

# Analysis of Deposited Byproducts of Volatile Organic Compounds (VOCs) Like Toluene, Xylene Subjected to Di-Electric Barrier Discharge (DBD)

S. Mohanty<sup>1</sup>, S. P. Das<sup>2</sup>

<sup>1,2</sup>Ravenshaw University, Cuttack-753003, Odisha, India

**Abstract:** Hazardous volatile organic compounds (VOCs) coming out as byproducts in industrial sector are matter of serious concern. The methods available to destroy are very costly. So in industries it is very difficult to solve this environmental problem from their budget. Decomposition of organic compounds (VOCs) using di-electric barrier discharge (DBD) technique using argon as base gas, is proved to be very efficient and cost effective method. In this communication the residue deposited on the floor of the chamber is analyzed by spectroscopic technique and the byproducts of decomposition of VOCs are diagnosed and possible chemical reactions to arrive at the byproducts from the products are reported.

**Keywords:** Volatile organic compounds (VOCs), DBD, FTIR, UV-Visible.

## 1. Introduction

Volatile Organic Compounds (VOCs) releasing from different industrial and agricultural processes is a serious problem for air pollution. Vocs like benzene, Toluene, Xylene etc. having toxic characteristic. Among which many Vocs are carcinogenic in nature as well as they from secondary primary as well as secondary air pollution like photochemical smog, secondary aerosol and ozone. So, serious problem to the environment [1]-[5].

Aromatic volatile organic compounds are identified a total of 40 VOCs in public transportation modes in Guangzhou, China from the samples of four popular public commuting modes like subway, taxis, non-air-conducted buses while traversing in urban areas of Guangzhou. VOCs like benzene, toluene, ethylbenzene, m/p-xylene and o-xylene were collected from traffic area and analyzed by thermal desorption (TD) and gas chromatography/mass-selective detector technique (GC/MSD) [6].

Therefore, control and decomposition of these VOCs are required. They should either be removed or these should be made less harmful gases like CO<sub>2</sub> with usable products like methane found by T.N.Das et al [7]. Also it is reported in our previous paper that breakdown of toluene starts first as compared to p-Xylene but glow region for xylene is achieved faster than toluene [8]. Different technologies for the abatement of VOCs are like thermal and catalytic incineration, adsorption, condensation, bio-filtration, membrane-separation or UV-oxidation [9]-[13]. The above mentioned methods required high range thermal energy as well as these are ineffective with energetically expensive for low VOC concentration. Along with serious problem is created due to catalytic poisoning and deactivation.

Therefore, a more effective and economical abatement technique is required which is fulfilled by non-thermal plasma (NTP) technology. NTP like Dielectric Barrier Discharge (DBD), Corona discharge, Surface discharge and packed-bed plasma reactors are used. From the above,

DBD with and without catalyst is more effective than the other depending upon the different conditions like surface area, concentration of voc, applied voltages, nature of the voc, GRD, catalyst, as well as carrier gas.

NTP-DBD plasma produced between two electrodes separated by a barrier, when high voltage current is applied to it. Then the energetic electrodes with high K.E are produced and react with the VOC molecules [14]-[17]. So our present work aims at decomposition of toluene and xylene using NTP-DBD reactor by studying the dielectric surface deposition and characterize these.

## 2. Experimental

The experimental set up is shown in figure:1 and described as it is [8] and figure:2. The experiment was done in a planar DBD where pyrex is the dielectric material and gap between the electrodes after covering it is 6mm and volume is 20x30x0.6 cm<sup>3</sup>. The applied voltage varied from 5 kV to 8kV. Toluene and Xylene is studied in the argon atmosphere. The flow rate is maintained at 1 lit/min. and experiment continued for 30 mins. Then the deposited yellowish mass was collected by washing it with ethanol from the dielectric surfaces. Then it was analyzed in FTIR and UV-spectrometer.

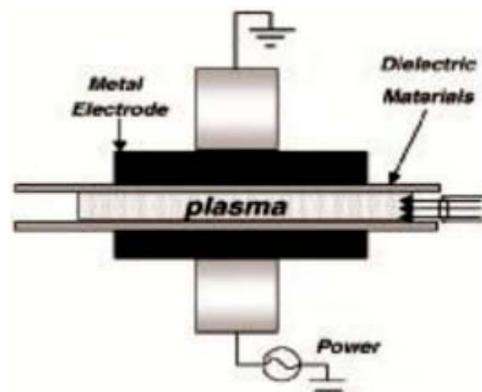
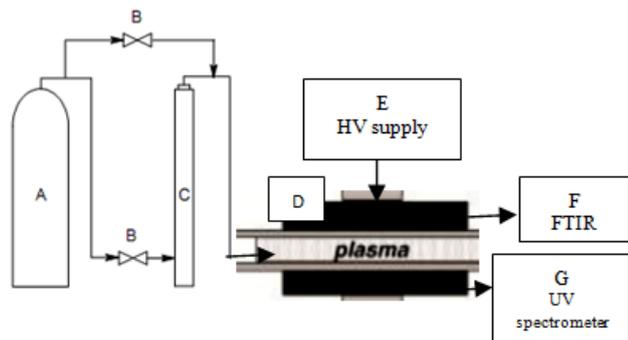


Figure 1: DBD reactor

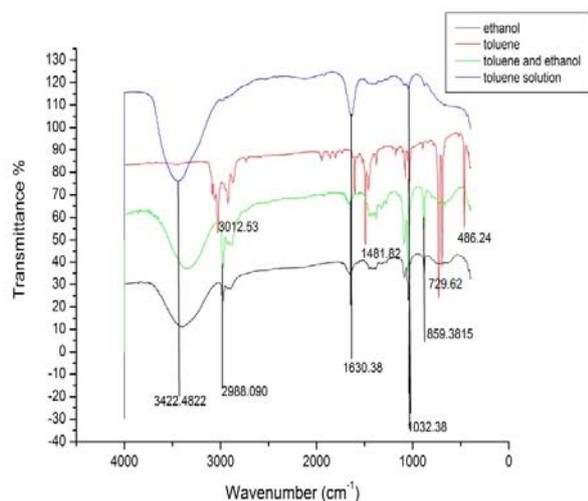


**Figure 2:** Experimental set up **A**-pressureised air, **B**-mass flow controller, **C**-bubbler system, **D**-plasma source, **E**-HV supply, **F**-FTIR & **G**-UV analysis

### 3. Result and Discussion

#### 1.1 Analysis of Toluene

From the Fig: 3, it is cleared that the deposition substance which was washed with ethanol was IR analyzed with the other pure compounds like ethanol, pure toluene, mixture of toluene and ethanol before plasma treatment and found that the graph of washing is different from others. The peaks at the positions like 3422.48, 1630.38, and 1032.38 are due to ethanol which is clear from the fig: 3. So, from above discussion it is clear that toluene decomposes. Also from surface deposition of benzene after the treatment of plasma, found phenol, biphenyl, 2- and 4-phenylphenols, Catechol, 2, 2, - Biphenol, 4-phenoxyphenol and Hydroquinone as various products by GC analysis [18]. By UV-spectrometer the washings are analyzed found the presence of phenol.

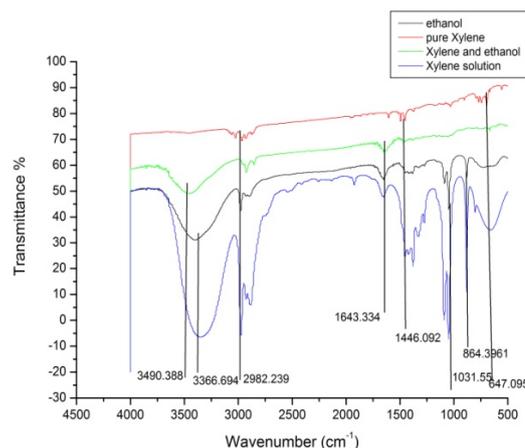


**Figure 3:** Comparison of IR data for toluene deposition

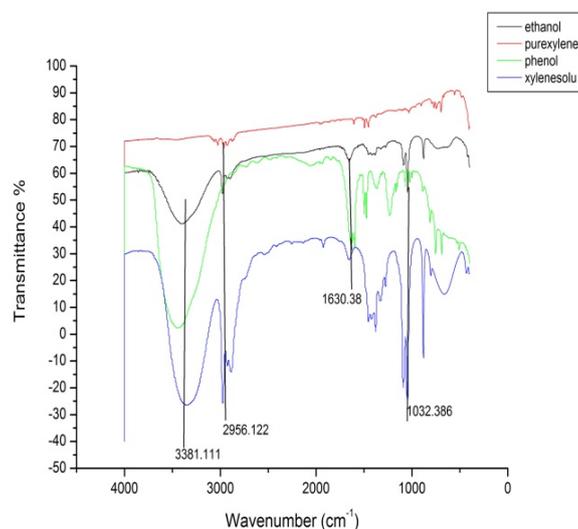
#### 1.2 Analysis of Xylene

From the Fig: 4 it is cleared that the deposition substance which was washed with ethanol was IR analyzed with the other pure compounds like ethanol, pure xylene, mixture of xylene and ethanol before plasma treatment and found that the graph of washing is different from others. The peaks at the positions like 3366.694, 2982.239, 1643.334 and 864.396 are due to ethanol which is clear from the fig:

4. So, from above discussion it is clear that xylene decomposes. And the extra peaks indicate the formation of other new compounds which matches with the values of phenol.



**Figure 4:** Comparison of IR data for xylene deposition



**Figure 5:** Comparison of IR data for xylene deposition

And also from the literature it is also found that xylene decomposes to  $\text{CO}_2$ ,  $\text{CO}$ ,  $\text{CH}_3\text{CHO}$ ,  $\text{CH}_3\text{COOH}$ ,  $\text{HCOOH}$ ,  $\text{H}_2\text{O}$ ,  $\text{N}_2\text{O}$ ,  $\text{O}_3$  etc with  $\text{N}_2$ ,  $\text{O}_2$ , and  $\text{H}_2\text{O}$  Vapor [19].

### 4. Conclusion

As the decomposition of VOCs occur in this type of planar DBD with larger surface area and this can be enhanced by using catalysts. The surface deposition also gives new idea about the surface modification, thin film preparation as well as dye mechanism in such a new system.

### Acknowledgements

This project is supported by a grant from the BRNS, India.

## References

- [1] K. Vercammen, "Non-thermal plasma techniques for the reduction of Volatile Organic Compounds in air streams: a critical review," *Journal of Advanced Oxidation Technology*, pp.312-329, 1997.
- [2] R. Atkinson, "Atmospheric Chemistry of VOCs and NO<sub>x</sub>," *Atmos. Environ.*, pp. 2063-2101, 2000.
- [3] J. R. Odum, T. P. W. Jungkamp, R. J. Griffin, H. J. L. Forstner, R. C. Flagan and J. H. Seinfeld, "Aromatics, Reformulated Gasoline, and Atmospheric Organic Aerosol Formation," *Environ. Sci. Technol.*, pp.1890-1897, 1997.
- [4] C. Subrahmanyam, M. Magureanu, A. Renken, L. Kiwi-Minske, "Catalytic abatement of volatile organic compounds assisted by non-thermal plasma: part. A novel bioelectric barrier discharge reactor containing catalytic electrode," *Catal. B: Environ.*, pp.150-156, 2006.
- [5] P.S. Monk et al., "Atmospheric composition change – global and regional air quality," *Atmos. Environ.*, pp.5268-5350, 2009.
- [6] L.Y. Chan et al., "Preliminary measurements of aromatic VOCs in public transportation modes in Guangzhou, China," *Environment International* 29, pp.429-435, 2003.
- [7] T. N. Das et al., "Methane from benzene in argon dielectric barrier discharge," *Journal of Hazardous Materials*, pp.469-477, 2013.
- [8] S. Mohanty et al., "Plasma Assisted Destruction of Volatile Pollutants using Dielectric Barrier Discharge," *International Journal of Advanced Chemical Science and Applications*, pp. 1-3, 2013.
- [9] X. Fan et al., "Removal of low-concentration BTX in air using a combined plasma catalysis system," *Chemosphere*, pp.1301-1306, 2009.
- [10] W. B. Li and H. Gong, "Recent Progress in the Removal of Volatile Organic Compounds by Catalytic Combustion," *Acta Phys-Chim. Sin.*, pp.885-894, 2010.
- [11] A. Kumar, J. Dewulf and H. Van Langenhove, "Membrane-based biological waste gas treatment," *Chem. Eng. J.*, pp. 82-91, 2008.
- [12] S. Mudliar, B. Giri, K. Padoley, D. Satpute, R. Dixit, P. Bhatt, R. Pandey, A. Juwarkar and A. Vaidya, "Bioreactors for treatment of VOCs and odours – A review," *J. Environ. Manag.*, pp.1039-1054, 2010.
- [13] K. Demeestere, J. Dewulf and H. Van Langenhove, "Heterogeneous Photocatalysis as an Advanced Oxidation Process for the Abatement of Chlorinated, Monocyclic Aromatic and Sulfurous Volatile Organic Compounds in Air: State of the Art," *Crit. Rev. Environ. Sci. Technol.*, pp. 489-538, 2007.
- [14] U. Kogelschatz, "Dielectric-Barrier Discharges: Their History, Discharge Physics, and Industrial Applications," *Plasma Chem. Plasma Processing*, pp.1-46, 2003.
- [15] U. Kogelschatz, B. Eliasson and W. Egli., "Dielectric-Barrier Discharges. Principle and Applications," *J. De Phys. IV*, C4-47-C4-66, 1997.
- [16] A. Fridman, A. Chirokov and A. Gutsol, "Non-thermal atmospheric pressure discharges," *J. Phys. D: Appl. Phys.*, pp. R1-R24, 2005.
- [17] A. Fridman, "Plasma chemistry," New York: Cambridge University Press, 2008.
- [18] G.R. Dey et al., "Variable products in dielectric-barrier discharge assisted benzene oxidation," *Journal of Hazardous Materials*, pp. 693-698, 2010.
- [19] H.M. Lee et al. "Abatement of Gas-phase p-Xylene via Dielectric Barrier Discharges," *Plasma Chemistry and Plasma Processing*, pp.541-558, 2003.

## Author Profile

**Suchitra Mohanty** completed M.Sc degree in Ravenshaw University, Cuttack in 2007 and continuing her PhD in Ravenshaw University.

**Dr. Smrutiprava Das, (Corresponding Author)**, Reader in Chemistry, Ravenshaw University, Cuttack, India