VALORIZATION OF STEEL INDUSTRY WASTEWATERS IN THE DECOLORIZATION OF DYES CONTAINING SOLUTIONS

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Abstract: The aim of the present work is to test the ability of the steel industry wastewater (SIWW) iron rich as an original coagulant to remove the textile dyes from wastewaters of textile industry. The SIWW was used in the treatment of four textile dye solutions, namely orange HER, red F2B, blue SRN, and as well as their mixture.
Jar-test experiments were employed in order to determine the optimum conditions for the removal of organic and colored matters. The results showed that: SIWW is effective in the removal of COD and color, it is efficient at a wide *pH* range, and produced a less volume of decanted sludge compared to classical coagulant $FeCl_3$.

Keywords: *textile dyes wastewater; steel industry wastewater (SIWW); coagulation-flocculation; valorization; jar-test.*

INTRODUCTION

More than 150 years ago, the first synthetic dye, Mauveine, was discovered [1]. Since then, more than 100,000 new synthetic dyes have been generated and used in different industries, including textiles, cosmetics, paper, leather, pharmaceutics, and food, with an annual consumption of about 0.7 million tons in 2003 [2]. The textile industry accounts for two-thirds of the total dyestuff market. Azo dyes, the largest chemical class of dyes with the greatest variety of colors, have been used extensively for textile dyeing, and paper painting [3].
Awareness of ecological problems principally arose during the 1970s, and currently, in the context of the coloration industry, wherein waste water contamination has become of particular concern [4].
Dye wastewater discharged from the textile industry can be highly hazardous to the environment if improperly disposed of. These highly colored components, when discharged with wastewater into water bodies, stop the re-oxygenation capacity of the receiving water and catch of sunlight, thereby harming biological activity in aquatic life.
In the textile industry, the choice of the most effective and less expensive treatment processes or their combinations depends on the dyestuffs and dyeing methods used during the production process [5].
Various methods have been developed for treating the dye wastewater such as physical-chemical (coagulation, flocculation, adsorption, Fenton's reagent, H_2O_2-ozone, H_2O_2-UV radiation, H_2O_2-peroxidase, filtration, reverse osmosis, ion exchange and neutralization), and biological process (aerobic and anaerobic biodegradation).
Direct biological treatment of dye wastewater is considered unsatisfactory because of low efficiency and low reaction rate. This technique uses a coagulant and produces flocks together with dye materials. The flocks are then separated from the aqueous solution by means of physical sedimentation.
Moreover, the physical-chemical method used is less expensive, does not require much space and could be adapted easily for the control of pollution due to the small production facilities. The latter originally disperse and form strong polluting loads. Adding to that, the technique used makes it possible to reduce the impact of the discharges of the water used on the environment, better still, treated water could be recycled. The aim of the present work is to test the ability of the steel industry wastewater (SIWW) iron rich as an original coagulant to remove the textile dyes.

MATERIALS AND METHODS

Four textile dye solutions were tested for its coagulation flocculation using SIWW as coagulants. The characteristics of theses dyes solutions are presented in Table 1.

Table 1. *Characteristics of textile dyes solutions*

Dye solutions	Class	λ_{max} [nm]
Orange HER	Reactive	493
Red F2B	Vat	526
Blue SRN	Disperse	568

These dyes were used at 100 $mg.L^{-1}$ concentration; red F2B, orange HER, blue SRN and mixture (red F2B, orange HER and blue SRN).
The SIWW was taken from Magreb Steel (Moroccan society) and was used as an original coagulant in this study. The characteristics of SIWW are given in Table 2.

***Table 2.** SIWW characteristics*

Parameter	Value
pH	< 1
Conductivity [$mS.cm^{-1}$]	27,000
Fe^{3+} [$mg.L^{-1}$]	1790
Cu^{2+} [$mg.L^{-1}$]	1.145

Analysis of SIWW sampled at the end pipe of this plant indicates a high level of $FeCl_3$. This rejection was valorized as coagulant in the treatment of textile wastewater.
Jar-tests were conducted using SIWW as an inorganic coagulant. In order to determine the optimum dosages and the *pH* conditions, jar-tests were carried out at various reaction conditions (volume of coagulants 0.2 – 2.4 $mL.L^{-1}$, *pH* 4 – 11).
The equipment used was a laboratory flocculator: solutions were observed in 4 parallel jars. All solutions were stirred for 5 min at 150 rpm, and after that they were stirred for 15 min at 75 rpm, and then 30 min at 20 rpm. Then, it was allowed to settle. Once the experiment performed in jar test, the beaker contents are transferred to special graduated conical containers (Imhoff cones).
The *pH* value was adjusted to the desired value with H_2SO_4 and NaOH. The chemical oxygen demand (COD) and other physical-chemical parameters for wastewater characterization measurement were performed according to standardized methods [6]. The volume of decanted sludge was estimated by the volumetric method using the Imhoff cones. After 2 hours of settling, the sludge production is determined by direct reading as $mL.L^{-1}$ of sludge of wastewater treated. Color was determined using a UV/Visible spectrophotometer (Model 7800 UV/VIS).

RESULTS AND DISCUSSION

Effect of *pH* coagulation on the removal of dye solutions

In the coagulation-flocculation processes using inorganic coagulant or polymer flocculent, *pH* plays an important role in determining coagulant efficiency. On the other hand, the aggregation of colloidal particles occurred through charge neutralization and sweep-flock effects [7]. The optimal *pH* was appropriate for the charge neutralization between the positively charged coagulant and negatively charged colloids.
The effect of coagulation *pH* on color removal of textile dye solutions by coagulation processes with SIWW is illustrated in Figure 1.

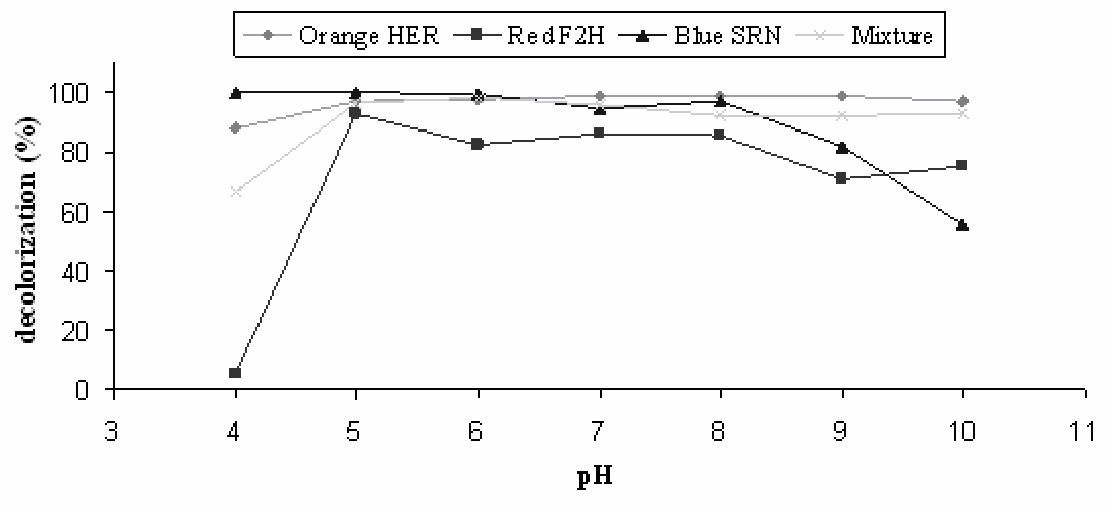

Figure 1. *Effect of coagulation pH on the color removal of dye solutions*

The results show an efficient removal of red F2H and Blue SRN dyes at *pH* range 5 – 8. However, the removal of Orange HER and dyes mixture were not attributed to coagulation *pH*.
The effect of *pH* on COD removal of textile dye solutions by coagulation processes with SIWW is illustrated in Figure 2.

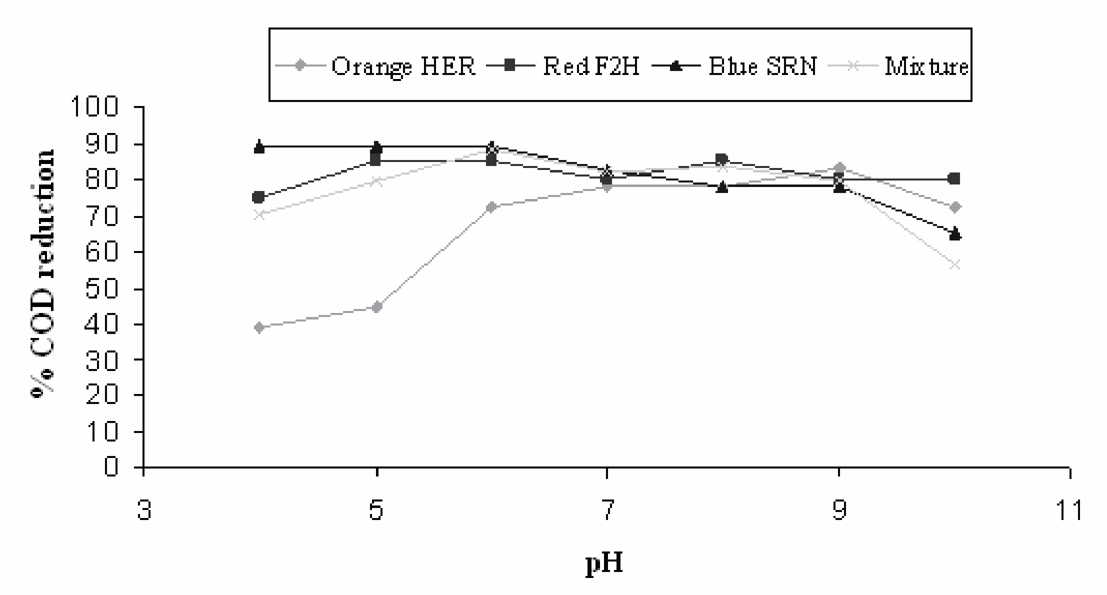

Figure 2. *Effect of coagulation pH on the COD removal of dye solutions*

For an effective COD removal, a coagulation *pH* ranging from 6 to 9 is required; the percent of COD removal is more than 70% for all dyes tested.

Effect of coagulant dosage on the removal of dye solutions

The effect of coagulant dosage on the removal of textile dye solutions by coagulation processes with SIWW is illustrated in Figures 3 and 4.

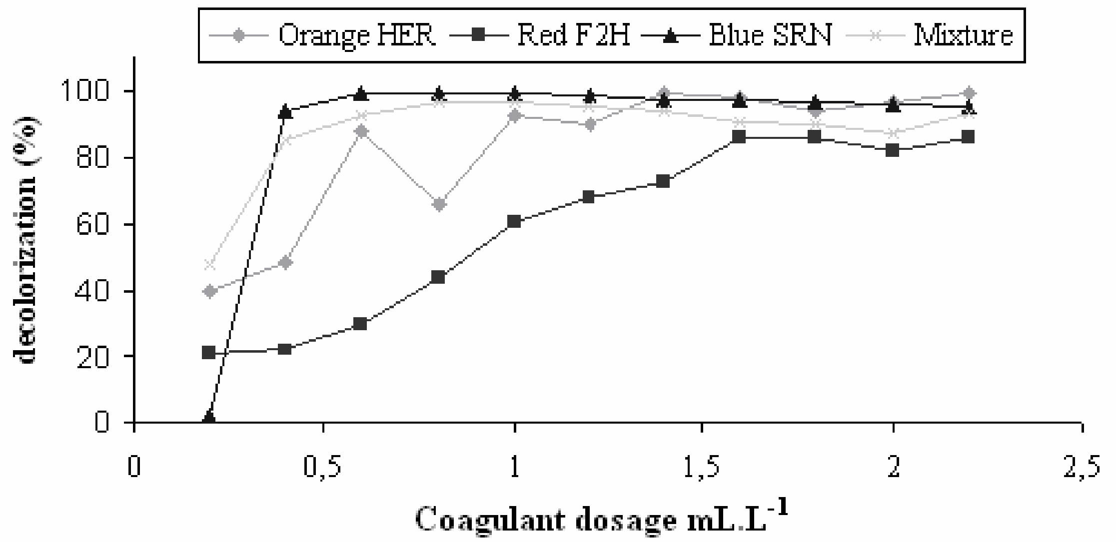

Figure 3. *Effect of coagulant dosage on the color removal of dye solutions*

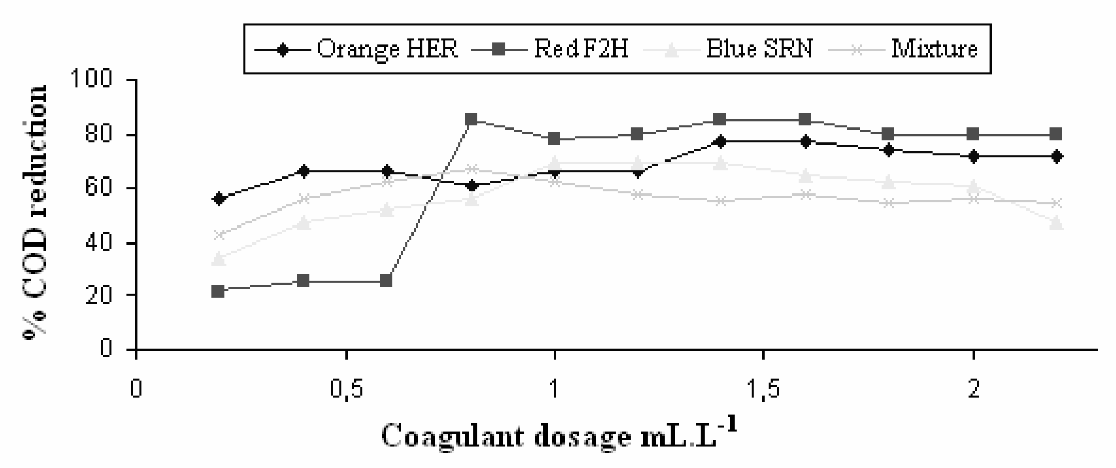

Figure 4. *Effect of coagulant dosage on the COD removal of dye solutions*

The study of the effect of coagulant dosage on the color and COD removals of textile dye solutions has been undertaken by varying the volume of SIWW in the solutions. Figures 3 and 4 show that the volume of 1.4 $mL.L^{-1}$ was needed to effectively removal the 99% color and 78% COD from orange HER solution, 1.6 $mL.L^{-1}$ to remove 85% COD and 86% color from red F2B solution, 1 $mL.L^{-1}$ to remove 69% COD and 99% color from blue SRM solution, and 0.8 $mL.L^{-1}$ to remove 67% COD and 97% color from mixture solution.

Comparison between the effect of SIWW and that of classic coagulant

In addition to pollutants removal, sludge production is considered in this work, as it may affect the economic feasibility of the proposed method. In the solid separation, sludge dewatering has been pointed out as one of the most expensive processes [8].
In order to compare the results obtained using SIWW and classic coagulant [9], the ratios between the amounts of sludge produced and the percent of COD or color removal has been estimated – Figure 5.

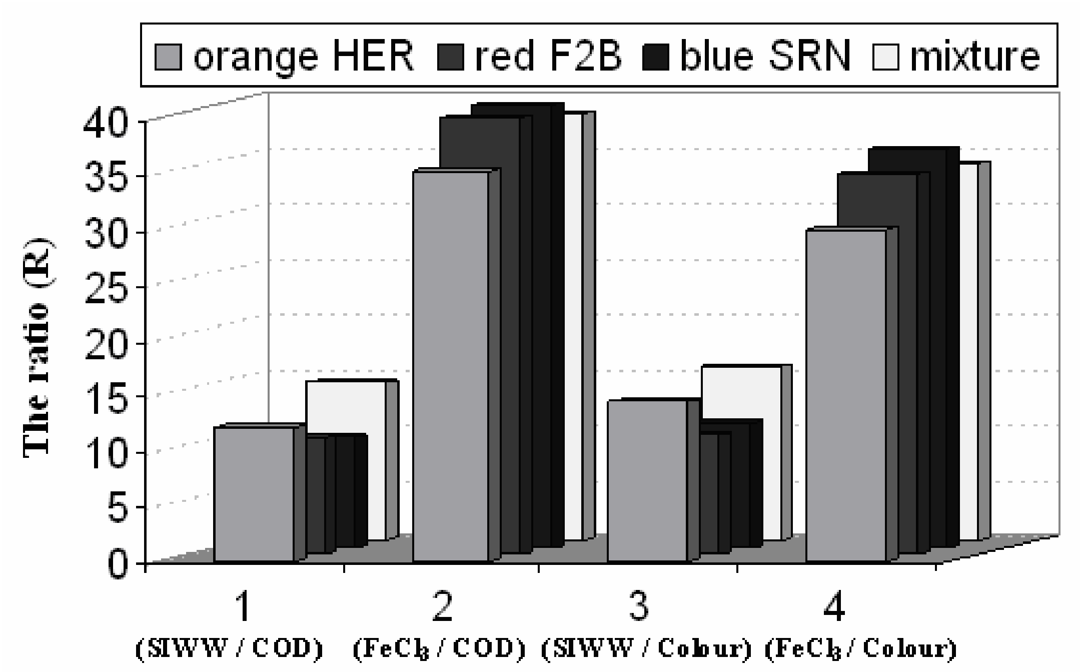

Figure 5. *Ratio between the amount of sludge produced by SIWW or $FeCl_3$ and COD or color reduction*

The ratio (*R*) between the amount of sludge produced by SIWW or $FeCl_3$ and COD or color reduction were calculated according to equation (1):

$$R = \frac{V_S}{\%RMD} \quad (1)$$

where, V_S is the volume of decanted sludge, %RMD is the percentage of dyes removal in solutions. The comparison between SIWW and $FeCl_3$ efficiencies indicates that both products are effective on the removal of COD and color for dye solutions. However, SIWW is efficient at a wide *pH* range and produces less amount of sludge than the iron chloride.

CONCLUSIONS

This work has demonstrated the use of the steel industrial wastewater as an original coagulant to remove the textile dye solutions.
SIWW can be used effectively without *pH* adjustment in the treatment of industrial wastewater with *pH* fluctuations, like textile wastewaters.
The advantages of the proposed coagulation in addition to pollutants removal, the processes using SIWW were mainly: simple, cost effective, and facile for onsite implementation.

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LIST OF NOTATIONS AND SYMBOLS

COD	Chemical oxygen demand.
R	Ratio between the amounts of sludge produced by SIWW or $FeCl_3$ and percentage COD or colour reduction.
SIWW	Steel industrial wastewater.
V_S	Volume of decanted sludge.
%RMD	Percentage of removal dye solutions (COD or color reduction).

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