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Post-treatment of banknote printing wastewater using polysilicate ferro-aluminum sulfate (PSFA)

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ABSTRACT

In this paper, a new kind of inorganic polymeric flocculant (IPF)—polysilicate ferro-aluminum sulfate (PSFA) was adopted to treat banknote printing wastewater. Effects of flocculants dosage on the colour and Chemical Oxygen Demand (COD) removal were examined. Experiments revealed that maximal colour removal efficiency of 98% and COD removal efficiency of 85% could be achieved at the optimal dosage of 30.33 g/L. And the colour and COD removal results treated by the PSFA flocculant were compared with those treated by aluminum sulfate. Experimental results showed that the most attracting parts of PSFA as compared with that of $Al_2(SO_4)_3$ were: (i) lower COD and colour contained effluents; (ii) less quantity and volume sludge; (iii) better dewatering behaviour and solid–liquid separation flocs; (iv) providing a possibility to eliminate the high labour intensity plate-frame pressure procedure and replace it by ordinary filtration. Therefore, the using of PSFA generally offered a lower cost of operation and maintenance choice to treat banknote printing wastewater as compared to that of $Al_2(SO_4)_3$.

1. Introduction

Banknote printing wastewater is a kind of printing and dyeing wastewater which is one of the most complicated wastewater in manufacturing industry because of its fragmented and heterogeneous character and high in Chemical Oxygen Demand (COD) and colour. Among the conventional methods, biological treatment, chemical coagulation and flocculation, chemical oxidation, and adsorption processes are the most popular ones [1] used to treat dying wastewater. Although biological treatment processes such as aerated lagoons are generally efficient in Biochemical Oxygen Demand (BOD) and Suspended Solid (SS) removal [2], they are ineffective for removing colour from the wastewater because of the low biodegradability of many chemicals and dyes. In a typical coagulation/incineration system, the coagulant requirement is, however, large [3]. Advanced oxidation processes such as ozonation, Ultraviolet (UV) and ozone/UV combined oxidation, photo catalysis (UV/TiO_2), Fenton reactive and ultrasonic oxidation are not economically feasible [4,5], while adsorption processes have the associated cost and difficulty of the regeneration process and a high waste disposal cost.

Besides, banknote printing wastewater contains high concentration of sodium hydroxide [>10 g/L] that can be recycled and reused. Therefore, ultra filtration has been adopted for treatment of wastewater by several banknote printing factories in China. However, ultra filtration, a physical chemistry separation procedure, can produce highly concentrated rejects effluents, which needs post-treatments such as coagulation [6–9], activated carbon absorption [10,11] before entering into municipal sewage treatment system. And the process flow in Nanchang banknote printing factory is illustrated as below (Fig. 1):

The process is as follows: printing wastewater and wash water are the process effluents of banknote printing works which are collected together and follow the treatment of ultrafiltration (UF) for maximum recycling of recovered waters. The permeate stream which contains water and small amount of soluble solutes and free surfactants is recycled and reused in the cleaning operations. Rejects (about 20% of the inlet volume, whose characteristics are presented in the Table 1), containing high concentrations of organic matter, non-biodegradable matter, oil, suspended and dissolved solids and alkalinity, are collected and allowed for coagulation to remove the colour. Precipitate generated from coagulation is incinerated or land filled while the clarified effluents are further treated at a municipal wastewater treatment system.

The colour of the UF rejects effluence is red or purple, depending on the production process. The main environmental impacts of the banknote printing wastewater come from the strong colour and a high concentration of dissolved solids (organic and inorganic materials), and their discharge into river may further aggravate the problem. Due to these factors, the banknote printing industry faces the challenge of balancing the environmental protection, its

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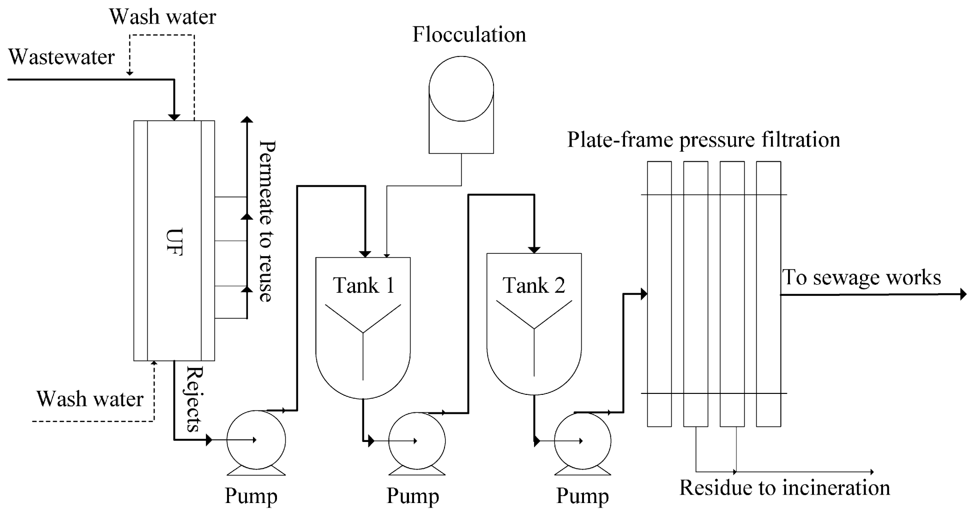

Fig. 1. Schematic diagram of the membrane ultrafiltration, coagulation and plate-frame pressure filtration procedure in Nanchang banknote printing factory.

economic viability and sustainable development. Therefore, these effluents should be treated before discharging.

There are many reports on the use of inorganic polymeric flocculants (IPFs) in water or wastewater treatments. However, few reports have been found on the use of PSFA in banknote printing wastewater treatments. The objective of this research was to investigate the efficiency of coagulation and flocculation processes for the removal of colour and the majority of organic matters from banknote printing UF rejects using a new kind of flocculants—poly-silicate ferro-aluminum sulfate. Flocculating performance comparison between polysilicate aluminum sulfate and other flocculant such as aluminum sulfate was also carried out.

2. Materials

2.1. Wastewater samples

Wastewater used in the experiments was obtained from Nanchang banknote printing factory (Jiangxi province, China), the mean characteristics of which were presented in Table 1. The samples were withdrawn from the end of the ultrafiltration equipment, after concentrated by the ultra filtration membrane and the effluents were used without any dilution. The wastewater was highly coloured and also had high COD and pH values.

2.2. Reagents

All of the chemicals used were of analytical reagent grade. $Na_2SiO_3{\cdot}9H_2O$ (MW 284.22) and $FeSO_4{\cdot}7H_2O$ (MW 278.02) were obtained from Shanghai Yanchen chemical Co, Ltd, China; $Al_2(SO4)_3{\cdot}18H_2O$ (MW 666.41) was purchased from Guangdong Xilong chemical factory, China; 98% sulfuric acid were provided by Hongdu reagent chemical factory, Nanchang, China.

Table 1
Characteristics of UF (ultra filtration) concentrated wastewater from Nanchang banknote printing factory.

Parameter	Value	Discharge standard[a]
COD_{Cr} (mg/L)	79800	100
Colour (times)	1000	180
SS (mg/L)	4900	800
Petroleum (mg/L)	1000	100
Temperature (°C)	45	–
pH	13	6–9

[a] According to integrated wastewater discharge standard (second grade of GB8978-1996, China).

3. Experiments and analytical methods

3.1. Preparation of flocculants

The flocculants used in this study were preparation as follows: firstly, 1.7 g sodium silicates 99.96 g aluminum sulfate and 27.80 g ferric sulfate were mixed in a glass reactor (1 L); secondly, 230 mL 98 wt.% sulfuric acid was added to the reactor, then 230 mL tap water was slowly poured into the reactor and the solution were stirred for a few minutes; finally, the solution were aged for 1.5 h to get the final flocculation PSFA. The flocculation was solid and white or yellow in colour, and its properties do not change for at lest 3 months.

In practical coagulation experiments, 20 wt.% PSFA stock solutions were prepared with tap water (density: 1.0866 g/mL, pH: 0.41). $Al_2(SO_4)_3$ used as a comparison in this study was dissolved in tap water to make a 20 wt.% coagulant solution (density: 1.1238 g/mL, pH: 2.51).

3.2. Coagulation–flocculation test procedures

The raw wastewater (UF rejects or UF concentrated wastewater) was used directly without any pH adjustment. Coagulation–flocculation studies were performed with batch cylinder test cylinder columns. Namely, 50 mL raw water and certain dosage of coagulant were added to a 100 mL of cylinder column and shaken by hand for 5 times.

3.3. Analytical methods

After the Coagulation–flocculation test procedure, the result suspension solution was filtered. Filtration was done under atmospheric pressure using a filtrate cloth provided by Nanchang banknote printing factory to simulate practical solid–liquid separation process.

The filtrate was analyzed for pH, COD, colour, while the filter residues were subjected to moisture content rate and residual yield measurements. The pH was measured by pH-3 meter (Rex, Shanghai Precision Scientific Instrument Co., Ltd, China) while