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Treatment Of Municipal Sewage By Electrochemical Technology

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***Abstract*—Reclamation of wastewater is one of the most effective ways to alleviate water resource scarcity. For some decentralized wastewater, quick and easy process for sewage treatment is necessary. This study aims to assess the removal efficiency for synthetic domestic sewage by electrolytic oxidizing technology, and exploring the main influence factors. The electrolysis oxidizing treatment process achieved some extent removal for COD and NH_4^+-N. The factors, such as electrochemical processing time, operating voltage, initial concentration of Cl^- and electrodes kinds have some certain impact on treatment efficiency for the synthetic sewage. Long processing time, high operating voltage and high initial concentration of Cl^- improves the removal efficiency for COD and NH_4^+-N. Different electrode materials achieves different treatment effect. Anode of metal is beneficial for the removal for COD and NH_4^+-N. In the experimental conditions, the electrodes material is the most significant factor influence the treatment effect.**

Keywords—electrochemical oxidation; reclaimed water; sewage treatment; electrolytic process

I. INTRODUCTION

With the rapid social development, water pollution is becoming a serious problem in many countries, especially in developing countries like China. Over the past several decades, China's surface water and ground water have been severely contaminated by industrial and municipal wastewater, agricultural activities and household wastes [1-3]. In recent years, with the fast development of economy and growing environmental protection consciousness of government and citizens, the sewage treatment capacity of China has been established quickly [4], while the total treatment rate is still limited. For example, by 2012, the national wastewater emissions were 68.5 billion tons, and increased by 3.7% over the last year [3]. Specifically, the chemical oxygen demand (COD) emissions were 24.2 million tons, and the ammonia nitrogen emissions were 2.5 million tons. Pollutants removal is the main object in this situation [5]. At the same time, the population suffering from water scarcity is presently 11% of the total worldwide population. It is estimated that the population with inadequate water will be 38% in 2025 and 50% of the total worldwide population in 2050 [6-7].

Reclamation of wastewater is one of the most effective ways to alleviate water resource scarcity [8]. China faces serious problems of water supply and water pollution, which are the key factors restricting economic development. Reclaimed water has been recognized as a sustainable secondary urban water resource that can reduce effluent discharges [1-2]. According to the estimations, at least 20 million hectares of agricultural land worldwide is irrigated with treated and untreated wastewaters [9]. Its use has increased recently because there are inadequate freshwater resources [10-12]. In some cities with limited water resources, highly treated municipal wastewater is being considered as an indirect potable reuse for the sustainable management for augmenting drinking water supplies [13].

Many countries, especially in arid and semi-arid regions have already recognized the necessity to use re-use wastewater because limitations in the availability of water are a severe constraint to development [14-15]. Reclaimed water from sewage has become increasingly important in solving water shortage problems in the world. China has been suffering from water shortages, especially in northern arid areas. In northern China, a growing number of sewage reclamation facilities have been constructed to produce water for irrigation, toilet flushing, and surface water supplementation [16-17]

By now, water reuse technology has made great developments, and many countries have established water reuse engineering [18]. For example, in Israel, to alleviate the pressure of water shortage, water recycling system is established. In American, the secondary sewage recycling ratio is very high, and urban water reuse has entered the stage of mass production application.

At present, the water reuse technology has achieved great development, but there still some problems in water recycling and reusing. In China, there are many Dispersed small-scale processing facilities

Although sewage reuse technology have got great development, but there are still many problems, especially in developing big countries like China. In China, the sewage treatment ratio is little than 70% [3], this means that there are still much sewage which was dispersed without being treated, which produce serious pollution for the water resources. How to collect and treat the sewage conveniently and effectively is important for the relieving of water shortage press and the controlling of water pollution.

In present, the main technologies for middle water treatment are physical-chemical and biology-chemical technologies [19]. In the technology of water treatment, physical chemical has the character of convenient, especially in patch treatment process and in small scale sewage treatment [20].

Electrochemical oxidation technology has been seen as a green environmental kindly technology in treatment for environmental pollution [21]. Murphy et al. have shown that in the process of shower water treatment with electro oxidation, the TOC could be reduced to 0.5 mg/L from initial 50-100mg/L. Gao et al. showed that the electro process had high efficiency for removal of turbidity and color in water reuse treatment. Chang Yu et al. studied the efficiency of electrochemical disinfection for effluent from second setting ponds in sewage treatment plant, and showed that electrochemical was the main process for sewage recycling treatment.

In this study, on the basis of preliminary studies, the electro oxidation technology was present for the treatment of municipal sewage.

II. MATERIALS AND METHODS

A. *Experimental Methods*

The experimental setup was consisted of an electrochemical reactor, with diameter of14cm × 10cm height, and effective volume of 1000 mL.

The electrochemical process was performed in batch mode in the reactor under vigorous stirring performed by a magnetic stirrer with rotating speed of 120r/min. The anode was a sheet iron of size of 9cm×9cm×0.2cm, and cathode was a graphite block with size of 10cm×10cm×0.2cm, and the distance between anode and cathode was 2cm (seen as Fig. 1). Electro process was performed with a DC power supply. In the experiments, the pH of the water was 7.3 of neutral and the electrolytic degree was regulated with 0.01mol/L Ns_2SO_4 solution.

The wastewater was synthesis wastewater from tap water with glucose and ammonium chloride, in which the COD was controlled to 500 mg/L, and the NH4+-N was 30 mg/L.

B. *Analytic Methods*

Samples analyses were pre-filtered (0.45μm). NH_4^+-N and COD were analyzed by standard methods [22]. The removal efficiency of COD and NH_4^+-N were calculated as (1):

$$\text{removal efficiency } (\%) = \frac{C_0 - C}{C_0} \times 100\% C_0 \qquad (1)$$

Where: C_0 represents the initial concentration in influent; C represents the permanent concentration if effluent.

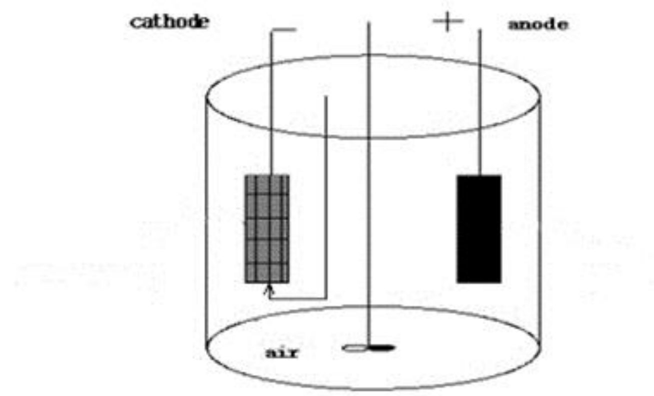

Fig. 1 The experiment setup

III. RESULTS AND DISCUSSION

A. *Influence of Electro Oxidation on Wastewater Treatment*

In this section, the wastewater was treated with technology of electro oxidation, and the technology of electro oxidation was proposed with graphite as electrodes, and the placing between the two electrodes was 3cm. The initial concentration of COD was 500 mg/L, the concentration of Cl^- of the wastewater was 200 mg/L, and the pH of water was 7.3.

1) *The influence of electrolytic time on treatment of wastewater:*

In this section, the electrolysis voltage was controlled to 20V. The electrolytic operating time was controlled to be in 150min. The effect of electrolytic time on removal efficiency of COD and NH_4^+-N was shown in Fig. 2.

From the results in Fig. 2, it could be seen that in the process of electrolysis, the COD and NH_4^+-N could be removed in some extent, and the removal efficiencies increased with the electrolysis time. The removal efficiency of NH_4^+-N increased fast in the first 30min, while the removal efficiency of COD increased with the same pace.

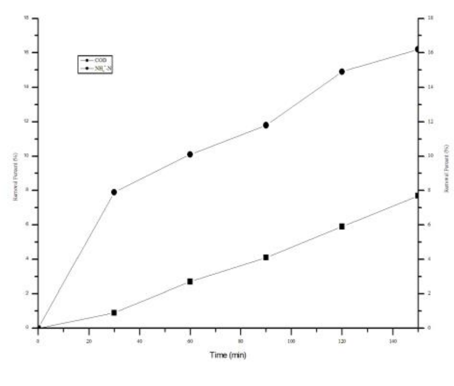

Fig. 2 The influence of electrolysis time on removal efficiency of COD and NH_4^+-N

In the process of electrolysis, there would be some oxidation materials, such as ·OH、ClO^-, be produced in the water, these oxidation ingredients could play the role of oxidation to convert the glucose and NH_4Cl to small molecules such as CO_2、H_2O, and so on. With the process of electrolysis, the effect would be continued, and the removal efficiencies of COD and NH_4^+-N increased.

2) The influence of voltage on wastewater treatment:

In this section, the electrolysis process lasted for 120min, and during the electrolysis process, the operate voltage was controlled to 25V、30V、35V and 40V respectively. The effect of operating voltage on removal efficiencies of COD and NH_4^+-N was shown in Fig. 3.

The results in Fig. 3 indicate that the removal efficiencies of COD and NH_4^+-N increased with the increase of operating voltage. For COD, the removal efficiency increased from 4.2% to 14.2%, and for NH_4^+-N, increased from 14.4% to 17.9%. The results show that in the electrolysis process, the increase of operating voltage leads to the increase of treatment efficiency of wastewater. High voltage is advantageous to the removal for pollutants, but will take more power consumption, which is unfavorable for economy.

3) The influence of concentration of Cl^- on wastewater treatment:

In this section, the initial concentration of Cl- was controlled to be 150mg/L to 400mg/L to evaluate the effect of Cl^- concentration on removal efficiencies of COD and NH_4^+-N. The operation voltage was 30V, electrolysis time was 120min. The results were shown in Fig. 4.

From the results in Fig. 4, it could be seen that the removal efficiencies increased with the increase of initial concentration of Cl^-. At concentration of 150mg/L of Cl^-, the removal percent of COD and NH_4^+-N was 13.2% and 8.9%, and with the concentration of Cl^- increased to 400mg/L, the removal percent increased to 18.9% and 19.9% respectively.

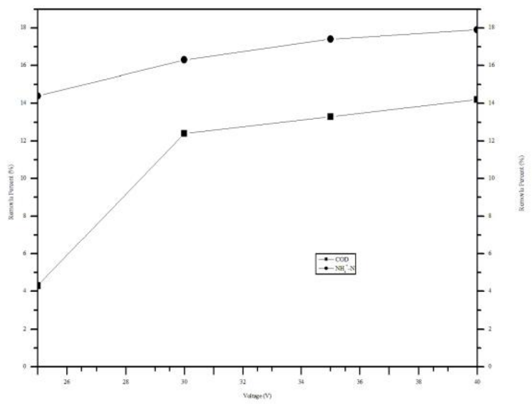

Fig. 3 Effect of voltage on municipal water treatment

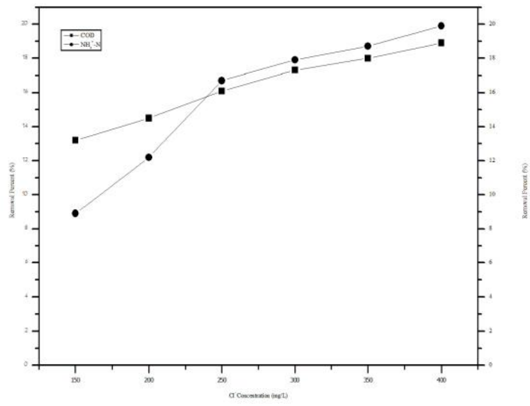

Fig. 4 Effect of initial concentration of Cl^- on municipal water treatment

The results show that more Cl^- is favored for pollutants removal. This is because that in the process of electrolysis, Cl^- would be oxidized to Cl_2 and HClO etc. and these components could oxidize the pollutants in water.

B. Effect of Electro Materials

The experimental results show that the electrolysis technology with graphite electrodes could reduce the concentration of COD and NH_4^+-N in some extents, but the removal efficiencies is not high in the experimental conditions. The electrodes material would influent the electrolysis effect. In this section, the electrodes were changed to evaluate the influence of electrodes material on wastewater treatment efficiency. In which, the operating voltage was controlled at 30V, electrolysis time was 120min, the initial concentration of Cl- was 300mg/L. The results of influence of electrodes were shown in Fig. 5.

As shown in Fig. 5, the material of electrodes has significant influence on the electrolysis. Among the electrodes in the experiment, the anode of iron and cathode of graphite is the best one for the removal of COD and NH_4^+-N, while the anode of graphite and

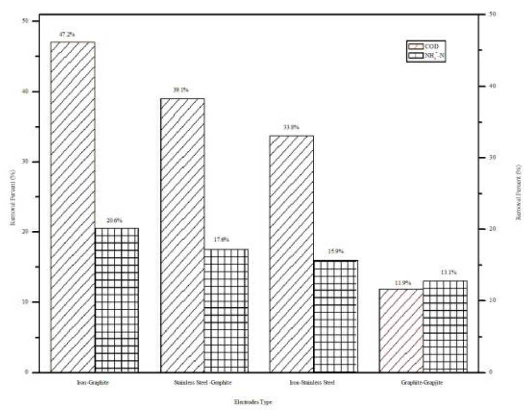

Fig. 5 Effect of electrodes material

cathode of graphite is the worst one. With anode of graphite and cathode of graphite, the removal efficiency of COD and NH_4^+-N was 11.9% and 13.1% respectively, while with anode of stainless steel and cathode of graphite, the removal percent of COD and NH_4^+-N was 39.1% and 17.6%, and with anode of iron and cathode of graphite, the removal percent of COD and NH_4^+-N was 47.2% and 20.6%. These results present that the wastewater treatment efficiency changed with electrodes material. For all of these, it could be seen that metal is better for anode and graphite is better for cathode.

During the experiment, it had be seen that when anode material was iron and steel, yellow flocculants could be produce at the begging of the electrolysis, and then the flocculants increased with the process of electrolysis, and the water turned to yellow and glue green color. This is because that when anode is iron and steel, there would be produce some Fe^{2+} and Fe^{3+}, and at neutral pH value of water, Fe^{2+} and Fe^{3+} would hydrolysis stepwise and form $Fe(OH)_3$ 、 $Fe(OH)_2$ and some hydroxyl polymers, these polymers could take some flocculation to help the removal of some pollutants.

The electrodes material has obviously effect on removal efficiency of COD and NH_4^+-N. At the neutral pH of water, the metal anode such as iron and stainless steel and graphite cathode is better.

C. Comparison of Influence Factors

The above experimental results show that in the treatment of wastewater with electro oxidation technology, the electrolysis time, operating voltage, concentration of Cl^- and electrodes material have influence on the treatment efficiency of COD and NH_4^+-N. Fig. 6 and Fig. 7 present the comparison of influence degree of the factors in removal efficiency of COD and NH_4^+-N. In which, the initial concentration of COD was 500mg/L, NH_4^+-N was 30mg/L, pH of the synthesis sewage was 7.3. The electrolysis time was changed from 30 to 150min, and the variation amplitude was 30min.

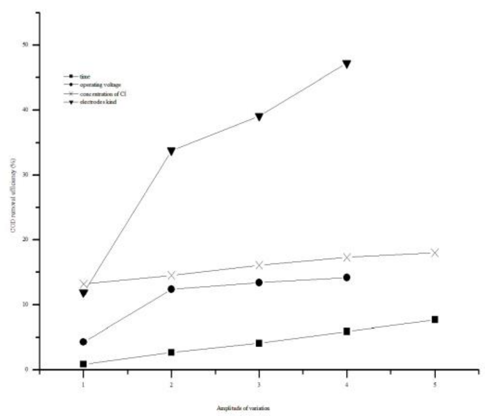

Fig. 6 Comparison of influence factors on COD removal

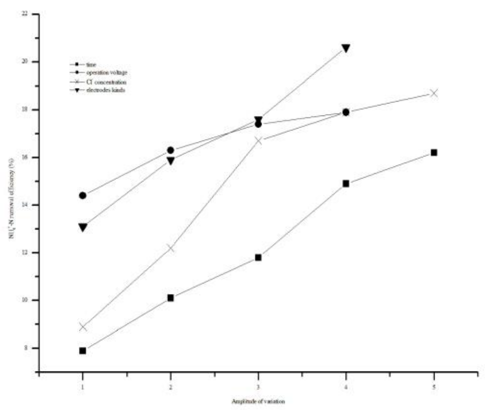

Fig. 7 Comparison of influence factors on NH_4^+-N removal

The operation voltage was changed from 25 to 40V, and changed with amplitude of 5V. The initial concentration of Cl^- was changed from 150 to 400mg/L, and changed with amplitude of 50mg/L. The electrodes kinds were anode-cathode of graphite-graphite, iron- stainless steel, stainless steel – graphite and iron – graphite.

From the results of COD removal efficiency in Fig. 6, it could be seen that in the several factors, the anodes material is the one which has the most obvious effect on removal efficiency of COD. At the same time, the effect on NH_4^+-N in Fig. 7 shows that the anodes kind is also the factor has the biggest effect on NH_4^+-N removal. Compare to electrodes kind, the other factors such as operating voltage, electrolysis time and concentration of Cl^- has slight influence on removal efficiency of COD and NH_4^+-N.

IV. CONCLUSIONS

This work has shown that the electro oxidation process has some effect on wastewater treatment. Under neutral pH value of water, many factors, such as electrolysis time, supporting electrolyte concentration of Cl^-, operational voltage and electrodes kind, affect the treatment efficiency for COD and NH_4^+-N removal.

At experimental conditions of neural pH of 7.3, the electrodes kind is the factor has biggest influence on removal of COD and NH_4^+-N.

The results presents that the study on electrodes material is very important in the development and usage of electrode oxidation technology. Compared to other factors, suitable electrodes material will improve the treatment efficiency significantly.

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