International Journal on Advanced Science Engineering Information Technology

Vol.12 (2022) No. 2
ISSN: 2088-5334

Produced Water Treatment using Electrocoagulation Combination Method with Aluminum (Al) and Iron (Fe) Electrodes and Activated Carbon Adsorption Treatment

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***Abstract*—Oil is the main source of energy and income for various countries today, and its production has become one of the most important industrial activities in the 21st century. Besides being produced, the oil and gas industry also has a problem with a large volume of waste, and 80% of the liquid waste produced is water, which is also referred to as produced water. Produced water is a by-product of oil and gas processing. This water is different from water because it contains hazardous chemicals and other elements in oil and gas. In this study, a combination of electrocoagulation processes using aluminum (Al) and iron (Fe) electrodes with filtration treatment using activated carbon from a coconut shell, comparing the performance of three processes: electrocoagulation process and adsorption and combination of the electrocoagulation-adsorption process with a continuous process. Electrocoagulation is a process using designed electric currents such as voltmeter circuits with voltage variations of 3, 6, 9, and 12 V, and time variations of 30, 60, 90, 120, and 150 minutes with Al and Fe electrodes were then carried out by their adsorption process using activated carbon from coconut shell waste. The main advantage of this method is the relatively short contact time, and electrode material is easily obtained, and this method is proposed as a substitute for a coagulation system with alum/alum material. The results showed that the decrease in the optimum decrease in COD (98.39%) from the initial content of 737.57 mg/L to 11.90 mg/L, TDS (93.54%) from the initial content of 16,610 mg/L to 1,073 mg/L ammonia (75.16%) from the initial content of 24.24 mg/ L to 6.02 mg/L, oil content (97.56%) from the initial content of 364.2 mg/L to 8.9 mg/L, and phenol (92.5%) from the initial content of 1.20 to 0.09 mg/L. With the optimum voltage parameters at 12 V and a time of 150 minutes. The result achieved in this process is the combination of electrocoagulation and adsorption obtained at 12 V for 150 minutes able to reduce the produced water so that it meets the quality standard by the regulation of the state minister of the environment concerning wastewater quality raw for businesses or oil and gas as well as geothermal activities.**

***Keywords*— Electrocoagulation; adsorption; produced water**.

Manuscript received 11 Aug. 2020; revised 25 Aug. 2021; accepted 14 Sep. 2021. Date of publication 30 Apr. 2022.

I. INTRODUCTION

Oil is one of the main sources of energy and income for various countries today, and its production has become one of the most important industrial activities in the 21 century. The world's demand for oil is increasing [1]. The structure of the gutters Jimar Prabumulih is one of the largest fields in Indonesia's oil and gas industry, with a total of 201 production wells and 73 injection wells [2]. The achievement of the upstream oil and gas industry production of the gutters Jimar Prabumulih structure will greatly affect the achievement of the overall oil and gas industry production target. Besides being produced, the oil and gas industry also has a problem that is having a large volume of waste, and 80% of the liquid waste produced is water, which is also referred to as produced water [3]. Generally, water as a by-product of oil and gas processing can contain large amounts of organic and inorganic contaminants and can be measured as high demand for COD, TDS, *ammonia, phenol*, and oil content, so it can not meet the threshold. This injection water contains high oil and gas extraction concentrations, which can adversely affect non-functioning manufactured water process equipment [4]. There is plugging in the injection well, and the large dissolved solid particle size causes the cartridge filter to be frequently clogged and replaced [5]. The quality of the produced water has a high dissolved ion content [6]. Produced water treatment equipment does not work optimally because the produced water to be injected into the injection well still contains high dissolved ions and does not meet the quality standards for disposal into the environment [7]. There has been no separating process between the oil and water content until now, resulting in a high oil concentration in the injection well [8]. Various methods have been proposed to remove ingredients that can damage the tool, pollute the environment, and disrupt oil production processes, processes such as adsorption ion exchange resins, chemical precipitation, membrane filtration, and electrocoagulation [9]. Some applications of electrochemical cells can also be found in the previous study [10].

A study by Myllymäki et al. [2] showed a successful removal of total organic carbon (TOC) (95%) from drainage pond water, which can cause eutrophication and algae growth using the adsorption method combined with electrocoagulation. Using the adsorption method with activated carbon (AC) as an absorber and continued with the electrocoagulation (EC) process and the use of a combination of the adsorption and electrocoagulation process can significantly increase the efficiency of TOC separation [11]. At present, electrocoagulation technology has been widely used by companies in several countries. However, in Indonesia, companies that use this technology to treat wastewater are still limited.

Electrocoagulation is also known as short wave electrolysis. Electrocoagulation is a process that passes an electric current into the water. It can be used as a real test with a very effective process for removing contaminants found in water. This process can reduce more than 99% of heavy metal cations. Metal electrodes will be oxidized from metal to cations so that water will become hydrogen gas and hydroxyl ions (OH) and (Mn+). Then, the water will become hydrogen gas and hydroxyl ions (OH) [12]. The working principle of this system is to use two electrode plates inserted into a vessel that has been filled with water to be purified. Also, the two electrodes are electrified with direct current so that an electrochemical process occurs. It causes the cation to move toward the cathode and the anion to move toward the anode.

Furthermore, in the end, it will form a flocculant that will bind to contaminants and particles from the raw water [13]. Electrodes are conductors through which an electric current passes from one media to another, usually from an electrical source to a device or material. Electrodes can take several different forms, including wires, plates, or sticks, and are most often made of metal, such as copper, silver, lead, or zinc [14].

In this study, wastewater treatment was done by comparing the electrocoagulation method (EK), the adsorption method (AD), combining the electrocoagulation process and the adsorption process (EK + AD) with a continuous process. This process employed an electric current that is designed like a voltmeter circuit and equipped with electrodes in the form of Aluminum (Al) and iron (Fe). Then, the adsorption process itself was carried out using activated carbon from coconut shell waste. The main advantages of this method are the relatively short contact time, low operational costs, and electrode material easily obtained and this method is a technology that separates the content of dissolved ions by comparing the electrocoagulation method (EK), adsorption method (AD), and combine the electrocoagulation process and the adsorption process (EK + AD) with a continuous process. This method is also done as a substitute for a coagulation system with alum/alum material.

The purpose of this study is to know the characteristics of produced water and to evaluate the effect of electrode voltage and the length of time of the electrocoagulation process coupled with the adsorption process to reduce the content of COD, TDS, *ammonia, phenol*, and oil & fat in the produced water treatment process. This study is expected to provide the information to treat the produced water in the oil and gas industry regarding waste treatment management.

II. Materials and Methods

An electrocoagulation reactor (B) equipped with aluminum (Al) and iron (Fe) electrodes was used to treat the produced water. The voltage source was from the power supply (C) that was connected to the reactor.

Besides, the instrument used is an adsorption tube containing activated carbon. Furthermore, it is activated by immersing coconut shell charcoal in H_2SO_4 solution for 24 hours. The coconut shell charcoal is filtered using filter paper (Whatman 42). Washed coconut shell charcoal with distilled water as much as 1 liter and then dried with an oven at 105 °C for 4 hours. Active carbon is needed in addition to the furnace function to heat the coconut shell. In addition to the treatment process, it takes 2 tanks for the initial waste collection and a collection of produced water treatment, then the results of the waste treatment are taken using a 300 ml plastic bottle and stored in the refrigerator. To calculate time variations, a digital stopwatch is used.

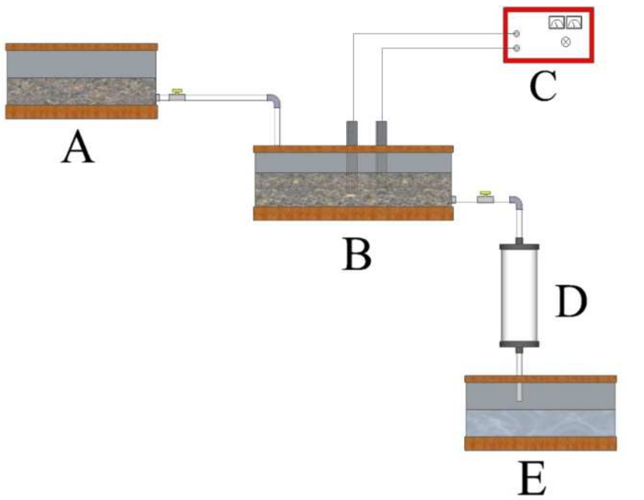

Fig. 1 Design of Produced Water Treatment Process equipment. (A = Tank of raw material (produced water), B = Electrocoagulation process tank, C = Travo / electrocoagulation process current source, D = Adsorption column, E = clean water tank).

A. *Activated Carbon from Coconut Shell Waste*

The coconut shell is then prepared, which has been cleaned from the husk and the remaining fruit flesh attached to the shell. It was then drying the coconut shell using the hot sun for 24 hours/day. Then the carbonization stage of the coconut shell is carried out by heating 650 grams of coconut shell in the furnace at a temperature of 300 °C for 1 hour. After that, the coconut shell charcoal is cooled to 30 °C., and the charcoal is reduced by using mortar and pestle, then sieved using a 6.3 mm sieve. The next stage was weighing 30 grams of coconut shell charcoal for each treatment. After weighing, coconut shell charcoal is immersed in H_2SO_4 solution for 24 hours.

The coconut shell charcoal is filtered using filter paper (Whatman 42). After being filtered, then washed coconut shell charcoal with 1 liter of distilled water, dried with an oven at 105 °C for 4 hours. After that, the activated carbon charcoal is cooled.

B. Produced water treatment by electrocoagulation (EK)

An initial sample of 12.8 liters in a storage tank was entered into an electrocoagulation tank for batch electrolysis. Furthermore, the electrolysis process of water is produced with voltage variations of 3, 6, 9, 12 volts and time variations of 30, 60, 90, 120, 150 minutes. After that, the analysis of produced water each time and voltage variations to determine the content of COD, TDS, *ammonia, phenol*, and oils content in the produced water.

C. Produced water treatment by filtration process (F)

The initial sample of 12.8 liters in the storage tank is slowly entered into adsorption to continuously carry out the adsorption process. Furthermore, the adsorption process of produced water with a variation of time 30, 60, 90, 120, 150 minutes continuously with coconut shell activated carbon as much as 30 g / L. After that, the produced water analysis is carried out every time in the laboratory to determine the content of COD, TDS, *ammonia, phenol*, and oil in the produced water to meet quality standards for disposal into the environment.

D. Produced Water Treatment with a Combination Process of Electrocoagulation and Adsorption with Activated Carbon Media (EK + AD)

The initial sample of 12.8 liters is processed continuously, starting at the tank holding tank. The initial sample is channeled to the electrocoagulation unit by electrified with voltage variations of 3, 6, 9, 12 volts from the travo to the iron and aluminum plates consisting of the cathode and anode with a thickness of 1 mm electrodes and variations in plate dimensions of 15 cm x 5 cm and time variations of 30, 60, 90, 120, 150 minutes. Then the output from the electrocoagulation unit flowed to the adsorption unit is carried out continuously with the coconut shell-activated carbon adsorption media as much as 30 g / L. Furthermore, the output of the filtration unit is accommodated in the beaker glass. After that, analysis of produced water every time to determine the content of COD, TDS, ammonia, phenol, and oil content in produced water.

III. Results and Discussion

Water Talang Jimar structures are shown in Table I. NH_3-N, COD, oil content, and total dissolved solid (TDS) have not met the standard quality of Wastewater Exploration and Oil and Gas Production Activities from onshore facilities long time regulated by Minister of Environment Regulation No. 19 the Year 2010. In this research, produced water treatment is carried out with 3 processes: Electrocoagulation in Table II, Adsorption with activated Carbon media in Table III, and Electrocoagulation Combination with filtration using activated carbon in Table IV.

TABLE I
RESULTS OF ANALYSIS OF INITIAL AIR SAMPLES PRODUCED IN THE UPSTREAM OIL AND GAS INDUSTRY IN TALANG JIMAR STRUCTURE OF THE PRABUMULIH FORMATION

Parameter	**Unit**	**Score**	**Quality Standards (PermenLH RI No. 19 of 2010)**
pH	-	8.26	6–9
Temperature	°C	27.0	45
Amonia	mg/L	24.24	10
COD	mg/L	737.57	300
Oil and Grease	mg/L	364.2	10
Phenol	mg/L	1.20	2
Sulfide (H_2S)	mg/L	0.20	1
Total Dissolved Solid (TDS)	mg/L	16,010	4,000

TABLE II
THE RESULTS OF THE ANALYSIS OF WATER TREATMENT ARE PRODUCED AFTER GOING THROUGH AN ELECTROCOAGULATION PROCESS

Voltage(V)	**Time EK (M)**	**Oil Content (mg/L)**	**Ammonia (mg/L)**	**Phenol (mg/L)**	**COD (mg/L)**	**TDS (mg/L)**
3	0	364.2	24.24	1.20	737.57	16,610
	30	360.3	17.70	1.19	422.25	12,280
	60	320.9	17.66	1.18	414.26	11,490
	90	281.5	16.87	1.17	406.27	10,900
	120	279.1	15.50	1.15	398.28	10,310
	150	180.5	14.97	1.13	390.29	9,720
6	0	364.2	24.24	1.20	737.57	16,610
	30	336.6	17.69	1.18	421.67	12,079
	60	296.2	17.64	1.16	313.09	11,488
	90	279.5	16.84	1.15	304.51	10,897
	120	180.1	15.49	1.14	295.93	10,306
	150	175	14.86	1.11	87.35	9,715
9	0	364.2	24.24	1.20	737.57	16,610
	30	315.4	17.66	1.17	380.35	11,076
	60	260.4	16.82	1.15	368.45	9,482
	90	195.16	16.79	1.14	270.55	9,088
	120	129.92	15.47	1.13	199.65	7,294
	150	50.8	15.30	1.10	85.75	3,601
12	0	364.2	24.24	1.20	737.57	16,610
	30	310.5	15.90	1.13	354.84	10,961
	60	239.5	14.01	1.11	294.23	9,098
	90	170.3	11.85	1.09	201.22	7,986
	120	129.98	13.17	1.08	113.17	9,905
	150	94.1	16.05	1.13	48.21	10,993

TABLE III
RESULTS OF THE ANALYSIS OF PRODUCED WATER TREATMENT AFTER GOING THROUGH ADSORPTION PROCESS

Conc.(g/L)	**Time (minute)**	**Oil Content (mg/L)**	**Ammonia (mg/L)**	**Phenol (mg/L)**	**COD (mg/L)**	**TDS (mg/L)**
20	0	364.2	24.24	1.20	737.57	16,610
	30	310.2	16.65	1.19	352.20	12,530
	60	284.5	14.50	1.18	292.17	11,164
	90	150.1	13.05	1.16	195.12	11,012
	120	99	11.97	1.10	110.89	10,920
	150	40.1	9.99	1.05	35.05	9,941

TABLE IV
RESULTS OF THE ANALYSIS OF WATER TREATMENT PRODUCED AFTER GOING THROUGH A COMBINATION OF ADSORPTION + ELECTROCOAGULATION PROCESSES CONTINUOUSLY

Voltage (V)	Time EK (M)	Oil Content (mg/L)	Ammonia (mg/L)	Phenol (mg/L)	COD (mg/L)	TDS (mg/L)
3V	0	364.2	24.24	1.20	30.91	16,610
	30	343.1	17.59	1.16	114.81	11,917
	60	299.3	16.45	1.14	193.67	11,164
	90	274.2	15.37	1.13	270.53	10,411
	120	263.7	14.55	1.06	354.39	9,658
	150	160.2	13.80	1.01	737.57	8,907
6V	0	364.2	24.24	1.20	120.01	16,610
	30	326.2	16.43	1.15	182.05	11,320
	60	272.1	15.33	1.09	246.10	9,985
	90	260.1	13.59	0.96	306.15	8,432
	120	150.5	11.98	0.86	369.20	7,957
	150	100.3	10.97	0.75	737.57	6,404
9V	0	364.2	24.24	1.20	737.57	16,610
	30	305.9	15.66	1.08	349.09	10,903
	60	250.2	14.59	0.85	265.77	8,936
	90	132.5	13.16	0.63	184.53	6,969
	120	98.01	9.85	0.42	104.29	5,002
	150	30.60	6.80	0.15	19.01	3,035
12V	0	364.2	24.24	1.20	737.57	16,610
	30	288.7	14.09	1.06	348.13	9,903
	60	183.1	12.09	0.82	290.43	6,823
	90	70.2	10.03	0.58	180.54	4,061
	120	17.3	8.66	0.34	70.11	2,314
	150	8.9	6.02	0.09	11.90	1,073

A. Effects of Electrocoagulation (EK), Adsorption (AD), and Combination of Electrocoagulation and Adsorption (EK + AD) on Chemical Oxygen Demand (COD)

In the oil and gas industry produced water, one important parameter that must be considered is the COD (Chemical Oxygen Demand) content contained in the produced water with a large enough value. High COD content will cause odor because the content of organic substances in it causes oxygen to be unable to break it down. The number of COD contained in produced water before being treated is 737.57 mg/L. This certainly does not meet the quality standards according to the Republic of Indonesia LH Regulation No 19 of 2010, which is 300 mg/L, so a processing process is needed to meet the standards of water produced by the oil and gas industry. The following is a graph of the reduction of COD in the electrocoagulation (EK), adsorption (AD), and combination of electrocoagulation and adsorption (EK + AD) processes.

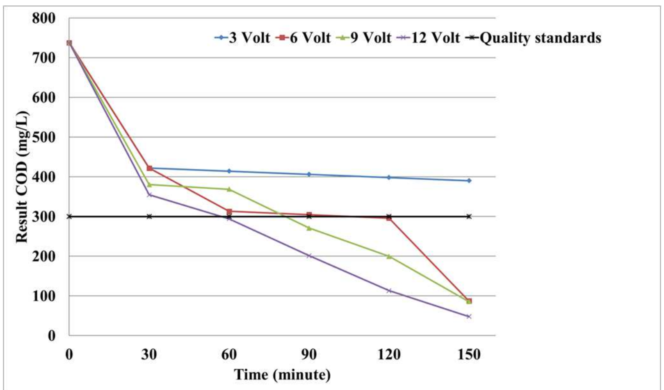

Fig. 2 The effect of the use of electrocoagulation (ek) at voltages of 3, 6, 9, 12 volts on COD

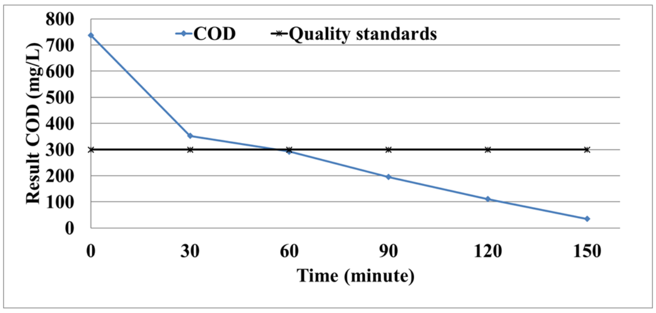

Fig. 3 Effect of the use of adsorption (ad) at 30, 60, 90, 120, 150 minutes on COD.

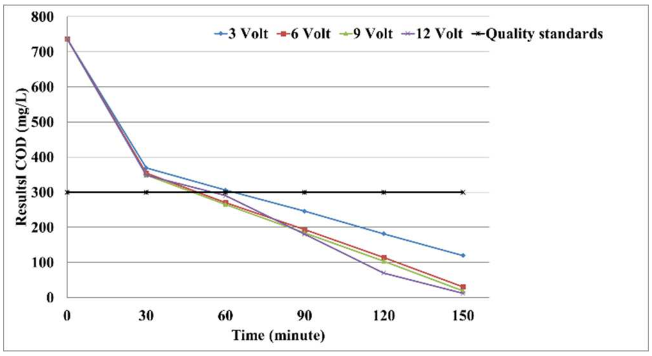

Fig. 4 The effect of using a combination of electrocoagulation (ek) and adsorption (ad) at 30, 60, 90, 120, 150 minutes on COD

From the graph above on the electrocoagulation (EK) process voltage of 12 volts with a flow rate of 12.18 liters and a flow rate of 300 ml at a contact time of 150 minutes shows the change in COD from initial waste 737.57 mg/L to 48.21 mg/L there was a significant decrease in COD content with the addition of voltage to 12 V. Whereas the adsorption process (AD) at 150 minutes contact time showed a change in COD from initial waste 737.57 mg/L to 35.05 mg/L. The value of COD decreased by increasing contact time to 150 minutes. And in the process of a combination of electrocoagulation and adsorption (EK + AD). This shows that the presence of electrocoagulation and adsorption (EK + AD) at a 12 V within 150 minutes can reduce the COD content of produced water to be discharged into the environment and surrounding waters. The reduction of COD in the combination of electrocoagulation and adsorption (EK + AD) is due to the presence of activated carbon which has adsorption and electrocoagulation properties so that it can be utilized in decreasing COD levels. Flocks that bind to contaminants are produced by the interaction between the electrodes and the voltage in the electrocoagulation and adsorption (EK + AD) process. The more flocks produced, the better the electrocoagulation and adsorption (EK + AD) process.

Compared to the previous process, the combined electrocoagulation (EK) and adsorption (AD) process was the best reduction in COD content at 12 V with a flow rate of 12.18 liters. At a contact time of 150 minutes, the COD changes to 11.90 mg/L from the initial waste sample. This shows that the COD content obtained meets the quality standards of water produced by the oil and gas industry according to the quality standard according to LH RI Regulation No. 19 of 2010. With a maximum COD content of 300 mg/L, the water produced is safe to be discharged into the environment. Compared with research conducted by Ouaissa et al. [5], conducting this research to overcome the problems associated with anthropogenic contamination is chrome toxicity for living organisms and reducing pollution of skin tanning waste and removing COD electrocoagulation method and adsorption decreased COD 480 mg/L with a percentage of 75%. So that when compared with research that has been done using a combination of electrocoagulation and adsorption (EK + AD) at a 12-volt voltage with a flow rate of 12.18 L and a flow rate of 225 ml at a water discharge of 7.5 ml/minute at 150 minutes contact time showed a greater percentage of rejection compared to previous studies that were 98,39%.

B. *Effects of Electrocoagulation (EK), Adsorption (AD), and Combination of Electrocoagulation and Adsorption (EK + AD) on Total Dissolved Solid (TDS)*

One of the parameters used to measure water quality in the form of decomposed and dissolved solids in water is Total Dissolved Solid (TDS). Produced water is a waste that has a high content of Total Dissolved Solid (TDS). Measurement of Total Dissolved Solid (TDS) is based on units of parts per million (ppm) milligrams per liter (Mg/L) or the ratio of the weight ratio of ions to water. The preliminary analysis of produced water in the oil and gas industry shows a TDS content of 16,010 mg/L, so to meet the standard quality standards for produced wastewater requires proper treatment. Produced water treatment uses electrocoagulation (EK), adsorption (AD), and a combination of electrocoagulation and adsorption (EK+AD) processes. The graph of TDS reduction is shown in the following figure.

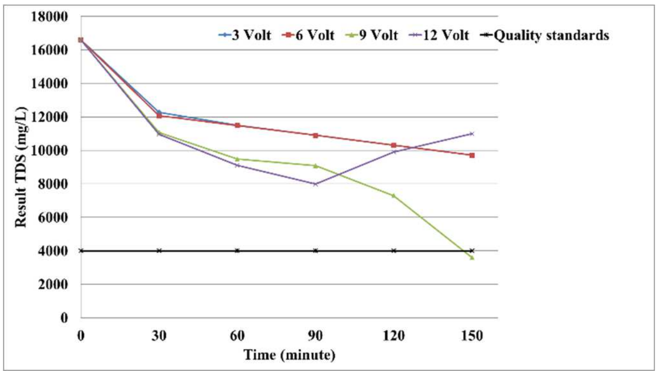

Fig. 5 The influence of the use of electrocoagulation (EK) at voltages of 3. 6. 9. 12 volts on TDS

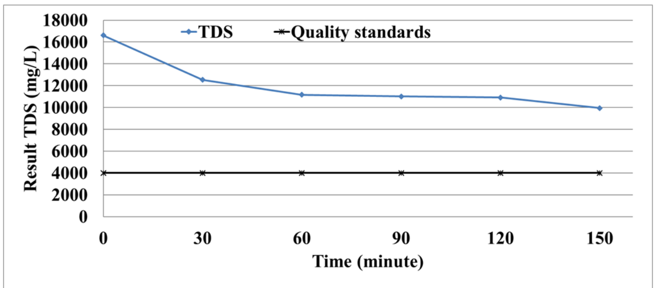

Fig. 6 Effect of adsorption (AD) at 30. 60. 90. 120. 150 minutes on TDS

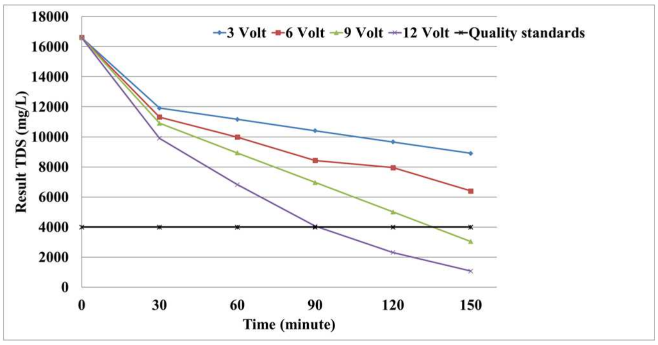

Fig. 7 Effect of combination of electrocoagulation (EK) and adsorption (AD) at 30. 60. 90. 120. 150 minutes on TDS

In the electrocoagulation (EK) process, the voltage of 9 volts at 150 minutes contact time begins to decrease past the quality standard, reaching 3,601 mg/L, and with a 12-volt voltage at 150 minutes contact time indicates a change in the content of the TDS value to 10,993 mg/L an increase in value from TDS with the addition of a voltage to 12 volts. This shows that the presence of electrocoagulation (EK) at a 12 V within 150 minutes has not been able to reduce the TDS content from the previous voltage of 9 V, analyzing the increase in TDS values due to decomposed electrodes shrinking or depleted, because the electrodes consisting of iron and aluminum decompose into a powder that dissolves in floc that has been formed. At the same time, the adsorption process (AD) with a contact time of 150 minutes showed a change in the content of the TDS value from the initial waste of 16,010 mg/L to 9,941 mg/L. This shows that the adsorption process (AD) is within 30. 60. 90. 120. and 150 minutes decrease in TDS content is not too significant because the filtration media used has been saturated so that the process of absorption of pollutants is reduced. And in the combination process of electrocoagulation and adsorption (EK + AD) at a 12 V with an inlet flow rate of 12,18 liters and an outflow rate of 225 ml. a 7.5 ml/minute water discharge at 150 minutes contact time, the best decrease is to 1,073 mg/L. This shows that there is a very significant decrease in TDS content using a combination of electrocoagulation and adsorption (EK + AD).

The decrease in TDS levels with the combination of electrocoagulation and adsorption (EK + AD) is caused by the clumping of particles carried out by the coagulation process with the electrodes as a coagulant forming unwanted flocks by perfecting the adsorption process (AD) pores in activated carbon smaller than the activated carbon on particulates produced water, so it can separate dissolved solid contained in produced water in the oil and gas industry. And the influence of the length of time and the addition of a high voltage or voltage successfully reduces the TDS content, which is very significant. In addition, the resulting TDS levels have met the quality standard according to LH RI Regulation No. 19 of 2010. A combination of electrocoagulation and adsorption (EK + AD) can continuously reduce the TDS content when the voltage and contact time was increased to 12 V and 150 minutes, resulting 93.54 % of removal. This study was consistent with the previous study, where 91% TDS was achieved [15].

C. Effects of Electrocoagulation (EK), Adsorption (AD), and Combination of Electrocoagulation and Adsorption (EK + AD) on Ammonia Total (NH_3-N)

NH_3-N is one of the water pollutants and toxic substances and harmful organic matter. The higher the NH_3-N in liquid waste, it will cause poisoning in the biota. Therefore, this parameter is listed in the quality standard of liquid waste, especially in the produced water of the oil and gas industry. The NH_3-N content contained in the produced water before processing is 24,24 mg/L, which indicates that the NH_3-N content does not meet the quality standards according to LH RI Regulation No 19 of 2010. The following graph shows the effect of using electrocoagulation (EK), adsorption (AD), and the combination of electrocoagulation and adsorption (EK + AD) to the reduction of NH_3-N.

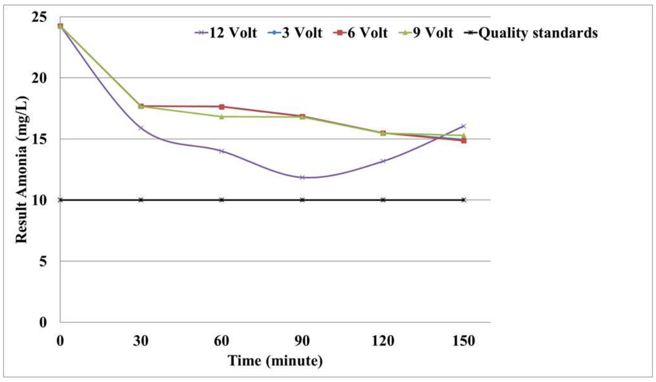

Fig. 8 Effect of electrocoagulation (EK) at voltages of 3. 6. 9. 12 volts on ammonia

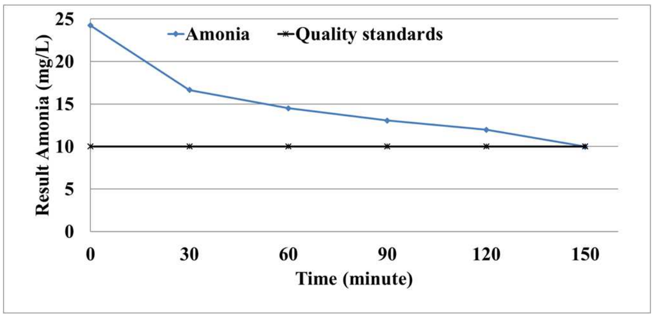

Fig. 9 Effect of adsorption (AD) at 30. 60. 90. 120. 150 minutes on ammonia

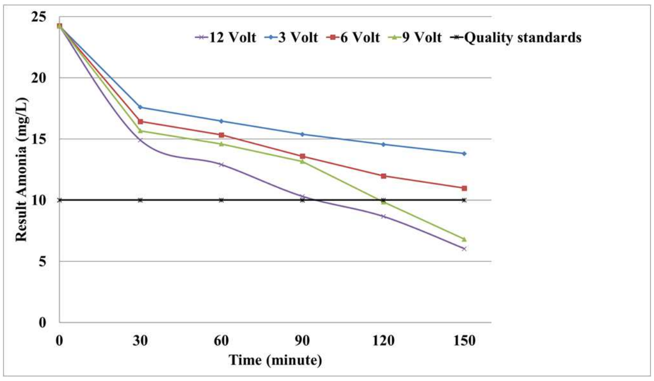

Fig. 10 Effect of combination of electrocoagulation and adsorption (EK + AD) at 30. 60. 90. 120. 150 minutes on ammonia

The electrocoagulation (EK) process at 9 V in 150 minutes contact time increased to 15.30 mg/L. With the voltage of 12 V in 150 minutes, contact time increased again from 9 V to 16.05 mg/L. In the adsorption process (AD) the contact time is 150 minutes with a decrease in NH_3-N to 9.99 mg/L with an initial waste of 24.24 mg/L compared to the electrocoagulation process without any other process. In the combination process of electrocoagulation and adsorption (EK + AD) at 150 minutes contact time, the decrease is not too far from the 9-volt voltage, which is 6.02 mg/L. This shows a very significant decrease occurred starting from 9 volts and 12 volts. NH3-N reduction occurs in a combination of electrocoagulation and adsorption processes (EK+AD), but the adsorption of pores and cavities containing activated carbon in the form of powder or activated carbon (PAC) causes an adsorption process. Hence, the NH3-N content in the produced water decreases. However, the electrocoagulation process only slightly reduces NH3-N with properties that only agglomerate particles in the form of floc or as a substitute for coagulants.

In the combination process of electrocoagulation and adsorption (EK + AD) with NH_3-N levels of 6.02 mg /L at 12 V with a flow rate of 12.18 liters and an outlet flow rate of 225 ml to get a water discharge of 7.5 ml/minutes at contact time 150 minutes. This shows that at 12 V the NH3-N can be separated higher than at 3.6. 9 V. Overall, reducing NH3-N content by using a combination of electrocoagulation and adsorption (EK + AD) processes can reduce the initial content of produced water. In addition, the NH_3-N content produced has met the Wastewater Quality Standard for Businesses and/or Oil and Gas Activities and Geothermal, in Appendix I Letter C., Wastewater Quality Standards for Oil and Gas Exploration and Production Activities from Land Facilities (Onshore) New. Compared with previous studies conducted by Solikhah *et al.* [16] using bagasse as activated carbon to decrease NH_3-N, the percentage of NH_3-N reduction was 540.97 mg / L or 44.87%. This result is certainly lower when compared to research that has been done using a combination process of electrocoagulation and adsorption (EK + AD) at a V voltage with an inlet flow rate of 12.18 liters and an outflow rate of 225 ml to get a 7.5 ml water discharge/minute at 150 minutes to contact time of 6.02 mg / L or NH_3-N rejection percentage of 75.16%, from the initial sample.

D. Effects of Electrocoagulation (EK), Adsorption (AD), and Combination of Electrocoagulation and Adsorption (EK + AD) on Phenol

Phenol or carbolic acid or benzenol are colorless crystalline substances that have a characteristic odor. Phenol is also in the form of water which creates taste and smell reacts with chlorophenol-shaped chlorine. The phenol content in the initial sample was examined, which was 1.20 mg/L from the maximum standard of 2 mg/L produced and met the requirements for produced water. but here whether by comparing the process of the combination of electrocoagulation and adsorption (EK + AD), electrocoagulation (EK) and adsorption (AD) against phenol can reduce significant levels of phenol from water produced by the oil and gas industry. The following graph shows the process of electrocoagulation (EK), adsorption (AD), a combination of electrocoagulation and adsorption (EK + AD) to reduce *phenol.*

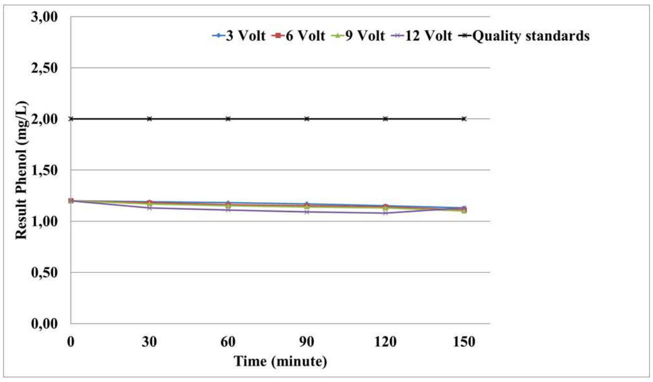

Fig. 11 Effect of electrocoagulation (EK) at voltages of 3, 6, 9, 12 V on phenol.

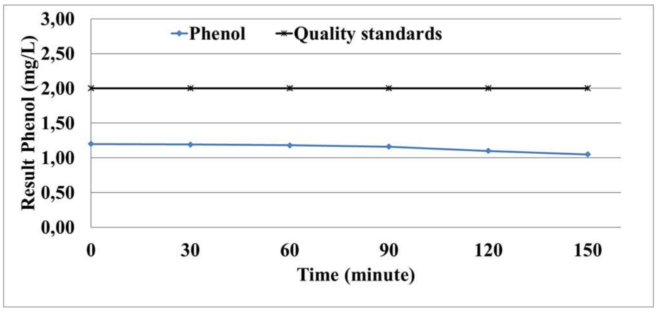

Fig. 12 Effect of adsorption (AD) at 30, 60, 90, 120 and 150 minutes on phenol.

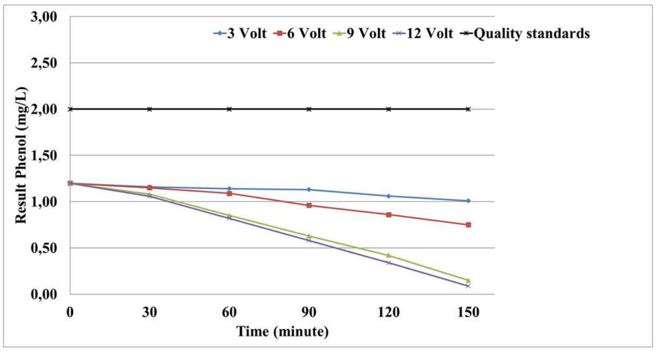

Fig. 13 Effect of combination of electrocoagulation (EK) and adsorption (AD) at 30, 60, 90, 120 and 150 minutes on phenol

The electrocoagulation (EK) process at 12 V in 150 minutes contact time increased by 1.13 mg/L. This shows that the increase in phenol content occurs at 12 V. reduction of phenol occurs in the electrocoagulation (EK) process occurs because the decomposed electrodes are shrinking or depleted, because the electrodes consisting of iron and aluminum decompose into powders that dissolve in floc that has been formed, which from the electrode itself contains phenol content in obtained from iron and aluminum plates so that the phenol content in water produced at a 12 V increases, whereas the use of the electrocoagulation process itself only slightly reduces the content of phenols with properties that only agglomerate in the form of floc particles or as a substitute for coagulants. For the adsorption process (AD), the contact time of 120 minutes has decreased again reaching 1.10 mg/L. and at 150 minutes contact time decreased by 1.05 mg/L. This has decreased the phenol content due to the presence of activated carbon which has adsorption and filtering or absorbing properties so that it can be utilized in reducing phenol levels. However, with increasing contact time, this can also occur because activated carbon's ability in adsorbing and filtering is also reduced. The reduced ability of activated carbon is caused by the pores on the surface of the carbon being saturated. Therefore, the produced water at 150 minutes contacts time with phenol reduction of 1.05 mg/L with an initial waste of 1.20 mg/L compared to the electrocoagulation process without any other process. In the combined electrocoagulation and adsorption process (EK+AD) with a flow rate of 225 ml, the water discharge was 7.5 ml/minute at a contact time of 150 minutes. The decrease is not too far from the 9-volt voltage, which is 0.09 mg/L. This showed a good decrease occurred at 12 V. Phenol reduction occurred in a combination of electrocoagulation and adsorption processes (EK+AD) due to the presence of pores and cavities in the adsorption containing activated carbon in the form of activated carbon powder (PAC) makes a filtration process occurred. Hence, the phenol content in the produced water decreases. At the same time, the electrocoagulation process only slightly reduces the phenol content with properties that only agglomerate particles in the form of floc or as a substitute for coagulants.

This shows that at a voltage of 12 V phenol can be separated higher than at a voltage of 3, 6, 9 volts. Overall, the reduction of phenol content by using a combination of electrocoagulation and adsorption (EK + AD) processes can reduce the initial content of produced water. In addition, the phenol content produced has met the Wastewater Quality Standards for Oil and Gas and Geothermal Business and/or Activities, in Appendix I Letter C., Wastewater Quality Standards for Oil and Gas Exploration and Production Activities from Land Facilities (On shore) New.

E. Effect of Electrocoagulation (EK), Adsorption (AD), and Combination of Electrocoagulation and Adsorption (EK + AD) on Oil Content

The content of oils content (organic matter) in uncontrolled wastewater can cause pollution and environmental damage. That the quality standard is in accordance with the Republic of Indonesia Regulation No. 19 of 2010, the content of pollutants in produced water must be maintained at 25 mg/L each. The oil content in the initial sample has been checked which is 364,2 mg/L of the maximum standard quality standard of the produced water 25 mg/L does not meet the requirements for produced water. Therefore, a combination of electrocoagulation and adsorption (EK + AD), electrocoagulation (EK) and adsorption (AD) processes is carried out to compare the process which can significantly reduce oil content from oil and gas produced industrial water. The following graph shows the effect of using a combination of electrocoagulation and adsorption (EK + AD) on oil content reduction.

Electrocoagulation (EK) process at 9 V in 150 minutes contact time decreased again reaching 50.8 mg/L, at 12 V voltage in 150 minutes contact time increased 94.1 mg/L. For the adsorption process (AD) at 150 minutes contact time decreased by 40.1 mg/L. In the combination process of electrocoagulation and adsorption (EK + AD) a very significant decrease occurred at a voltage of 12 volts. The decrease in oil content occurs in a combination of electrocoagulation and adsorption processes (EK+AD) because the pores and filtration cavities contain activated carbon powder (PAC), causing an adsorption process so that the oil content in the produced water decreases. The use of the electrocoagulation process only slightly reduces the oil content. The properties only agglomerate particles in the form of floc or as a substitute for coagulants. This study showed that at a voltage of 12 V the oil content can be separated higher than at a voltage of 3, 6 and 9 V.

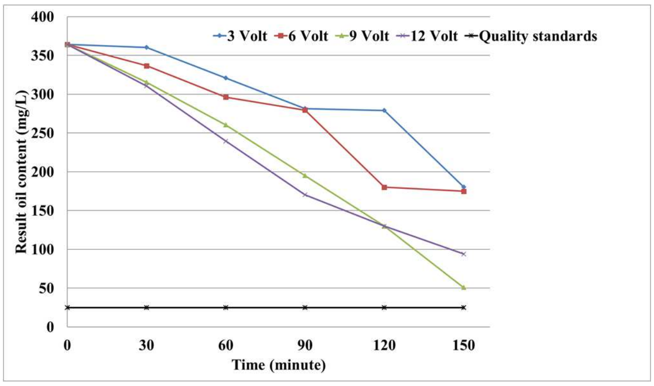

Fig. 14 Effect of electrocoagulation (EK) at voltages of 3, 6, 9 and 12 volts on oil content.

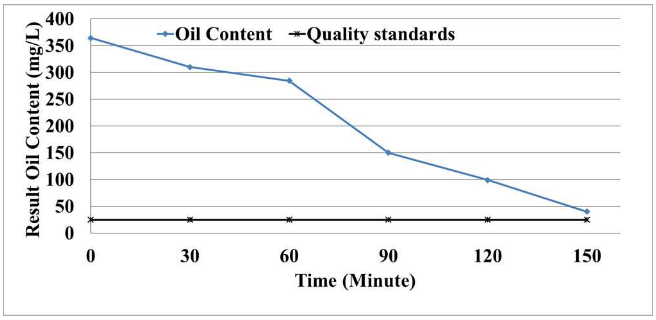

Fig. 15 Effect of adsorption (AD) at 30, 60, 90, 120 and 150 minutes on oil content.

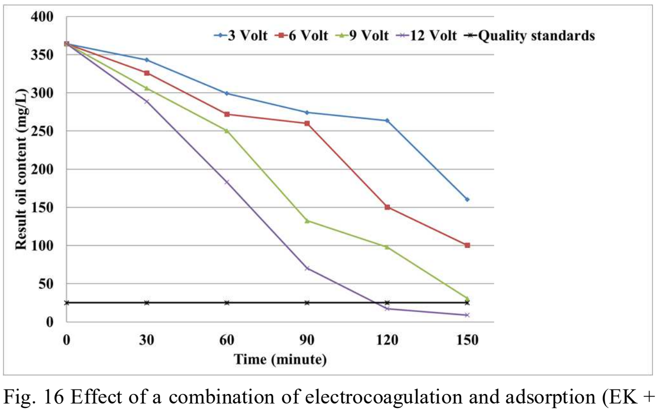

Fig. 16 Effect of a combination of electrocoagulation and adsorption (EK + AD) at 30, 60, 90, 120 and 150 minutes on oil content

Overall, the reduction of oil content by using a combination of electrocoagulation and adsorption (EK + AD) processes can reduce the initial content of produced water. In addition, the oil content produced has met the Wastewater Quality Standard for Businesses or Oil and Gas Activities and Geothermal, in Appendix I Letter C., Wastewater Quality Standards for Oil and Gas Exploration and Production Activities from Land Facilities (On shore) New. By using a combination of electrocoagulation and adsorption (EK + AD) at a 12 V with an inlet flow rate of 12.18 liters and an outflow rate of 225 ml, a 7.5 ml/minute water discharge at a 150 minute contact time of 8,9 mg/L and the percentage of rejection of oil and content obtained was 97,56%.

IV. CONCLUSION

The conclusions obtained from the treatment of produced water using the process of electrocoagulation (EK), adsorption (AD), and a combination of electrocoagulation and adsorption (EK + AD), that is: Voltage and time variations in the electrocoagulation (EK) method have an influence on the reduction of contaminants in produced water, with a reduction percentage of COD 93.46%, TDS 40.37%, ammonia 33.78%, oil content 74.16%, and phenol 5.83% of initial waste. The time variation in the adsorption process (AD) has an influence on the reduction of contaminants in produced water, with a reduction percentage of COD 9.24%, TDS 40.15%, ammonia 58.78%, oil content 88.89%, and phenol 87.5% of the initial waste. Voltage and time variations in the combination of electrocoagulation and adsorption (EK + AD) processes have an effect on decreasing the content of COD, TDS, ammonia (NH3-N), oil content, and phenols from produced water with the optimum percentage reduction in COD 98.39 %, TDS 93.54%, ammonia 75.16%, oil content 97.56%, and phenol 92.5% of the initial waste. With the optimum voltage parameters at 12 V and a time of 150 minutes. Overall produced water treatment by comparing the electrocoagulation (EK), adsorption (AD) methods and the combination of electrocoagulation and adsorption (EK + AD) have been able to reduce contaminants contained in produced water but which meet the quality standards according to LH RI Regulation No. 19 In 2010 only using a combination of electrocoagulation and adsorption (EK + AD) methods.

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