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Swimming Pool Water Treatment by Electrocoagulation Technicque with Aluminum-Graphite Electrode

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Abstract: This research aims to improve the quality of swimming pool water at Faculty of Sport Science, Yogyakarta State University by electrocoagulation process with aluminum-graphite electrode. An effectiveness of the electrocoagulation was based on process time, electrical voltage, separation efficiency of metals ion, TDS, and pH values. The samples and electrodes were characterized by using scanning electrone microscope (SEM) and X-ray diffraction (XRD). The results showed that the optimum condition of potential and time of electrocoagulation were 10 volts and 24 hours respectively. Aluminum electrode that used as anode had some impurities. The quality of the swimming pool water based on the pH and TDS parameter after electrocoagulation process according to the regulation of Indonesian Ministry of Health No. 416 / Menkes / Per / IX / 1990 is as well as water quality standard of swimming pool which has the pH 6.7 and TDS 231.3.

Keywords: Swimming pool water, electrocoagulation, aluminum-graphite electrode.

1. Introduction

Water is the most important thing in life. Living being on this earth cannot be separated from the need of water. The water is relatively clean highly coveted by humans, both for daily living, for industrial purposes, for the city sanitation hygiene, as well as for agriculture and another purposes [1]. Major water sources used for human purposes are derived from surface water, rain water, and ground water. The ground water is more widely used because its quality is better than other water sources [2].

Swimming pool is one of the most popular places for leisure activities, such as exercising to get the health benefit. Hence, the quality of swimming pool water is the outmost concern related to human health. The water treatment usually includes coagulation, sand filtration, and subsequent disinfection. Chlorine is commonly used for disinfection of swimming pool due to its rapid killing rate of bacteria and viruses [3]. However, chlorine reacts with contaminants introduced in water by the bathers to produce numerous undesirable disinfection by products (DBPs), such as organic and inorganic chloramines, haloacetic acids (HAAs), and trihalomethanes (THMs) [4,5]. The major concern regarding DBPs formation is their effects on human health. Some studies reported that DBPs in swimming pool were significantly more genotoxic than in

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drinking water and tap water [6]. The DBPs can cause eye irritation and respiratory tract. Furthermore, it increases the risk of bladder cancer [7].

In recent years, electrochemical technology has been applied in the treatment of water and wastewater. Due to its environmental compatibility, high removal efficiency, and potential cost effectiveness, electrochemical technology such as electrocoagulation, electrodeposition, electrooxidation, electrodisinfection, electrofenton, electroflotation, and electrosorption has attracted great attention. Among them, electrocoagulation and electrodisinfenction have a great potential in the treatment of drinking water, waste water, swimming pool, and industrial water. Electrocoagulation has been successfully used to eliminate a variety of pollutants in wastewater [8-10], tannery water [11], and drinking water [12-14]. In electrocoagulation, various pollutants are removed by coagulant and hydrogen from sacrificial of anode and cathode [15-16].

Electrocoagulation (EC), the passing of electric current through water, has been proven very effective to remove contaminants from water [17]. EC systems have existed for many years using a variety of anode and cathode geometries, including plates, balls, fluidized bed spheres, wire mesh, rods and tubes [18]. In the past few decades, it has been used for the treatment of water containing foodstuff wastes, oil wastes, dyes, suspended particles, chemical and mechanical polishing waste, organic matter from landfill leachates, defluorination of water, synthetic detergent effluents, mine wastes and heavy metal-containing solution. EC has become one of the affordable wastewater treatment processes around the world by reducing electricity consumption and miniaturization of the needed power supplies.

In this research, we will develop electrocoagulation-electrodisinfection (EC-ED) technicque with aluminum-graphite electrode for treatment of swimming pool water. However, it will start from the study of electrocoagulation process.

2. Experimental

2.1. Materials and instruments

Swimming pool water samples used were taken from Yogyakarta State University, Indonesia. Some materials for electrolysis included aluminum electrode, graphite electrode, and pure water. All analytical grade aluminum(III) chloride, iron(II) chloride, and calcium chloride were obtained from Merck (Germany).

Freshly stocks Al(III), Fe(II) and Ca(II) solutions were prepared by dissolving suitable quantity of analytical grade aluminum(III) chloride, iron(II) chloride, and calcium chloride in distilled deionized water.

Instruments that were used include pH-meter (Orion 720, USA), TDS-meter (HM Digital, USA), scanning electron microscope, SEM (Coxem EM-30, Korea) and atomic adsorption spectrometer, AAS (Shimadzu AA-7000, Japan).

2.2. Procedure

Electrocoagulation was done by applying electrolysis concept of aluminum and graphite electrode. The scheme of the process can be seen in the Figure 1. Electrocoagulation process was done by putting swimming pool water sample in the compartment and variefy the potential value from 1 to 12 volts. An electrocoagulation time was recorded from 1 to 24 hours.

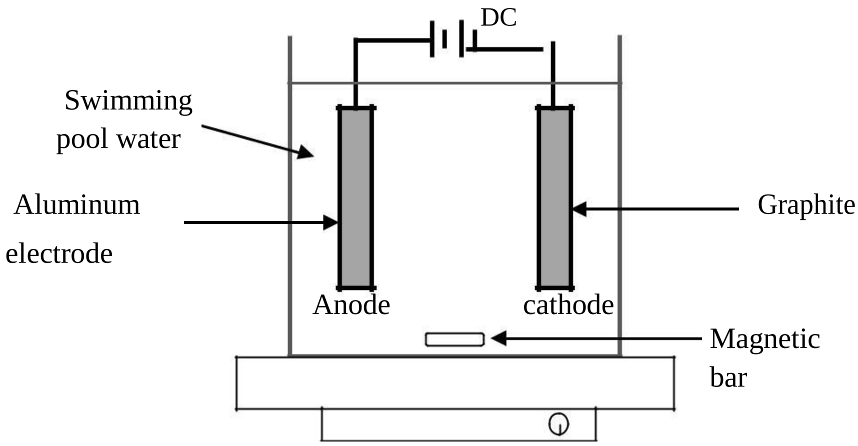

Figure 1. Electrocoagulation scheme.

A good condition of electrocoagulation was noted as an optimum condition that used in the treatment of sample.

2.3 Analysis

The analysis some pollutant component in the water was done to find the quality of swimming pool water. In this research we analyzed the pH, TDS, concentration of Ca, Fe and Al. Metals ion concentration was analyzed by AAS. Surface area of aluminum electrode was analyzed by SEM.

3. Results and Discussion

The purpose of the research is to develop a new method of water treatment for swimming pool water. We apply electrolysis process for precipitation some materials in the swimming pool water. By setting some variables that will be measured, data were obtained and presented in some tables below. Before the treatment of swimming pool water by electrocoagulation, the water tested of the pH was reported by Suyanta [16]. The result showed that the pH of swimming pool water has value 3.27 scale. This value is very acidic and very dangerous for people that used the swimming pool. The best condition if the value is 7.00 scale. The object was to change the pH water from 3.27 to near. Changing the pH from 3.27 to near 7.00 (neutral water) was tried to be done by electrocoagulation process.

The electrocoagulation was run by finding condition of effective potential and time. The pH, TDS, and some concentration of metal ion value also were measured.

3.1. Variable of potential

Variation of potential were set to find the condition (potential) that can precipitate matterials. The result of condition potential for measurement of TDS, pH, and metals ion concentration were shown in Table 1 and Table 2.

Table 1. Variation of potential electrocoagulation to the TDS and pH.

No.	E (Volt)	I (Ampere)	pH		TDS	
			Before	After	Before	After
1.	2	0.005	3.27	3.37	277	256
2.	4	0.016	3.27	3.67	277	246
3.	6	0.028	3.27	3.97	277	259
4.	8	0.041	3.27	4.20	277	256
5.	10	0.053	3.27	4.57	277	242
6.	12	0.061	3.27	4.70	277	240

Table 2. Variation of potential electrocoagulation to the concentration of metals ion.

No.	E (Volt)	Al^{3+} (ppm)		Ca^{2+} (ppm)		Fe^{2+} (ppm)	
		Before	After	Before	After	Before	After
1.	2	0.3440	0.3847	23.88	22.29	0.0354	0.0938
2.	4	0.3440	4.6657	23.88	20.70	0.0354	0.4073
3.	6	0.3440	7.1195	23.88	22.29	0.0354	0.7154
4.	8	0.3440	0.1455	23.88	20.70	0.0354	0.2585
5.	10	0.3440	8.6810	23.88	19.90	0.0354	0.2320
6.	12	0.3440	7.2738	23.88	19.90	0.0354	0.1735

From the data in Table 1 and Table 2, based on measurement of pH, TDS and concentration ion of Al^{3+}, Ca^{2+}, and Fe^{2+}, variation of electricity potential from 2 volt until 12 volt gives the good condition at potential 10 volt. This potential is recommended for electrocoagulation process.

3.2. Variable of time

Variation time were set to find a good condition for the electrocoagulation. The setting times were from 2 up to 24 hours. The result of electrocoagulation process as fungsion of pH and TDS also some concentration of metals ion can be seen in Table 3 and Table 4.

Table 3. Variation time of electrocoagulation to pH and TDS.

No.	Electrocoagulation time (hour)	E (Volt)	I (Ampere)	pH		TDS	
				Before	After	Before	After
1.	2	10	0.053	3.27	5.07	277	242
2.	4	10	0.053	3.27	5.47	277	239
3.	8	10	0.053	3.27	6.07	277	233
4.	16	10	0.053	3.27	6.40	277	224
5.	24	10	0.053	3.27	6.70	277	219

Table 4. Variation time of electrocoagulation to concentration of some metals ion.

No.	Electrocoagulation time (hour)	E (volt)	Conc. of Al^{3+} (ppm)		Conc.of Ca^{2+} (ppm)		Conc.of Fe^{2+} (ppm)	
1.	2	10	0.3440	5.4540	23.88	21.49	0.0354	0.0992
2.	4	10	0.3440	8.3768	23.88	21.49	0.0354	0.0513
3.	8	10	0.3440	0.3792	23.88	21.49	0.0354	0.2426
4.	16	10	0.3440	0.2677	23.88	21.49	0.0354	0.2107
5.	24	10	0.3440	0.2056	23.88	19.90	0.0354	0.2320

From the data at Table 3 and Table 4, variation of time electrocoagulation gives the changing quality of swimming pool water with the indicator value of pH, TDS and some metal ion concentration. The time that gives significant changing is about 8 – 24 hour. The best quality is that if the time is 24 hours.

Basic concept of electrocoagulation is oxidation and reduction reaction. In the electrocoagulation cell, oxidation is in the (+) electrode (anode) and reduction in the (-) electrode (cathode). Another important in the electrocoagulation is water as electrolyte solution that functions as supported hydroxide ion to make coagulant with aluminum ion. The electrocoagulation process for precipitation of the same metal ion and other materials is schematic in Figure 2 that was reported by Deknomet [18].

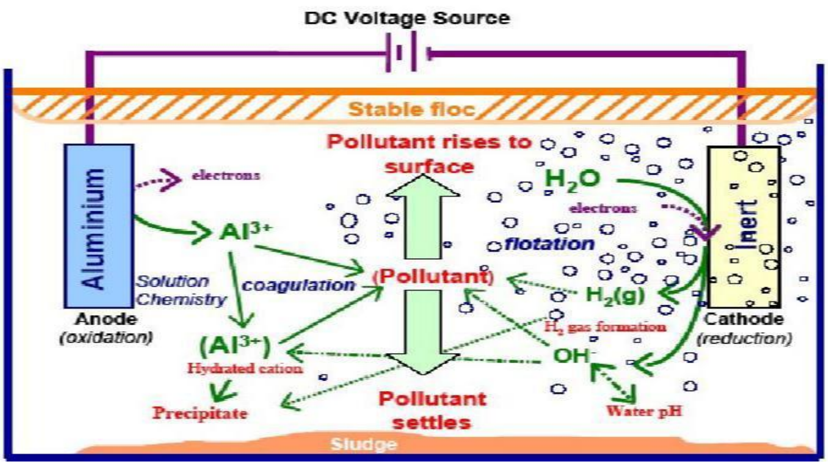

Figure 2. Mecanism in the electrocoagulation
(Holt, Barton & Mitchell: 2006).

3.3. Characterization of aluminum electrode

Efficiency of electrocoagulation can be seen from changing of mass of aluminum electrode used as anode. Changing of aluminum mass before and after electrocoagulation was shown in Table 5.

Tabel 5. Mass of Aluminum before and after electrocoagulation.

No.	Mass of Aluminum (gram)	
	Before	After
1.	2.872	2.514
2.	2.959	2.599
3.	2.804	2.415

From the value of aluminum mass in Table 5, there are reducing mass of aluminum electrode, because the aluminum is oxidized and soluble result Al^{3+}. Changing of aluminum also can be seen on shape of aluminum electrode that used before and after electrocoagulation (Figure 3a and 3b).

Figure 3a. Shape of aluminum before electrocoagulation

Figure 3b. Shape of aluminum after electrocoagulation

The aluminum electrode that used as anode was analyzed by SEM instrument to check the microstructure of aluminum surface. The result shown that the changing shape of aluminum surface electrode before and after electrocoagulation (Figure 4).

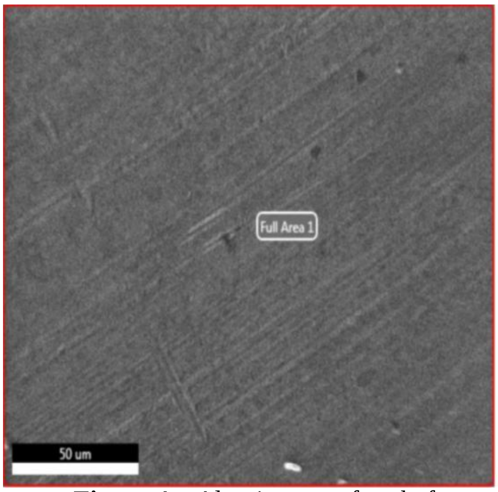

Figure 4a. Aluminum surface before electrocoagulation.

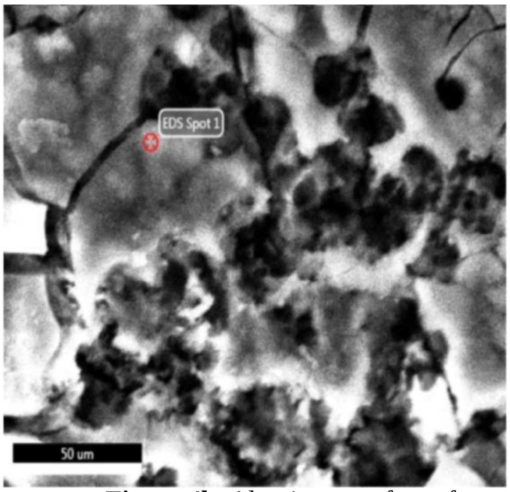

Figure 4b. Aluminum surface after electrocoagulation.

From the SEM analysis, the composition of metal electrode (aluminum) can be checked. The result is presented in Figure 5 and Figure 6.

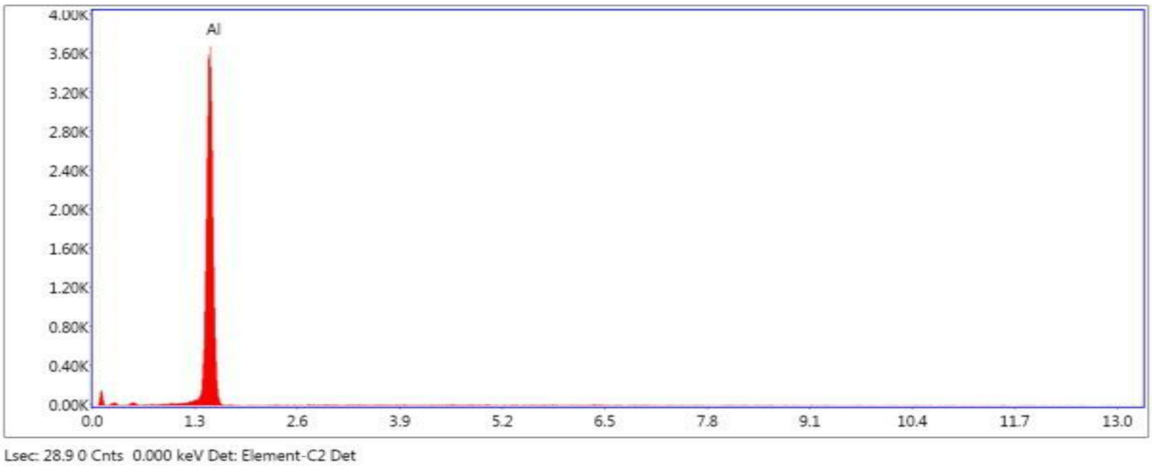

Figure 5. The composition of aluminum electrode before electrocoagulation.

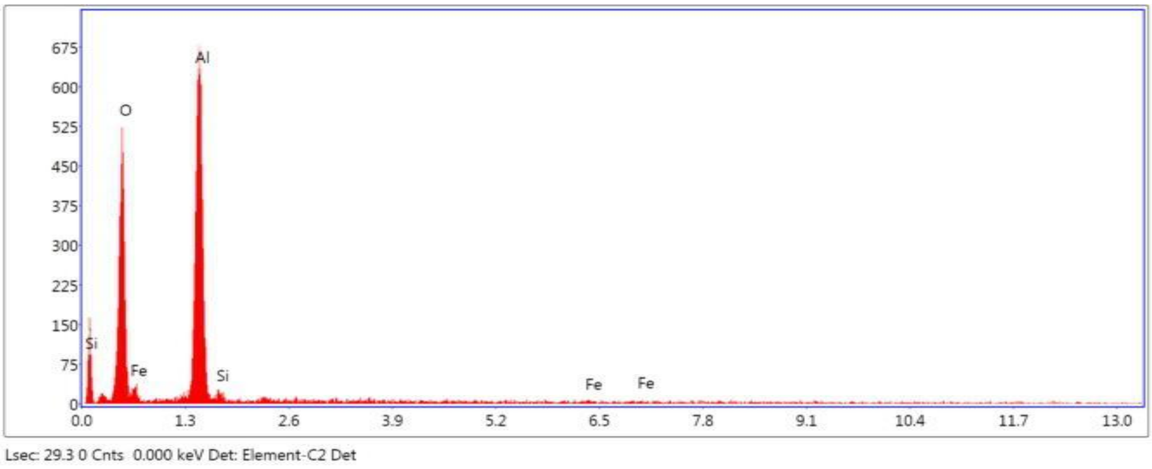

Figure 6. The composition of aluminum electrode after electrocoagulation.

From the Figure 5 and Figure 6, the composition of aluminum electrode can be calculated by SEM analysis and the result is tabulated in Table 6 and Table 7.

Table 6. The composition of aluminum surface before electrocoagulation.

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
AlK	100.00	100.00	1269.17	1.51	1.0000	1.0000	1.0000	1.0000	1.0000

Table 7. The composition of aluminum surface after electrocoagulation.

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
O K	47.35	63.27	142.22	8.89	0.1936	1.0727	0.9669	0.3813	1.0000
FeL	12.08	4.63	6.24	16.47	0.0326	0.8426	1.1213	0.3212	0.9972
AlK	39.09	30.98	228.36	6.84	0.2074	0.9563	1.0085	0.5536	1.0022
SiK	1.48	1.13	6.06	26.34	0.0056	0.9775	1.0153	0.3848	1.0028

From the Table 6 and Table 7, result show that original electrode (surface) have as pure aluminum (100 %) but after its used for electrocoagulation composition is include Fe and Si metal in the electrode. It can be said that surface electrode is as pure aluminum but in the inner has mixture with some metal (Fe and Si).

4. Conclusion

Based on the research, the results showed that the optimum potential was 10 volt and the optimum time of electrocoagulation process was 24 hours. The quality of the water pool based on the pH parameter after electrocoagulation process according to the regulation of Indonesian Ministry of Health Regulation No. 416 / Menkes / Per / IX / 1990 is as well as water quality standard for swimming pool that has pH 6.7 and TDS 231,3.

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