

# Application of Electrocoagulation Process for Continuous Coal Stockpile Wastewater Treatment System

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## Abstract

Coal wastewater is characterized by high total suspended solid (TSS), heavy metals, and low acidity (pH). The purpose of this study was to research the effects of the operating parameters such as applied voltage, the number of electrodes, and reaction time on a real coal stockpile wastewater in the continuous electrocoagulation process. For this purpose, aluminum electrodes were used in the presence of potassium chloride as an electrolyte. It has been shown that the removal efficiency of TSS and heavy metals content increased with increasing the applied voltage and reaction time. The results indicate that the electrocoagulation process is efficient and able to achieve 88.67% TSS removal, 95.65% ferrous removal, 99.11% manganese removal, and pH increased until 7.1 at 24 volts during 120 min, respectively. The experiments demonstrated the effectiveness of electrocoagulation methods for the treatment of coal stockpile wastewater.

*Keywords:* coal stockpile wastewater, electrocoagulation, electrode

## Abstrak (Indonesian)

Limbah cair batubara dicirikan dengan tingginya kadar total padatan terlarut (TSS), kadar logam berat dan rendahnya nilai pH. Tujuan dari penelitian ini adalah mempelajari pengaruh beberapa parameter proses elektrokoagulasi secara kontinu terhadap limbah cair stockpile batubara, seperti tegangan yang disuplai, jumlah elektroda, dan waktu reaksi. Untuk mencapai tujuan tersebut digunakan elektroda aluminium dan larutan kalium sebagai larutan elektrolit. Hasil penelitian menunjukkan bahwa efisiensi penurunan dari kadar TSS dan logam berat meningkat dengan meningkatnya tegangan yang disuplai dan waktu reaksi. Dari penelitian ini menunjukkan proses elektrokoagulasi sangat efisien dan dapat menurunkan kadar TSS 88,67%, logam besi 95,65%, mangan 99,11% dan pH meningkat hingga 7,1 dengan suplai tegangan 24 volt selama 120 menit. Eksperimen ini menunjukkan keefektifan metode elektrokoagulasi dalam mengolah limbah cair stockpile batubara.

*Kata Kunci:* limbah cair stockpile batubara, elektrokoagulasi, elektroda

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## INTRODUCTION

Electrocoagulation is an electrochemical method of treating polluted water whereby sacrificial anodes corrode to release active coagulant precursors (usually aluminum or iron cations) into solution. Accompanying electrolytic reactions evolve gas (usually as hydrogen bubbles) at the cathode [1].

Electrocoagulation has a long history as a water treatment technology and having been employed to remove a wide range of pollutants. However, electrocoagulation has never become accepted as a conventional water treatment technology. The lack of a

systematic approach to electrocoagulation reactor design/operation and the issue of electrode reliability (particularly passivation of the electrodes over time) have limited its implementation. However recent technical improvements combined with a growing need for small-scale, decentralized water treatment facilities have led to a re-evaluation of electrocoagulation [2, 3]. In essence, an electrocoagulation reactor is an electrochemical cell wherein a sacrificial metal anode, usually aluminum but occasionally iron, is used to dose polluted water with a coagulating agent [4]. Electrocoagulation introduces metal cations in situ

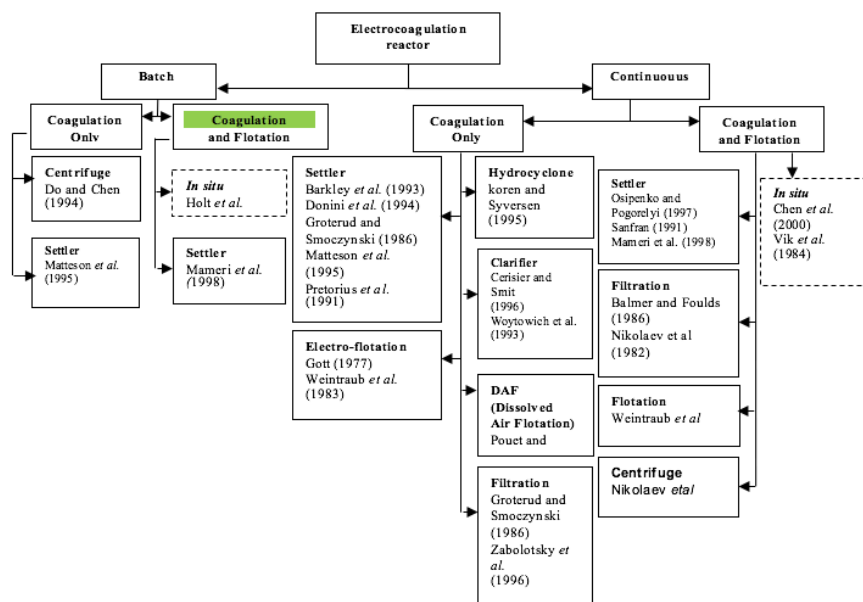


Figure 1. Classification of electrocoagulation reactor system

rather than via external dosing. Simultaneously electrolytic gases (typically hydrogen) are generated at the cathode. Depending on the reactor operating conditions and the pollutant to the surface.

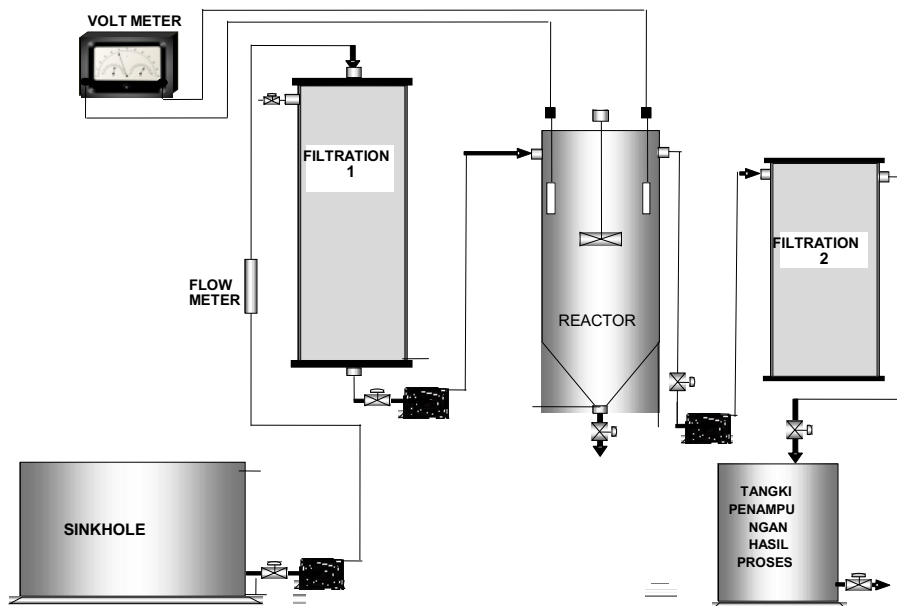
Electrocoagulation is not a new technology. Indeed, the literature indicates that it has been regularly ‘discovered’ over the last hundred years or so, both in batch and continuous application. In more recent times, there has been some renewed interest in continuously feed water treatment plants based on electrocoagulation technology (some sizeable throughputs) for specialized industrial applications, such as the removal of fine material from coal wash water. However, because of its proven ability to remove an extremely wide range of pollutants effectively, together with its inherent simplicity of design and operation, electrocoagulation is being re-examined as a localised low-cost treatment technology [5, 6].

Published electrocoagulation reactor designs may be classified as shown in Fig. 1. The first major distinction between alternative designs is whether a reactor was configured as a batch or a continuous system. It is clear that the majority of application fall into the latter category, having a continuous feed of wastewater and operating under (pseudo) steady-state conditions. A key advantage of such reactor system is that their coagulant requirements are essentially fixed, a major advantage in terms of both design and operation. Batch reactor applications on the hand typically operate with a fixed wastewater volume per treatment cycle but suffer from the perceived disadvantage (from a design

and operational standpoint) that conditions within the reactor change with time [7].

This dynamic behavior is clearly illustrated in a batch system where the experimental data are given for the removal of suspended solids and metal contents from stockpile wastewater [8]. Here the time dependent behavior results from the fact that coagulant precursor (i.e. aluminum cations) is continuously ‘fed’ to the reactor as the anode corrodes. The aluminum cations are hydrolysed to a form capable of aggregating the pollutant which is then removed from solution by sedimentation and/or flotation. As a result, both pollutant and coagulant levels shift over time as material is added the solution, is modified within the solution, and is removed from the solution.

The second major distinction between alternative reactor design is the role of flotation. A reactor that does not exploit the separation of aggregated pollutant via electrochemically generated bubble is labeled in Fig. 1 as ‘coagulant only’ process. Integrated units have two main pollutant removal paths, flotation and settling [9]. Separation by settling is the more common option, with the fact that electrolytic gases are also being produced simultaneously with the dosing process often viewed as an unnecessary operational complication [10, 11]. The prime differentiator between pollutant removal by settling or flotation would seem to be the current density employed in the reactor. A low current produces a low bubble density, leading to a low upward momentum flux – conditions that encourage sedimentation over flotation [12]. As the current is increased, so the bubble density increases resulting in a greater upwards



**Figure 2.** Flow diagram of pilot-scale electrocoagulation process

momentum flux and thus more likely removal by flotation.

‘Coagulation only’ processes can be further differentiated by the type of aggregated pollutant separation technology that used. As shown, electrocoagulation dosing has been combined with most common separation technologies including dissolved air flotation, electroflotation, filtration, and clarification. Basically, pollutant separation is either integrated into the reactor’s design, or else occurs in a separate (downstream) unit.

The value of the hierarchic structure shown in Fig. 1 is that it succinctly summarizes previous electrocoagulation reactor design practice and demonstrate that it is possible to reduce a myriad application to combinations of just three core design decisions [13]:

- Batch or continuous operation.
- The role played by electrolytically generated bubbles.
- The means of separating out the aggregated pollutant.

Consequently, the design of any future localized water treatment facility built around electrocoagulation technology may be simplified by making initial reactor design and operation consideration as combinations of these three design decisions.

## MATERIALS AND METHODS

Fig.2 displays the layout of the electrocoagulation process for coal stockpile wastewater with a continuous process. The inlet coal stockpile wastewater, drawn from a sinkhole, was fed to the electrolysis cell at 2 L/h. The dimensions of the reactor were determined according to our previous laboratory study [14]. Reactor system with vertical plate aluminum electrodes where the separation of the aggregated pollutant in integral to the reactor design with use being made of electrolytic gas flotation.

A pair of electrodes used is aluminum (anode and cathode) electrodes spaced 3 cm. To determine the level of efficiency of electrocoagulation, look for the optimum conditions of process time by varying the voltage supplied. Operating time ranged from 60-120 minutes with a voltage variation of 6 - 24 volts.

Stage of the process begins with the feed flow to the first filter tube is filled with silica sand to separate the impurities contained in waste water and to reduce the burden on electrocoagulator. From Filter I, feed flow into the coagulator is equipped with aluminum electrodes and stirrer. At the time feed flow enters coagulator, the adapter that is connected to the electrodes turned on (selected voltage appropriate) so that the electrocoagulation process starts running. This process takes at least 1 hour. In the current electrocoagulation process progresses, Fe and Mn metal ions will be attracted by the electrode to form flocs which over time will grow and settle to the bottom of

coagulator. Once the process is complete, the upper liquid was clear and then flowed to filter II that is filled with polyethylene membrane measuring 0.5 microns. This stage purpose to separate the remains of pollutants that are carried to meet the final result of the separation of environmental quality standards.

The pH of solutions was measured by pH meter (Thermo Orion Model), metal concentrations were measured by atomic adsorbtion spectrofotometer (GBC AAS 932 Plus) and TSS determinations by gravimetry method.

In all experiments, to measure the elimination percentage, the following formula has been used:

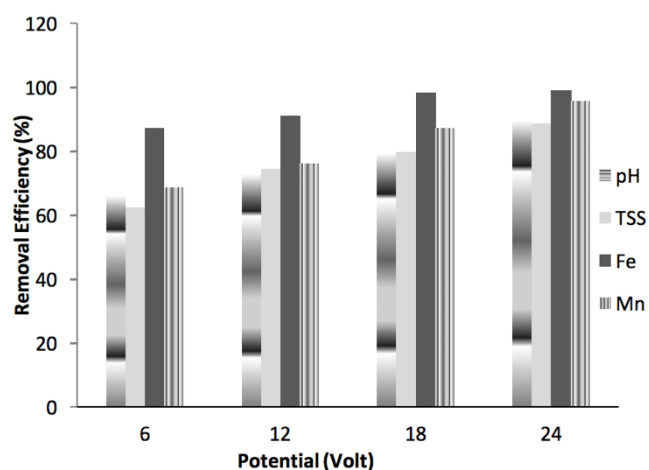
$$CR (\%) = C_0 - C / C_0 \times 100 \quad (1)$$

Where  $C_0$  and  $C$  are the concentration of wastewater before and after electrocoagulation in mg/L, or ppm, respectively.

## RESULT AND DISCUSSION

### The influence of an electrical potential to the pollutant removal efficiency

In the process of electrolysis, the current source is located between two electrodes submerged in water/solution. With selected electrical potential and reaction time was varied, applied directly to the liquid waste coal stockpile. Selected electric potential is expected to provide a high influence on the process of electrolysis to decreased levels of TSS, metals (Fe and Mn), as well as raise the pH value.



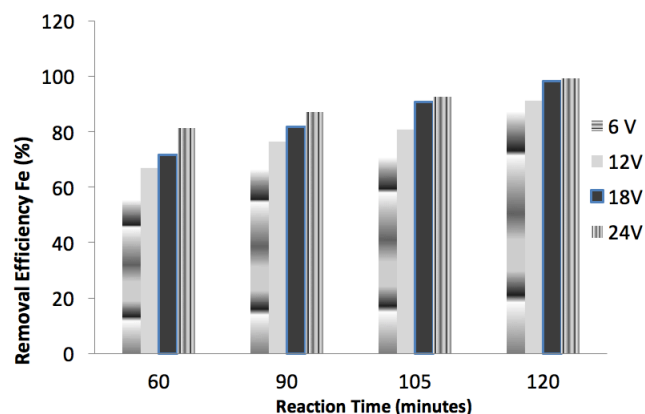
**Figure 3.** The influence of electric potential variation (V) of the removal efficiency

The potential electric influx in electrocoagulation process can release  $Al^{3+}$  ions from the electrode and increase the number of flocs generated. Furthermore,  $Al^{3+}$  ions dissolved in solution and form  $Al(OH)_3$  which continued to increase during the process [8, 9]. The electrocoagulation process can also be known that the electrical potential not only causes the number of flocs that is formed but also cause the formation of bubbles and the growing rate of floc size can affect the treatment efficiency of the electrocoagulation process.

Figure 3 shows the effect of variations in the electrical potential to decrease the efficiency of pollutants such as TSS, metals Fe and Mn. Reduction efficiency can reach 99% after 120 minutes of process time for all potential variations of the electricity used (6-24 V). It showed the increasing potential power of 6-24 volts and pollutant concentrations decreased significantly. For TSS, 88.67% removal efficiency obtained at 24V, while for Fe metal may reach 95.65% at 24V higher than the decrease in Mn metal which only reached 99.11%. The increasing pH value from 3.29 to neutral, 7.1, demonstrate the effectiveness and performance tool designed high electrocoagulation.

### The influence of process time on pollutant removal efficiency

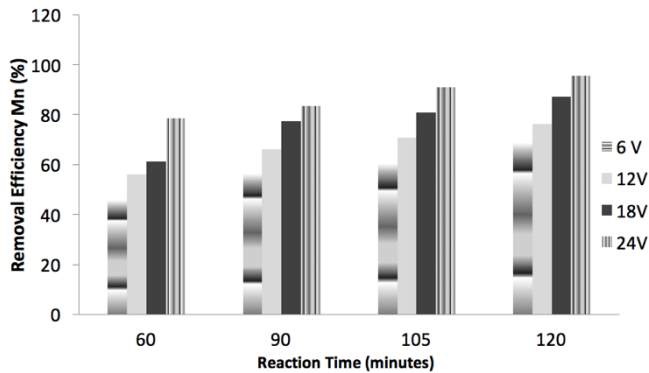
The main purpose of this treatment is to compare the reduction of Fe and Mn metals in wastewater coal stockpile with electric potential variation (V) and time efficiency of the process so that can determine the performance of a tool in decrease the metal Fe and Mn content. Voltage variations are used in the electrolysis method is 6V, 12V, 18V, and 24V, while the process time used are 60 minutes, 90 minutes, 105 minutes and 120 minutes as shown in Figure 4-6.



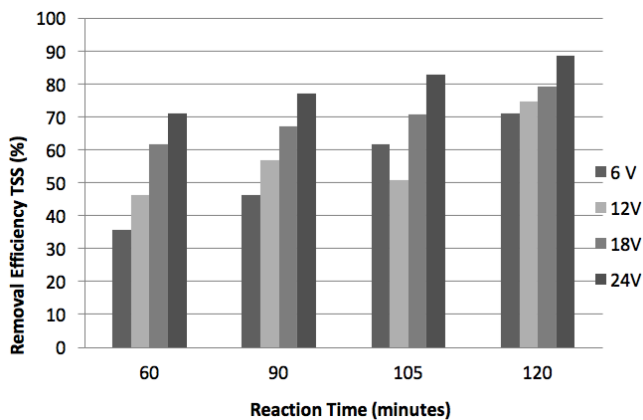
**Figure 4.** The influence of process time to the Efficiency to decrease Fe

Oxidation of  $Fe^{2+}$  and  $Mn^{2+}$  by oxygen in the air to be  $Fe^{3+}$  and  $Mn^{4+}$  shaped colloids will cause turbidity of

the water in the coal stockpile. The colloidal particles during the process of electrolysis will be destabilized to form larger flocs. Formation of H<sub>2</sub> gas at the cathode causes the flocs formed having flotation, so it will be the accumulation of flocs which is containing gas in the surface layer of water in the form of sludge.



**Figure 5.** The influence of process time to the Efficiency to decrease Mn



**Figure 6.** The influence of process time to the Efficiency to decrease TSS

The Concentration of Fe decreased from 2.3483 mg/L to 0.01 mg/L. This proves that the electrocoagulation process can reduce levels of metals Fe in the effluent coal stockpiles, though the analysis of Fe content tended to decrease but it still insignificant. The best results on decreased concentrations of Fe metal is in the use of voltage 24 V and 120 minutes. Metal Fe removal efficiency was lower than the metal Mn that was only 95.65% of Mn with a potential difference of 24 V and a process time of 120 minutes. For TSS reduction only reached 88.67% after 120 minutes of process time and used 24 V electrical potential. Figure 4-6 showed decreased levels of pollutants efficiency and performance tool electrocoagulation.

## CONCLUSION

The removal efficiencies of TSS and metal contents from coal stockpile wastewater were experimentally done by electrocoagulation technique. The processes were measured in the continuous process of a single stirred reactor. The monopolar aluminum (Al) plate electrodes were used in this work and were set at distance of 100 mm in the reactor (volume 10L).

The results show that TSS removal efficiency is as high as 98.16%, ferrous removal efficiency 97.42%, and manganese removal efficiency 98.21% of electrocoagulation process with potential 24 volts and reaction time 120 min.

In general, the results obtained from the curves of reaction time indicates that the electrocoagulation technology can enhance the settling velocity of suspended solids and removal of TSS and metal contents. It means that the electrocoagulation technology can improve wastewater quality.

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