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ORIGINAL ARTICLE

Feasibility of electrocoagulation/flotation treatment of waste offset printing developer based on the response surface analysis

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Abstract In the printing plate developing process, the offset printing developer undergoes changes, as well as enrichment by the various chemicals, i.e. metals, organic binders and photosensitive compounds. The objective of this study was to investigate the electrocoagulation/flotation (ECF) treatment efficiency for the removal of copper, turbidity and organic substances from the waste offset printing developer (WOPD). The effect of operational parameters, such as electrode materials, current density, interelectrode distance and operating time, was studied. Also, the response surface analysis was applied to evaluate the effect of main operational variables and to get a balanced removal efficiency of investigated WOPD parameters by ECF treatment. The removal efficiency increases significantly with the increasing of operating time and mainly increases with the increasing of current density. The obtained results show that the interelectrode distance and combinations of electrodes determine the removal efficiency of copper, turbidity and organic substances. Based on the obtained results, the optimized parameters for the ECF treatment removal of investigated WOPD parameters were identified as: Al(−)/Fe(+) electrode combination with interelectrode

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distance of 1.0 cm, operating time of 5 min and current density of 8 mA cm^{-2}. This study confirms the practical feasibility of ECF method for treating real printing industrial effluent under optimum conditions.

1. Introduction

The electrocoagulation/flotation process includes the in-situ generation of coagulants via the electro-dissolution of a sacrificial anode, which usually consists of iron or aluminum. Only a very few reports on the combined use of both aluminum and iron electrodes in the same cell were published (Jewel et al., 2007; Katal and Pahlavanzadeh, 2011; Linares-Hernández et al., 2009). The use of combination electrodes of dissimilar metals may provide an alternative method for the efficient removal of heavy metals, turbidity and organic substances from the wastewater (Linares-Hernández et al., 2009) such as WOPD.

The interaction between the coagulant and the pollutant is the most complicated aspect of the ECF process (El-Shazly et al., 2011). The ECF process combines three main interdependent processes, operating synergistically to remove pollutants: electrochemistry, coagulation and hydrodynamics (Bazrafshan, 2008; Nouri et al., 2010). This process may be summarized as follows (Adhoum et al., 2004; Phalakornkule et al., 2010):

- Compression of the diffuse double layer around the charged species by the interaction of ions generated by oxidation of the sacrificial anode.
- Charge neutralization of the ionic species present in wastewater takes place due to the counter-ion produced by the electrochemical dissolution of the sacrificial anode. These counter-ions reduce the electrostatic interparticle repulsion to the extent that the Van der Waals attraction predominates, thus causing coagulation.
- The flock formed as a result of coagulation creates a sludge blanket that entraps and bridges colloidal particles still remaining in the aqueous medium.

Industrial growth is of utmost importance to mankind but the environmental pollution due to it is never desired. Heavy metal contamination exists in aqueous wastes of many industries and these usually contain metal-ion concentrations much higher than the permissible levels and do not degrade easily into harmless products (Narayanan and Ganesan, 2009). Separation techniques of heavy metals, such as chromium, cadmium, copper, zinc and nickel, from industrial wastewater include precipitation, ion exchange, adsorption, electro-dialysis and filtration, but these techniques have limitations (Nouri et al., 2010). Ion exchange, for example, while highly effective in removal of certain charged contaminants, requires resin regeneration or replacement at a high cost (Escobar et al., 2006). The costs of adsorption, ultrafiltration, reverse osmosis and ozonation exceed that of chemical coagulation. While chemical precipitation is a simple process, it does generate a high volume of sludge. When chemical coagulation is used to treat wastewater, the pollution may be caused by a chemical substance added at a high concentration. Excessive coagulant material can be avoided by ECF process (Merzouk et al., 2009). The ECF process has been successfully employed in the removal of cadmium (Mahvi et al., 2010; Khaled et al., 2015), zinc (Nouri et al., 2010), copper (Adhoum et al., 2004; Akbal and Camcı, 2010; Escobar et al., 2006; Hunsom et al., 2005), nickel (Dermentzis et al., 2011; Mouedhen et al., 2008), chromium (Bazrafshan, 2008; Zongo et al., 2009a), silver (Hangeidman and Wolfg, 2008) and arsenic (Oehmen et al., 2011; Pan et al., 2010) from a variety of liquid wastes. It has been shown that ECF process is able to eliminate tannin and organic dyes (Nandi and Patel, 2013; Sanromán et al., 2004; Trujillo-Ortega et al., 2013), phenolic compounds (El-Ashtoukhy et al., 2013), benzoquinone (Can and Bayramoglu, 2010), natural organic matter (Mohora et al., 2012; Vepsalainen et al., 2012) and different organic substances from various types of liquid by using sacrificial aluminum or iron electrodes. The literature publications show that the ECF process has been proposed as an effective method of treating various effluents such as textile wastewater, paper mill wastewater, baker's yeast wastewater, restaurant wastewater, urban wastewater, laundry wastewater, nitrate and phosphate bearing wastewater, electroplating wastewater, and chemical mechanical polishing wastewater (Can et al., 2006; Kobya and Delipinar, 2008; Narayanan and Ganesan, 2009; Nouri et al., 2010). On the other hand, the ECF process has not yet been taken into consideration for the treatment of WOPD.

The critical physicochemical phenomenon, during the developing processes in offset printing, is the generation of the non-image area on the printing plate surface by using an aqueous solution known as the offset printing developer. The printing plate is introduced in the developer bath, in order to make the image areas visible. The image areas become ink-receptive thanks to a chemical change on the previously coated printing plate surface. The non-image areas stay water-receptive (Andrade et al., 2012). After semi-automatic offset plate insertion into the platesetter, rollers accept and pass the plate to the offset printing developer tank. In the developer tank, a roller brush makes the offset plate clean. After the developing process, the offset plates are washed with water, preserved and dried. In the preservation process, plate is covered with a thin solution of "*gum arabic*" or similar chemical, which gives the non-image areas storage-resistant hydrophilic properties (Kipphan, 2001). The waste offset printing developer is expected to contain residual ingredients and products present in the offset plate surface such as organic binders and photosensitive compounds (Vengris et al., 2004). All these processes resulted in a high amount of metals (part of the offset plate), organic substances (originated from chemicals) and turbidity in WOPD. Therefore, the offset printing sites should apply measures that would be focused on monitoring, prevention and then on preparation for re-use of the WOPD before being discharged into water and soil recipients.