Research on VOCs Treatment of Electrophoresis Coating Process

Wenhao Zeng \textsuperscript{1}, Shaotao Zhong \textsuperscript{1}, Dingsheng Chen \textsuperscript{1,2,3,*}, Huanmu Zeng \textsuperscript{1}, Zhihang Chen \textsuperscript{1}, and Chaoping Cen \textsuperscript{1,2,3}

\textsuperscript{1} South China Institute of Environmental Sciences, the Ministry of Ecology and Environmental of PRC, Guangzhou, China
\textsuperscript{2} Key Laboratory of Water and Air Pollution Control of Guangdong Province, Guangzhou, China.
\textsuperscript{3} Guangdong Province Engineering Laboratory for Air Pollution Control, Guangzhou, China.

*Corresponding author e-mail: chendingsheng@scies.org

Abstract. The coating process is the main source of VOCs emissions in the aluminium profile industry. The electrophoretic coating process is a surface processing method widely used by aluminium profile companies. However, the electrophoretic coating process generates a large amount of exhaust gas, and the main component of the exhaust gas is VOCs. This paper combined with the monitoring of the exhaust gas treatment project of an electrophoresis coating workshop of a large aluminium profile company, and found that the main component is xylene. The exhaust gas treatment process uses "activated carbon adsorption + spray absorption" and more than 97% of emissions could be achieved.

1. Foreword
In recent years, China's aluminum profile industry has developed rapidly and has become the world's largest aluminum profile production base and consumer market. However, the environmental protection work of this industry is relatively backward and restricts the development of the industry. The aluminum profile industry mainly causes waste gas, waste residue, Waste water has the greatest impact on the environment [1]. The electrophoretic coating process is a widely used surface treatment method in the aluminum profile industry. However, the electrophoretic coating exhaust gas is generated during the aluminum profile electrophoretic coating process. The exhaust gas contains a large amount of volatile organic compounds (VOCs). If it is directly discharged without treatment, will cause important harm to human health and the environment. VOCs is one of the major pollutants in the atmosphere and is an important substance involved in atmospheric photochemical reactions. It is a major factor in the formation of O\textsubscript{3} and PM2.5 [2]. Therefore, the formation of high concentrations of ozone and secondary fine particles in urban areas are all around volatility. Photochemical reaction process of organic matter. In addition, some VOCs are toxic and can enter the human body through breathing and skin contact, which can cause various acute and chronic health problems, including respiratory diseases, and even cause cancer health hazards [3].
China has strengthened the management of VOCs in the solvent industry. Under the trend of "oil to water" and "oil to powder", the characteristics of VOCs emissions in the surface coating industry have changed significantly [4]. Based on the monitoring of the coating waste gas treatment project of the electrophoretic workshop of a large aluminum profile company (referred to as JM plant), this paper studies the generation and treatment of VOCs in the electrophoretic coating process. The research results can provide reference and basis for the treatment of VOCs in the aluminum profile industry.

2. Analysis of waste gas generation in electrophoretic coating process

2.1. Electrophoretic coating process

Electrophoretic coating is to put the workpiece and the corresponding electrode into a water-soluble coating. After connecting the power supply, rely on the physical and chemical action of the electric field to make the resin and pigments in the coating uniformly precipitate on the surface of the electrode to be coated A coating method that deposits to form a water-insoluble paint film. The aluminum material is subjected to electrophoresis after pre-treatment, and the electrophoretic paint is selected according to the type. Generally, the electrophoretic paint is divided into acrylic and polyurethane [5]. After the electrophoretic paint is coated, the cross-linking reaction occurs after baking, which makes the surface of the aluminum profile form a dense oxide film, which enhances the corrosion resistance and mechanical properties. The specific process of electrophoretic coating process in JM factory is shown in Figure 1 below.

![Flow chart of electrophoretic coating process in JM factory](image)

**Figure 1.** Flow chart of electrophoretic coating process in JM factory

2.2. Sources and types of exhaust gas

The main source of VOCs generated by the electrophoretic coating process is the drying stage of the paint film, including the solvent volatilization, the thermal melting of the coating film, and the high temperature thermal curing stage. The JM plant uses anodic electrophoresis. Polyurethane and acrylic electrophoretic paints will produce solid powders that are difficult to volatilize at the initial stage of high-temperature heating, which will generate oil fume. After post-baking, the smoke contains incomplete thermal decomposition products of polymers, such as benzene, Esters, ketones, alcohols, amines, aldehydes, isocyanates, etc. The types of VOCs are relatively complicated, and some of them are toxic. If they are not collected and processed in a timely manner, it will cause harm to staff health. The main VOCs components are shown in Table 1.
Table 1. Main components of VOCs in electrophoretic coating

| Main components of VOCs in exhaust gas for electrophoretic coating |
|---------------------------------------------------------------|
| benzene                        | Tetrahydrofuran |
| Toluene                        | Dichloromethane |
| M / p-xylene                   | Ethyl acetate   |
| O-xylene                       | Isopropanol     |
| Ethylbenzene                   | Methyl ethyl ketone |
| P-diyethyl benzene             | acetone         |

3. Study on Waste Gas Treatment in JM Plant

3.1. Comparison of various governance methods
There are many technologies for treating exhaust gas pollution in the aluminum profile industry. Li Xia et al [6] investigated the treatment of VOCs in the aluminum profile coating process and found that most companies mainly use biological treatment, plasma purification, UV photolysis, activated carbon adsorption, spray absorption while single or multiple combined processes, but in the actual application process, the processing efficiency of VOCs in each process is not ideal. The distribution of VOCs technology is shown in Figure 1, and the advantages and disadvantages of the technology are shown in Table 2 below.

Table 2. Comparison of VOCs end governance technologies

| Technical name            | Advantage                                      | Disadvantage                                      |
|---------------------------|-----------------------------------------------|---------------------------------------------------|
| Thermal combustion        | High efficiency and wide range of VOCs        | Generate by-products and high energy consumption   |
| Catalytic combustion      | Wide application range and good effect         | Catalyst is susceptible to poisoning              |
| Adsorption technology     | Wide adsorption range and good effect          | Easy to secondary pollution, high cost of adsorbent|
| Absorption technology     | Mature technology and good results             | Difficult maintenance, waste liquid needs to be treated |
| Condensation method       | Simple operation and recovery of VOCs          | Small scope                                       |
| Membrane separation       | High recovery rate, no secondary pollution     | Not suitable for high temperature and high flow gas|
| Plasma technology         | Wide variety of VOCs                          | Poor stability and immature technology             |
| Biological purification   | Simple and safe process                        | High selectivity and large footprint               |
| Photocatalytic oxidation   | Low processing costs                          | Large investment and poor stability                |
3.2. Waste gas collection and treatment facilities and processes

3.2.1. Exhaust gas collection system. JM factory has 4 baking ovens to dry and solidify aluminum profiles. Extracting exhaust gas directly from the furnace will cause large temperature and pressure fluctuations in the furnace and affect the quality of the finished product. There is a gap in the top cover of the baking furnace, which can extract the pipeline through negative pressure. In addition, the top cover of the baking furnace has a control valve. During the curing process, the valve is closed, the lid is opened, and air is extracted to avoid affecting the curing process; and a cover plate is installed on the upper part of the electrophoresis solution storage tank, and the vacuum is used to evacuate.

3.2.2. Governance facilities and processes. Adopt "adsorption + spray absorption" to strengthen the combined treatment technology. Firstly, the collected exhaust gas is adsorbed by activated carbon, and the particulate matter in the exhaust gas is adsorbed and filtered, and then passed through the purification spray absorption tower to further remove particulate matter and gas pollutants, and finally the flue gas is discharged. The specific process flow is shown in Figure 2 below.

3.3. Monitoring results
Monitoring method: Determination of particulate matter and gaseous pollutants in exhaust gas from fixed pollution sources (GB/T 16157-1996), Appendix E of "Characterization of Volatile Organic Compound Emissions from Surface Coating (Automotive Manufacturing)" (DB 44 / 816-2010).

The sampling points are at the collection gas pipe on the top cover of the baking furnace, before the exhaust gas treatment pipes of the waste gas collection pipes on both sides of the baking furnace, and at the discharge cylinder at the end of the treatment facility. Sampling is performed 3 times in each curing cycle, and 3 cycles in each sampling period. During the monitoring period, the total operating condition...
of the baking oven is guaranteed to reach more than 75%. The monitoring results are shown in Table 3 below.

**Table 3. Statistics of sampling and monitoring results**

| Monitoring data | First period mean | Second period mean | Third period mean | Average emission rate | Standard emission limit |
|-----------------|-------------------|--------------------|-------------------|-----------------------|------------------------|
| **Import**      |                   |                    |                   |                       |                        |
| benzene         | 0.0120            | 0.0023             | 0.0022            | ---                   | ---                    |
| Toluene, xylene | 10.23             | 15.1               | 13.1              | ---                   | ---                    |
| VOCs            | 36.4              | 42.3               | 36.7              | 0.237-0.268           |                        |
| benzene         | O                 | O                  | O                 | O                     |                        |
| **Export**      |                   |                    |                   |                       |                        |
| Toluene, xylene | 0.214             | 0.261              | 0.201             | ---                   | 18                     |
| VOCs            | 1.09              | 1.10               | 1.15              | 0.026-0.032           | 50                     |
| VOCs removal rate | 97.0%             | 97.4%              | 97.1%             | ---                   | ---                    |

Remarks: concentration (mg / m$^3$); discharge rate (kg / h); “O” represents no detection.

3.4. Monitoring data analysis

3.4.1. Sampling port inlet concentration analysis. As can be seen from Table 3 above, the concentration of VOCs at the inlet and outlet sampling data is relatively low. The reason is that when the top cover of the baking oven is opened during sampling, a large amount of exhaust gas is instantly released, and air convection exists in the workshop. Collection efficiency; In addition, there is a leakage phenomenon in the negative pressure extraction device of the curing furnace, and the extraction effect is not ideal, resulting in a low concentration of sampling pollutants.

3.4.2. VOCs removal rate does not meet the standard analysis. From the monitoring results of the three cycles, it can be known that the maximum removal rate of VOCs is 97.4%, which has reached 90% required by the emission standard (DB44 / 816-2010), and the treatment effect is ideal.

3.4.3. Pollutant analysis. High concentrations of VOCs will be released during the curing phase. Due to insufficient collection, VOCs tend to diverge, and when the roof of the baking oven is opened, the VOCs concentration will reach a maximum, and the air in the workshop will cause the concentration to gradually decrease, resulting in a relatively low sampling concentration at the inlet Big fluctuations.

The monitoring of VOCs includes more than ten common organic compounds. According to the data, the chromatograms show that xylene accounts for the largest proportion. This may be due to the fact that the electrophoretic paint of JM factory mainly uses xylene as a diluent.

4. Conclusion

(1) The main component of VOCs exhaust gas for electrophoretic coating at is xylene, which is because the plant uses xylene as diluent for electrophoretic paint.

(2) There is still something unreasonable about the electrophoretic coating exhaust gas collection system of the JM plant, which needs to be further improved. From the monitoring data and on-site investigation, it can be inferred that the treatment effect of the “activated carbon adsorption + spray absorption” treatment facility configured by the plant is highly effective.

Acknowledgments

The research was funded by the Guangdong Science and Technology Plan Project (2017A030223005), the Guangzhou Science and Technology Plan Project (20180410147, 201710010186), the National
Natural Science Foundation of China (NSFC-51408256), and the National Air Pollution Prevention Joint Research Project Funded China Center (DQGG0204), Special Funds for Research from the Environmental Charity Project of South China Institute of Environmental Sciences (PM-zx703-201703-011, PM-zx703-202003-101).

References

[1] Shaonan Zheng. Explore the aluminum industry production of emission control technology[J]. environment, 2011 (S1): 5-7.

[2] Zhengping He. Volatile Organic Pollutant Emission Control Process, Materials and Technology [M]. Beijing: Science Press, 2016: 3-4.

[3] Zhou J, You Y, Bai Z, Hu Y, Zhang J, Zhang N, Health risk assessment of personal inhalation exposure to volatile organic compounds in Tianjin, China[J]. Science of The Total Environment. 2011, 409(3): 452-459.

[4] Ziwei Mo, Min Shao, Sihua Lu. Research progress on the composition of volatile organic compounds (VOCs) emission sources in China[J]. Journal of Environmental Sciences. 2014, 34 (9): 2179-2189.

[5] Shaoming Luo, Chunfu Huang. Study on the Current Situation of Waste Gas Treatment by Electrophoretic Coating of Aluminum Profiles in Nanhai District[J]. Chemical Industry Management, 2017 (19): 100-101.

[6] Xia Li, Weijian Su, Bixia Li, Miao Long, Lili Li, Zhou Zhang, Yuegang Yu, Yunpeng Wang, Xinning Wang. Composition of VOCs Emissions from Surface Coating of Typical Aluminum Profile Industry in Foshan City[J]. Environmental Science, 2018, 39 (12): 5334-5343.