TREATMENT OF BRILLIANT BLUE FCF USING GAS-LIQUID PHASE REACTOR BY PULSE POWER TECHNOLOGY

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Dedicated to my beloved parents

And my family

For their supports and blessings

To my supervisor

Dr. Muhammad Abu Bakar Sidik

And FKE staffs

For all the supports and encouragement

All your kindness would not be forgotten

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ABSTRACT

Currently the harm effects of wastewater from industrial sectors to the environment become one of public major concern. There are several wastewater treatment methods and techniques which have been introduced by using biological, chemical, and physical process. However, it is found that there are some shortcomings in the current available methods and techniques. For instance application of chlorine can cause bacterial disinfection of water but still this method produce secondary harmful carcinogenic disinfection by-product and application of ozone treatment which is one of the most reliable technique need to improve due to production of ozone and treatment system. In order to obtain a better understanding in wastewater treatment processing, a study to improve the wastewater treatment system and hybrid discharge reactor to acquire gas-liquid phase corona like discharge is accomplished. Furthermore, design and development of frequency controller which will be applied to Blumlein pulse power generator is accomplished. In this experiment pulse power technology used to generate a high voltage pulses in a very short range of time such as nano second and micro second. Also pulse width modulation circuit helps to control and obtain an ideal frequency for a direct current motor to gain better efficiency in terms of output pulse. Hybrid Discharge reactor designed to obtain a gas-liquid phase Therefore Spark discharge in liquid is benefit to treat contaminant extra completely than corona discharge. The Hybrid Discharge reactor could produce both spark discharge in gas phase and liquid phase (spark-spark discharge). Though separately after hydrogen radicals it is shown that oxygen (typical shape of oxygen OI) as well as ultraviolet high each yield through the actual release performs a good essential part within often the treatment and also reactive species especially and electric conductivity increase dramatically in terms of parameter of waste water unlike PH and temperature.

ABSTRAK

Pada masa ini, kesan-kesan bahaya air sisa dari sektor industri kepada alam sekitar menjadi salah satu daripada kebimbangan utama orang ramai. Terdapat beberapa kaedah rawatan air sisa dan teknik-teknik yang telah diperkenalkan dengan menggunakan biologi, kimia, dan proses fizikal. Walau bagaimanapun, didapati bahawa terdapat beberapa kelemahan dalam semasa kaedah dan teknik. Bagi permohonan contoh klorin boleh menyebabkan pembasmian kuman bakteria air tetapi masih kaedah ini menghasilkan menengah pembasmian karsinogen berbahaya oleh-produk dan aplikasi rawatan ozon yang merupakan salah satu teknik yang paling dipercayai perlu meningkatkan kerana pengeluaran ozon dan sistem rawatan. Dalam usaha untuk mendapatkan pemahaman yang lebih baik dalam pemprosesan rawatan air sisa, kajian untuk menambah baik sistem rawatan air sisa dan reaktor pelepasan hibrid untuk memperoleh gas-cecair corona fasa seperti pelepasan dicapai. Tambahan pula, reka bentuk dan pembangunan pengawal frekuensi yang akan digunakan untuk Blumlein nadi penjana kuasa dicapai. Dalam eksperimen ini nadi teknologi kuasa yang digunakan untuk menjana denyutan voltan tinggi dalam lingkungan yang sangat singkat seperti nano kedua dan kedua mikro. Juga nadi modulasi lebar litar membantu untuk mengawal dan mendapatkan kekerapan yang sesuai untuk motor arus terus untuk mendapatkan kecekapan yang lebih baik dari segi nadi output. Pelepasan reaktor hibrid yang direka untuk mendapatkan fasa gas-cecair itu Spark pelepasan dalam cecair adalah manfaat untuk merawat pencemaran tambahan sepenuhnya daripada menunaikan korona. The Pelepasan reaktor Hybrid boleh menghasilkan kedua-dua pelepasan percikan bunga api dalam fasa gas dan fasa cecair (pelepasan percikan bunga api). Walaupun secara berasingan selepas radikal hidrogen ia menunjukkan bahawa oksigen (bentuk biasa oksigen OI) serta ultraviolet tinggi setiap hasil melalui siaran sebenar melakukan bahagian penting baik dalam sering rawatan dan juga spesies reaktif terutamanya elektrik dan peningkatan kekonduksian secara mendadak dari segi parameter air sisa seperti PH dan suhu.

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LIST OF SYMBOLS

T	-	Pulse Width
L	-	The Length of Line
ε_r	-	Dielectric Constant of the Material Filled between the Coaxial Conductor of Line
R_{lim}	-	Limiting Resistance
Z_L	-	Load Impedance
V	-	Charging Voltage
Z_0	-	The Characteristic Impedance of the Coaxial Cable

LIST OF ABBREVATIONS

HV	-	High Voltage
HVDC	-	High Voltage Direct Current
AC	-	Alternating Current
DC	-	Direct Current
HD	-	Hybrid Discharge
AOPs	-	Progressive oxidation procedures
PFL	-	Pulse Forming Lines
UV	-	Ultraviolet
PWM	-	Pulse Width Modulation

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CHAPTER 1

INTRODUCTION

1.1 Background of Project

Global and nationwide rules have attractive dramatically increase simple regarding the value for the surroundings, thus also quantity for contaminants depleting in terms of kinetic energy to waste water rivers as of changed procedure experiment [3].

In water treatment, wastewater is decontaminated by a genetic process or a chemical technique and these techniques have some problems due to degeneracy of time and cost for the treatment, the requirement of large facilities and being of some contaminants that are not easily vanished [4]. The essential for typical energy effective technique to making of extremely oversensitive temporary types has been interested investigation on the application of high voltage electrical liberation in liquid decontamination. Currently, water treatment using ozone is being used at some capitals as new treatment technique of biological mixtures in water, for the reason that ozone has strong oxidizing influence. It is effective for decomposition of insistent biological complexes in water. Furthermore, it has power for deodorization and purification. Nonetheless, this process takes some difficulties. In this system, ozone is produced by an ozonized. Then the ozone is elated to treatment chamber comprising wastewater by an air push. The one delinquent is that the treatment cannot usage a share of produced ozone for water behavior since a part of the generated ozone is spoiled. Additional difficult is that the treatment cannot use extra

produces making in the ozonized, for example OH radical, O radical and ultraviolet ray [5]. Water treatment approaches by pulsed power technology can answer those harms. Now one of these ways, discharge is produced in water. Thereby OH radical, ozone and ultraviolet can be produced in water. Furthermore, shockwave as well can be produced in water. Since OH radical has mostly tougher dissolving power than ozone, the discharge in water can spoil biological mixtures in water more efficiently than the ozone treatment. However the discharge in water requirements to use a large pulsed power generator in a capability, because the breakdown voltage of water is greater than that of air. Furthermore, it is problematic that streamer discharge is produced consistently in water [6].

Biological colors are used in numerous manufacturing, alike fabrics; paper, elastic, leather, toner etc. They characterize a significant foundation of ecological contamination. Meanwhile these mixtures are extremely solvable in water, they can be elated over large distances when they are discharged in torrents and rivers [7]. Biological colors might reason harm to the alive bacteria by discontinuing the re-oxygenation ability of water and furthermore obstructive sunshine, in that way alarming the natural growing action of water lifetime .On behalf of the elimination of color contaminants, old-style physical procedures can normally be used professionally, conversely they are non-destructive, subsequently they just transfer the contaminant from watery to compact phase, thus causing subordinate contamination [2].

The greatest well-known performance used is founded on organic approaches. The most important key assistances for the organic action procedures has it is own little price. It is comprehensively besides efficiently for the action of civic wastewater besides particular manufacturing wastes. Nevertheless, notwithstanding developments in bio, organic schemes have incapable toward eliminate efficiently numerous modules of impurities, including many poisonous complexes. Additionally, these procedures have a habit of having very huge because toward the relaxed amount for the organic responses. Bodily behavior methods normally one discrete the wastewater after whichever through a provision organization before

through transporting all to added phase and shall not include biological changes of contaminants [2].

1.2 Problem Statements

Particular contaminant insist to old-style systems of wastewater treatment approximately categorized as organic, physical and biochemical organizations likewise the greatest broadly used technique for bacteriological decontamination of water is chlorination. By using chlorine as a decontamination instrument, damaging secondary cancer-causing decontamination by-products can be shaped. This is principally correct uncertainty the water surrounds biological combinations furthermore particular mixtures similar chlorine and ammonia that had not been capable to decompose by old-style technique or it was expensive to decompose [4]. The water contamination is a delinquent needed be resolved in recent years. Now the treatment of waste water, scratches of extra sludge, decomposition of compounds whose rottenness is tough, purification of microbes which origin infection, advanced efficacy and worse energy depletion are being required. Current main systems for the treatment of waste water are an organic technique or a biochemical technique. Nevertheless these procedures have subsequent difficulties. Services are too bulky. It grosses period and charge. Particular contaminants that are not easily decomposed have seemed. Considerable sludge and damaging by-products are produced.

1.3 Objectives

1. To improve wastewater treatment system and the reactor to acquire gas-liquid phase reactor

2. Design a frequency controller to be used with Blumlein pulse power generator.

1.4 Scope of Research Project

In order to achieve the objectives of this project, there are several scopes that have been outline. The scope of this project included:

1. The characteristic of Blumlein pulse generator and its role on variable frequency.

2. The projects just focus in two subsystem; pulse generator and chamber system.

3. There are two critical point observed; variable frequency pulse power and wastewater treatments.

1.5 Outline of Thesis

This thesis consists of the five chapters. Their contents are as following:

Chapter 1 explains briefly about the idea of objectives and scope of this project as long as the summery of the project.

Chapter 2 will discuss more on theory and literature reviews about the application of high voltage electric pulses and the gas, liquid and gas-liquid treatment system.

Chapter 3, the discussion will be on the experiments arrangement including the instrument that was needed in project. Beside, this chapter will present the design and construction of the laboratory-size prototype of treatment chamber and a double Blumlein pulse generator.

Chapter 4 explains and discuss about the results which obtain during experiment.

Chapter 5 will discuss the fruitful results and also the recommendation of this project.

References

1. Rossi, J., M. Ueda, and J. Barroso, *Design and Construction of a150kV/300A/1μs Blumlein Pulser.* 2003.
2. Minamitani, Y., et al., *Decomposition of dye in water solution by pulsed power discharge in a water droplet spray.* Plasma Science, IEEE Transactions on, 2008. **36**(5): p. 2586-2591.
3. Frey, W., et al. *Inactivation of microorganisms by pulsed electric field treatment: the influence of pulse parameters on the inactivation rate*. in *Plasma Science, 2006. ICOPS 2006. IEEE Conference Record-Abstracts. The 33rd IEEE International Conference on*. 2006. IEEE.
4. Espie, S., et al. *Investigation of dissolved ozone production using plasma discharges in liquid*. in *Pulsed Power Plasma Science, 2001. PPPS-2001. Digest of Technical Papers*. 2001. IEEE.
5. Gupta, S.B. and H. Bluhm, *The potential of pulsed underwater streamer discharges as a disinfection technique.* Plasma Science, IEEE Transactions on, 2008. **36**(4): p. 1621-1632.
6. Tamaribuchi, H., et al., *Effect of Pulse Width on Ozone Generation in Pulsed Streamer Discharges.* 2007.
7. Wen, X.Q., G.S. Liu, and Z.F. Ding, *Streamer Propagation in a Large-Volume Underwater Corona Discharge Reactor.* Plasma Science, IEEE Transactions on, 2010. **38**(12): p. 3330-3335.
8. Ruan, J.-j., et al., *Decomposition of simulated odors in municipal wastewater treatment plants by a wire-plate pulse corona reactor.* Chemosphere, 2005. **59**(3): p. 327-333.
9. Namihira, T., et al., *Electron temperature and electron density of underwater pulsed discharge plasma produced by solid-state pulsed-power generator.* Plasma Science, IEEE Transactions on, 2007. **35**(3): p. 614-618.
10. Zhang, Y.-Z., et al. *Parameter Testing on Pulsed Discharge Reactor for Water Treatment*. in *Bioinformatics and Biomedical Engineering,(iCBBE) 2011 5th International Conference on*. 2011. IEEE.
11. Sugai, T., et al. *Application to water treatment of pulsed high-voltage generator using semiconductor opening switch*. in *Power Modulator and High Voltage Conference (IPMHVC), 2012 IEEE International*. 2012. IEEE.
12. Liu, J., et al. *Characteristics of Tertiary Treatment on Complex Chemical Secondary Wastewater*. in *Digital Manufacturing and Automation (ICDMA), 2010 International Conference on*. 2010. IEEE.
13. An, W., K. Baumung, and H. Bluhm. *Investigation of Pulsed Corona Discharges in Water by Fast Imaging Diagnostics*. in *Plasma Science, 2005. ICOPS '05. IEEE Conference Record - Abstracts. IEEE International Conference on*. 2005.

14. Kempkes, M.A., et al. *Commercial Pulsed Electric Field (PEF) Systems for Food and Wastewater Processing*. in *Plasma Science, 2007. ICOPS 2007. IEEE 34th International Conference on*. 2007. IEEE.

15. Grymonpré, D.R., et al., *Suspended activated carbon particles and ozone formation in aqueous-phase pulsed corona discharge reactors.* Industrial & engineering chemistry research, 2003. **42**(21): p. 5117-5134.

16. Samaranayake, W.J.M., R. Hackam, and H. Akiyama. *Ozone synthesis in oxygen using a pulsed discharge*. in *Electrical Insulation Conference and Electrical Manufacturing & Coil Winding Conference, 2001. Proceedings*. 2001.

17. Handa, T., Y. Minamitani, and Y. Higashiyama. *Decomposition of brilliant blue fcf in water by pulsed power discharge in a water droplets spray*. in *Pulsed Power Conference, 2007 16th IEEE International*. 2007. IEEE.

18. Sugai, T., T. Abe, and Y. Minamitani. *Improvement of efficiency for decomposition of organic compound in water using pulsed streamer discharge in air with water droplets by increasing of residence time*. in *Pulsed Power Conference, 2009. PPC'09. IEEE*. 2009. IEEE.

19. Feng, C., et al., *Development of a high performance electrochemical wastewater treatment system.* Journal of hazardous materials, 2003. **103**(1): p. 65-78.

20. Sugai, T., et al., *Investigation of optimum applied voltage for water treatment by pulsed streamer discharge in air-sprayed water droplets.* Electrical Engineering in Japan, 2012. **180**(2): p. 1-8.

21. Ishikawa, A., et al. *The sterilization of underwater bacteria by pulsed streamer discharge generated in air spraying water droplets*. in *Plasma Science, 2010 Abstracts IEEE International Conference on*. 2010. IEEE.

22. Gusbeth, C.A., R. Strässner, and W. Frey. *Lifetime and design considerations for anodes for pulsed underwater corona discharges*. in *Plasma Science, 2010 Abstracts IEEE International Conference on*. 2010. IEEE.

23. Jing, X. and S.-k. Yang. *The Study on the influence factors for the treatment of oil wastewater by Ti electrode-Low-voltage pulse electrolysis*. in *Water Resource and Environmental Protection (ISWREP), 2011 International Symposium on*. 2011. IEEE.

24. Pokryvailo, A., et al., *High-power pulsed corona for treatment of pollutants in heterogeneous media.* Plasma Science, IEEE Transactions on, 2006. **34**(5): p. 1731-1743.

25. Wen, X.Q., M. Wang, and X.H. Liu, *Effect of Electrode Configuration on the Wastewater Treatment by Underwater Electrical Streamer Discharge.* Plasma Science, IEEE Transactions on, 2012. **40**(4): p. 1089-1093.

26. Zhu, L., Y. Wang, and J. Zhao. *Removal of Nitrobenzene in Water by High Voltage Pulsed Discharge*. in *Measuring Technology and Mechatronics Automation (ICMTMA), 2011 Third International Conference on*. 2011. IEEE.

27. Shang, K., F. Wang, and J. Li. *Degradation of phenol in water with suspended TiO2 by pulsed streamer discharge*. in *Bioinformatics and Biomedical Engineering (iCBBE), 2010 4th International Conference on*. 2010. IEEE.

28. Lee, M.-Y., et al. *Study of water treatment process using AC-pulsed discharge in water*. in *Plasma Science-Abstracts, 2009. ICOPS 2009. IEEE International Conference on*. 2009. IEEE.

29. Sullivan, D.L., et al., *Study of laser target triggering for spark gap switches.* Dielectrics and Electrical Insulation, IEEE Transactions on, 2009. **16**(4): p. 956-960.

30. Xu, Y., et al. *Bipolar pulsed discharge in the Gas-liquid-solid mixture and its application for water treatment*. in *Properties and Applications of Dielectric Materials, 2009. ICPADM 2009. IEEE 9th International Conference on the*. 2009. IEEE.

31. Xu, L., et al. *The application of frequency and amplitude response spectroscopy analyzing*. in *Instrumentation and Measurement Technology Conference (I2MTC), 2010 IEEE*. 2010. IEEE.

32. Xinghua, H., et al. *A study on dyeing wastewater by application of impulse discharge*. in *Pulsed Power Plasma Science, 2001. PPPS-2001. Digest of Technical Papers*. 2001. IEEE.

33. Li, S., S. Hu, and H. Zhang, *Formation of Hydroxyl Radicals and Hydrogen Peroxide by a Novel Nanosecond Pulsed Plasma Power in Water.* Plasma Science, IEEE Transactions on, 2012. **40**(1): p. 63-67.

34. Takahashi, K., et al., *Purification of High-Conductivity Water Using Gas–Liquid Phase Discharge Reactor.* Plasma Science, IEEE Transactions on, 2010. **38**(10): p. 2694-2700.