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Textile wastewater in Tlemcen (Western Algeria): Impact, Treatment by combined process

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A B S T R A C T

Algerian water resources are scarce, and unequally distributed. The region is facing severe water shortage problems due to climate conditions, uneven precipitations, and the long periods of drought. Moreover, the demand for water from the urban population, industry, and especially agriculture is rapidly increasing. Water management represents an economic and ecological challenge to cope with this demand, conserve the water resources and reduce the environmental pollution. The present paper reviews the textile wastewater treatment and feasibility of reuse. The treatment was performed using a combined process; Adsorption on Bentonite (B) followed by electroflotation (EF). The effects of B concentration, pH, contact time and current density, were investigated under optimal conditions for maximal dye elimination. Water reuse activity, the potentials, risks and issued associated with reclaimed water reuse are also reviewed. The results were well fitted by both Langmuir and Freundlich isotherm models and show that the effluent treated by this combined method contained essentially no turbidity, color or COD 99, 01%, 99, 49% and 99, 8% are the removal rates obtained, respectively. The treated effluent quality satisfied the requirement of water discharges standards. Yet, integration of many factors is needed to reuse this water.

Capsule Summary: Textile wastewater impact, treatment and reuse possibilities are discussed.

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INTRODUCTION

Rapid industrial development in the world, particularly in developing countries, has helped to understand the relationship between pollution, public health and the environment (Ogunlaja1 et al., 2009). The textile industry is a complex fragmented and heterogeneous sector characterized by its high water consumption, chemical usage and wastewater discharge, containing great amounts of Dyeing Chemicals, Textile wastewater is often characterized by low biodegradability, and high salinity (Vajnhandl et al., 2014) Contributing to severe water problems and a significant amount of pollution, which represents a major threat to the local environment and human health.

Health and environmental hazards

Among the many chemicals in textile wastewater, dyes are considered important pollutants and cause serious environmental and health problems. Effluent from textile mills also contains residues of reactive dyes and chemicals, such as complex components, many aerosols, and chemical oxygen demand COD and biological oxygen demand BOD at high concentrations (Ranade et al 2014).

Dyes are complex aromatic molecular structures which are intended to be stable and consequently are difficult to degrade, most of them are toxic substances to human and aquatic life (Alinsafi et al., 2005). Discharged into the surrounding water sources can have a negative impact on local ecosystems.

The main objective of this work was the treatment of textile dyeing wastewater by economic and efficient way. The used combined process is summarized in adsorption using natural clay, followed by Electroflotation process.

MATERIAL AND METHODS

Study area

The Algerian company of industrial textiles DENITEX, located in the north east of the town of Sebdou, 38kms southern wilaya of Tlemcen covering a total area of 16.9 hectares has emerged as a leading textile industry in western Algeria, the largest complex in the region. DENITEX-Sebdou complex is powered by the drilling DERMAM .The transferred water is in the order of almost 50% of the flow; the rest is used for drinking supply of the city. The resort's water needs are estimated at 20 L/S, used in boilers cooling, air conditioning and various domestic uses with a water storage capacity of 1300 m^3.The unit rejects nearly 10,000 m^3 to 12,000 m^3 of wastewater monthly at WadiTafna after treatment(industry documents).

The colored effluent samples used in this study were collected at the output of the of cotton dyeing unit, Denitex, Tlemcen (Algeria). This unit uses a large variety of colorants for dyeing its various tissues.

Natural clay minerals are well known from the earliest day of civilization (ERRAIS et al., 2011). Because of their low cost, high surface area, high porosity, and abundance in most continents, clays are good candidates as adsorbents. The bentonite (B) used for this study comes from Maghnia (Western Algeria) Produced by the national company ENOF. It was used as it was provided to the in its raw powder state as shown in table 1.The amounts of clay were added to different samples and have stirred (300 rpm) 15 minutes before the adsorption tests.

Adsorption studies

Adsorption studies were carried out using Bentonite (B). Increasing amounts of B were added to 500 mL of on real textile waste water in a stirred (300 rpm) flask, placed in thermostated baths for 1 hour, at 25 °C. Solid-liquid separation was carried out by filtration under vacuum conditions. The dye concentration in the filtrate was then measured.

Equilibrium Isotherm Models

Two models were used to fit the experimental data, Langmuir isotherm (Langmuir, 1918) and Freundlich isotherm (Freundlich, 1907). The Langmuir isotherm is based on assuming a monolayer sorption onto a surface with a fixed number of well-defined sites; the equation is given below:

$$\frac{m}{x} = \frac{1}{q_m} + \frac{1}{q_m\, b} \times \frac{1}{C_e} \tag{1}$$

The Freundlich adsorption isotherm is an empirical equation used to describe heterogeneous system. The Freundlich coefficients can be determined by linear regression from the plot of $\log\frac{m}{x}$ versus $logC_e$ on the basis of the linearized equation given by:

$$log\frac{m}{x} = logk_f + \frac{1}{n} logC_e \tag{2}$$

Where, C_e: dye concentration at equilibrium (mg/L), $x = (C_0 - C_e)$: the amount of dye fixed (mg /L), m: the mass of adsorbent (g), q_m: the ultimate adsorptivity (mg/g), k_f, n, b : adsorption constants.

Electroflotationstudies (EF)

Electroflotation tests were performed on samples that have been processed in a rectangular Plexiglas cell with cross-sectional dimensions of 7 cm × 9 cm x 30 cm high, in optimum conditions. The electrode used is provided by Dr. G. Chen, University of Science and Technology, Clear Water Bay, Hong Kong, China (Chen and al., 2001, Chen and al., 2002; 2004). The circuit is composed of a power generator Leybold Didactic CMBH, 2 (30 V, 2.5 A), an ammeter connected in

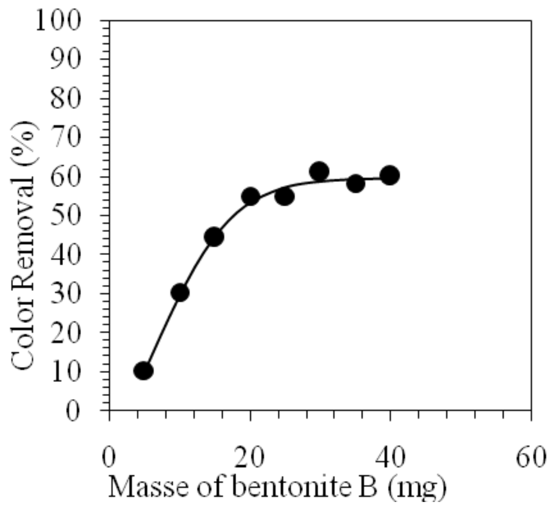

Fig. 1: Color removal as a function of the bentonite B masse (V sample = 500 mL ; Temperature=25 ±1°C ; pHi= 7± 0.05; Contact time=1 h).

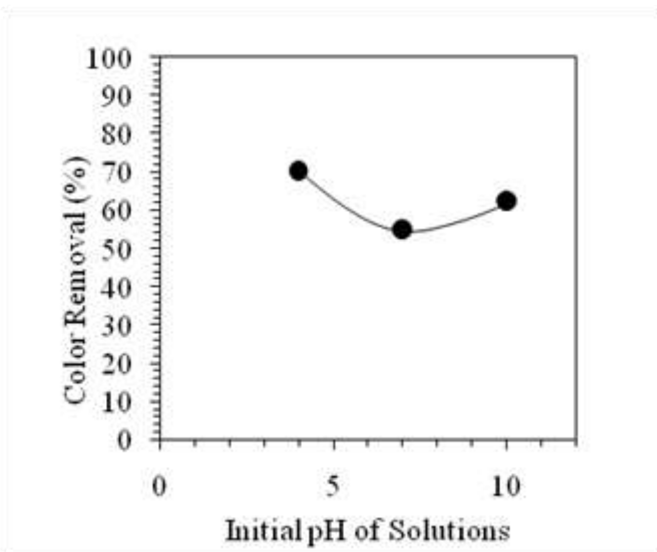

Fig. 2: Color removal as a function of initial pH of solutions (V sample = 500 mL; mPAC = 20 mg ; Temperature=25 ±1°C ; Agit =300 rpm ; Contact time = 1 h).

series and a voltmeter connected in parallel (Bouyakoub et al, 2010). The temperature in the cell was kept constant at 20 ± 1C ° with a pH of 6 ± 0.05. To recoup the electroflotation technique, the monitoring of the evolution of the removal of color, turbidity and COD on the one hand, and the calculation of the energy consumption on the other hand, was performed for each test, on a volume siphoned off using a syringe, from the separated water.

Dye Concentrations in water was determined using UV-visible spectrophotometer (SHIMADZU UV-2401PC, Japan). The calibration curves in the range of concentration from 0 to 100 mg/L obey the Beer - Lambert law. Residual dye concentrations were deduced from absorbance values, according to the relation:

$$C = \frac{A}{A_0} C_0 \quad (3)$$

Where, C_0 and C are the initial and equilibrium (or residual) liquid-phase concentrations (mg/L), A_0 and A are the initial and equilibrium absorbances, respectively.

RESULTS AND DISCUSSION

ADSORPTION

Effect of adsorbent dose

The effect of adsorbent dose on removal of color at different amounts of B has been shown in figure1. The results show that adsorption kinetics becomes faster by increasing the mass of clay to a value of 20 mg and the removal efficiency was determined to be 54.97 %. Beyond that, the transfer rate is practically zero. In addition, the mass transfer rate is proportional to the concentration gradient and the exchange surface. In our case the initial dye concentration is constant; an increase in the clay mass in solution increases the transfer surface and the adsorption speed.

Effect of pH

The pH of the solutions plays an important role in the adsorption process (figure 2), as the adsorbent surface acquires positive or negative charge in response to change in pH (Abollino et al., 2003, Bhattacharya et al.,2006).The curve indicates that the maximum dye uptake was recorded at pH=4. Özcana et al. (2007) studied shows that the optimal pH for adsorption of reactive dyes by modified bentonite is acidic. Akar and Uysal (2010) used clay without treatment (processing) and noticed that an acid pH increased the capacities of adsorption of the coloring agent. This is explained by the fact that in the acid state, the positive charge dominates the surface of adsorbing it. Thus, a high electrostatic attraction between the positive charges of the surface of the adsorbent and the negative charges dye (Isa et al., 2007). In basic pH in spite of the presence of the OH^- ions, we notice that the capacity of adsorption is upper compared with the neutral pH, Thus we can say that there is always an attraction between coloring agents and B, there would be only a low competition between OH^- ions and the anion of coloring agents at basic pH (Errais et al., 2011).

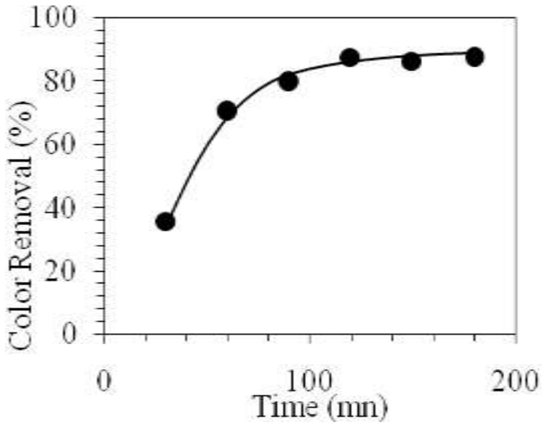

Fig. 3: Color removal as a function of contact time (V sample = 500 mL; pHi = 4 ± 0,05 ;mB = 20 mg ; T = 25 ±1 °C; Agit. = 300 rpm).

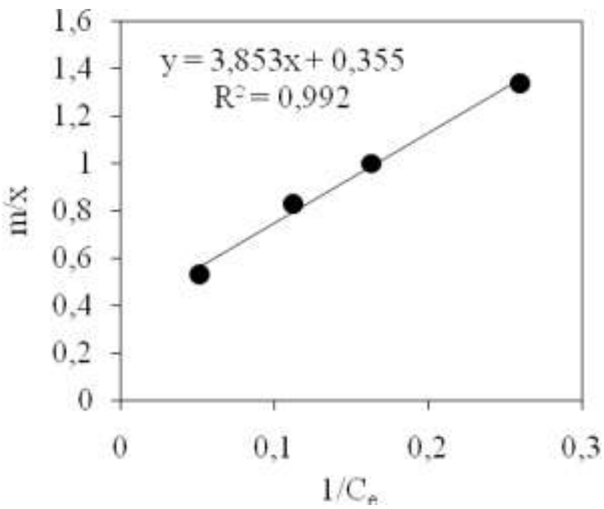

Fig. 4: Langmuir Adsorption isotherm of dye onto natural bentonite.

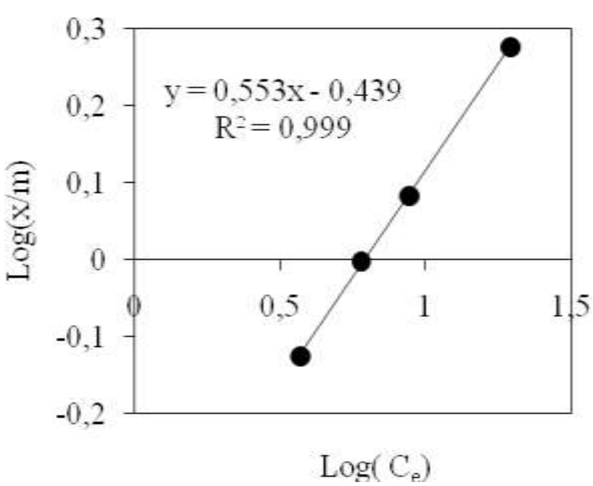

Fig. 5: Freundlich Adsorption isotherm of dye onto natural bentonite.

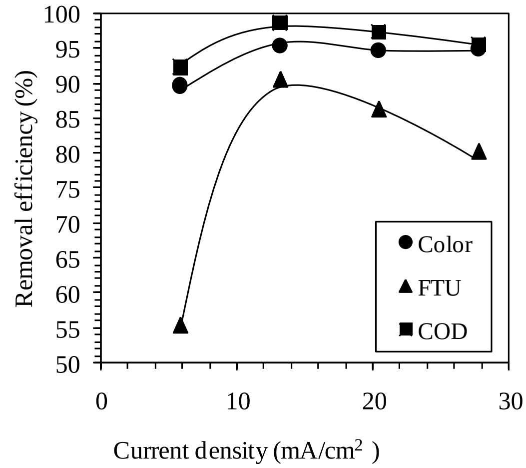

Fig. 6: Removal efficiency of color (●), COD (■) and residual turbidity (▲)as a function of Current density.

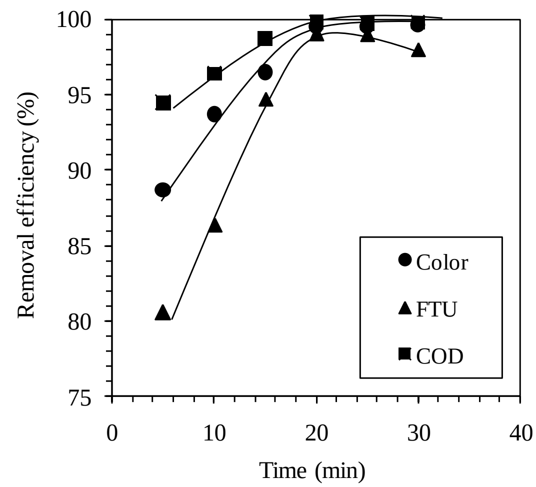

Fig. 7: Removal efficiency color (●), COD (■) and residual turbidity (▲).

Determination of the optimum contact time

The contact time is a very important factor which influences the dye fixation. A series of contact time experiments have been carried out within the time range of 30 to 180 min at 25°C. Figure 3 shows that short contact time appears insufficient, because it does not permit the formation of the physicochemical bonds between the aqueous dye and the adsorption sites of the solid phase. The amount adsorbed increased with increase in contact time, at some point in time, it reaches a constant value beyond which no more is adsorbed. At this point, the amount of dye being adsorbed onto the adsorbent was in a state of dynamic equilibrium.

Table I: Physical properties of Bentonite (B) for pHB=10,11 at 20 °C.

Bentonite (B)	S_{BET} (m^2/g)	V_m (m^2/g)	$S_{micropore}$ (m^2/g)	$S_{mesopore}$ (m^2/g)	S_{totale} (m^2/g)
	69.35	15.87	27.74	47.54	75.28

Table 2: The value of parameters for each isotherm model used at 25 °C

Langmuir model			Freundlich model		
q_m(mg/g)	b (l/mg)	R^2	n	k_f	R^2
2.81	0.09	0.992	1.80	0.36	0.999

The time required to attain this state of equilibrium is termed the equilibrium time.

Equilibrium isotherm models

Adsorption isotherms are important to examine the relationship between adsorbent and adsorbate when the adsorption process reaches an equilibrium state, and search for the maximum sorption efficiency, In order to describe experimental data of adsorption isotherms, several mathematical models can be used is represented in Figures 4-5 respectively.

The values of the Langmuir parameters q_m, b and Freundlich parameters K_f, n and the calculated regression correlation coefficients were reported in table 2.The regression coefficients R^2 = 0,992 and 0,999 respectively suggest that the color of adsorption can be modeled by the Langmuir model as well as Freundlich model.

ELECTROFLOTATION

Effect of current density on electroflotationprocess

The current density has a great effect on the EF process. It speeds up the formation of gas bubbles. Yet, higher current densities are unsuitable for flotation because they promote the formation of larger gas bubbles, giving rise to a turbulence phenomenon. Figure 6 reveals the efficiency of elimination of the turbidity, DCO and color according to the value of the current density. The maximum rate of removals of turbidity, COD and color were observed at 13.14 mA/cm^2 (90, 57%, 98, 67% and 95, 34% respectively)

Effect of EF time

The results of treatment of the textile effluent by electroflotation shows that floating time plays an important role (figure 7). The removal rate increases with the contact time applied up to 20 minutes, the process seems to reach its best performance; the effectiveness of abatement are: 99.01%, 99.8% and 99.49 % for turbidity , COD and color , respectively. Beyond the optimum time, the process of solid-liquid separation is found slowed and stabilized. This can be explained by the fact that the suspended particles that could be attached to the bubbles are different sizes; larger are easily removed, while the particles of low dimension remain in suspension since they hardly adhere to the bubbles (Bouyakoub et al 2010).The process reached limitation under these conditions (Hosny, 1996).

Effectiveness of the combined treatment

Large amount of dyes are used for various industrial applications, especially in the textile manufacturing where the removal of these dyes from effluent is a major environmental challenge there is a permanent requirement to develop an effective processing technology which can efficiently remove these dyes (Lee et al., 2006). The choice of a particular process Treatment is based on two important criteria: cost and effectiveness. To ensure the latter criterion, it is necessary to combine two or more methods depending on the nature of the dyes used and dyeing methods used during production (Vera et al., 2005, Bouyakoub et al., 2009; 2010). The high-quality effluent confirms the Effectiveness of the combined process. The treated wastewater can be utilized for recycling or reuse purposes.

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