of precipitate and removal of color. An increase in the current density also causes a proportional increase of the consumption of electrical energy by the system as seen from the Fig. 7. As is seen in Fig. 7 that when current density was applied as 20, 50, 70, 100, 120, 150, 200, 250  $A/m^2$ , unit energy consumptions were obtained as 0.03, 0.14, 0.27, 0.4, 0.67, 0.90, 1.71, 2.62  $kWh/m^3$ , respectively of treated direct blue dye.

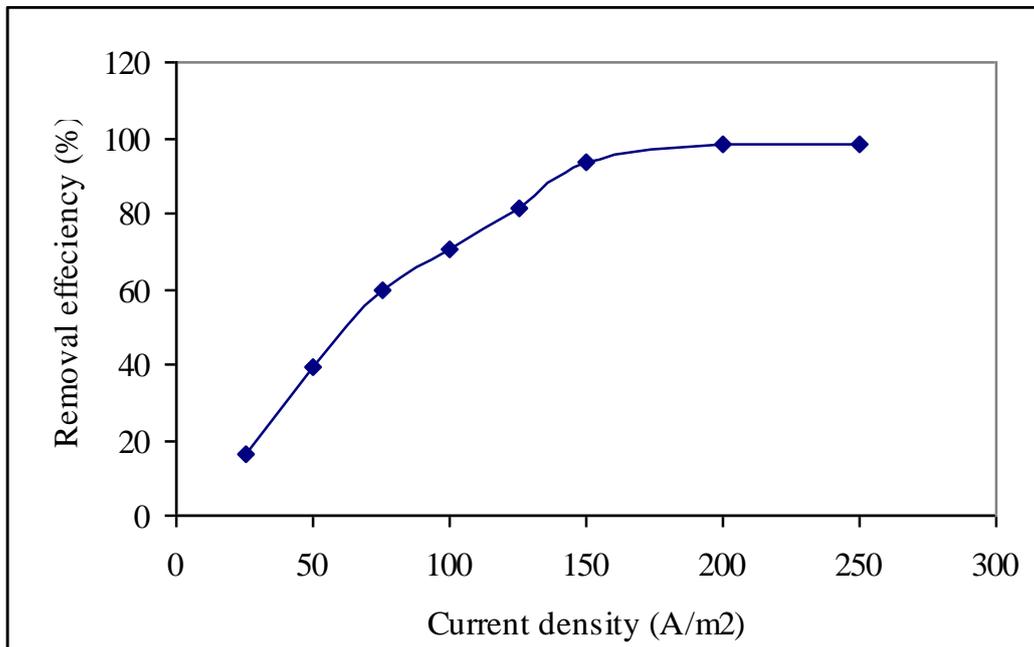


Fig. 6 Effect of current density on dye removal

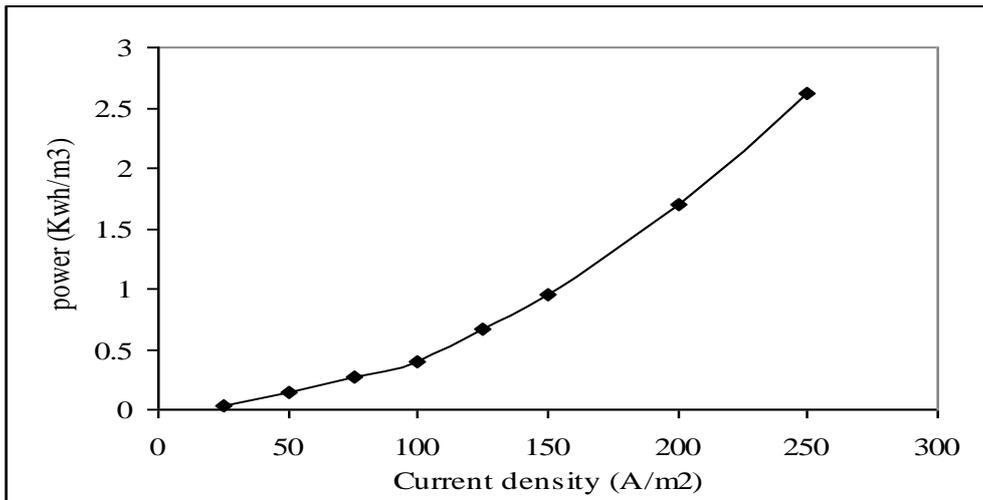


Fig. 6 Effect of power consumption on dye removal

### 3-3- Effect of initial dye concentration and time

The dye solution with different initial concentrations in the range of 50 - 200 mg/L was treated by EC in optimized current density (200 A / m<sup>2</sup>), conductivity 1,160 ms/cm and pH 4. According to the results in Fig. 7, with increase of dye concentration color removal percent decrease, because in constant condition, production of flocs and adsorption of dye to them is constant value. Up to the 7min, in all of concentrations the removal efficiency of dye is reach 99% for all color concentration.

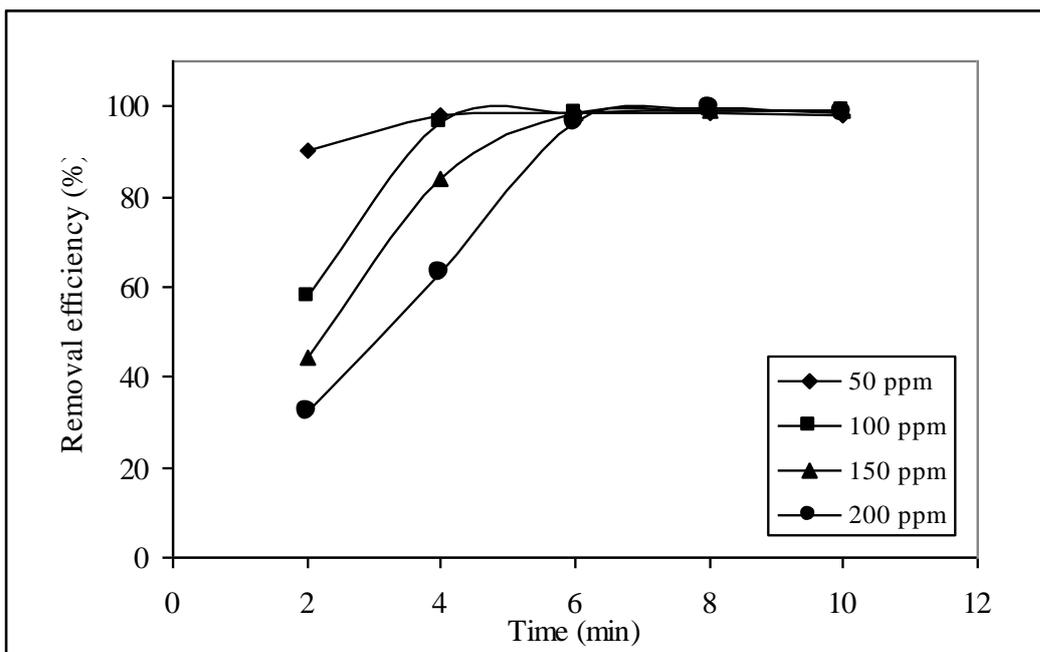


Fig. 7 Effect on initial dye concentration on dye removal

## 4- Conclusion:

Electrocoagulation is an efficient process to treat textile wastewater characterized by high dyes content. The decolorization of dye solution (direct blue) by means of electrocoagulation was affected by the current density, initial pH of the solution, electrolyte concentration, and time of electrolysis. The results showed that the optimum conditions when the initial concentration of the dye was 100 ppm are PH 4, Current density 200 A/m<sup>2</sup>, and time of electrolysis 7 min. The removal efficiency of color is 98,71% and energy consumed 1,7 KWh/m<sup>3</sup> at temperature of approximately 298 K, and interelectrode distance of 1.0 cm.

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