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Study on the utilization of electrocoagulation concept as a disinfectant substitute in hospital wastewater

Key words: electrocoagulation, disinfectants, contact time, number of electrode plates, Coliforms, hospital wastewater

Introduction

Hospital as a place or service facility to handle, take care of, and treat will produce a large amount of wastewater and its quality needs attention because it has ingredients that are hazardous to health of the society and its environment (Tchamango, Nanseu-Njiki, Ngameni, Hadjiev & Darchen, 2010; Deepak, 2014; Rad & Lewis, 2014; Jagadal, Hiremath & Shivayogimath, 2017; Ahmad et al., 2019).

In addition to having a positive impact on society, namely as a place to heal the sick, hospital also has the possibility of having a negative impact (Akansha, Nidheesh, Gopinath, Anupama & Kumar, 2020). All medical service activities in the hospital will produce by-products in the form of garbage and waste that can be indicated as a reservoir, which can have a negative impact on health (Hakim & Hardianti, 2017). One of them can be in the form of pollution from an activity process, that is, if the resulting waste is not managed properly considering all hospital wastewater is likely to contain chemicals (toxic), infectious and radioactive (Niati & Widarto, 2006). Based on the results of Rapid Assessment in 2002 by the Directorate General of the Pemberantasan Penyakit Menular dan Penyehatan Lingkungan (P2MPL), there were 648 hospitals out of 1,476 hospitals which 49% of them had new incinerators and 36% of them had wastewater treatment plants (WWTP). Based on this amount, the quality of wastewater that has gone through management process that meets the requirements has only reached 52% (Djaja & Maniksulistya, 2006).

Waste management in hospitals is generally done to reduce the level of pollution both physically, chemically, and microbiologically. Specifically, for microbiological management, the waste management unit in this hospital uses Coliform bacteria as an indicator of its parameters. These bacteria are a large and heterogeneous group of Gram-negative rods that are within certain limits similar to *Escherichia coli* (Tapotubun, Savitri & Matrutty, 2016).

There are various methods used in deriving microbiological parameters in wastewater. Most hospitals in Indonesia use chlorine (chlorination) in the process of disinfection of waste water, because it is considered the cheapest on the market. However chlorine is beneficial for human life, and toxic to the environment and human health. The chlorine nature as a strong oxidizer makes it easy to bind to other compounds, forming toxic compounds such as organochlorine which has a carcinogenic effect. Therefore, there needs to be other alternatives that are more environmentally friendly and have minimal impact on human health. One method that can be developed is the electrocoagulation system.

Electrocoagulation is a water purification method (Liu et al., 2019). The working principle of electrocoagulation is to use two electrode plates inserted into a vessel filled with water to be purified. Furthermore, the two electrodes are electrified with direct current so that an electrochemical process occurs which causes the cation to move toward the cathode and the anion to move toward the anode (Hakizimana et al., 2017). Flocculants are eventually formed which will bind contaminants or particles from the raw water. There are anodes and cathodes in electrocoagulation. At the anode occurs the release of active coagulant in the form of metal ions into the solution, while at the cathode an electrolysis reaction occurs in the form of hydrogen gas release (Miwa, Malpass, Machado & Motheo, 2006; Önder, Koparal & Öğütveren, 2007).

Electrocoagulation requires simple equipment and is easy to operate (Chen, Chen & Yue, 2002; Cańizares, Jiménez, Martínez, Sáez & Rodrigo, 2007; Lakshmanan, Clifford & Samanta, 2010). Electrocoagulation can reduce colloidal//smallest particle content faster, and can provide high enough process efficiency for various conditions, no pH regulation is needed, without the use of chemical additives, deposits formed from the electrocoagulation process are more easily separated from water, can move particles smaller colloidal particles, and the electric current can be regulated (Van Genuchten, Addy, PenÞa & Gadgil, 2012; Lu, Li, Yin, Ma & Lin, 2015).

Existing researches related to electrocoagulation are limited to decreasing physical and chemical parameters of wastewater (Silva, Graca, Ribeiro & Rodrigues, 2018), phosphates (Dura & Breslin, 2019), suspended solids (Sadeddin, Naser & Firas, 2011), Cu, Ni, Zn, and Cr (Kim, Kim & Zoh, 2020), oil (Chen, Chen & Yue, 2000; Fajardo, Rodrigues, Martins, Castro & Quinta-Ferreira, 2015), and arsenic contaminated water (Nidheesh & Singh, 2017; Syam & Nidheesh, 2020), they are not applied to microbiological parameters. Research conducted by Wiyanto et al. (2014) shows that the electrocoagulation process can reduce the percentage of sulfide levels in water. Research conducted by Setianingrum, Agus and Sarto (2016) shows that at 10-volt electricity voltage and contact time for 60 min can reduce the color parameters in batik waste water reaching 80% and COD of 71.3% (distance between electrode plates is 3 cm). Whereas the research of Darmawanti, Suhartana and Widodo (2010) shows that a contact time of 180 min and a current of 2.5 A can reduce the color of waste reaching 88.51%. Furthermore, research from Ni'am, Caroline and Afandi (2017) shows that using a 12-volt voltage, 4 electrodes, and a 45-minute contact time, can reduce COD level to 61% in wastewater.

Based on these limitations, it is necessary to conduct a research by applying electrocoagulation in reducing microbiological parameters in wastewater. Anodes and cathodes use aluminum (Al) because aluminum is a reactive electrode, a good reductant, resistant to corrosion, cheap, and easy to obtain.

Material and methods

Research type and strategies

An experimental type of research with factorial randomized design, namely looking for an effect of certain treatments on others, under controlled conditions (Notoatmodjo, 2010). Variables controlled in the study were:

- Current of 5 A and 12 V voltage.
- In order to overcome the absorption effect of electrodes, the type of electrode plate used was aluminum electrodes.
- Distance between the electrodes was 8 cm.
- Thickness of the electrode plate was 1 mm.
- The pH should be less than 9.0.

Population and sample

Population is a generalization area consisted of objects/subjects that have certain quantities and characteristics determined by researchers to be studied and then drawn conclusions. The population in this study was wastewater from effluent hospital in Bandung City (Standar Nasional Indonesia [SNI], 2008). The number of hospitals sampled in this study is one sample, namely Kebon Jati Hospital, Bandung City.

The sample size was based on the number of treatments and repetitions in the study (Gomez & Gomez, 2007). The treatments used in this study were 3 treatments using a ratio of contact time for 30, 60, and 90 min, and the number of plates (4, 6, and 8 electrode plates). The sample size calculation used the Gomez formula:

$$t(r-1) \geq 15$$

where:
t (treatment) – many treatments,
r (replica) – many repetitions.

Then:

$$t(r-1) \geq 15$$
$$3(r-1) \geq 15$$
$$3r - 3 \geq 15$$
$$3r \geq 18$$
$$r \geq 6$$

The number of repetitions in this study was 6 times. The amount of wastewater needed in a repetition was 12.5 l, so the sample size for 3 treatments was:

3 treatments × 6 repetitions = 18 samples
18 samples × 12.5 l = 225 l of wastewater sample × 2 = 450 l

The volume of the wastewater sample was adjusted to the needs of examination and analysis parameters in the laboratory, which was 100 ml (the minimum sample for Coliform examination in wastewater). The sampling technique used was grab sampling.

Data analysis

Bivariate analysis was carried out on the variables suspected to be related or influence, and saw the magnitude of the influence of independent variable on dependent variable. Bivariate analysis used was two-way ANOVA (with $\alpha = 5\%$).

Results and discussion

Average temperature and pH of wastewater based on number of plates and contact time

Based on Table 1, it shows that the highest average temperature (26.3°C) occurred in the electrocoagulation process with 8 plates in 60 min contact time, while the lowest temperature (25.67°C) occurred in the electrocoagulation process with 4 plates in 90 min contact time.

The results of this study also showed an increase in temperature from 25.75 to 26.0°C, and the highest average temperature (26.0°C) was in the electrocoagulation process with 8 plates. Likewise, with the contact time variable, it also showed an increase in temperature from 25.83 to 25.94°C, and the highest average temperature (25.94°C) was in the electrocoagulation process with 60 min contact time.

The use of electrocoagulation method can increase temperature. This is in line with the increasing number of plates and

TABLE 1. Average temperature of wastewater based on number of plates, contact time and average pH

Number of plates	Contact time [min]	Average temperature [°C]	Average pH
4	30	25.833	7.750
	60	25.750	7.617
	90	25.667	7.583
6	30	25.833	7.750
	60	25.750	7.500
	90	25.917	7.733
8	30	25.833	7.717
	60	26.333	7.583
	90	25.833	7.767

contact time used. The increase in temperature is due to the strong electric current that spreads to the aluminum plate and direct contact with the wastewater to be treated. Another factor that can affect the high and low temperature is the temperature of the air during processing, the higher the air temperature will affect the temperature in the wastewater.

Table 1 also shows that the highest average pH (7.767) occurred in the electrocoagulation process with 8 plates in 90 min contact time, while the lowest average pH (7.5) occurred in the electrocoagulation process with 6 plates in 60 min contact time. The increase in pH value is caused by the accumulation of OH in the electrocoagulation process. Rindatami, Bangun and Prayitno (2016) states that cathode in the electrocoagulation process produces OH^{-} ions which will increase the pH value. The pH value of the solution also affects the number of ions in the solution as well as the solubility of the formed product. The pH of the solution affects the overall efficiency and effectiveness of electrocoagulation. This is consistent with research conducted by Kobya and Demirbas (2015) which states that the range of $6 < pH < 9$ is effective in reducing COD in textile wastewater by electrocoagulation. The number of electrodes and the amount of voltage used affect the electrocoagulation pro-cess. Flocks that bind the contaminant are produced by interaction between the electrode and the voltage in the electrocoagulation process. The more flocks produced the better the electrocoagulation process (Hanif, Khai & Adin, 2012). This increase in pH is normally attributed to the water reduction reaction at the cathode, and this in turn will depend on the rate of the alloy dissolution reaction. The pH will influence the nature of the aluminum hydroxy species. It is evident that the monomeric hydroxyaluminum cations are stable at low pH, while increasing the pH to values close to 7 leads to the production of cationic aluminum hydroxy species, and the $Al(OH)_3$ precipitate (Dura & Breslin, 2019).

Table 2 shows that there was no significant difference between the number of plates ($p = 0.628$), contact time ($p = 0.856$), and the number of plates and contact time (p = 0.814) and the temperature in electrocoagulation process. The same results were also shown in pH analysis. The results showed that there was no significant difference between the number of plates ($p = 0.89$), contact time ($p = 0.108$), and the number of plates and contact time ($p = 0.664$) and the pH in electrocoagulation process.

TABLE 2. Analysis of differences in temperature and pH values based on the number of plates and contact time in electrocoagulation process

Source	Sig.(temperature)	Sig.(pH)
Corrected model	0.940	0.514
Intercept	0.000	0.000
Number of plates	0.628	0.890
Contact time	0.856	0.108
Number of plates × Contact time	0.814	0.664

Total Coliforms in electrocoagulation process

The results related to total Coliforms in this study showed that the total Coliforms was in the range of 2–2.735 colonies, with an average of 333 colonies and a standard deviation of ±572,102. Based on Table 3, the lowest average total Coliform occurred in the electrocoagulation process was with 6 plates at 90 min (138 colonies), and the highest was at 4 plates at 60 min contact time (669 colonies).

TABLE 3. Average total Coliforms in wastewater based on number of plates and contact time

Number of plates	Contact time [min]	Mean
4	30	294.167
	60	669.167
	90	580.000
6	30	183.333
	60	300.000
	90	138.333
8	30	140.667
	60	228.667
	90	463.333

TABLE 4. Bivariate analysis of total Coliforms differences based on number of plates and contact time in electrocoagulation process

Source	Sig.
Corrected model	0.727
Intercept	0.000
Number of plates	0.269
Contact time	0.537
Number of plates × Contact time	0.863

The results of bivariate analysis (two-way ANOVA) shown in Table 4 showed that there was no significant difference between the number of plates (p = 0.269), contact time (p = 0.537), and the number of plates and contact time (p = 0.863) and the total Coliforms in electrocoagulation process.

The interaction between variables number of plates and contact time showed that the lowest average total Coliforms occurred in the electrocoagulation process with 6 plates at 90 min, i.e. only 138 Coliform colonies. Although the results of the bivariate analysis showed no significant difference between the number of plates (p = 0.269), contact time (p = 0.537), and number of plates and contact time (p = 0.863), these results indicate effectiveness in using the concept of electrocoagulation compared to the use of other disinfectants. This result can be seen in the figure, which shows that the use of other disinfectants commonly used in hospitals is not very effective in reducing total Coliforms, this is indicated by the presence of a value that exceeds the quality standards for wastewater set by the government, namely at the first inspection with a total Coliforms of 11,067 colonies and a fifth examination with a total Coliforms of 12,009 colonies (maximum standard is 3,000 colonies). Whereas in the use of electrocoagulation, everything is below the environmental quality standard set by the government. This means that this concept is quite effective in use, as a substitute for disinfectants.

Table 5 shows effectiveness of the use of electrocoagulation concept based on the number of plates and contact time. The results showed that by using 6 plates

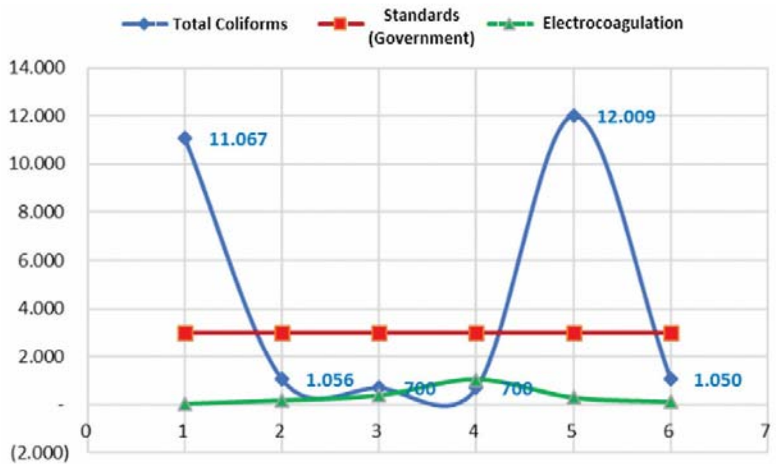

FIGURE. Comparison of total Coliforms based on the use of disinfectants and electrocoagulation concept

TABLE 5. Effectiveness of the use of electrocoagulation in reducing Coliforms [%]

Number of plates	Contact time		
	30 min	60 min	90 min
4	80.49	76.78	48.06
6	73.87	82.68	88.38
8	78.30	78.01	84.45

and 90 min contact time showed the best results in reducing Coliforms (effectiveness of 88.38%). While the lack of effectiveness was shown in the electrocoagulation process using 4 plates with 90 min contact time.

The mechanism of Coliform death in wastewater after electrocoagulation treatment is when hospital wastewater flows through the electrodes. Electron jumps in the electric field from the cathode (negative) to the anode (positive) will "shoot" Coliform bacteria in wastewater. Electric shock in the electrocoagulation system will break down cell walls, which will eventually kill the bacteria.

Conclusions

There is no significant difference between the contact time (p = 0.537), number of electrode plates (p = 0.269) and the total Coliforms in electrocoagulation process. The use of 6 plates and 90 min contact time shows the best results in reducing total Coliforms in the electrocoagulation process with an effectiveness reaching 88.38%. The concept of electrocoagulation can be used as a substitute for disinfectants in reducing total Coliforms in hospital wastewater. Recommendations for the policy makers or end users is to try implement this method as a substitute for disinfectant. Because so far, chemical disinfectants used to reduce microbiological parameters (total Coliforms) have a negative impact on humans and the environment.

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Summary

Study on the utilization of electrocoagulation concept as a disinfectant substitute in hospital wastewater. The purpose of this study is to identify differences in variations of contact time and number of electrode plates in electrocoagulation process on the decrease of total Coliforms in Bandung City hospital wastewater. An experimental research with factorial randomized design. The volume of wastewater sample to check the total Coliforms was a minimum of 100 ml, using 3 treatments and 6 repetitions. Data analysis used was two-way ANOVA test. The results showed that there was no significant difference between the number of plates (p = 0.269), contact time (p = 0.537), and the number of plates and contact time (p = 0.863) with the total Coliforms in electrocoagulation process. The use of 6 plates and 90 min contact time showed the best results in reducing total Coliforms, with effectiveness reaching 88.38%. This means that the concept is quite effective to use as a substitute for disinfectant.

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