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INVESTIGATION OF DIFFERENT ELECTRODES IN ELECTROCOAGULATION OF DOMESTIC WASTEWATER TREATMENT

Alfa-Sika Mande Seyf-Laye[1,2,3*], Tchakala Ibrahim[2], Dougna Akpénè Amenuvevega[2,3], Djaneye-Boundjou Gbandi[2], Bawa L. Moctar and Chen Honghan[1]

[1]Beijing Key Laboratory of Water Resources & Environmental Engineering, China University of Geosciences (Beijing), Beijing 100083, P.R. China

[2]Water Chemistry Laboratory, Faculty of Science, University of Lome, BP. 1515, Togo

[3]Faculty of Science and Technology, University of Kara, BP. 404, Togo

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ABSTRACT

Electrocoagulation method with iron/iron, and Cu and Ti/IrO_2 electrodes as cathode and anode were used, to treat the domestic wastewater in batch reactor. The performance of electrocoagulation (EC) process was investigated for phosphorous, chemical oxygen demand (COD) and $NH_4^+ - N$ reduction. The effects of the relevant key operating conditions such as amperage and electrolysis time were studied in order to evaluate the performance of electrodes. The result indicates that electrocoagulation is very efficient and was able to achieve phosphorous removal (99.46%), COD removal (56.11%) and $NH_4^+ - N$ (58.37%) at 0.8A in 60 min in the presence of iron electrode. The $NH_4^+ - N$ removal by Cu and Ti/IrO_2 electrodes were achieved at 99.82% at 0.8A in 45 min. The results revealed that the ammonium was removed and 2.33 mg/L of nitrate was found with the weak formation of nitrite. Finally the Ti/IrO_2 electrode was not affected by the process. It means that total suspended solids were removed by Fe electrode.

KEYWORDS: Electrocoagulation, domestic wastewater, phosphorous, COD, $NH_4^+ - N$.

I. INTRODUCTION

Water is the source of life (Saleem et al., 2011). It is essential forallbeings and living ecosystems. The quality of the water distributed to the consumer's tap depends on the water quality of the river or aquifer in which the water was taken and the treatments carried out after the levy. Evacuating organic matter in water, it affects the balance of aquatic environment through the depletion of oxygen level and impoverished the soil of nutrients. Water quality is composed of a multitude of parameters some relevant to filtration, followed by either aerobic or anaerobic microbial degradation on the surface such total suspended solid (Mameri et al., 2011) and as known the excess of phosphate and nitrogen compound from wastewater are responsible for the phenomenon of eutrophication which negatively affect the aquatic life (Bektas et al., 2004; Irdemez et al., 2006). The presence of free ammonia in wastewater can also cause several problems in the environment due to its high toxicity especially at pH higher than 8 (Reginatto et al., 2005).

However, municipal wastewater is a mixture of domestic wastewater (the basic component), small amounts of industrial and storm water drain water surface infiltration and groundwater. The direct discharge of untreated sewage in nature is not desirable as the decomposition of organic waste could deteriorate the water quality and the environment. Knowledge of the average concentrations of the parameters characterizing the wastewater as well as ranges of possible variations is crucial to ensure adequate wastewater treatment. Traditionally biological method is used in treatment of domestic wastewater (Ouyang et al., 2000). This method has some disadvantages such as air supply, high operating coast (skilled labor , energy, etc) long treatment time and necessary sludge disposal (Pidre et al., 2001) but new technologies such electrocoagulation is susceptible to improve more the efficiency removal of wastewater through the production flock of higher size and density ((Larue and Vorobiev, 2003). The electrocoagulation is considered as low sludge producing and flock formed relatively large contain less bound water and more suitable (Niam et al., 2007). Therefore in this study firstly the suspended solid was investigated by electrocoagulation removal by iron electrode and then the water used by electro-oxidation of ammonia to nitrate by copper electrode.

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II. MATERIALS AND METHODS

2.1. Materials

The domestic effluent used in the experiments was obtained from Tsinghua University Wastewater Treatment Plant in Beijing. The characteristics of the effluent are presented in Table 1.

Table 1. Characteristics of wastewater used

Parameter	Units	Value
pH	-	7.98
Chemical oxygen demand (COD)	mg/L	318.7
$NH_4^+ - N$	mg/L	80
PO_4^{3-}	mg/L	5

2.2. Apparatus and instruments

The experimental setup is schematically shown in Fig. 1. The electrocoagulation unit consisted of a 0.3L electrochemical reactor with iron anode and cathode in the first step and in the second step the anode from titanium coated with TiO_2 and cathode was sheet of copper. The distance between electrode set was 2 cm. The electrochemical reactor was made of Plexiglas.

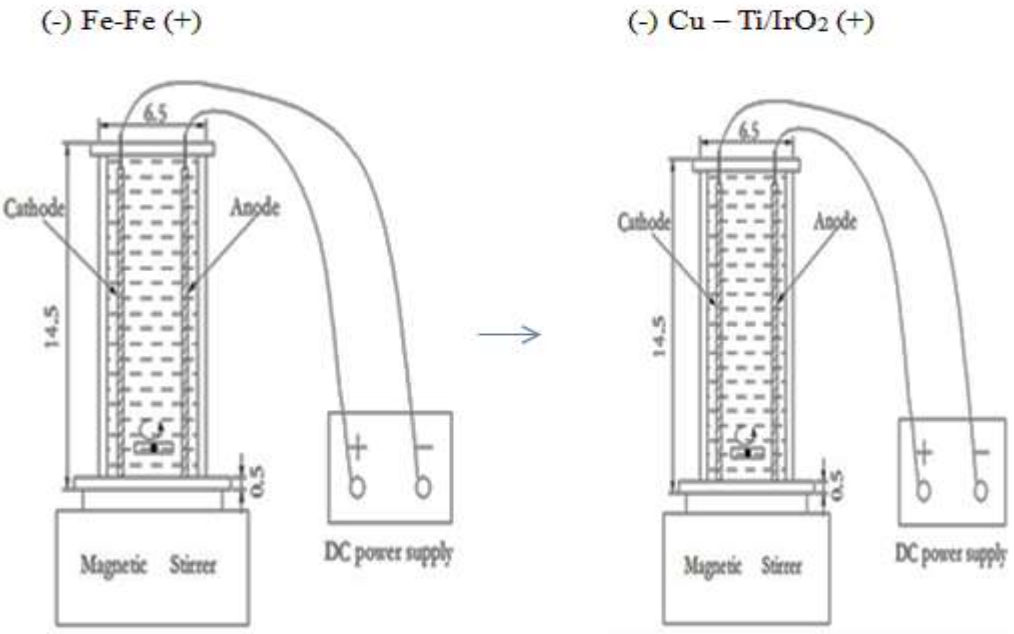

Figure 1. Schematic view of the EC reactors

2.3 Experiment Methods

The experimental setup of electrocoagulation study given in (Fig 1). At the beginning of each run, the solution of wastewater (300 mL) was fed in the reactor and the solution of NaCl 0.5 g/L (as electrolyte) was added to increase the solution conductivity. This study was made in two steps; firstly the experiment was carried out with iron electrode as anode and cathode in order to remove suspended solid presenting in the solution. The intensity of current was adjusted to the value of 0.8A, and finally the sampled wastewater was filtered in preparation for chemical analysis. In the second step the experiment was conducted with titanium electrode as anode and copper electrode as cathode in order to reduce ammonium to nitrite and nitrate. The whole experiment was performed during 1 hour and the sampling wastewater was made every 5 minutes.

III. RESULTS AND DISCUSSION

3.1. Fe electrode

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According to (Figure 2) removal of pollutants such as phosphorus, COD and $NH_4^+ - N$ is 99.8%, 56.11% and 58.37% respectively in 60 minutes. It was estimated that the phosphorus in the form of orthophosphate was removed from the effluent by direct precipitation with multivalent metal ions. Total phosphorus was extracted, meanwhile by a complex combination of adsorption and interaction with flocks and aggregates produced during the coagulation process (Aguilar et al., 2002). The removal of COD was due to precipitation of dissolved organic. The removal rate of COD depended mainly of hydroxides flock which bound with time (Golder et al., 2005). However the elimination of the TSS can be attributed to the rapid and effective destabilization of suspended particles with an effective mixing (Neil et al., 2014). A decrease in the value of pH was observed after the treatment time from 7.98 to 7.00. This decrease in pH was attributed to the formation of $Fe(OH)_3$ near the anode which freed hydrogen ions (Fuat et al., 2011). According to correlation study (Bektas et al, 2004), the maximal elimination of phosphorus is between a value of pH equal to 6 and 7. The Fe electrodes used in the experiment were reactive leading to the erosion of the metal by suspended solid. Thus protective oxide film formed (Hu et al., 2003). The presence of the film on iron electrode increased the potential and led to the release of chlorine ion. The generated molecular chlorine was hydrolyzed to form hypochlorous acid (Eckenfelder et al., 1991) which was consecutively changed to hypochlorite ion. The hypochlorous acid and hypochlorite ion could decompose ammonium to nitrogen gas because of their high oxidative potential.

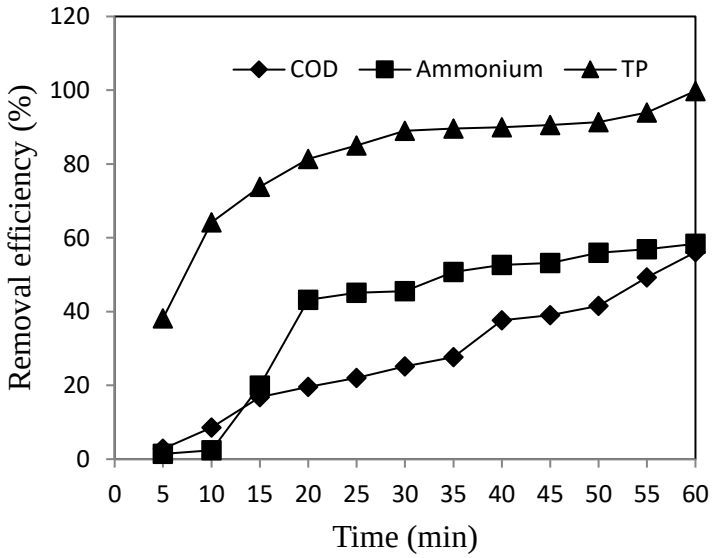

Figure 2 Removal of $NH_4^+ - N$, TP, COD (I = 0.8 A, $NH_4^+ - N$ = 80 mg/L, TP = 5 mg/L, COD = 318.75 mg/L, NaCl = 0.5 g/L).

4.3.2 Cu electrode

As shown in the (Fig 3) efficiency removal of ammonium is 100%. Whereas the accumulation of nitrate increased sharply to 2.33 mg/L the whole at 50 minutes. Generally the mechanism of ammonium removal by electrolytic oxidation consists of direct and indirect oxidation reactions (Lee et al., 2010). The direct reaction oxidation of ammonium at first occurs at anode and indirect reaction oxidation also takes place through oxides created during the process of electrolysis.

Chlorine (Cl^-) in wastewater can lose electrons to the anode and then turn into chlorine gas (Cl_2). Hypochlorous acid (HOCl) is formed by chloride ions dissolved in the waste water after deaerating of gaseous chlorine. The hypochlorous acid reacts with ammonia to be finally removed as gaseous nitrogen. This reaction is as follows:

$$2NH_4^+ + HOCl \rightarrow N_2 + 3H_2O + 5H^+ + 3Cl^-$$

The rate of removal of ammonium decreased over the process of electrolysis. This can be explained by the fact that the ammonium ions presented as dissolved free ammonium which increased the value of pH during the process of electrolysis. Concerning the formation of nitrates, it slightly increased due to the reaction between

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hypochlorous acid and ammonium ion. This reaction is illustrated as follows:

$$0.25NH_4^+ + HOCl \rightarrow 0.25NO_3^- + 0.25H_2O + 1.5H^+ + 3Cl^-$$

Whereas the reaction of nitrate removal is illustrated as follows:

$$NO_3^- + 6H_2O + 8e^- \rightarrow NH_3 + 9OH^-$$

It means the elimination of ammonium have produced nitrate which not only come from the indirect oxidation but also the hydroxyl radicals. The pH value after treatment was 6.51. It means the removal process of ammonium is affected by a low value of pH and then the formation of hypochlorite ion ($HClO^-$) is usually favored by low pH value which is a strong oxidant than chlorate ion (ClO_3^-) in that kind of the condition

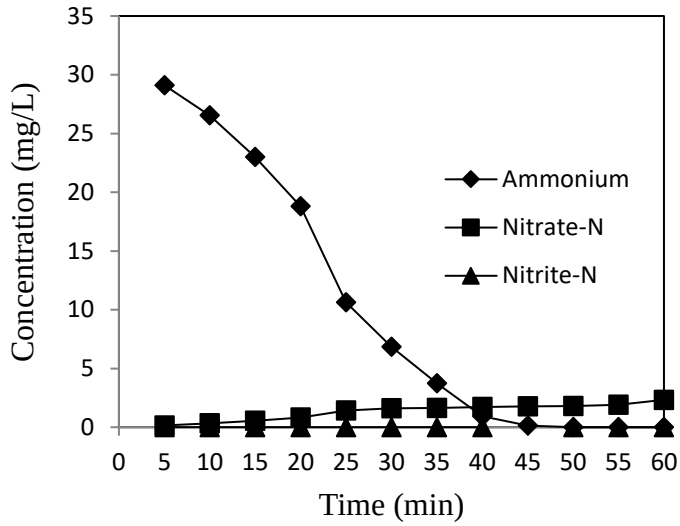

Figure 3: Reduction of $NH_4^+ - N$ (I = 0.8 A, $NH_4^+ - N$ = 35 mg/L, NaCl = 0.5 g/L, pH = 7. 98).

IV. CONCLUSION

In this study, the wastewater from Tsinghua University (China) was treated in two steps. The first step involved the treatment by the electrodes of iron. In that case the removal efficiencies of pollutants such as TP, COD and $\boldsymbol{NH_4^+ - N}$ were 99.98%, 58.00%, and 58.37% respectively. The objectives of wastewater treatment by iron electrodes were to remove the suspended solids and avoid the erosion of the Ti/IrO2 electrode in the second step. In the second step of the process, the same water was used to oxidize ammonium by products of nitrate and nitrite with Cu and Ti/IrO2 electrode as cathode and anode. The results revealed that the ammonium was removed and 2.33 mg/L of nitrate was found with the weak formation of nitrite. The pH in the acid condition influenced the process. Finally the Ti/IrO2 electrode was not affected by the process. It means that total suspended solids were removed by Fe electrode.

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