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The Application of Non-Thermal Plasma and Electrocoagulation as Purifier of Liquid Waste in Home Industries

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ABSTRAK

Penelitian ini bertujuan untuk mengkaji metode penguraian limbah cair pada industri rumah tangga khususnya pada industri tahu dengan menggunakan metode plasma non termal dan elektrokoagulan yang ramah lingkungan dan dengan energy rendah. Dalam penelitian ini, metode plasma, metode elektro-koagulan, dan kombinasi keduanya (elektro-koagulan diikuti metode plasma dan plasma diikuti metode elektro-koagulan) digunakan untuk menguraikan limbah cair di industri tahu. Hasil penelitian menunjukkan bahwa plasma non termal dilanjutkan dengan metode elektrokoagulan paling efektif menurunkan nilai TDS sebesar 1983 ppm (nilai minimum dari total TDS kontrol sekitar 2702 ppm), nilai minimum konduktivitas listrik (EC) sekitar 3967 (μs/cm), dan juga diperoleh nilai pH 7,0. Berdasarkan hasil penelitian, plasma non termal dikombinasikan dengan metode elektrokoagulan dapat diterapkan untuk mengurai limbah cair khususnya pada industri tahu secara lebih optimal. Metode kombinasi plasma dan elektrokoagulasi untuk mengurai limbah cair industry tahu yang ramah lingkungan adalah kebaruan dari penelitian ini.
Kata kunci: elektrokoagulasi, pH, plasma non thermal, limbah cair

ABSTRACT

This study aims to examine the decomposition method of liquid waste in the home industry, especially in the tofu industry, by using non-thermal plasma and electrocoagulant methods that are environmentally friendly and with low energy. In this study, the plasma method, electro-coagulant method, and a combination of both (electro-coagulant followed by plasma method and plasma followed by electro-coagulant method) were used to decompose liquid waste in the tofu industry. The results showed that non-thermal plasma followed by the electrocoagulation method was the most effective in reducing the T.D.S. value of 1983 ppm (the minimum value of the total control T.D.S. was around 2702 ppm), the minimum value of electrical conductivity (E.C.) was around 3967 (μs/cm), and also obtained a value of 3967 (μs/cm). pH 7.0. Based on the research results, non-thermal plasma combined with the electrocoagulant method can be applied to more optimally decompose liquid waste, especially in the tofu industry. The combination method of plasma and electrocoagulation to decompose the tofu industrial wastewater, which is environmentally friendly, is the novelty of this research.

Keywords: electrocoagulation, pH, non-thermal plasma, liquid waste

INTRODUCTION

Home industries are the industries that employ many people in Indonesia. The tofu and textile industries are home industries commonly found in the surrounding environment. Fahrurozi et al. (2010) stated that the tofu and textile industries had problems decomposing wastewater. Tofu liquid waste contains high levels of organic pollutants, and if it is disposed of in the surrounding environment. It can reduce water and soil quality in the surrounding environment. Tofu is a daily food for Indonesians, a source of vegetable protein. The resulting waste also increases with the number of tofu processing industries, causing environmental pollution. Pollution is caused by solid waste and liquid waste. Liquid waste is produced from processing tofu, soaking, and boiling soybeans. The small and medium scale tofu industry is characterized as an industry with a low level of energy efficiency with a high level of pollution due to the lack or absence of a good waste management system (Fahrurozi et al., 2010).

The application of physics in various fields has been carried out by many researchers (Putra, Mohamad, et al., 2020) (Zongo, Maiga, et al., 2009) (Sakthisharmila, Palanisamy, et al., 2018). Putra, Mohamad, et al. (2020) implemented plasma physics in the textile by using the principle of plasma waves to reduce liquid waste from textile organic chemicals. According to Putra, Mohamad et al. (2020), the area of plasma physics is expected to spearhead the development of new technologies in solving wastewater treatment problems, especially in the issue of textile waste and other organic liquid waste. Murti & Putra (2020) and Putra & Wijayono (2019) stated that plasma is an ionized gas consisting of positively charged ionized atoms (positive ions) and negatively charged electrons, as well as radicals and U.V. rays. Plasma is formed from ionized gas in the tube, classified into two, weakly ionized and strongly ionized (Putra & Wijayono, 2019).

Putra & Wijayono (2019) stated that the ionization process requires energy in the electron to remove electrons, so in making plasma particles, the outer energy of a system must be added. Hernaningsih (2017) reported that electrocoagulation combines electrochemical processes and flocculation-coagulation processes. This process is the method of choice for treating radioactive waste and liquid waste. The advantage of the electrocoagulation process for treating liquid waste is that there is no chemical addition. The electrocoagulation process includes equalization, electrochemical, sedimentation, and filtration processes (Hernaningsih, 2017). The equalization process is used to uniform the liquid waste to be treated, especially in pH conditions; there is no chemical reaction at this stage. Electrocoagulation can often neutralize the charges of particles and ions, precipitate contaminants, reduce concentrations lower than can be achieved by chemical deposition, and replace or reduce the use of expensive chemicals such as salts and metals polymers (Palanisamy & Manikandan, 2018).

Kalliala & Talvenmaa (2000) and Bilińska, Gmurek, et al. (2017) also stated that industrial wastewater containing pollutants needs to be treated before discharge. Liquid waste is the most generated waste in home industries and has the most potential to cause environmental pollution. The production process in an industry, such as the textile industry, is de-sizing, scouring, bleaching, dying, and coloring and rinsing processes that produce colored wastewater with chemical content—high oxygen demand or C.O.D, as well as a cloudy color. C.O.D is the amount of oxygen needed to oxidize organic and inorganic substances in liquid waste by utilizing an oxidizing agent, potassium dichromate, as a source of oxygen. The C.O.D or Chemical Oxygen Demand value is the amount of water pollution by organic and inorganic substances, which can naturally be oxidized through biological processes and reduce dissolved oxygen in the water. Substances suspended in textile wastewater, in general, are organic and inorganic substances contained in water, and these substances are one of the causes of turbidity in the liquid and result in the solution blocking sunlight from entering the base of the liquid; however, in the research of these researchers, the processing of liquid waste in the tofu industry has not been studied, which is organic liquid waste. Several researchers, such as Zongo, Maiga, et al. (2009), Sakthisharmila, Palanisamy, et al. (2018), Darmawanti, T. (2010), Hernaningsih, T. (2017) used a physical method, as by using electrochemical applications (electrocoagulation), which functions to remove color in wastewater treatment. However, the disadvantage of processing this waste is that it requires a high cost of electrode material; the same thing was done by Chafi, Gourich, et al. (2011), who have carried out waste treatment using the electrocoagulation method. The results showed decreased C.O.D. levels in liquid batik wastewater, but it was not too significant and efficient in waste treatment. According to several researchers such as Dors, Metel, et al. (2007), Sunka, Babicky, et al. (1999), Sato and Yasuoka (2008), Locke, Sato, et al. (2006), Amril, H. (2015), Bilińska, Gmurek et al. (2015),

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Lukes and Locke (2005) to solve the problem of wastewater treatment, new alternatives are needed to treat textile industrial wastewater that is effective and efficient in reducing organic pollutants and dyes. One alternative that can be used is plasma technology. According to several researchers Dors, Metel, et al. (2007), Sunka, Babicky, et al. (1999), Sato and Yasuoka (2008), Locke, Sato, et al. (2006), Lukes and Locke (2005), Putra, Mohamad, et al. (2020), plasma technology does not use chemicals in waste treatment because plasma technology only uses electrical processes with high voltage. Processing liquid textile waste will be better because this technology will produce less sludge waste than electrocoagulation methods or chemical and biological methods. An important factor in forming a discharge or electrical discharge is the voltage used. This method can remove suspended particles, heavy metals, turbidity, and color, but in the research of these researchers, the liquid waste treatment in the tofu industry has not been studied, which has a level of turbidity and color caused by organic substances in the tofu making process. According to Kobya, Can, et al. (2003), Şengil, and Özacar (2009), the electrocoagulation methods of waste treatment treat liquid waste by using a direct current source from two metal sources electrodes that are inserted into the wastewater. The electrocoagulation process combines the electrochemical process and the flocculation-coagulation process. Kobya, Can, et al. (2003), Şengil and Özacar (2009), and Putra, Mohamad, et al. (2020) stated that many researchers in wastewater processing have widely studied the electrocoagulation method. However, researchers have not studied liquid waste treatment in the tofu-making industry, organic liquid waste. Based on the research by Fahrurozi et al. (2010), tofu liquid waste has pH, E.C., C.O.D, T.D.S, and B.O.D properties, which exceed the threshold of wastewater quality standards. Although the application of plasma and electrocoagulation technology has been widely applied to the purifying of liquid waste by some researchers as Khlyustova, Khomyakova et al. (2016), Gharagozalian, Dorranian, et al. (2017), Shengxia, Xia, et al. (2017), Kim, Churl-Shin Yang et al. (2013), and Shang, Wang, et al., (2017). However, it is still rare to find the application of this technology in purifying liquid waste from the tofu industry using corona discharge plasma as a non-thermal plasma generator. Based on the study of several kinds of literature, the novelty of this research is a design method of purifying liquid waste, especially in the tofu processing industry wastewater using plasma and electrocoagulation methods. This research aims to design a method of decomposing liquid waste in the home industry, especially the tofu industry, with non-thermal plasma and electrocoagulation methods. The benefit of this research in the future is that there is a technology to decompose liquid waste on a home industry scale that the public can use.

RESEARCH AND METHODS

The research method, tools, and materials in this study were discussed, and the research stages included three stages: the research preparation, implementation, and data analysis stages.

Tools and Materials

The tools and materials used in this research were: Multi-Point-Field Corona Glow Plasma Generator Prototype, assembled by the Physics-Mechatronics Laboratory, Polytechnic STTT Bandung, West Java, Indonesia, in collaboration with Trisakti University, Jakarta, Indonesia, with specifications: 1. A type of non-thermal cold plasma with atmospheric pressure; 2. Gas is used in the ambient air (ambient air); 3. Input voltage 0-220 Volt (A.C); 4.Output voltage = 0-30kV (D.C); 5. Multi-point field electrodes; Electrocoagulation prototype, assembled by the Physics-Mechatronics Laboratory, Polytechnic STTT Bandung, West Java, Indonesia, with specifications: 1. Two electrode plates were made of thin copper plates; 2. The output voltage type was set to 5-15 volts D.C; 3. The input voltage was set to 0-220 volt A.C. power source. The sample material for the liquid waste test was a sample of tofu industrial liquid waste taken from the waste product directly from the tofu industry

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with a color specification that was visually cloudy white.

Preparation Phase

The preparatory stage consists of taking a sample of industrial tofu waste, testing the initial characteristics of a tofu industrial waste sample, and testing a multi-point plasma generator and an electrocoagulation device. The material for the test sample or sample of tofu industrial liquid waste was taken from one home industrial tofu waste. Analysis of the waste sample (T.D.S, E.C., pH) was carried out first as an initial description of the condition of the waste to be treated. The parameters tested were T.D.S., E.C., and pH values, and then the waste processing equipment was tested in the Physics-Mechatronics Laboratory of the STTT Bandung, West Java, Indonesia. The trial of the waste treatment tool was intended to properly determine the tool's performance, following the working principles in the literature. Methods of testing by running a plasma and electrocoagulation device in this study included reading the voltage at the D.C. voltage source for the plasma at the time of the plasma discharge and testing the presence of current in the electrode plate for the electrocoagulation method. The waste treatment process using a multi-point plasma generator for 30 minutes with an input voltage of 30 kV was carried out at the Physics-Mechatronics Laboratory of the STTT Bandung Polytechnic, West Java, Indonesia. In this study, plasma was formed in the ambient gas phase, which required an electrical input voltage of 30 kV, and the water level was maintained so that the water's surface was in direct contact with the electrodes. The series of tools were arranged before processing. In this study, a series of tools is shown in Figure 1.

Based on Figure 1, the liquid waste from the tofu industry was placed in a waste container and placed in the plasma reactor chamber for 30 minutes in a flat multi-tip configuration. The input voltage was regulated via an A.C. voltage source where the voltage was appeared on the instrument and was adjusted using the Variac to get an output voltage of 30 kV D.C. Tofu industrial wastewater treatment was also carried out by electrocoagulation method for 30 minutes with a D.C. voltage of 5 volts, using copper plates as the working electrode. The schematic of the electrocoagulation device circuit is as follows (Figure 2).

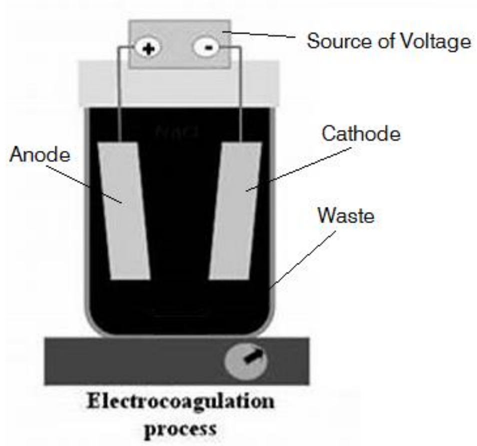

Figure 2. Scheme of electrocoagulation

Figure 1. Scheme of Plasma Reactor

RESULTS AND DISCUSSIONS

In this research, several parameters of the quality of wastewater were obtained. The results of measuring tofu wastewater before treatment are as follows (Table-1).

Table 1. Initial Characteristics Test Results of Waste Sample (control)

No	Parameters	Results

1	T.D.S. (Total Dissolved Solids)	2702 (ppm)
2	E.C. (electric conductivity)	4144 $(\mu s/cm)$
3	pH value	5.1

This preliminary data showed that tofu wastewater contains very high metals seen from the electric conductivity (E.C.) value, where this value showed the conductivity properties. The results of the T.D.S. test are given as follows (Table-2).

Table 2. T.D.S. Test Results Characteristics of Waste Samples

Methods	Parameters	Results (ppm.)
Electrocoagulation	T.D.S.	2070
Electrocoagulation – plasma (electrocoagulation followed by plasma)	T.D.S.	1983
Plasma – Electrocoagulation (plasma followed by electrocoagulation)	T.D.S.	2318
Plasma	T.D.S.	2482

Total Dissolved Solids (T.D.S.) measure the combination of organic and inorganic substances in a liquid that includes anything present in water other than the pure water molecules. These solids are primarily minerals, salts, and organic matter that can be a general indicator of water quality. The results showed. After electrocoagulation followed by the plasma process, this method reduced the T.D.S. value. Before being treated, it was 2702 ppm to 1983 ppm. The results of the electric conductivity (E.C.) test obtained the following data (Table-3).

Table 3. Electric Conductivity Test Results Characteristics of Waste Samples

Methods	Parameters	Results $(\mu s/cm)$
Electrocoagulation	E.C.	4140
Electrocoagulation followed by plasma	E.C.	3967
Plasma followed by electrocoagulation	E.C.	4636
Plasma	E.C.	4965

Based on the above analysis, electrocoagulation followed by plasma treatments could reduce the E.C. value by 3967(μs/cm). This E.C. value is related to the conductivity properties; it was estimated that the wastewater contains metal, so the E.C. value gives a high value when measured. The electrocoagulation-plasma treatment process helped reduce the E.C. value to 3967. In chemistry, pH, historically denoting "potential of hydrogen" (or "power of hydrogen"), is a scale used to specify the acidity or basicity of an aqueous. Calculating the pH value is related to the degree of wetness. Initial pH analysis of liquid tofu waste showed an acidic character with a pH of 5.1. After going through the electrocoagulation followed by the plasma process, it can increase the wetness of the tofu wastewater to neutral, a value of 7. (Figure 3).

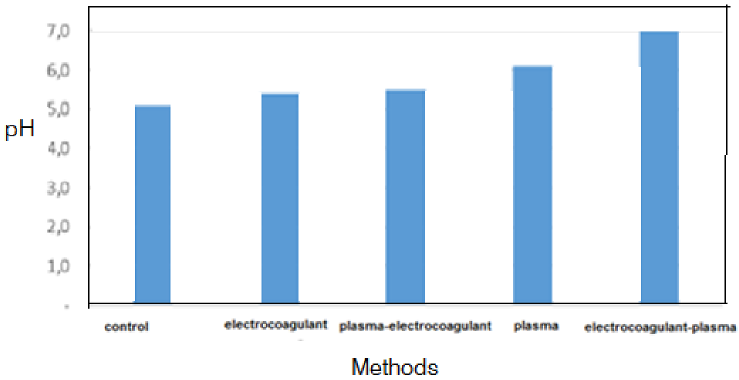

Figure 3. The pH results of several methods

Based on the results of experiments and data analysis, the advantages and disadvantages of several waste treatment methods can be explained as follows:

Plasma Method

In wastewater treatment using the plasma method, the resulting reduction in T.D.S. levels is not too significant, only around 220 ppm with a T.D.S. size of 2482 ppm from the initial sample T.D.S. amount of around 2702 ppm. This evidence can happen because, in the plasma process, the organic compounds contained in the waste are only broken down so that the results are not too significant-plasma technology functions as an oxidizing process for organic compounds. The reaction action in the plasma reactor is the formation of positive ions, negative ions, radicals, ultraviolet (U.V.) light, and electrons in the plasma reactor in industrial wastewater. The presence of ultraviolet (U.V.) light and the movement of ions and electrons will cause water molecules (H_2O) to break down and produce active species such as O.H., O, H, and H_2O_2. However, the plasma process can increase the pH value to 6.1 from the initial pH value of around 5.1.

Electrocoagulation method

In waste treatment using the electrocoagulation method, the decrease in T.D.S. levels produced is the highest, around 632 ppm, with a T.D.S. size of 2070 ppm from the total T.D.S. of the initial sample of around 2702 ppm. With an E.C. value of 4140 (μs / cm) and a pH value of 5.4. This evidence can happen because, in the electrocoagulation process, the organic compounds formed still have a large enough size to be not too biodegradable. In waste processing using electrocoagulation, the process destabilizes suspensions, emulsions, and solutions containing pollutants, namely through a direct flow of electric current (D.C.) through the liquid waste to form easily separated clumps. The advantage of this method is that the electricity used has a low voltage and is not dangerous. The weakness of this method is that it has low efficiency and requires a large metal electrode.

Plasma Followed by Electrocoagulation Method

In wastewater treatment using the plasma followed by electrocoagulation method, the resulting reduction in T.D.S. levels was quite significant, as 384 ppm with 2318 ppm from the initial sample T.D.S. amount of around 2702 ppm. With an E.C. value of 4636 (μs / cm) and a pH value of 5.5. This evidence can happen because, in the plasma followed by the electrocoagulation process, the organic compounds in the waste have been described in advance by active species such as O.H., O, H, and H_2O_2 that appear in the plasma process so that when the process occurs, more organic compounds are formed into floc. The smaller particle size makes it easier for the floc to form. The advantage of this method is that it has excellent efficiency in breaking down liquid tofu waste and can produce a relatively significant reduction in T.D.S. levels. The weakness of this method is that it requires a larger voltage and a combined device between a plasma generator and an electrocoagulation device.

Electrocoagulation Followed by a Plasma method

In wastewater treatment using the electrocoagulation followed by plasma method, the decrease in T.D.S. levels produced was the largest among other methods, around 719 ppm with a T.D.S. size of 1983 ppm from the total T.D.S. the initial sample (control) of around 2702 ppm. With an E.C. value of 3967 (μs / cm) and a pH value of 7.0. This evidence can occur because organic compounds were formed into flocs in the electrocoagulation process, but not all organic compounds were formed because the particle size was still large enough. In the plasma process, organic compounds not formed into floc were broken down.

The results showed that the non-thermal plasma combined with the electrocoagulation method (electrocoagulation -plasma) was the most effective in reducing the total dissolved solids (T.D.S.) value of 1983 ppm (the minimum value from the total control T.D.S. of around 2702 ppm), the minimum value of electric conductivity (E.C.) around 3967 (μs / cm), and the pH value of 7.0 was also obtained.

CONCLUSIONS

This research study on wastewater in the tofu industry shows that the electrocoagulation-plasma process is optimal for reducing T.D.S. and E.C. values, as 1983 ppm and 3967 μs / cm. The plasma electrocoagulation process can change and increase the wetness of tofu wastewater from 5.1 to 7 (neutral).

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