International Proceedings of Chemical, Biological and Environmental Engineering, V0l. 90 (2015)
DOI: 10.7763/IPCBEE. 2015. V90. 23

On the Application of Ion clusters for Treatment of Odors

Ji Ye Yoo +, Jin Yong Choi, Eun Ji Woo and Chan Jin Park

Department of Energy and Env. Engineering, Incheon National University, Republic of Korea

Abstract. Wastewater treatment plants and residential areas are closely located in residential region developed by urbanization. Therefore, complaints of wastewater treatment plants near local residents have been increasing continuously. So, this study is related to an ion cluster application device for removing the complex odors from wastewater treatment plants. It was designed that mechanical framework based on electrochemical property and applied to the work site in which to properly generate a non-thermal. Therefore, it was studied that making the ion clusters suitable in wastewater treatment plants, and handling the main malodorous/ substances occurring ions generated by using the ion clusters. To handle the major malodorous substances that occur in wastewater treatment plants a dielectric barrier discharge was adopted by utilizing such characteristics using is one of the principles of non-thermal plasma in this study. In this research, the main goal of is compared batch type and continuous type. And then, we are going to find the method by applying the appropriate method in the process of removing a variety of malodorous substances.

Keywords: Odor, odor reduction, ion cluster

1. Introduction

Recently, the number of civil petitions on odor has soared, and a great deal of attention has been paid to odor in Korea. Odor has been a major pollution element with many civil petitions filed as an environmental pollution index. Every year the number of civil petition cases related to odor in Korea increases. The major cause of civil petition is that residential and manufacturing areas are in close vicinity, and consequently it has caused large manufacturing plants to restructure their policies. The Environmental Protection Agency takes action and reduces odor through technical support for small and medium-sized companies and making a database of odor emitting facilities, deodorization fuel, and odor-victimized areas [1], [2].

2. Theoretical Background

2.1. Odors

Odors are defined as sensations that occur when chemical substances (called odorants) stimulate receptors in the nasal cavity. Most odors perceived in the environment are made up of a multifaceted mixture of odorants. The compounds that make up particular odors are often present in small concentrations and can act in the human nose in a complex effect making their regulation by the setting of emissions limits (as is standard for other ambient air pollutants) complicated. The effects of odors are equally complicated and range from the associative and the psychological to the measurable and the physiological.

A common example of this emotionally associative experience occurs when we sense a particular smell triggering vivid memories of experiences that happened long ago. These associative and emotional characteristics of the sense of smell may be important in the field of odor regulation because negative associations to odors, once formed, seem to be difficult to change. For instance, a neighborhood may develop a negative association to a particular odor during a period of intense odorous emissions. This negative association may be maintained even after odors are substantially and measurably reduced [1].

+Corresponding author. Tel.: +82-32-835-4923; fax: +82-32-835-4940.
E-mail address: yoojiye@inu.ac.kr.

2.2. Non- thermal plasma

Non-thermal plasma uses a reactor that utilizes a similar effect. The reactor consists of two electrodes (one electrode is in the form of a metal pipe, and the other electrode is a metal wire that runs down the middle of the pipe) separated by a void space that is lined with a dielectric material and is filled with glass beads. This type of reactor is called Dielectric-Barrier Discharge (DBD).

Emissions flow inside of the pipe. A phenomenon occurs when the voltage through the beads exceeds the insulating effect of the beads and millions of micro-discharges occur. The duration of these discharges is measured in nano-seconds.8 The individual discharges cannot be seen with the human eye, but the overall effect produces a silent glow. This effect will only occur when the power source is alternating current (AC). DBD cannot be induced with direct current (DC) power because the capacitive coupling of the dielectric necessitates an AC field [3].

2.3. Dielectric barrier discharge, DBD

Dielectric barrier discharge (DBD) is the electrical discharge between two electrodes separated by an insulating dielectric barrier. Originally called silent (inaudible) discharge and also known as ozone production discharge or partial discharge, it was first reported by Ernst Werner von Siemens in 1857.

The DBD possesses essential advantages in surface processing and plasma chemistry. DBD is a low-temperature discharge, usually working at atmospheric pressure. DBD plasma is typically obtained between two parallel electrodes separated by a gap of some millimeters and excited by alternating current(ac) voltage with frequency in the range of 1–20 kHz. The dielectric barrier can be made from glass, quartz, ceramics, or polymer—materials of low dielectric loss and high breakdown strength [4], [5].

As an example, steel tubes coated by an enamel layer can be effectively used in the DBD. The DBD proceeds in most gases through a large number of separate current filaments referred to as micro discharges. These micro discharges have complex dynamic structure and are formed by channel streamers that repeatedly strike at the same place as the polarity of the applied voltage changes, thus appearing to the eye as bright filaments. The extinction voltage of the micro discharges is not far below the voltage of their ignition. Charge accumulation on the surface of the dielectric barrier reduces the electric field at the location of a micro discharge, which results in current termination within tens of nanoseconds after breakdown. The short duration of current in micro discharges leads to low heat dissipation, and the DBD plasma remains strongly non-thermal [6].

Recently, there has been interest in characterizing and understanding the diverse phenomena that can be found in atmospheric pressure discharges. The nature of the discharge depends on the gas mixture employed, the dielectric, and the operating conditions. Both glow and filamentary discharge modes were observed at atmospheric pressure, and the experimental conditions leading to ordering or patterning of micro discharges have been reported [7]. However, the development of experimental methods, such as imaging techniques, for quantitative characterization of micro discharges (filaments) and associated cooperative phenomena in atmospheric pressure discharges is still lacking. Furthermore, theoretical models describing cooperative phenomena in these discharges are incomplete.

2.4. Present situation of non-thermal plasma on practical use

As I've discussed, non-thermal plasma has been attracted attention as a new technology of flue gas treatment for the next generation in recent years. Among the many air pollution control of non-thermal plasma, NOx removal and VOCs treatment have been particularly considered as a promising technology.

The energy efficiencies and its performances of air pollution control technique using non-thermal plasma are still unfavorable regrettably. Therefore, a plasma-catalytic hybrid system is currently employed in a practical sense. The complex of a non-thermal plasma and catalyst can be utilized these characteristics of high responsiveness to persistent substance of non-thermal plasma and high reaction selectivity of catalyst. Additionally, there are many merits of the this hybrid system from the point of view of catalyst such as reduction of precious metal catalyst use, regeneration effect of catalyst by plasma irradiation and durability improvement of catalyst by inhibition of reaction temperature etc. [8]-[18].

This hybrid system is commonly combined in one of two ways. The first is the introduction of a catalyst in the plasma discharge (in plasma catalysis, IPC), the second by placing the catalyst after the discharge zone (post plasma catalysis, PPC). Fig. 1 shows typical process flow diagrams and description of main functions of IPC and PPC systems. In IPC system, catalyst is activated by plasma exposure. IPC system is a method to improve reaction efficiency and a reaction characteristic by plasma activation of catalyst. In fact, many researchers have reported composite effects such as improvement of decomposition efficiency and reduction of byproduct production by using IPC system. Moreover, it is well known that the catalyst become activated by plasma irradiation in low-temperature region where the catalyst doesn't exhibit catalytic activity. A reactor utilizing these composite effects is named as Plasma-Driven Catalysis (PDC) [8], [9].

The effect of IPC system differs depending on a combination of the electrical discharge method and the type of catalyst. Therefore, it is considered that the combinatorial optimization is important for IPS system. In addition, it is reported that the influence of reaction field where the catalyst is placed is quite large. Typically, catalyst should be placed on a location where the plasma density is higher in pulse corona discharge reactor or dielectric barrier discharge reactor. Because, more radials and energetic electrons are exist in there. A packed-bed reactor is a typical example of IPC system in common with PDC.

Additionally, catalyst or ferroelectric or both are employed as packing material between electrodes. The reason why the ferroelectric is packed is extremely high energetic electrons are produced near the contact points of ferroelectric pellets packed-in the plasma Non-Thermal Plasma Technic for Air Pollution Control 227 reactor, because of a huge electric field generated near the contact points. As explained in the previous section, the energetic electrons are employed directly to dissociate and ionize the pollutants as well as carrier gas molecules to produce various radicals to react with and convert a part of pollutants. Fundamental characteristics of a dielectric barrier discharge (DBD) in a ferro-electric packed bed reactor have been studied for the Barium Titanate (BaTiO3) based spherical-shaped pellets for the specific dielectric constant from 660 to 104 from the viewpoint of reactor performance improvement [10]. The dielectric constant of pellet packed in the reactor affects discharge characteristics such as power consumption of the reactor, micro discharge onset voltage, number of micro discharge. As the results, the performance of packed bed plasma reactor depends on the dielectric constant and material of the pellet packed in the reactor.

2.5. H_2S measurements

H_2S measurement is very common in sewage treatment works odour assessment and offers several advantages [19]-[22].

- it is usually the dominant odorant associated with sewage odours;
- even when not the major odorant, it is usually present and as such acts as a marker for sewage odours;
- gas-phase H_2S concentrations can be related to liquid-phase measurements and theoretical models of sulphide formation;
- it is easily and rapidly measured down to low ppb levels by hand-held equipment. As a result, many measurements can be made in a short period of time at relatively low expense. Sampling or pre-concentration are not necessary.

The ease of in situ measurement of H_2S has led to widespread use in sewage treatment works odour assessment. It is widely used in odour surveys, whereby many measurements are made at various locations throughout sewage treatment works, with resulting concentrations being plotted (usually as contours) on a map of the sewage treatment works. This provides a visual indication of the major odour sources and if careful recording of meteorological conditions is made can also be used for emission rate estimation in conjunction with an atmospheric dispersion model [23].

3. Materials and Methods

Test gas was uniformly injected by using a syringe mixed with a carrier gas (air) was formed so that constant level is maintained. The concentration of the inflow/outflow of the gas-phase hydrogen sulfide and ammonia was measured real-time by using a direct-reading type gas measuring instrument with real-time measurement. Changing the output of the plasma with measuring the ion production also offered considerable hydrogen sulfide and ammonia removal efficiency. At that time, the ion count was measured by the output of the plasma by using an anion measuring equipment [24]-[29].

In addition, we experimented batch type and continuous type. So, we should compare batch type and continuous type.

4. Results and Discussions

In the batch experiments, voltage and frequency rises as amount of generated ions are increased. The Case of 3500V is much better efficiency than the other voltage, therefore, hydrogen sulfide, ammonia and other odor removing effect showed an excellent effect.

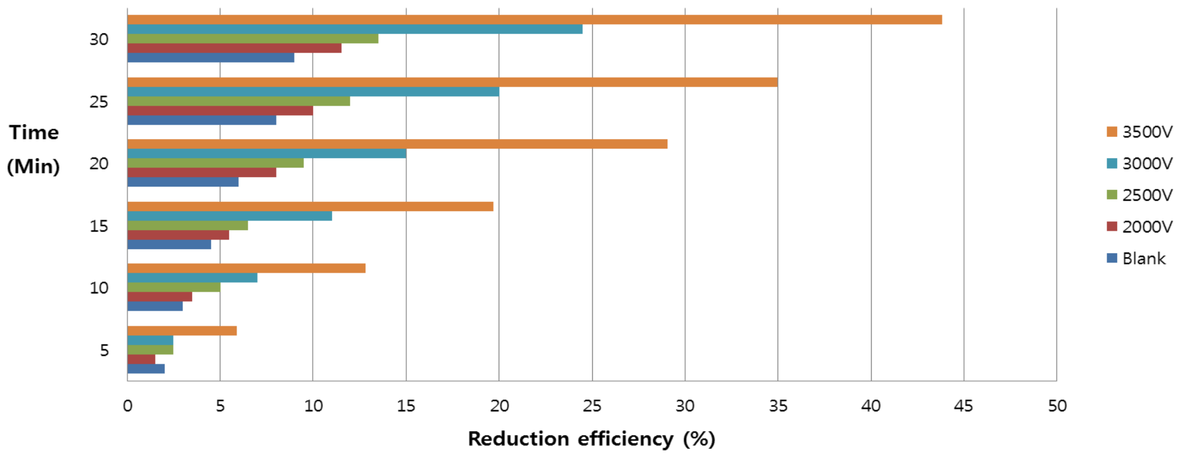

Fig. 1: Hydrogen Sulfide Reduction efficiency to Different Voltages

And volume of odorous air at the odor threshold also relevant to voltage. [Fig. 2] It is showing the odor intensity change by ozone's masking effect.

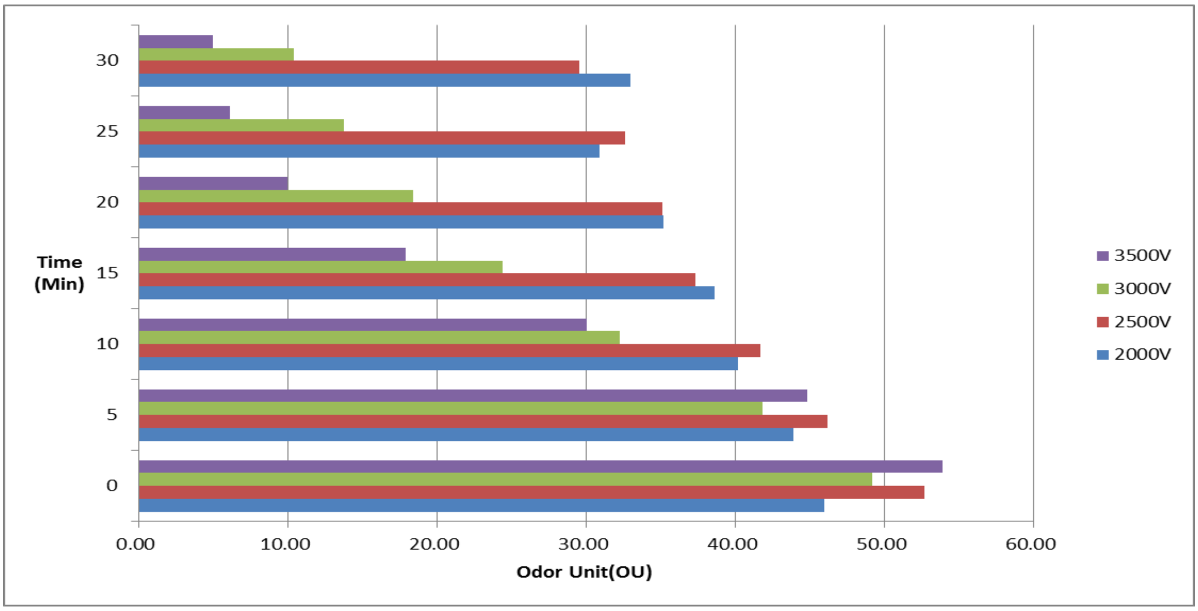

Fig. 2: Odor Change to Different Voltages

In the continuous experiments, on the other hand, more effective for controlled by-product.

Therefore, try to study in order to find a maximum condition for minimal energy requirements and maximal target efficiency to reduce greenhouse gases. As a result, the method by using the ion clusters, which is highly effective and relatively easy could be appropriate choice. Further study would be continued comparing advantages and disadvantages in this laboratory.

5. Acknowledgements

This work was supported by the National Research Foundation of KOREA (NRF) and Center for Women In Science, Engineering and Technology (WISET) and supported by C&J CO., LTD. Incheon, Republic of Korea.

6. References

[1] *Ministry of Environment, Investigation study to improve the management system of odor emission sources*, 2001.

[2] Sang Jin Park, *The Regulation and Measurement of Odor in Korea*, Dept. of Civil & Environmental Engineering Woosong University, 2001.

[3] The Clean Air Technology Center (CATC), U.S. Environmental Protection Agency (E143-03), Research Triangle Park, North Carolina 27711, *Using Non-Thermal Plasma to Control Air Pollutants*, EPA-456/R-05-001, 2005.

[4] J. R. Roth. *Industrial Plasma Engineering*, Vol. 1, Institute of Physics Publishing, Bristol and Philadelphia, 1997.

[5] Hyun-Jung Hwang, Hae-Young Ann, Seung-Kyu Shin, Ji-Hyeon Song, *Application of Non-Thermal Plasma for the Simultaneous Removal of Odor and Sludge*, Journal of Korean Society of Water and Wastewater Vol.24, No.1, 85~92, 2010.

[6] Hyun-Jung Hwang, Hae-Young An, Ji-Hyeon Song, *Performance of a Non-thermal Plasma System for the Treatment of Wastewater Sludge*, Korean Journal of Odor Research and Engineering, Vol. 9, No.3, 172~176, 2010.

[7] *For a recent review of the diverse phenomenon in barrier discharges*, U. Kogelschatz. IEEE Trans. Plasma Sci. 30 (4), 1400~1408, 2002.

[8] Durme, J. V. *Combining non-thermal plasma with heterogeneous catalysis in waste gas treatment*, Applied Catalysis B, Vol. 78, 324~333, 2008.

[9] Fan, H. Y., *High-efficiency plasma catalytic removal of dilute benzene from air*, *J. Phys. D: Appl. Phys.*, Vol.42, 225~105, 2009.

[10] Takaki, K., Takahashi, S., Mukaigawa, S., Fujiwara, T., Sugawara, K., Sugawara, T. *Influence of pellet shape of ferro-electric packed-bed plasma reactor on ozone generation and NO removal*, International Journal of Plasma Environmental Science and Technology, Vol. 3, No. 1, 28~34, 2009.

[11] Chena, L., Zhanga, X., Huanga, L., Le, L, *Application of in-plasma catalysis and post-plasma catalysis for methane partial oxidation to methanol over a Fe2O3-CuO/γ- Al2O3 catalyst*, Journal of Natural Gas Chemistry, Vol. 19, issue 6, 628~637, 2010.

[12] Durme, J. V., Dewulf, J., Leys, C., Langenhove, H. V., *Combining non-thermal plasma with heterogeneous catalysis in waste gas treatment, Applied Catalysis B:Environmental*, Vol. 78, 324~333, 2008.

[13] Takaki, K., Chang, J.-S., Kostov, K.G, *Atmospheric pressure of nitrogen plasmas in a ferroelectric packed bed barrier discharge reactor. Part I. Modeling*, IEEE Trans. Diel. Elect. Insul., Vol. 11, No. 3, 481~490, 2004.

[14] Uchida, Y., Takaki, K., Urashima, K., Chang, J.-S., . *Atmospheric pressure of nitrogen plasmas in a ferroelectric packed-bed barrier discharge reactor. Part II*. *Spectroscopic measurements of excited nitrogen molecule density and its vibrational temperature*, IEEE Trans. Diel. Elect. Insul., Vol. 11, No. 3, 491~497, 2004.

[15] Rajanikanth, B. S., Srinivasan, A. D., *Pulsed plasma promoted adsorption/catalysis for NOx removal from stationary diesel engine exhaust*, IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 14 (2). 302~311. 2007.

[16] Yamamoto, T., Yang, C. L., Beltran, M. R., Kravets, Z., *Plasma assisted chemical process for NOx control*, IEEE transactions on industry applications, Vol. 36, No. 3, 923~927, 2000.

[17] Vandenbroucke, A., Morent, R., Geyter, N. D., Dinh, M. T. N., Giraudon, J. M., Lamonier, J. F., Leys, C. *Plasma-catalytic decomposition of TCE*, International Journal of Plasma Environmental Science & Technology, Vol. 4, No. 2, 135~138, 2010.

[18] Kim, H. H., Oh, S. M., Lee, Y. H., Ogata, A., Futamura, S., *Decomposition of gasphase benzene using plasma-*

driven catalyst (PDC) reactor packed with Ag/TiO_2 catalyst, Applied Catalysis B: Environmental, Vol. 56, 213~220, 2005.

[19] Hobson J., and Walsh M. *Application of contour mapping of hydrogen sulphide levels to odour control at sewage treatment works*, Foundation for Water Research, Report FR0060, 1990.

[20] Koe L. C. C., *Hydrogen sulphide odor in sewage atmospheres*, Water Air Soil Pollut. 24, 297~306, 1985.

[21] Stuetz R. M., Engin G. and Fenner R. A., *Sewage odour measurements using a sensory panel and an electronic nose*, Water Sci. Technol. 38, 331~335, 1998.

[22] Vincent A., Hobson J., *Odour control. CIWEM Monographs on Best Practice No. 2,* Chartered Institution of Water and Environmental Management, Terence Dalton Publishing, London, 1998.

[23] P. GOSTELOWM, S.A. PARSONS* and R.M. STUETZM, *ODOUR MEASUREMENTS FOR SEWAGE TREATMENTWORKS*, Water Research, Volume 35, Issue 3, 579~597, 2001.

[24] Hong-Gyun Park, Jin-Sook Noh, Eun-Young, Go-Su Yang, *A Study on Treatment Characteristics of Odors [TMA, Acetaldehyde] by using a Microwave Plasma*, Korean Journal of Odor Research and Engineering Vol. 6, No. 4, 234~238, 2007.

[25] Hea-Woo Park, Dong-ah Ko, Dae-Sung Lee, Su-Hyung Hwang, Young-Min Jo, *Decomposition of Odorous Toluene Vapor by Peroxide Ions*, Korean Journal of Odor Research and Engineering Vol. 11, No. 4, 159~166 (2012).

[26] Eun-Gi Hong, Jeong-Min Suh, Kum-Chan Choi, *Application of DBD Plasma Catalysis Hybrid Process to remove Organic Acids in Odors*, Journal of Environmental Science International 23(9), 1627~1634, 2014.

[27] Ju-Sang Lee, *Removal Technology of Odors Gases by Surface Discharge Induced Plasma*, J. Korean Society of Environmental Administration Vol. 7, No. 1, 69~75, 2001.

[28] Yun-Ki Nam, Hae-Young Ahn, Ji-Hyeon Song, *Effects of relative humidity for the removal of sulfur compounds in a non-thermal plasma and catalyst system*, Journal of Korean Society of Odor Research and Engineering, Vol. 12, No.4, 231~239, 2013.

[29] Hae-Wan Lee, Sam-GonRyu, Myung-Kyu Park, Hyun-Bae Park, Kyung-Chang Hwang, *Decomposition of Trichloroethylene Using a Ferroelectric Packed-Bed Plasma Reactor*, HWAHAK KONGHAK Vol. 41, No. 3, 368~376, 2003.