

Analysis of the Activated Carbon Used by VOCs Governance—Take the Guangming District of Shenzhen as an Example

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Abstract

In recent years, because of the low cost and obvious effect, active carbon adsorption become more and more popular in SMEs after the single low-temperature plasma, photooxidation, photocatalysis, and other inefficient treatment technologies were gradually phased out. However, the standard system and technical requirements for activated carbon are not comprehensive enough, so many enterprises do not know how to use the active carbon normally which leads to a low treatment effect. This paper will analyze the type, material, iodine value, and replacement frequency of activated carbon through random sampling of 100 enterprises in the Guangming District and conclude the common problem in the use of active carbon and offer some suggestions from the perspective of regulatory authorities and enterprises. The air quality of the Guangming District will be improved after the concentration of O₃ is decreased by using the active carbon normally.

Keywords

Activated carbon, wasted gas treatment, the volatile organic compounds

1. Introduction

Since 2020, ozone (O₃) has gradually become the main air pollutant in Shenzhen. In the past few years, the average annual concentration of ozone in Guangming District ranks last among all districts in Shenzhen. Ozone is a secondary pollutant whose main precursors are volatile organic compounds (VOCs) and nitrogen oxides (NO_x) [1]. According to the observation data of Shenzhen Photochemical Network from January to July 2023, the photolysis rate of O¹D, JO¹D, JHCHO_M, JNO₂, and JHCHO_R in Guangming District is much higher than that of other districts in Shenzhen. The VOC component interpretation results show that industrial emission characteristics of VOCs are obvious in the Guangming District. According to statistics, there are 1,064 VOC-related industrial enterprises in Guangming District, with annual emissions reaching 2800 tons. After low-efficiency treatment technologies such as single low-temperature plasma, photooxidation, and photocatalysis began to be phased out, the activated carbon adsorption process with lower price and more obvious effect has been favored by more and more small and medium-sized enterprises [2]. Among the 1,064 VOCs-related companies, 902 companies are using activated carbon (including single activated carbon adsorption, secondary activated carbon adsorption, other processes + activated carbon adsorption, etc.). The "Technical Specifications for Industrial Organic Waste Gas Treatment Engineering by Adsorption" (HJ 2026-2013) mentions that the purification efficiency of the adsorption device should reach 90% [3]. However, in the actual application process, companies often fail to standardize the use of activated carbon such as: using inferior activated carbon, filling carbon boxes improperly, and replacing activated carbon untimely and so on which leads to low waste gas treatment efficiency and even ineffective treatment [4]. For regulatory authorities, due to the incomplete system of technical indicators of activated carbon, insufficient technical requirements, and the large number of activated carbon companies, it is difficult to supervise the use of activated carbon effectively by relying on manpower [8]. So, the waste gas treatment efficiency of VOC-related companies in

the Guangming District is generally low. This article investigates the use of activated carbon by VOCs-related companies in the Guangming District through a sampling survey, then summarizes the common problems and provides information for regulatory authorities to strengthen supervision and for companies to implement their own environmental protection responsibilities and improve environmental protection levels [5]. By improving the treatment efficiency of activated carbon adsorption equipment of VOCs-related enterprises in the Guangming District, reducing VOC emission levels, slowing down the generation rate of ozone, and achieving the purpose of improving the air quality of the Guangming District.

2. Activated carbon adsorption treatment

The adsorption method refers to the method of using substances with adsorption capacity such as activated carbon, silica gel, zeolite molecular sieves, etc. to adsorb harmful components to eliminate pollution. This method is mainly used in low-concentration waste gas treatment. There are various types of adsorption devices, including moving beds, solid bed moving beds, combined processes, etc.

(1) Fixed bed adsorber. There are two types of fixed bed adsorbers, vertical and horizontal, with single, double, or multi-layer adsorption layers inside. They are the most commonly used type.

(2) Moving bed adsorber. A device in which both gas and solid phases pass through at a constant speed, such as a wheel device, etc., but activated carbon is rarely used as an adsorbent.

(3) Fluidized bed adsorber. It is a complex device that fluidizes the adsorbent and then fully contacts the waste gas. It causes a large loss of adsorbent and is basically not used in the Guangming District.

2.1 Activated carbon

(1) Definition of activated carbon. Carbonaceous materials are carbonized and activated to form porous adsorption materials with developed pore structures and a huge specific surface area.

(2) Material of activated carbon. At present, the commonly used activated carbon in waste gas treatment is divided into wood, coal, and biomass according to the material. According to its appearance, it can be divided into honeycomb activated carbon, granular activated carbon, and activated carbon fiber felt.

(3) Activated carbon performance indicators. Physical properties include appearance, shape, specific surface area, compressive strength, fracture ability, etc. Chemical performance indicators include ash content, PH, ignition point, etc. The adsorption performance mainly includes iodine adsorption value, carbon tetrachloride adsorption rate, benzene adsorption rate, etc.

(4) Factors affecting the adsorption capacity of activated carbon. Its own performance (pore structure and surface chemical structure), adsorbate properties (inlet concentration, physical and chemical properties), and operating conditions (temperature, humidity, replacement frequency, etc.) [6].

(5) Current standards of activated carbon. The current national standards for the activated carbon adsorption method mainly include the "Technical Specifications for Industrial Organic Waste Gas Treatment Engineering by Adsorption Method" (HJ 2026-2013) and its supplementary "Notice on Accelerating the Resolution of Current Outstanding Issues in Volatile Organic Compounds Treatment", which mentioned clear requirements for the iodine value of activated carbon: "When honeycomb activated carbon is used as an adsorbent, its iodine value should not be less than 650mg/g; when granular activated carbon is used as an adsorbent, its iodine value should not be less than 800mg/g; using When activated carbon fiber felt is used as an adsorbent, its specific surface area is not less than 1100m²/g (BET method)." The "Guangdong Province Industrial Source Volatile Organic Compound Emission Reduction Accounting Standard" and the Local Standard "Shenzhen Technical Guidelines for Replacement of Activated Carbon for Organic Waste Gas Control" further stipulate wind speed, filling thickness, and replacement frequency.

3. Research

100 companies involved in the use of activated carbon in the Guangming District were randomly selected for investigation. The survey showed that about 40.3% of companies use UV + activated carbon, 25.4% of companies use water spray + activated carbon, the proportion of companies use single activated carbon adsorption and secondary activated carbon adsorption equipment each accounts for about 11.9%, about 1.5% of companies use UV + activated carbon + water spray and about 9.0% of companies use other types of treatment (Figure 1); For the shape and appearance of activated carbon, it appears that about 75.9% of companies use honeycomb activated carbon, about 22.2% of companies use granular activated carbon, and only 1.9% of companies use activated carbon fiber felt (Figure 2). In terms of activated carbon materials, about 82.8% of companies use coal-based activated carbon, and about 17.2% of companies use wood-based activated carbon (Figure 3). From the perspective of activated carbon replacement mode, about 60% of companies purchase and replace it themselves, about 35.6% of companies purchase activated carbon by themselves but have it replaced by a third-party company, and only 4.4% of companies purchase and replace it entirely by a third party (Figure 4). From the perspective of the activated carbon replacement cycle, 20.3% of companies

replace activated carbon every three months, 40% of companies replace activated carbon every six months, 24.4% of companies replace activated carbon every year and 15.3% of companies replace activated carbon irregularly (Figure 5). Summarize the price of activated carbon, 38.9% of the companies purchased activated carbon at a unit price of 6,000-10,000 yuan/ton, 27.8% of the companies purchased activated carbon at a unit price of 3,000-6,000 yuan, and 27.8% of the companies purchased activated carbon at a unit price of 6,000-10,000 yuan/ton. Above 10,000 yuan, 5.6% of companies purchased activated carbon with a unit price of less than 3,000 yuan (Figure 6).

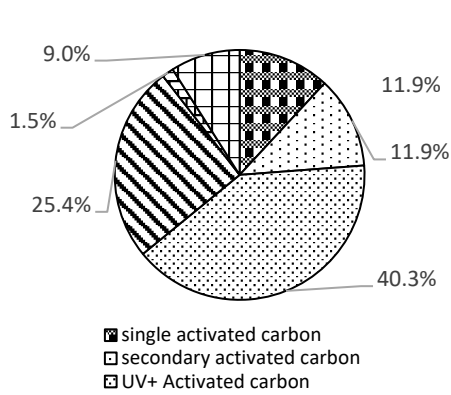


Figure 1. Distribution of treatment.

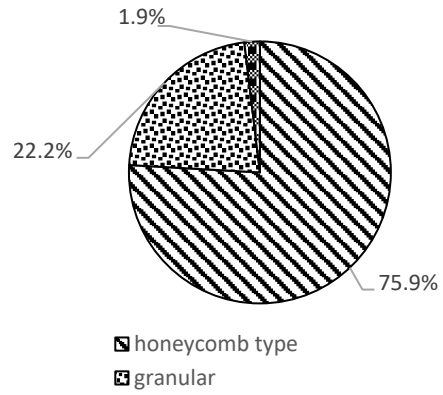


Figure 2. Distribution of appearance.

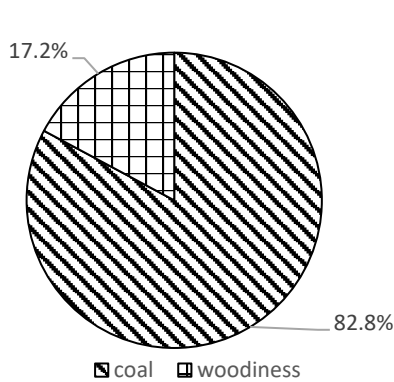


Figure 3. Distribution of material.

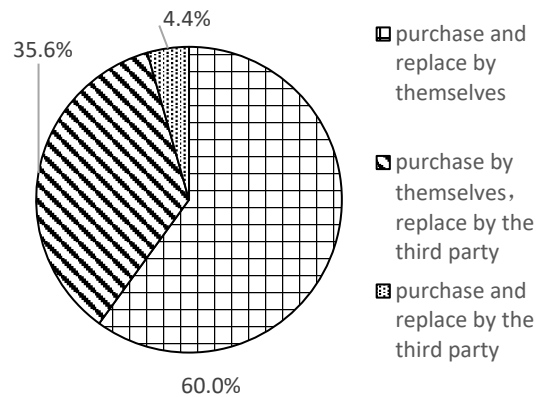


Figure 4. Distribution of replacement mode.

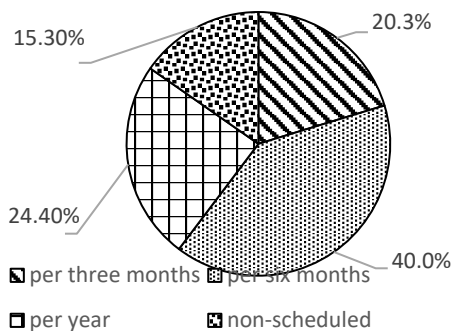


Figure 5. Distribution of replacement frequency.

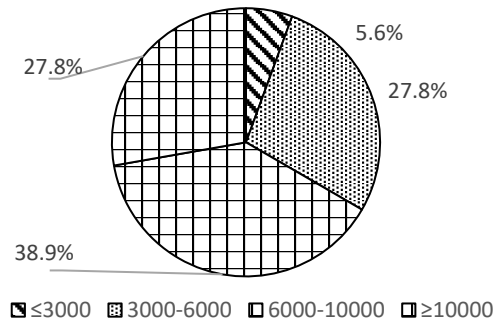


Figure 6. Distribution of unit price.

4. Analysis

(1) According to the results, a considerable number of companies (40.3%) are still using inefficient UV photolysis treatment. Although it is used with activated carbon adsorption equipment, there is no significant improvement over using a single activated carbon adsorption device. Therefore, whether from the perspective of environmental protection or the perspective of enterprise input and output ratio, the use of UV + activated carbon adsorption equipment is cost-effective.

(2) The result shows that most (60%) companies choose to purchase and replace activated carbon by themselves. During the investigation, we found that due to a lack of professional knowledge, those companies rarely pay attention to whether the quality parameters of activated carbon meet the standard during the process of purchasing carbon, and do not know they can ask for product quality certification documents for suppliers; during the carbon replacement process, there are also certain knowledge blind spots about the frequency of carbon replacement, filling density, thickness, and identification of deactivated carbon, etc. However, one advantage of such companies is that they will basically establish an activated carbon replacement ledger and record the date of carbon replacement. For companies that purchase or replace the activated carbon from a third party, the activated carbon they use basically has relevant quality certification documents. The density, thickness, and replacement frequency of activated carbon filling are all guaranteed to a certain extent. However, the disadvantage is that they usually didn't establish the activated carbon replacement ledger, and the date and quantity of the last carbon replacement can only be traced through chat records, etc.

5. Problem

(1) The iodine value is not up to standard. 40 companies were randomly selected to test the iodine value of activated carbon. The test results showed that up to 88% of the companies used activated carbon with an iodine value that did not meet the standard (Figure 8). Judging from the unit price distribution of activated carbon that meets the iodine value standard and does not meet the standard, the unit price of activated carbon that meets the iodine value standard is basically more than 10,000 yuan/ton (Figure 7). And 80.7% of the activated carbon companies who used activated carbon with standard iodine value could offer quality certification documents (Figure 9), while only about 33.4% of activated carbon companies with unqualified iodine value have quality certification documents (Figure 10). Most companies that use substandard activated carbon said that when purchasing activated carbon, they did not pay attention to the quality and did not know how to distinguish high-quality carbon from low-quality carbon. What they were most concerned about was the purchase cost.

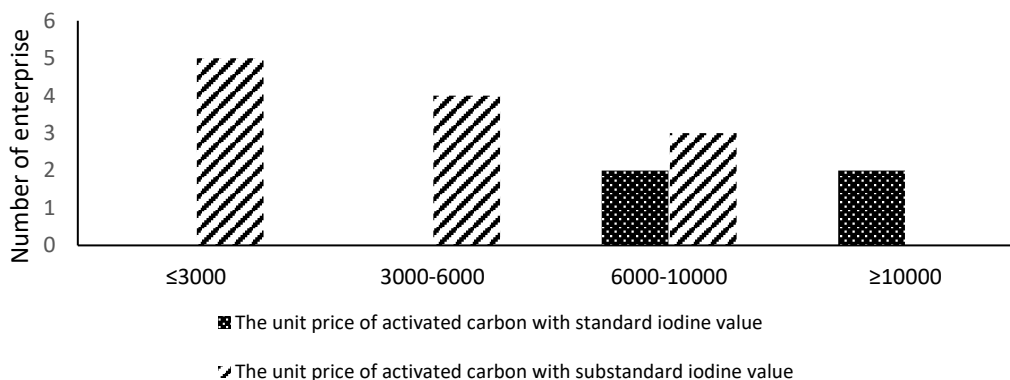


Figure 7. Distribution of unit price of activated carbon.

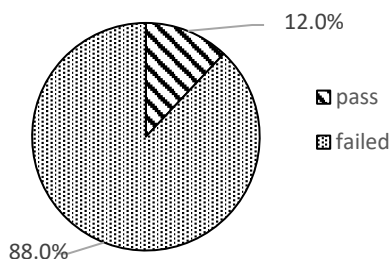


Figure 8. Distribution of Iodine value detection

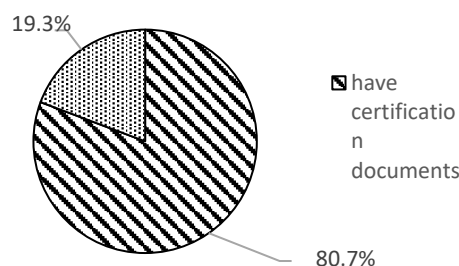


Figure 9. Distribution of enterprise use standard activated carbon has a quality test report.

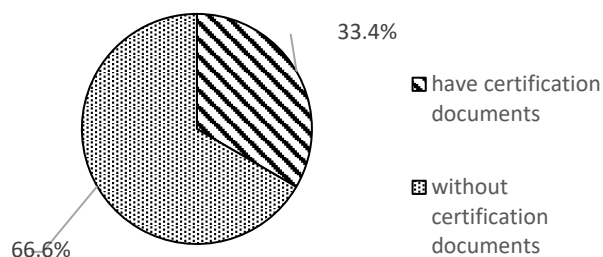


Figure 10. Distribution of enterprise use substandard activated carbon has certification documents.

(2) The replacement frequency does not meet the standard. According to the requirements of the "Shenzhen Technical Guidelines for Activated Carbon Replacement for Industrial Organic Waste Gas Control", the activated carbon replacement cycle should generally not exceed 500 hours of cumulative operation or 3 months. According to the survey above, only 20.3% of enterprises meet the requirement of at least once every three months/500 hours for activated carbon replacement, and most of them are large enterprises, and the cost of carbon replacement does not impose an economic burden on them. All other companies complained that if they strictly implement the 3-month/500-hour replacement requirement, the huge operation and maintenance costs incurred will bring considerable economic pressure.

(3) Deactivated activated carbon. During the on-site inspection, it was found that the activated carbon of some enterprises had been inactivated, such as whitening, clogging, and brokenness. They are mainly low-emission small and medium-sized enterprises. Their frequency of carbon replacement is mostly once a year, and most of them do not establish standardized waste gas treatment device operation and management standing book, and no dedicated employees or third-party companies are used to regularly operate and maintain the equipment.

(4) An activated carbon replacement standing book has not been established. During the on-site inspection, it was found that a small number of companies have not established/not standardized activated carbon replacement standing book. The main reason is that some companies entrust third-party companies to purchase and replace carbon.

6. Suggestions for next steps

In response to the problems discovered in this survey, from the perspective of regulatory authorities strengthening management and enterprises implementing their own environmental protection responsibilities, follow-up work suggestions are put forward:

(1) Problem of inferior activated carbon. From the perspective of regulatory authorities, activated carbon that fails the iodine value test should be traced to suppliers, deal with some inferior carbon suppliers, and at the same time, strengthen product quality testing of activated carbon merchants on the market to ensure the quality of activated carbon from the source. From the perspective of the enterprise itself, the enterprise should purchase through formal channels and give priority to suppliers that can provide quality certification documents with the qualification certification mark of the inspection and testing agency. After purchasing, companies can use three small skills to distinguish if it is high-quality activated carbon: (a) Look. Enterprises can identify by looking at the appearance of the purchased activated carbon. High-quality carbon is short, straight, and inky black; inferior carbon is long and curved in shape, gray in color, and rusty. (b) Weigh. In the same container, if it is filled without knocking firmly, the quality of high-quality charcoal will be lighter and the quality of inferior charcoal will be heavier. (c) Try. When high-quality charcoal is put into clean water, it will discharge tiny bubbles and continue to make a "hissing" sound; when low-quality charcoal is put into clean water, it will take a shorter time to remove bubbles, or even no bubbles will be produced.

(2) Activated carbon replacement problem. From the perspective of the regulatory authorities, due to the large number of activated carbon companies in the jurisdiction, relying on manpower to verify and supervise is inefficient, and it is easy for supervision to be inadequate. In recent years, a new type of activated carbon replacement supervision and law enforcement method has appeared on the market, which is mainly implemented through some applications. The application estimates the reasonable frequency of activated carbon replacement for different companies by integrating data such as corporate emission concentration, actual production hours, and equipment air volume. When the carbon replacement time is approaching, it will notify companies to replace activated carbon through text messages and regularly push notifications to companies that do not change carbon as required which greatly reduces the pressure on regulatory authorities. From the perspective of enterprises implementing their own environmental protection responsibilities, enterprises should establish and improve the operation and management system of waste gas treatment facilities, conduct regular operation and maintenance of equipment, promptly replace activated carbon that has become white and inactive, and standardize the establishment of daily operation management records of waste gas treatment facilities and activated carbon Replace the ledger. The ledger content includes but is not limited to (a) The start and stop time of the activated carbon adsorption device. (b) Purchase amount, replacement amount, and concrete

time of activated carbon. (c) Daily maintenance status of main equipment and operation accident maintenance status. (d) Regular inspection and evaluation. At the same time, operation, maintenance, and related operating procedures are formulated, and activated carbon adsorption equipment is regularly maintained according to relevant systems and procedures to ensure normal operation of the equipment. Ensure that the equipment operates normally and the waste gas reaches the standard after being effectively treated.

7. Conclusion

In summary, due to its low operation and maintenance costs, activated carbon adsorption is still the preferred way of treatment for many small and medium-sized companies [7]. Whether the use process is standardized will directly affect the treatment efficiency of activated carbon adsorption equipment. This survey found that more than 90% of VOCs-related companies in the Guangming District use activated carbon adsorption equipment, but there are some common problems during the process they operate the device like iodine value of activated carbon does not meet the standard, shoddy quality of activated carbon does, replacement frequency does not meet requirements which reflect that there is still much room for improvement in the efficiency of waste gas treatment in the Guangming District.

In order to improve the overall waste gas treatment efficiency in the Guangming District, from the perspective of the regulatory authorities, since the number of companies using activated carbon is large, it is necessary to use some scientific and technological ways to improve regulatory efficiency [8]. A supplier traceability system should be established for activated carbon that does not meet quality standards to prevent inferior carbon from flowing into the market at the source [9]. From the perspective of enterprises, they should actively enrich relevant environmental protection knowledge, actively improve environmental management levels, establish and improve environmental protection management systems, and implement their own environmental protection main responsibilities [10]. Only through a two-pronged approach can we comprehensively improve the level of VOC control in the Guangming District, thereby achieving the purpose of reducing ozone concentration and improving air quality.

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