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On the Application of Ion Clusters for Treatment of Odors from the Wastewater Treatment Plants

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Abstract. This study is related to an ion cluster application device for removing the complex odors from wastewater treatment plants. It is intended to handle the complex odors for the indoor space workers reside in the 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 chemical ion components. A non-thermal plasma is not in thermodynamic equilibrium, either because the ion temperature is different from the electron temperature, or because the velocity distribution of one of the species does not follow a Maxwell–Boltzmann distribution. 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 the this study.

Keywords: Odor, wastewater treatment plants, ion cluster, dielectric barrier discharge

1. Introduction

Wastewater treatment plants and residential areas are closely located in residential region development by urbanization. Therefore, complaints of wastewater treatment plants near local residents has been increasing continuously. In the case of wastewater treatment plants there were a lot of malodor such as storage tank, settling tanks, digesters, thickener, dewatering facilities [1], [2]. Of course, wastewater treatment plants try to preventing malodor diffusion to the atmosphere. However, due to the need of odor control facilities and deodorization separate piping, it would bring many problems such as ensuring the space for installation and the ground, the increase in installation cost. 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. Typical process of wastewater treatment plants is illustrated in Fig. 1 [3].

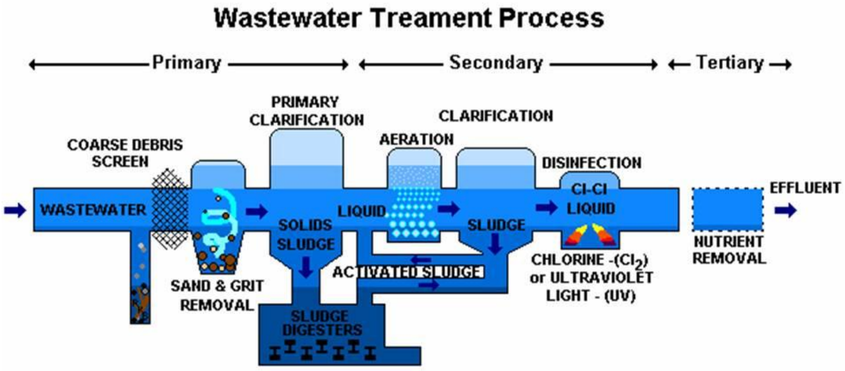

Fig. 1: Typical process of wastewater treatment plants [3]

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Primary treatment consists of temporarily holding the wastewater in a quiescent basin where heavy solids can settle to the bottom while oil, grease and lighter solids float to the surface. The settled and floating materials are removed and the remaining liquid may be discharged or subjected to secondary treatment.

Secondary treatment removes dissolved and suspended biological matter. Secondary treatment is typically performed by indigenous, water-borne micro-organisms in a managed habitat. Secondary treatment may require a separation process to remove the micro-organisms from the treated water prior to discharge or tertiary treatment.

Tertiary treatment is sometimes defined as anything more than primary and secondary treatment in order to allow rejection into a highly sensitive or fragile ecosystem.

Odors can be generated and released from virtually all phases of wastewater collection, treatment, and disposal. Most odor-producing compounds found in domestic wastewater and in the removed solids result from anaerobic biological activity that consumes organic material, sulfur, and nitrogen found in the wastewater.

2. Theoretical Background

2.1. Generating Principle of Air Ion

Most matter in the universe is "ionized." In the high vacuum of space, atoms and molecules are present in excited energized states and possess electrical charges. An ionized gas is called a "plasma" [4]. By contrast, most matter on earth (and in the earth's atmosphere) is not ionized. A source of sufficiently high energy is required to induce ionization and separation of charge. Energy can be supplied by natural or artificial (anthropogenic) sources, as derived from nuclear, thermal, electrical, or chemical processes.

Ionization is the process, or result of a process, whereby an electrically neutral atom or molecule acquires either a positive or a negative electrical charge. Ionization occurs when energy in excess of the ionization energy is absorbed by an atom yielding a free electron and a positive ion. A free electron can also combine with another atom to form a negative ion. Atmospheric ions have been of scientific interest for more than a century [5]. Observations of chemical actions in electrical discharges in gases go back equally far [6]. The term ―air ions‖ refers broadly to all airborne ―particles‖ that possess electrical charges whose movements are influenced by electric fields [7]. The chemical evolution of air ions, whether created naturally outdoors or artificially indoors depends on the composition of each environment and especially on the types and concentrations of trace species [8]. Specific reactions depend upon the physical properties of individual atoms and molecules, e.g., ionization energy, electron affinity, proton affinity, dipole moment, polarizability, and chemical reactivity. The primary positive ions N_2^+, O_2^+, N^+, and O^+ are very rapidly converted (microseconds) to protonated hydrates, $H^+ \bullet (H_2O)_n (n<10)$, while the free electrons quickly attach to oxygen to form the superoxide radical anion $O_2^{\bullet-}$, which also can form hydrates. These intermediate species are collectively called cluster ions [9], [10].

Cluster ions react further with trace volatile and particulate constituents. A single cluster ion may collide with as many as 10^{12} molecules in air at ground level during its brief (~1 min) lifetime [9]. Subsequent molecular disassociations and reactions in the gas phase and on particulate surfaces complicate reaction schemes in real-world atmospheres. Ion chemistry continually changes through reactions, molecular rearrangements, and growth of molecular ion clusters and ionically charged particulates. Protonated hydrates are about one nm (0.001 m) in diameter with electrical mobilities of 1–2 cm^2/V-s. Ion clusters are about 0.01–0.1 um, with mobilities of 0.3×10^{-6} m^2/V-s. The later are larger in size, but orders of magnitude less electronically mobile. Fog droplets or dust particles range up to 10 μm [11].

Ions and electrons together define overall space charge, i.e., the total free unbalanced charge existing in the atmosphere. Unipolar positive or negative space charge densities can be measured. Fair-weather values for air ions at sea level are ~200–3000 ions/cm^3 of both polarities. Small ions increase significantly during rainfall and thunderstorms due to natural activation: negative ions may increase to 14000 ions/cm^3; while positive ions may increase to 7 000 ions/cm^3. The ratio of positive to negative air ions at ground level normally is about 1.1–1.3, decreasing to about 0.9 following certain weather events. Illustrations of ionized oxygen clusters is shown in Fig. 2 [12].

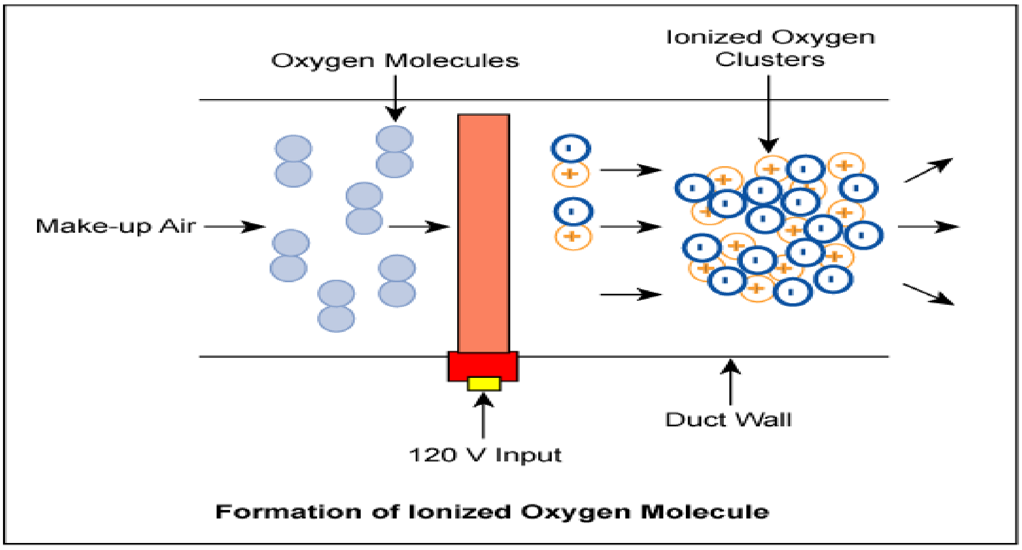

Fig. 2: Illustrations of ionized oxygen clusters [12]

2.2. 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 [13], [14].

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 [15].

Recently, there has been interest in characterizing and understanding the diverse phenomena that can be found in atmospheric pressure discharges [16]. 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 [16]. 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.

2.3. Wastewater Treatment Plant Odors

To investigate the each substance in emission concentration for each process in the target odor source in wastewater treatment plant to located in Seoul, the data was illustrated in Table I [17].

3. Materials and Methods

In this study, explored how to handle a major malodorous substances among others hydrogen sulfide and ammonia generated from wastewater treatment plants.

Table I: Main emission concentration for each process in wastewater treatment [17]

Plant	Process	Substance(ppb)					odor Concentration (OU/m³)
		H_2S	CH_3SH	DMS	DMDS	NH_3	
A	incinerator	78.6	65.7	0.7	1.1	104.0	4,871
	sludge storage	4.1	ND	ND	1.6	479.7	4,096
	biofilter	2,078.4	52.2	2.7	5.8	81.1	8,192
B	Incinerator	1,349.3	189.6	323.4	ND	82.6	27,554
	sludge storage	3.2	ND	ND	0.4	1,191.3	5,793
	night soil treatment	3,399.8	80.7	ND	ND	958.1	23,170
	aeration tank	3.5	2.1	1.3	1.1	96.7	512
C	sludge storage	4.2	ND	ND	0.5	229.9	2,896
	night soil reservoir	131.1	1.3	ND	ND	54.2	3,444
	thickener	556.4	ND	22.8	86.4	2,021.8	46,341
	night soil treatment	2,783.3	90.8	ND	ND	1,021.8	19,484

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 [18]-[23]. Schematic diagram of experimental setup is shown in Fig. 3.

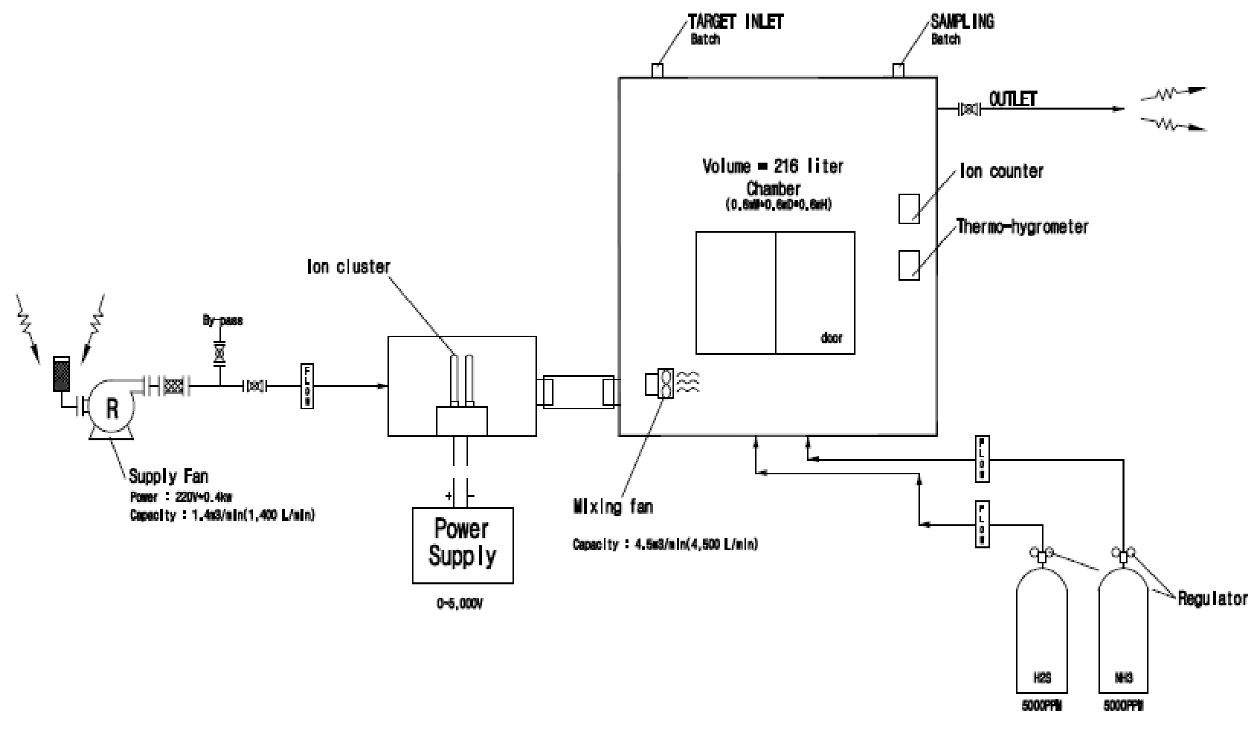

Fig. 3: Schematic diagram of experimental setup

4. Conclusions

Voltage and frequency rises as amount of generated ions are increased. Therefore, hydrogen sulfide, ammonia and other odor removing effect showed an excellent effect.

The most important method of choice requires careful selection effectively controlled by applying the appropriate method in the process of removing a variety of malodorous substances. 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

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6. References

[1] Yong-Deok Jo, *The unit processes by environmental facilities Status and management practices on odor Study*, Ajou University, 2013

[2] Gu-Hoe Jeong, *A study on the character of odor emission in the sewage treatment process*, Daejeon University, 2005

[3] http://scioly.org/wiki/index.php/Water_Quality

[4] A. M. Tyndall and G. C. Grindley, *The mobility of ions in air. Part I. Negative ions in moist air*, Proc. R. Soc. A, vol. 110, no. 754, pp.341–358, Feb. 1, 1926.

[5] J. A. Pollack, *The ions of the atmosphere*, Science, vol. 29, no. 754, pp. 919–928, June 11, 1909.

[6] S. C. Lind, *The theory of chemical action in electrical discharge*, Science, vol. 67, no. 1745, pp. 565–569, 1928.

[7] H. Tammet, *CRC Handbook of Chemistry and Physics*. Boca Raton, FL: CRC, pp. 14-30–14-32, 1997

[8] P. B. Comita and J. I. Brauman, *Gas-phase ion chemistry*, Science, vol. 227, pp. 863–869, Feb. 22, 1985.

[9] T. D. Bracken, *Small air ion properties, in Air Ions: Physical and Biological Aspects*, J. M. Charry and R. I. Kavet, Eds. Boca Raton, FL: CRC, ch. 1, pp. 1–12, 205, 1987

[10] Stacy L. Daniels., *On the Ionization of Air for Removal of Noxious Effluvia (Air Ionization of Indoor Environments for Control of Volatile and Particulate Contaminants With Nonthermal Plasmas Generated by Dielectric-Barrier Discharge)*, IEEE TRANSACTIONS ON PLASMA SCIENCE, VOL. 30, NO. 4, AUGUST 2002

[11] Walder, G., Margreiter, D., Winkler, C., Grill, V., *Production and stability of oxygen cluster cations and anions' Atoms*, Molecules and Clusters 20(1), 201-203, 1991

[12] Cliff Hoelscher and Ray Kemp, Paul Bonnici. *Pilot Testing of Oxygen Ionization for Odor Control at City of Fort Collins WRF.*

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

[14] 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

[15] 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

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

[17] Seung-Seong Yoo, Jae-Sik Jeon, Seok-Ryul Oh, Seung-Mi Kwon, Deok-Chan Kim, *Odor Emission Characteristics of the Sewage Treatment Plants*, Korean Society for Atmospheric Environment, 369-370, 2004

[18] 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

[19] 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)

[20] 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

[21] 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

[22] 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

[23] 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