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Statistical Analysis of Reducing Biochemical Oxygen Demand (BOD) on Industrial Rubber Wastewater using Dielectric Barrier Discharge Plasma

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Abstract. Dielectric Barrier Discharge plasma (DBD) is one of type non-thermal plasma (non-equilibrium plasma) or can be referred to as cold plasma. In this research, DBD plasma be utilized to reduce organic compounds like Biochemical oxygen demand in the wastewater rubber processing. In the environment field DBD plasma has been used as a treatment for reducing air pollutants such as gas CO_x, NO_x and HC. In addition DBD plasma have been developed to processed wastewater as an alternative technology in wastewater treatment. DBD plasma appears when the electrode is given a high voltage so that, it will form electric field in the area of the electrodes which allows the ionization and the presence of high-energy electrons in the area. The presence of these electrons will ionize molecules of H₂O into active species such as OH•, H• and H₂O₂. The active species that can oxidize into CO₂ and H₂O so, BOD that can be degraded. In this research for wastewater treatment used high voltage are 10kV, 11kV, 12kV and 13kV and variations of processing time for 5, 10, 15, 20, and 25 (minutes). By increasing the voltage and extend the contact time then the speed variation of electrons to ionize the greater and more active species to be formed to degrade the pollutants to the maximum. This research used quantitative analysis with statistical analysis using SPSS software.

1. Introduction

Dielectric-barrier discharges plasma (DBD), also referred to silent discharges have found amount of interesting industrial applications in addition to the historical ozone generation[1]. Originally it was called the silent discharge in contrast with a spark discharge. From a fundamental point of view, the main difference between DBD and spark discharges is the presence of the dielectric barrier which precludes AC operation of the DBD[2]. Configuration of DBD plasma is a discharge having two dielectric barrier boundaries has many similarities with discharges operated between metal electrodes[3]. Plasma occurs when the electrode is given a high voltage so that the area around the electrodes form an electric field to ionize and the formation of electrons with great energy. On development of plasma technology, DBD is currently widely used as a treatment of wastewater to reduce polluter [4]-[7]. Characteristic of DBD can be provided atmospheric pressure. In this paper DBD plasma is used for treating industrial wastewater. Biochemical oxygen demand is a parameter that be studies researched to decreased of amount on the variation of voltage and duration of time application.



2. Fundamental Theory

2.1 Dielectric Barrier Discharge Plasma

Dielectric Barrier Discharge (DBD) Plasma or usually called as silent plasma is gas ionized, when given by high voltage on the atmospheric pressure. DBD plasma can be generated between two electrodes. Electrodes are located outside and inside the dielectric barrier. The electrode can be termed as active electrode to be energized with High-voltage AC in specific capacity, and beyond the electrode is located on outside of dielectric barrier affairs called passive electrode surrounding of Pyrex-glasses as a dielectric barrier. When given two of electrode high voltage will be generated electricity that can form a plasma discharge between the electrodes around the room. The electrodes materials made from metal which is good conductor such as iron, copper, aluminum etc. The voltage source typically used to generate High voltage derived from the AC voltage of 1-100 kV [8]. The following Figure 1 is a geometric configuration DBD plasma reactor with forms of coplanar.

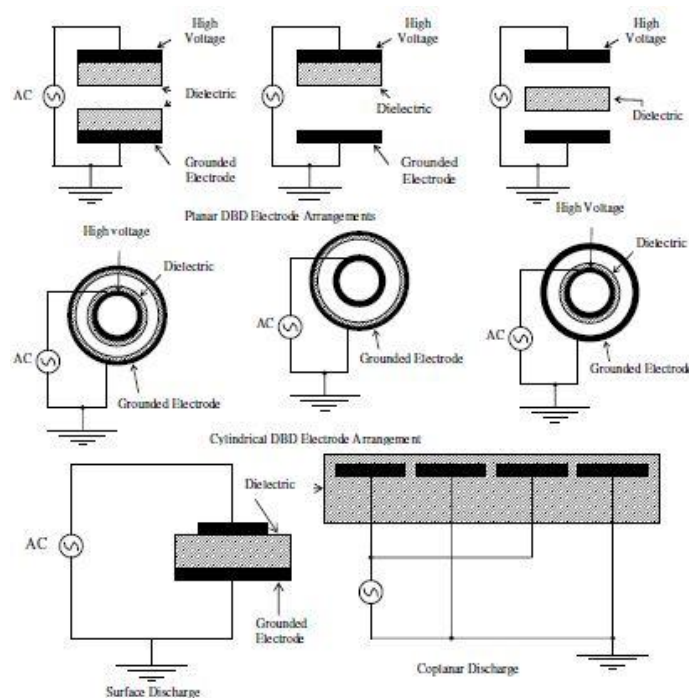


Fig. 1 Typical electrode arrangements of DBD configurations

On Figure 1 DBD plasma type is shaped coaxial with having two electrodes. The electrodes are cylinder or coaxial shaped. Inside electrodes could be replace as active electrode will be energized with high voltage and beyond a passive electrode will be streamed on ground.

2.2 Geometry Horizontal Roughing Filtration

Horizontal Roughing Filtration (HRF) is a physical filter that has the ability to keep the solids in large enough quantities. Solids are filtered on filter media that will settle to the bottom filter. On the HRF filters used are typically made of a filter which has pores that are large and broad media surface, so that it can absorb a maximum of solids.

The solids are absorbed will be deposited on the basis of a filter that can be optimized to filtrated of suspended solid. HRF flowed with the flow horizontal or straight stream that passes through the filter 3-4 compartment [9].

2.3 Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) or organic matter is the amount of oxygen that needed by micro-organisms to break down organic matter in the water. BOD in water will break down into

carbondioxide and NH_3 . Organic substances contained in the water because of industrial activity in the disposal of waste in water bodies.

Disposal of waste with high levels of BOD or organic substances that are high enough to be causing problems to water due the amount of oxygen dissolved in water decreases. It can harm the ecosystem living things in the water [10].

3. Experimental Set Up

3.1 Materials

Configuration materials of DBD Plasma reactor are: pyrex glass, active electrode is aluminium (Al), passive electrode is copper wire, natural rubber wastewater, beaker glass, pipette and measuring cup.

3.2 DBD Plasma Reactor

Dimension and size of Pyrex glass as barrier between high voltage electrode and ground electrode as shown in Fig. 2. Diameter of Pyrex is 16 mm. At the centre of Pyrex, there is aluminium as high voltage electrode. The radius of aluminium is 3 mm.

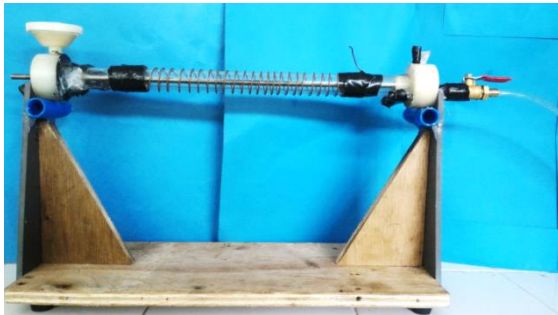


Fig 2. Geometry Plasma DBD Reactor

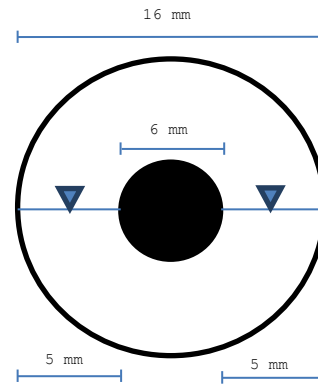


Fig 3. Geometry Plasma DBD Reactor

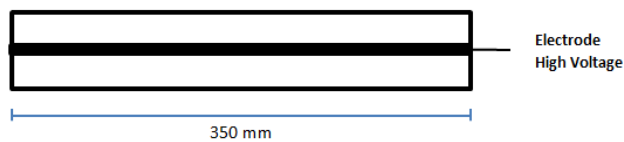


Fig 4. Geometry of Plasma DBD Reactor

3.3 Test Circuit

Plasma is generated from high voltage application in aluminium electrode in the Pyrex tube. While the copper wire was wrapped around the Pyrex tube. The test circuit for generating dielectric barrier discharge plasma as shown in Fig 5 as follow.

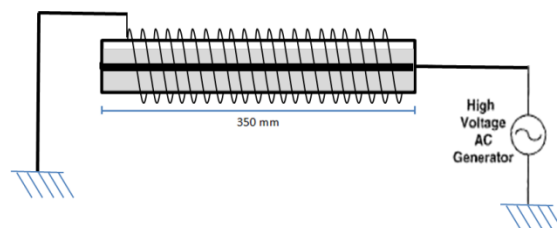


Fig 5. Test Circuit for Generating DBD Plasma

3.4 Titration Test

Standard specifies a method for the determination of the biochemical oxygen demand (BOD) of wastewater following SNI 6989.72:2009. The principle of Biochemical Oxygen Demand (BOD) test sample are added diluent solution saturated oxygen has been added a solution nutrients (1 ml buffer phosphate, 1 ml $MgSO_4$, 1 ml $CaCl_2$, and 1 ml $FeCl_3$) and microbial seed, then add demineralised water to 1 litter and mix until homogenous. incubated in the dark at a temperature of $20\text{ }^\circ\text{C} \pm 1\text{ }^\circ\text{C}$ for 5 days. value BOD calculated based on the difference in the concentration of dissolved oxygen 0 days and 5 days.

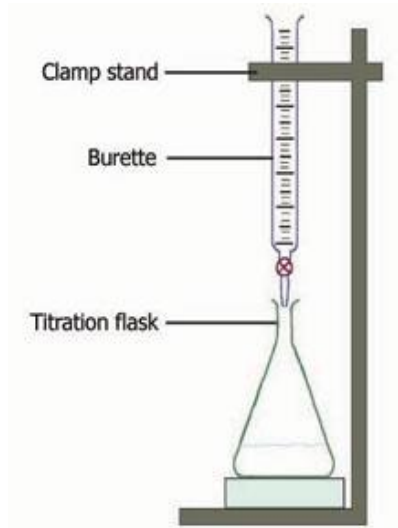


Fig 6. BOD Titration Test

3.5 SPSS Analysis

In this paper used the software SPSS 17 for testing the quantitative analysis. SPSS performed including normality test to ensure that the normally distributed data, correlation to know the how much the relationship between independent variables and the dependent variable, and regression test to determine how much influence the dependent variable to the independent variables and give equality to achieve the test expected

4. Results and Discussion

Measurement results of the BOD concentration after treatment wastewater of rubber industry with DBD plasma will be discussed. Becomes treatment with DBD plasma, wastewater of rubber industry performed pre-treatment first with Horizontal Roughing Filtration (HRF) to reduce the work DBD plasma reactor because a lot of suspended solid contains BOD is an indicator of contaminants that could pollute the environment. The previous study showed a reduction of BOD concentration after DBD plasma treatment. The following graph shows a decrease in the concentration of BOD after treatment.

On this research, the treatment of wastewater variation of times contact and voltages DBD plasma. BOD measurement is an indicator of the presence of organic compounds that can interfere with the environment. The Organic compounds contained in the rubber industrial wastewater coming from the washing process the raw material rubber (latex). Reduction of BOD concentrations were shown in Figure 7 and 8. Decrease of BOD because of the presence of active species such as $OH\cdot$, $H\cdot$ and H_2O_2 contained in DBD plasma due to the ionization of H_2O crushed by electrons.

Increasing the voltage and variation of duration contact times in this paper due to being a different amount of electrons and energy electrons generated with increased voltage. In the high voltage electrons produced will be more [11] that shows the process of ionization, dissociation and excitation

in the plasma. Increasing number of electrons, the active species such as OH •, H • and H₂O₂ formed will be more rapid and substantial to oxidize organic compounds such as BOD in wastewater.

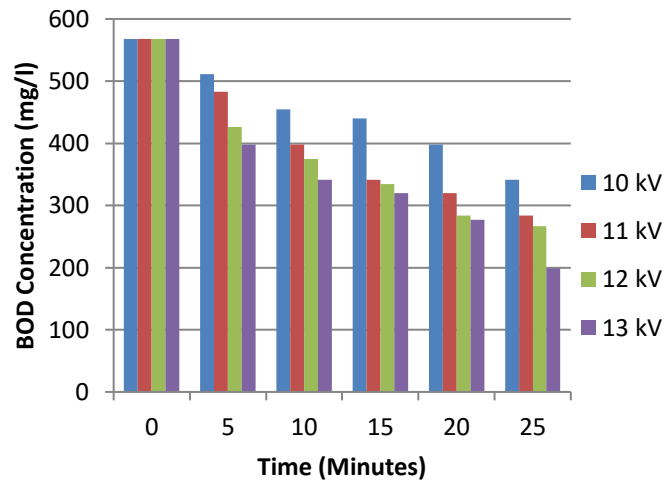


Fig 7. Graph of reducing concentration of BOD with Plasma DBD for time variation.

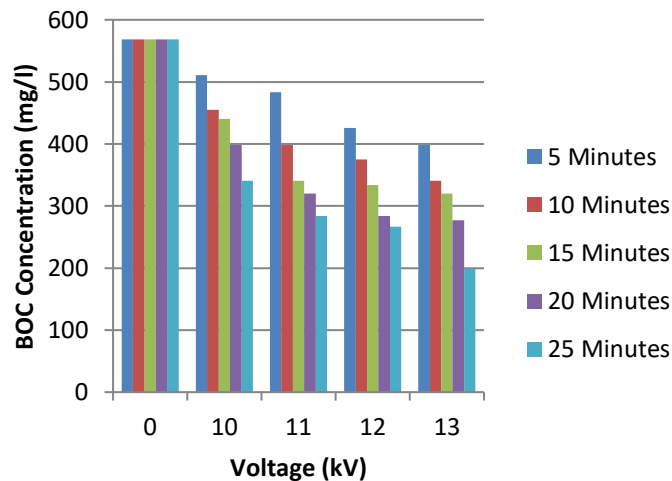


Fig 8. Graph of reducing concentration of BOD with Plasma DBD for Voltages variation.

Table 1 One-Sample Kolmogorov-Smirnov Test

		Unstandardized Predicted Value
N		20
Normal Parameters ^{a,b}	Mean	365.8125000
	Std. Deviation	71.05676834
Most Extreme Differences	Absolute	.093
	Positive	.093
	Negative	-.093
Kolmogorov-Smirnov Z		.415
Asymp. Sig. (2-tailed)		.995

Quantitative analysis was performed by statistical tests. To know normally distributed data or not, it is necessary to test for normality. BOD normality test results shown in column Kolmogorov-Smirnov Z obtained a value of 0.415 (>0.05) so that BOD distribution is the norm.

Table 2 Correlations BOD with Voltages

		BOD1	Voltage 1
BOD	Pearson Correlation	1	-.499*
	Sig. (2-tailed)		.025
	N	20	20
Voltages	Pearson Correlation	-.499*	1
	Sig. (2-tailed)	.025	
	N	20	20

*. Correlation is significant at the 0.05 level (2-tailed).

Table 3 Correlations BOD with Contac Times

		BOD	Contact Time
BOD	Pearson Correlation	1	-.599**
	Sig. (2-tailed)		.005
	N	20	20
Contac Times	Pearson Correlation	-.599**	1
	Sig. (2-tailed)	.005	
	N	20	20

**. Correlation is significant at the 0.01 level (2-tailed).

The relationship test for determine how much influence the voltage and the contact time of the BOD concentration. Based on the results of correlation on Table 2 and 3, it can be seen that the correlation between the independent variable voltage and contact times with BOD concentration had a correlation coefficient of -0.499 and -0,559 it means to have a medium relationship. Figures negative correlation coefficient indicates the opposite relationship; in this case, the greater the voltage applied and contact times with BOD concentration will decrease. Values of Sig. (2-tiled) $0.005 < 0.05$ its means that the voltage and contact times independent variable relationship with the BOD concentration significantly, meaning that the variable voltage and contact times give great on influence decreasing of BOD.

To determine the influence of the voltage and the contact time of wastewater by the DBD plasma concentrations of BOD then do regression testing. Table 4 shows that the influence of the independent variable voltage and the contact time of the BOD concentration. The test results show regression R^2 of 0.887. That is, the variable contact time has an influence of 88.7 % of the BOD concentration. The other 11.3% is influenced by other variables that are not performed in this study. Tabel 5 is regression test produces the following equation:

$$y = 1087,946 - 51,354(a) - 9,130(b)$$

where:

y = concentration of BOD

a = the Voltage

b= the contact time

Table 4 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.942 ^a	.887	.868	36.380

Table 5 Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1087.946	91.763		11.856	.000
	Voltage	-51.354	7.877	-.632	-6.519	.000
	Time	-9.130	1.253	-.706	-7.288	.000

5. Conclusion

Based on the results of laboratory tests and statistical analysis can be concluded that when higher voltage and the duration of the contact were applied to the treatment of wastewater using DBD plasma has the effect of reducing the BOD concentration of 88.7%. The combination of the two independent variables resulted in a decrease in the concentration of BOD significantly. BOD normality test results shown in column Kolmogorov-Smirnov Z obtained a value of 0.415 (>0.05) so that BOD distribution is the norm. The correlation between the independent variable voltage and contact times with BOD concentration had a correlation coefficient of -0.499 and -0,559 it means to have a medium relationship.

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