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COMPARISON OF ALUMINUM AND NICKEL ELECTRODES IN THE ELECTROCOAGULATION PROCESS

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Abstract

Electrocoagulation is a process that involves the reaction of electric current and voltage in treating water and wastewater. The performance of current and voltage parameters is affected by the electrode material. This study focuses on the comparison of the use of metal electrodes, namely aluminum (Al) and nickel (Ni). These two material electrodes were tested through an electrochemical process in water treatment with the modified continuous flow single channel reactor. The type of water used in this test is house food wastewater. The results obtained are that the use of aluminum electrodes is more efficient, effective and conductive than those made of nickel.

Keywords: Electrodes Material, Electrocoagulation, Aluminum, Nickel

1. INTRODUCTION

Electrocoagulation (EC) is a technique, method, technology, process, processing strategy, and so on, which follows the working principles of conventional coagulation. Generally, conventional coagulation is known to use chemicals or the addition of substances from outside the wastewater (exitu). The difference with electrical coagulation lies in the coagulant input. Electrocoagulation produces coagulants in the wastewater (insitu) [1].

This coagulant is formed by an electrochemical reaction. This electrochemical reaction is caused by electrical induction (energy/electrons). In simple terms, electrocoagulation utilizes electricity to change and destabilize/dissolve the charge of pollutant particles in wastewater (Drogui et al., 2022). This process causes the mass to agglomerate to form a precipitate. Strictly speaking, coagulation is a chemical process, in which coagulants [eg, dissolved metal salts, $FeCl_3$, $Al_2(SO_4)_3$] are added to wastewater [2].

Furthermore, a mass of gelatin or gel is formed which acts as a binder between the particles. The binding of these particles aims to collect particles that were initially scattered, then bind to each other to form a large enough mass, so that they are easily deposited. In wastewater, colloidal particles are in the range of 0.001 to 10 micrometers. These particles determine the levels of contaminants (e.g. turbidity and color) in wastewater [3].

Operational parameters that affect the electrocoagulation process, such as reactor design, electrode connections, coagulation agent production, energetic parameters, power supply, electrode material, pH, wastewater conductivity, processing time, distance between electrodes, and temperature [4]. Aluminum (Al) and iron (Fe) electrodes are often used as a choice of electrocoagulation electrode material [5]. Aluminum electrodes appear to be superior to iron electrodes for treating wastewater, particularly from textile businesses. The use of aluminum

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electrodes as an anode material can improve the removal performance compared to pure metal which was observed. Alloys of aluminum and zinc (Al–Zn) can be used as anodes to treat water containing phosphate, iron, arsenate, chromium, and copper [6]. This research focuses on the comparison of electrode materials, namely aluminum and nickel in the energy transfer process, which is manifested by current and voltage fluctuations monitored and removal efficiency.

2. METHODOLOGY

A. Design of Modified EC Reactor

In general, the design of the treatment system used is a continuous flow single channel (CFSC) reactor (Fig. 1) [7]. In the modification, with reactor dimensions of 60.5 (length) cm x 10 cm (width) x 25.5 cm (thickness). The working volume is 9 L. The electrolytic volume is 3, 6 L. The type of electrode used is an aluminium (Al) plate, 30 cm (length), 2 cm (width) and 0.2 cm thickness, placed with four pairs of monopolar of parallel arrangements which are placed starting on the 7th channel of each down-flow until the 13th channel.

Each electrode is connected via copper wires. The cathode and anode are connected to the DC-power supply (12V/7.5A). A wooden rod 60 cm long and 1.6 cm thick is placed in the middle of a pair of electrodes, and this is the inter-electrode distance. Channels 1 to 6 are intended for removal (trap) of food waste in oil and grease from wastewater. In channel 1 installed wire mesh with a whole diameters of 0.53 cm. Furthermore, channels 7 to 14 are intended for the electrocoagulation process. And the 16th to 20th channel is intended for the mixing process. As a comparison of the aluminium electrodes used, nickel electrodes (battery grid nickel plates) are installed with the same arrangements, but different electrodes sizes. The size of the grid battery nickel (Ni) plates is 30 cm (length) x 1 cm (width) x 0.012 cm (thickness).

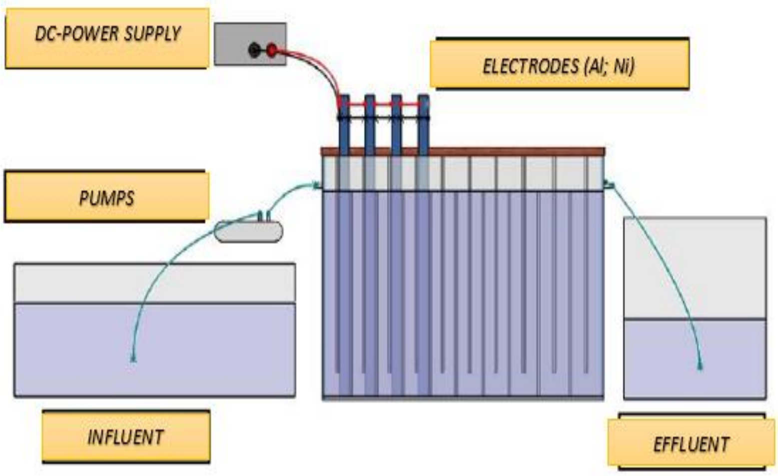

Fig. 1: Continuous flow single channel reactor

B. Influent and Effluent Analysis

For the measurement of TSS, oil and grease based on laboratory standards that refer to the

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provisions of the Standard Methods Committee of the American Public Health Association, American Water Works Association, and Water Environment Federation. 2540 solids In: Standard Methods For the Examination of Water and Wastewater. Lipps WC, Baxter TE, Braun-Howland E, editors. Washington DC: APHA Press, and Methods 5520: Gravimetry. Furthermore, the type of wastewater (WW) used in this study is food house wastewater, located in Makassar city, South Sulawesi, Indonesia. This WW containing high TSS, oil and grease, which results in the characteristics of this wastewater as shown in Table 1. To calculate the removal efficiency of contaminant concentration, we use Equation 1, Where, RE is the removal efficiency, C_{in} is the concentration of wastewater parameters in the influent (mg/L), C_{out} is the concentration in the effluent [8][9].

Table 1: Characteristics of Makassar food house wastewater

*TSS (mg/L)	*Oil and grease (mg/L)
1220	1494

*Data in the table are the average numbers from 9 times of grab sampling during 3 days in 3 weeks interval of observation.

$$RE = \frac{C_{in} - C_{out}}{C_{in}} \times 100\% \quad (1)$$

3. RESULT AND DICUSSION

Figure 2 shows that there is a significant difference in the allowance between aluminum (Al) and nickel (Ni) electrodes used in this study. The use of aluminum electrodes provides significant contaminant (TSS, oil and grease) removal results.

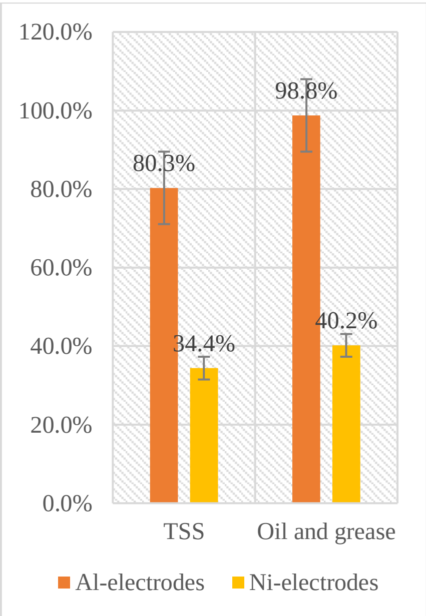

Fig. 2: Removal efficiency

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Table 2: Different concentration removal with Al and Ni-electrodes

Electrodes Material	Al	Ni
TSS-C_0 (mg/L)	1220	1220
TSS-C_1 (mg/L)	240	800
Oil and Grease-C_0 (mg/L)	1494	1494
Oil and Grease-C_1 (mg/L)	19	893

Meanwhile, the use of nickel electrodes shows the opposite results in removing TSS, oil and grease, as shown in Table 2. Verification of these results can be seen in Figure 3. Energy fluctuations, such as voltage supply (VS), current supply (CS), voltage electrodes (VE), and current electrodes (CE) by electrodes made of aluminum are larger than nickel. The optimal results were obtained at the time of electrolysis for 20 minutes. Meanwhile, for less than 20 minutes it produces a less than optimal allowance (after the simple sample test was carried out). Likewise, when it exceeds 20 minutes, a saturation or stagnation condition occurs which causes the electric coagulation/electrolysis reaction in water to stop (constant) functionally. This condition causes solid particles that have agglomerated to decompose again in the water. The decomposition of these coagulation particles causes a decrease in the quality of processed products [10]. The current densities used are 5 and 10 mA/cm2 for nickel and aluminum. Based on the results of the statistical test/verification, current and voltage parameters affect the initial contaminant removal, as the duration increases, the pollutant removal efficiency increases.

However, after the optimal duration is exceeded, the removal rate becomes constant. Hydroxide production takes place as the electrolysis time increases. This condition causes the metal hydroxide to increase. This increase helps the formation of flocs, thus increasing the removal efficiency. However, if the number of available flocs is sufficient (reaching the limit) to remove the pollutant or exceeds the optimal electrolysis time, then the production of metal hydroxide will not affect the removal of contaminants. This state is commonly referred to as hydroxide saturation [11].

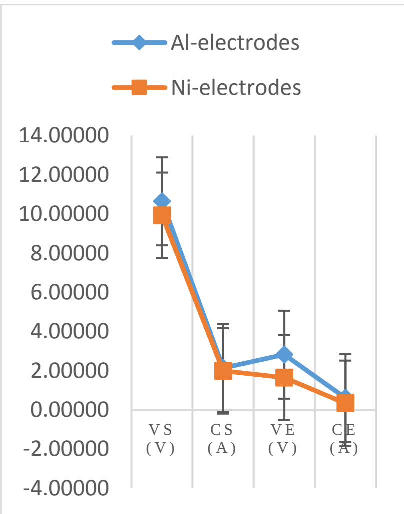

Fig. 3: Electrical fluctuation

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The effect of electrolysis time (5 to 25 minutes) on domestic wastewater treatment has been observed. The optimum electrolysis time is 20 minutes [12]. However, the effect of electrolysis time is not discussed in detail in this research. The average percentage of contaminant removal using aluminum electrodes is above 80%, while using nickel electrodes it is below 40%. The results were different from the previous contaminant removal trial by Khanitchaidecha et al., (2022) in <10 minutes (8 minutes electrolysis). The removal efficiency obtained is quite large [13]. Meanwhile, the authors only get an average removal result below 90% using aluminum electrodes. This result contradicts previous research, despite the similar treatment of wastewater influents. Then, in a similar study, successful efficiencies were recorded at 92.79% and 100% for COD and oil-fat removal. These results were obtained by El-Ezaby et al., (2020) in less than 60 minutes (electrolysis) [14].

Studies show higher removal efficiencies are observed with aluminum. For example, the efficiency of phosphate removal is 99% and 87% with aluminum or mild steel, respectively. The use of copper (Cu) electrodes is effective for removing COD and total organic carbon from petroleum waste water. Subsequent studies have also revealed that aluminum electrodes increase the efficiency of wastewater treatment for food and beverage service providers which are loaded with oils and fats as well as various other organic materials. In addition, stainless steel electrodes have been used for the processing of esters from phthalic acid, nitrites, chromium, abamekti pesticides, and heavy metals [15].

However, besides these advantages, there are also disadvantages. The use of metal as an electrode can leave contaminants as a result of the reduction. Although classified as safe for electrodes made of aluminum. According to US-EPA guidelines, the maximum contamination is 0.05 to 10 mg L^{-1}. According to data, aluminum has lower residual contaminants in wastewater than most other metals. In addition, the use of aluminum as an electrode is a appropriate choice because this type of metal is one that is easily found (besides iron, steel, copper and zinc) on the market in various shapes and sizes, and is more effective than nickel electrodes [15].

4. CONCLUSION

The average removal efficiency using aluminum electrodes is 89.55%. Meanwhile, using nickel-based electrodes, which is 37.3%. This is evidenced by the aluminum electrodes supplying more energy than nickel electrodes. Recommendations for further research include detailed verification of electric charge, the theoretical number of hydrogen bubbles, current efficiency and variations in food house wastewater contaminants, such as pH, temperature, BOD, COD, and ammonia.

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