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REMOVAL OF PHENOL FROM WATER BY ADVANCE OXIDATION PROCESS USING PLASMA SYSTEM

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ABSTRACT

The objective of this study is to evaluate the degradation of phenol in water using advance oxidation process by plasma system. Source of water was collected from Kuranji River in Padang City, West Sumatra, Indonesia. The experiments were carried out to see the effect of flow rate on first order reaction of phenol, removal efficiency and energy efficiency. The results shown that the first order reaction and removal efficiency are decreases with increasing of flow rate. The energy efficiency (G_{phenol}) decreases from 2.98 to 1.98 µmol/Joule as flow rate increases from 30 to 100 mL/minute. These results found that the flow rate is important parameter to control the degradation of phenol in water using plasma system.

Keywords: phenol, advance oxidation process, water treatment, degradation.

INTRODUCTION

Phenol is hazardous and poisonous material to organisms even at low concentration. The main sources of phenol in water environment are effluent of wastewater treatment plant (WWTP) from textile, petrochemicals, pesticides, biomass gasification and pharmaceuticals industries. This waste water has 2-3% phenol, 3-6% acetone and 2-4% sodium salts such as format and sulphate [1]. Phenol has high solubility in water and easy to discharge into water environment. The effluent standard of phenol by Environmental Protection Agencies (EPA) is 1 mg/L and in drinking water is 0.005 mg/L. Phenol is not effective to treat with conventional biological processes because poor biodegrability. To environmental protection, the removal of phenol from wastewater is very important. The removal of phenol has been studied by adsorption [2,3,4,5]. However, the regeneration process of adsorbent is very complicated. Alternative processes to remove phenol from wastewater and water using advanced oxidation processes (AOPs) [6,7,8].AOPsare environmentally kindly technologies without hazardous chemical. These aim of these researches to increase the removal efficiency, minimize energy consumption and by-product formation. Radio frequency has potential to generate species and molecules radicals such as •H, •OH, H_2O_2 and O_3. Hydroxyl radical has the highest an oxidation potential of 2.8 V. Their ability to eliminate the phenol has been studied in batch process using glow discharge plasma [6] and radio frequency [7]. The objective of this study was to investigate the degradation of phenol with radio frequency plasma system to see the effects of flow rate.

MATERIALS AND METHODS

Source of water

Water sample was collected from Kuranji River in Padang city, Indonesia. Sampling sites is at coordinates S00º54'20.0 "E100º22'28.8".The water quality is shown in Table-1.

Table-1. The water quality.

Parameters	Unit	Sample
COD	mg/L	66.4
Fe	mg/L	0.07
Mn	mg/L	0.21
Nitrate	mg/L	<1
Nitrite	mg/L	<0.01
Phenol	mg/L	0.03

Experiments

Reactor was made of glass (thickness of 2 mm and length of 30 cm). The reactor wrapped with copper wire (diameter of 1 mm). Detail of experimental set up could be seen in Desmiarti et al [9].The experiments were studied the effect of flow rate on degradation kinetic of phenol at applied frequency of 3.0 MHz. The flow rate was set at 30, 50 and 100 mL/minute and well controlled using peristaltic pump. DC voltage of 220V was applied to start experiments. Phenol was analyzed by UV-2100 UV-Visible Spectrometer.

RESULTS AND DISCUSSIONS

Degradation kinetic of phenol

In order to calculate the degradation kinetic of phenol was assumed to be first order reaction as described below:

$$\frac{dC}{dt} = -kC \quad (1)$$

Where C is the concentration of phenol (mg/L), *k* is the degradation kinetic constant (1/h) and t is time (h). The k was calculated by plotting of ln C/C_0 vs *t* as following equation (2).

$$\ln\frac{C}{C_o} = kt \quad (2)$$

The removal efficiency of phenol was calculated using following equation (3).

$$\text{Removal Efficiency}\,(\%) = \frac{C_0 - C}{C_o} x100 \quad (3)$$

As shown in Figure-1, the correlation coefficients (R^2) are 0.75 ~ 0.96. The *k* values can be calculated from the slopes are 0.38, 0.29 and 0.17 for flow rate 30, 50 and 100 mL/minute, respectively. These results suggesting that the flow rate is controlling the degradation of phenol in plasma system. Further research is important to study the other parameters such as applied frequency, diameter reactor and the mechanism reaction of phenol.

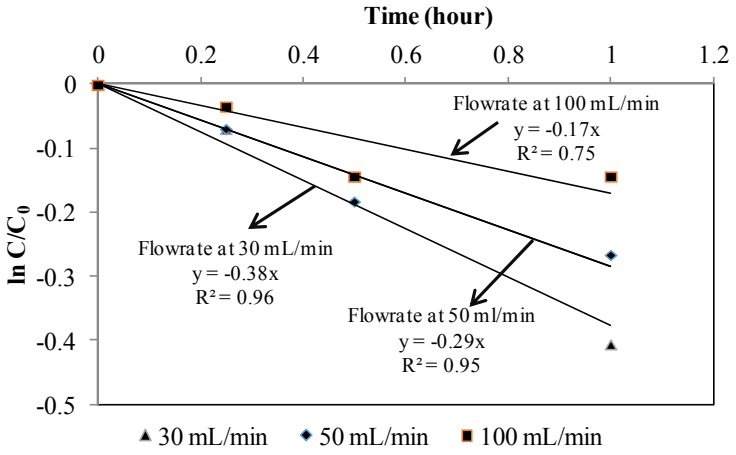

Figure-1. Effect of flow rate on the first order reaction of phenol.

Removal efficiency of phenol for running at 60 minutes was decreased to 33, 24 and 13% for flow rate at 30, 50 and 100 mL/minute, respectively. The comparisons of removal efficiency of phenol with previous studies are displayed in Table 2. These results are almost the same with adsorption process using graphene oxide from 12-40% [3] but lower than by activated carbon [4, 5]. The results obtained in this study indicate that combination of plasma system with other process is necessary to increase removal efficiency of organic matter in water [10]. Jiang et al [10] have been studied the degradation of organic dye using combination of pulsed discharge non-thermal plasma technology with activated carbon fiber (ACF). They found that modified of ACF could be increased the removal efficiency of methyl orange dye and chemical oxygen demand more than 90% due to larger adsorption capacity.

Table-2. Comparison removal of phenol with previous studies.

Process	Removal efficiency (%)	Authors
Glow Discharge Plasma in Batch Process	32-60	[6]
Radio frequency plasma system in batch process	62-79	[9]
Adsorption using graphene oxide/polypyrode composites	12-40	[3]
Adsorption on thermal modified activated carbon	80-90	[4]
Adsorption using activated carbon impregnated with iron oxide (Al_2O_3), aluminum oxide (Fe_2O_3)and titanium oxide (TiO_2).	$AC–Al_2O_3$: 93.1 $AC–Fe_2O_3$: 90.5 $AC–TiO_2$: 89.5 ACs : 74.4	[5]
Radio frequency plasma system	13-33	This study

Energy efficiency

Energy efficiency is an essential parameter before application. The energy efficiency for phenol degradation [6,11,12] could be defined as follows:

$$G_{phenol}=\frac{(1/2)C_0 Vol}{Pt_{1/2}} \quad (4)$$

where C_0 is the initial phenol concentration, Vol is the volume of water, $t_{1/2}$ is the time for half of phenol removal, P isthe electrical power. The values of G_{phenol} are shown in Figure-2. The G_{phenol} decreases with the increase of flow rate. The G_{phenol} decreases from 2.98 to 1.98 µmol/Joule as flow rate increases from 30 to 100 mL/minute. The decreased phenomena could be described by hydroxyl species production following reaction below [6]. To degrade phenol, hydroxyl radicals arethe key species active.

$$C_6H_5OH + 2^{\bullet}OH \rightarrow C_6H_4(OH)_2 + H_2O \quad (5)$$

$$^{\bullet}OH + ^{\bullet}OH \rightarrow H_2O_2 \quad (6)$$

The results in the present study is lower than degradation phenol using glow discharge plasma due to higher initial concentration of phenol [6].

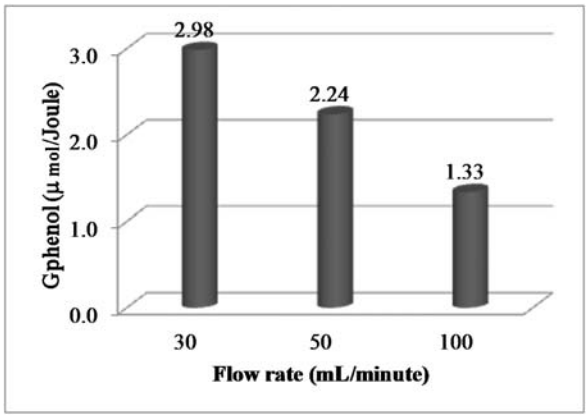

Figure-2. Effect of flow rate on energy efficiency (voltage; 220 V, current; 0.9A; applied frequency; 3 MHz).

CONCLUSIONS

The degradation of phenol in water using radio frequency plasma system was examined. The experimental was studied to see the effect of flow rate on degradation rate, removal efficiency and energy efficiency. The degradation was assumed to be first order reaction. The values of R^2 obtained were 0.76~0.96, suggesting that the degradation process following the second order reaction. The first order reaction of phenol increases with decreasing of flow rate. The removal efficiency was 13-33% and energy efficiency was 2.98 to 1.98 µmol/Joule as flow rate increases from 30 to 100 mL/minute. Finally, the experiments indicated that radio frequency plasma system could be used for removal of phenol in water.

ACKNOWLEDGEMENTS

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REFERENCES

[1] W. Kujawski, A. Warszawski, W. Ratajczak, T. Porebski, W. Capala, I. Ostrowska. 2004. Removal of phenol from wastewater by different separation techniques. Desalination. 163: 287-296.

[2] S. Bousba, A.B. Meniai. 2014. Removal of phenol from water by adsorption onto sewage sludge based adsorbent, Chemical Engineering Transactions. 40: 235-240.

[3] R. Hu, S. Dai, D. Shao, A. Alsaedi, B. Ahmad, X. Wang. 2015. Efficient removal of phenol and aniline from aqueous solutions using graphene oxide/polypyrole composites. Journal of Molecular Liquids. 203: 80-89.

[4] D. Zhang, P. Huo, W. Liu. 2016. Behavior of phenol adsorption on thermal modified activated carbon, Chinese Journal of Chemical Engineering. 24: 446-452.

[5] B. Abussaud, H.A. Asmaly, Ihsanullah, T.A. Saleh, V.K. Gupta, T. Laoui, M.A. Atieh. 2016. Sorption of phenol from waters on activated carbon impregnated with iron oxide, aluminum oxide and titanium oxide. Journal of Molecular Liquids. 213: 351-359.

[6] L. Wang, X. Jiang. 2009. Unsual catalytic effects on iron salts on phenol degradation by glow discharge plasma in aqueous solution, Journal of Hazardous Materials. 161: 926-932.

[7] R. Desmiarti, A. Hazmi, E. Sari, Y. Trianda, Januerin and Zalvi. 2014. Removal of phenol in water by thermal plasma system, Proceeding SNTL Unand, ISSN: 15: 2356-4938 (in Indonesian).

[8] Narengerile, M.H. Yuan, T. Watanabe. 2011. Decomposition mechanism of phenol in water plasma by DC discharge at atmospheric pressure. Chemical Engineering Journal. 168: 985-993.

[9] R. Desmiarti, A. Hazmi, E. Sari, Y. Trianda. 2015. Fecal Coliforms and Total Coliforms Removal in Water Using Radio-Frequency (RF) Plasma System. Modern Applied Science. 9(7): 80-85

[10] B. Jiang, J. Zheng, X. Lu, Q. Liu, M. Wu, Z. Yan, S. Qiu, Q. Xue, Z. Wei, H. Xiao, M. Liu. 2013. Degradation of organic dye by pulsed discharge non-thermal plasma technology assisted with modified activated carbon fibers, Chemical Engineering Journal. 969: 215-216, 969-978.

[11] Jiang B., Zheng J., Liu Q., Wu M. 2012 Degradation of azo dye using non-thermal plasma advanced oxidation process in a circulatory airtight reactor system. Chemical Engineering Journal. 204–206, 32–39.

[12] F. Holzer, B.R. Locke. 2008. Influence of High Voltage Needle Electrode Material on Hydrogen Peroxide Formation and Electrode Erosion in a Hybrid Gas-Liquid Series Electrical Discharge Reactor. Plasma Chem. Plasma Process. 28: 1-13.