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Evaluation of Ti/Pt Anode Efficiency and Energy Consumption in Turbidity and Suspended Solids Removal from Paper Industry Wastewater: The Effect of pH and Support Electrolyte Type

Cansu Elgün[1*] and Baybars Ali Fil[1]

[1]*Environmental Engineering Department, Balikesir University, Türkiye*

(cansuelgun_1996@hotmail.com)

Abstract **–** In the research, different experimental setups were used to examine the treatment of wastewater from the paper industry using the electrooxidation method, one of the electrochemical treatment methods in the batch system. In the 2000 mL volume jacketed glass reactor utilized for the treatment of wastewater from the paper industry, 4 anode and 4 cathode sieve type plates of 7 cm x 10 cm dimensions were positioned at 0.5 cm intervals, and 1200 mL wastewater was used in the tests. Coated sieve type Ti/Pt electrodes were employed as the anode in the electrooxidation studies, and uncoated sieve type Ti electrodes were used as the cathode. It was determined that the active anodic wet surface area was 1078 cm^2. The removal rates of pollutant parameters such as turbidity and SS (Suspended Solids) in the experiments; the effects of wastewater initial pH value and supporting electrolyte type parameters were investigated. According to the results, the most effective pH value for Ti/Pt anode type at 400 rpm mixing speed was determined to be waste water natural pH (7.5), and 0.50 M NaCl was the most successful supporting electrolyte type. 96.92% Suspended Solids removal efficiency and 95.38% turbidity removal efficiency for Ti/Pt anode were achieved under ideal conditions. In addition, 312.05 kW-hour/kg COD is determined as the energy consumption value.

Keywords – Wastewater Treatment, Electrooxidation, Ti/Pt Anode, Turbidity, Suspended Solids

I. INTRODUCTION

Due to the accelerated population growth brought on by industrialization, drinking and utility water resources are quickly depleted. Large amounts of water are required for industrial activity in both developed and developing countries. These wastewaters, which are created as a result of water consumption, must be treated before being released into the ecosystem that will receive them. The pollution produced by wastewater has highly substantial and negative effects, such as disturbing the ecological balance in these places, because it is often discharged into receiving ecosystems like lakes and seas, which are located closest to industry. The environment is severely polluted by industries such as paper, textile, chemistry, and food that are present in or adjacent to villages [1].

Industrial wastewater must first be processed using chemical coagulation, flotation, adsorption, biological treatment, and electrochemical treatment techniques before being discharged.

The paper industry produces significantly more effluent and pollutants than other sectors of the economy combined. The production process, supplementary chemicals, and raw materials employed have a significant impact on contaminations coming from the paper sector [2].

The most popular techniques for treating effluent from the paper industry include adsorption [3, 4], chemical oxidation [5, 6], and biological [7, 8] purification techniques.

Turbidity caused by the presence of suspended solids (SS) and colloidal particles in the paper industry wastewater cannot be removed by classical methods such as filtration and conditioning [9]. Due to these disadvantages, the use of electrochemical methods should be preferred in the treatment of paper industry wastewater. Electrooxidation methods; graphite [10], [11], coated titanium [12], [13], platinum [14], [15], boron-coated diamond [16], [17] is based on the direct or indirect oxidation of organic materials using an insoluble anode material [18].

This study investigated into the electrooxidation method, one of the electrochemical treatment methods used in batch systems, for treating effluent from the paper sector. For this purpose, optimum turbidity and SS removal in electrooxidation method; When Ti/Pt anode is used, the effects of supporting electrolyte types such as $NaNO_3$, Na_2SO_4, NaCl and KCl without supporting electrolyte and wastewater initial pH value were investigated.

II. MATERIALS AND METHOD

The effluent from the paper industry was treated in the experiment using the electrooxidation method, one of the electrochemical treatment steps in the batch system. 1200 mL of wastewater were used as the wastewater volume in the experiments employing Ti/Pt anode to examine the effects of supporting electrolyte type and wastewater beginning pH value on turbidity removal and SS removal by electrooxidation technique from paper industry wastewaters.

In the jacketed glass reactor with a volume of 2000 mL utilized for the treatment of wastewater originating from the paper industry, 4 pieces of 7 x 10 cm anode and 4 pieces of cathode sieve type plates were positioned at intervals of 0.5 cm. Ti/Pt electrodes were employed as the anode material in the study, and uncoated sieve type Ti electrodes were used as the cathode material. It was determined that the active anodic wet surface area was 1078 cm^2.

The apparatus was powered by a direct current power supply, and the solution was continually stirred using a magnetic stirrer. To keep the temperature of the leaving water under control, a constant temperature water circulator was also utilised.

The electrooxidation reactor is seen in Figure 1.

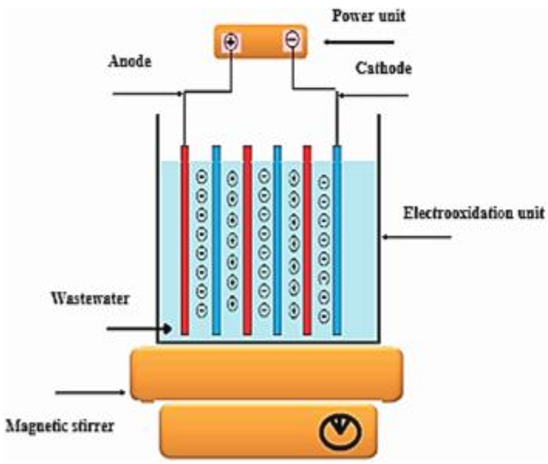

Fig. 1 Electrooxidation reactor

The experimental setup is shown in Figure 2.

Fig. 2 Experimental configuration
(1. Direct current power unit, 2. Constant temperature water circulator, 3. Magnetic stirrer, 4. Glass reactor, 5. Ti cathode, 6. Ti/Pt anode)

With the help of the equations shown below, the removal efficiencies and energy consumptions were determined for the Ti/Pt anode type.

Removal efficiency: $$\eta\ (\%)=\left(\frac{C_0 - C_e}{C_0}\right) \times 100 \quad (1)$$

Energy consumption: $$W\left(\frac{kW\text{-}hr}{m^3}\right)=\frac{V \times I \times t}{v} \quad (2)$$

Given in the equations, C_e: pollutant concentration remaining in wastewater at time t (mg/L), C_0: initial pollutant concentration in wastewater (mg/L), W: energy consumption value (kW-hr/m^3), t: time (Minute), V: potential difference in the system (Volt), v: total solution volume in the reactor (m^3), I: applied current strength (A), is expressed as.

III. Results

A. Effect of Supporting Electrolyte Type on Removal Efficiency

The effect of supporting electrolyte types such as $NaNO_3$ (Sodium Nitrate), Na_2SO_4 (Sodium Sulphate), NaCl (Sodium Chloride) and KCl (Potassium Chloride), which are used as support electrolytes in studies using Ti/Pt as the anode type, at 0.50 M concentrations, reaction time for 180 minutes. SS and turbidity removal efficiencies were investigated at pH≈7.5, 18.55 mA/cm^2 current density and 400 rpm mixing speed during the process, and the results are shown graphically in Figures 3 and 4.

It was concluded that the removal efficiencies of SS were 81.58%, 96.92%, 94.38%, 86.36% and 90.63% for wastewater medium without supporting electrolyte, NaCl, KCl, Na_2SO_4 and $NaNO_3$, respectively.

Turbidity removal efficiencies were obtained as 84.29%, 95.38%, 93.64%, 90.00% and 92.31%, respectively.

In support electrolytes containing chlorine in its structure, the purification is higher than other supporting electrolytes. For this reason, it was preferred to use NaCl salt as the supporting electrolyte type throughout the ongoing studies.

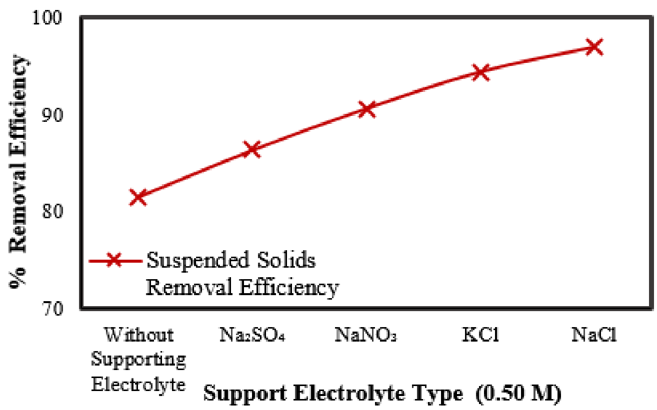

Fig. 3 Effect of SET on SS removal efficiency when Ti/Pt anode is used

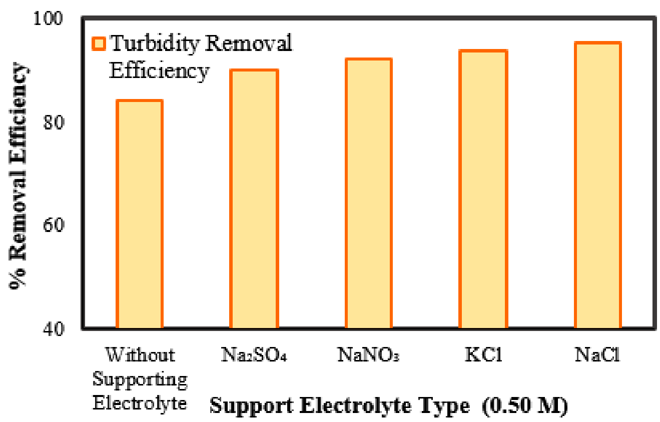

Fig. 4 Effect of SET on turbidity removal efficiency when Ti/Pt anode is used

Figure 5 displays the findings from tests looking at how the type of supporting electrolyte affected energy use.

According to the experiments in which Ti/Pt anodes were used as the anode type, the energy consumption of 312.05 kWh/kg COD was calculated when NaCl, the best supporting electrolyte type, was used after 3 hours of electrolysis.

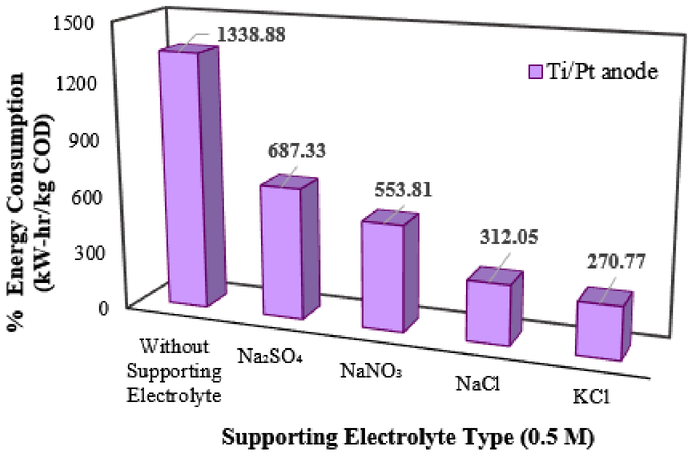

Fig. 5 Effect of supporting electrolyte type on energy consumption for Ti/Pt anode

The amount of electrolyte in the surrounding environment is one of the most crucial factors impacting electrooxidation. Because the presence of salt in the environment will increase conductivity and indirectly electrooxide more [19]. As can be observed, when Ti/Pt anodes were utilized, the NaCl salt type produced the maximum purification efficiency for the SS and turbidity pollution parameters.

The breakdown of pollutants in wastewater was enhanced by the catalytic activity of the chlorine ion in the structure of the NaCl and KCl supporting electrolyte types, which had the highest removal efficiency [20], [21], [22]. Studies in the literature [23], [24], [25] and [26] support a similar situation.

B. Effect of Wastewater Initial pH Value on Removal Efficiency

Trials using Ti/Pt anode as anode type and observing the effect of wastewater initial pH value; It was studied at 18.55 mA/cm^2 current density, 0.50 M NaCl supporting electrolyte type and concentration, 400 rpm mixing speed, 3 hours reaction time and pH: values between 3-11 and the results are given in Figures 6 and 7.

SS removal efficiencies were obtained as 86.47%, 92.56%, 96.92%, 78.13% and 71.00% for pH values 3, 5, 7.5, 9 and 11, respectively. It was concluded that turbidity removal efficiencies for pH values 3, 5, 7.5, 9 and 11 were 86.92%, 89.71%, 95.38%, 82.14% and 77.78%, respectively.

In the later stages of the study, the initial pH value of the wastewater was chosen as pH:7.5 (natural pH) and experiments were carried out.

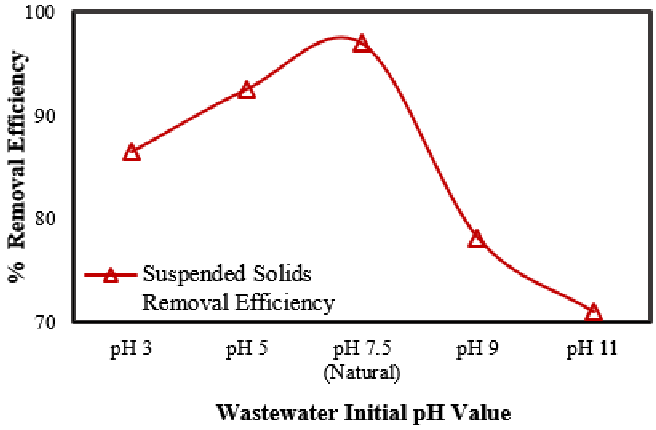

Fig. 6 Effect of wastewater initial pH value on SS removal efficiency when Ti/Pt anode is used

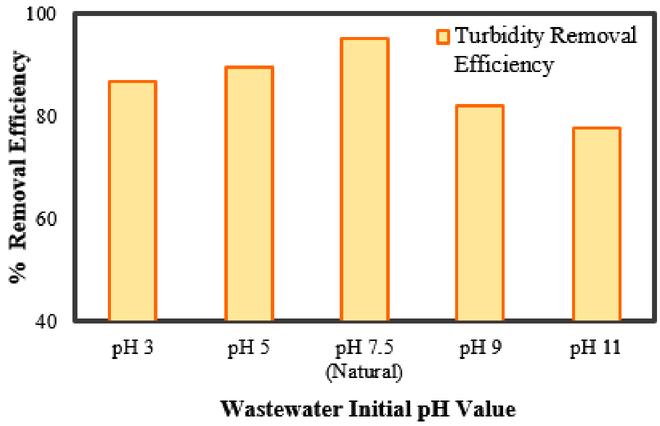

Fig. 7 Effect of wastewater initial pH value on turbidity removal efficiency when Ti/Pt anode is used

Figure 8 shows the findings from tests that looked at how the initial pH of the wastewater affects energy use.

According to the experiments in which Ti/Pt anodes were used as the anode type, 312.05 kW-hour/kg COD energy consumption was calculated when the experiments were carried out at pH: 7.5, which is the initial pH value of wastewater with the best removal efficiency after 3 hours of electrolysis.

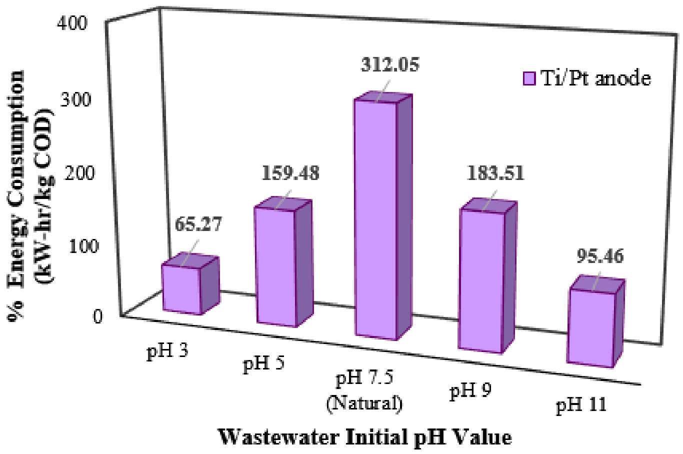

Fig. 8 Effect of wastewater initial pH value on energy consumption for Ti/Pt anode

More than 99% of active chlorine is found as ClO^- (hypochlorite) in basic environments, and more than 99% as HClO (hypochlorous acid) in acidic environments [27].

In electrochemical processes, when chlorine ions are present in the environment, oxidation is generally in acidic conditions; The reason why it gives more effective results than basic or neutral conditions is that hypochlorous acid is a stronger oxidant than hypochlorite. Previous studies also support that free chlorine is the dominant oxidizing agent in acidic conditions. Similar studies are available in the literature [28].

IV. DISCUSSION

A. *Effect of Supporting Electrolyte Type on Removal Efficiency*

Table 1. SS and turbidity removal efficiencies under the influence of supporting electrolyte type

Anode type: Ti/Pt		
Support electrolyte type	**SS(%)**	**TURBIDITY(%)**
Without Support Electrolyte	81.58	84.29
NaCl	96.92	95.38
KCl	94.38	93.64
Na_2SO_4	86.36	90.00
$NaNO_3$	90.63	92.31

As can be seen from the results, it was determined that the highest purification efficiency for SS and turbidity parameters was obtained in the NaCl support electrolyte type. According to the results obtained from the experiments when Ti/Pt anode was used, NaCl was preferred as the most effective supporting electrolyte type.

B. *Effect of Current Density Applied on Removal Efficiency*

Table 2. SS and turbidity removal efficiencies under the effect of wastewater initial pH value

Anode type: Ti/Pt		
Wastewater initial pH value	**SS(%)**	**TURBIDITY(%)**
pH 3	86.47	86.92
pH 5	92.56	89.71
pH 7.5 (Natural)	96.92	95.38
pH 9	78.13	82.14
pH 11	71.00	77.78

As can be seen from the results, it has been determined that the highest treatment efficiency for SS and turbidity parameters is at pH:7.5, which is the natural pH value of wastewater.

According to the results obtained from the experiments when Ti/Pt anode was used, the natural pH value of the wastewater (pH≈7.5) was preferred as the initial pH value of the wastewater.

V. CONCLUSION

In the study, SS and turbidity removal efficiencies were investigated under optimum conditions when Ti/Pt anode was used as the anode type. 0.50 M NaCl supported electrolyte type, 400 rpm mixing speed, wastewater natural pH value (pH:≈7.5), 96.92% SS and 95.38% turbidity removal efficiencies were obtained after 3 hours of trials.

At the same time, the energy consumption value was obtained as 312.05 kW-h/kg COD.

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