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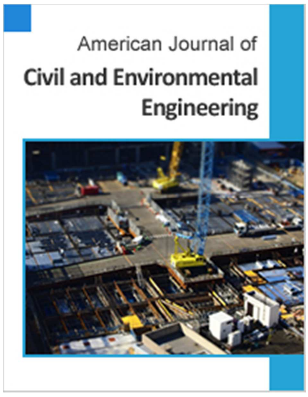

Pollution Control of VOCs Emission from Electronic Waste Recycling

Wei Li, Hao Yuan, Guan Jie

School of Environmental and Materials Engineering, Shanghai Polytechnic University, Shanghai, P.R. China

Email address
yuanhao@sspu.edu.cn (Hao Yuan)

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Abstract
Recycling of e-waste is increasingly recognized as an important strategy for resource management and resource efficiency. However, such recycling technology requires attention from an environmental perspective because it can release pollutants including volatile organic compounds (VOCs). In the case of the manual dismantling of a television printed circuit court using electric heating furnaces sixteen VOCs, with total concentrations ranging from 1.6×10^3 to 6.7×10^3 $\mu g/m^3$ could be identified. For the elimination of these VOCs an integrated treatment technique including spray tower (ST), electrostatic precipitation (EP), and photocatalysis (PC) were used. In this paper, we elaborates on the treatment technology of VOCs: physical method (masking, dilution, and diffusion), chemical method (chemical oxidation, photocatalytic oxidation, absorption, burning), adsorption method, biological method, and low-temperature plasma purification method. Finally, the study discusses the development trends in VOCs control technology and its potential applications. Realizing the current existing regulation related to VOCs emission in China cannot be reasonably used as control criteria for electronic product processing and manufacturing, which has led to severe pollution problem in certain area. As a result, by learning the China regulations system of air pollution control and analyzing the VOCs management scheme, the regulating situation for processing and manufacturing of E-waste recycling industry was assessed.

1. Introduction

Electronic waste refers to the use of abandoned electrical and electronic products. The world's annual e-waste about 20-5000 million tons, an average annual growth of about 4% [1, 2]. In view of the high potential profits, the annual removal and recovery of millions of tons of e-waste [3]; Thus, due to these processes, many volatile organic compounds (VOCs) are released into the atmosphere [4]. It is well known that prolonged exposure to VOCs in working and living conditions can lead to chronic health hazards such as cancer and the risk of non-cancer. In order to solve these problems, new technologies are needed to effectively reduce the risk of volatile organic compounds in the atmosphere and the risk of nearby e-waste treatment facilities.

Recently, advanced oxidation technologies (AOTs), including Fenton oxidation, photocatalytic oxidation, electrochemical oxidation, have been expected to become VOCs for emission reduction technologies [5]. In these AOTs, photocatalytic (PC) has been applied to the degradation of organic matter in view of its ability to generate strong and non-selective oxidant active substances [6]. In addition, VOCs with small molecular weight and high molecular weight can successfully photocatalyze under various conditions Degradation, indicating that PC technology has excellent non-selective ability to remove VOCs [7, 8]. However, this single processing technique has significant drawbacks, as photocatalyst deactivation may occur, leading to a decrease in PC activity.

To address these issues, researchers have developed a combination of biotechnology and PC technology (post or pretreatment) that can successfully eliminate volatile organic compounds to maximize synergies [9]. However, the use of microorganisms in biological systems requires a longer period of adaptation [10, 11]. Therefore, in order to achieve higher VOCs removal efficiency and reduce health risks, We sum up faster start-up time and high VOCs removal ability of alternative technology should be further developed.

2. Harmfulness of VOCs

VOCs (volatile organic compounds), which is volatile organic compounds, it refers to a class of saturated vapor pressure at room temperature greater than 70 Pa, atmospheric pressure boiling point of not higher than 260°C organic compounds [12]. From an environmental point of view, VOCs refer to gaseous organic matter that can cause environmental pollution. VOCs are mainly two kinds of hazards, one is a direct hazard, will stimulate the human and animal respiratory system, leading to respiratory disease, and many types of VOCs have carcinogenic, teratogenic, mutagenic effect; the other is secondary hazards, VOCs in the air will lead to some photochemical reactions, resulting in haze and photochemical smoke and other disasters [13].

3. VOCs Processing Technology

For VOCs treatment technology domestic and overseas, two methods are mainly used: recycling and elimination. Recovery technology generally refers to the application of specific temperature and pressure conditions by physical methods, separation of waste gas, and recycling [14]. Other methods include adsorption, condensation, and membrane separation. VOCs can also be eliminated using light, heat, catalysis, and the action of microorganisms (such as converting pollutants into low-toxic and non-toxic material), combustion, low-temperature plasma technology, photocatalytic oxidation, and biological methods [15].

3.1. Recycling Technologies

3.1.1. Masking Method

The masking method is one of the physical techniques of dealing with VOCs pollution. The technique usually uses a containing aromatic smell of gas mixed with target fetor, thus decreasing the foul smell small relative to the two other kinds of smell [16]. The method involves a simple procedure, low-cost, and can quickly reduce the stench in the affected environment; however, this method can only temporarily eliminate the influence of odorous compounds in its environment, and using a temporary solution does not provide a permanent cure [17].

3.1.2. Condensation Method

Condensation is the use of odorous pollutants under different temperatures with different saturated vapor pressure. The specific properties, with lower temperature, improve the system pressure. Thus, in gaseous pollutants (such as VOCs) condensate separation and exhaust gas [18]. The method is suitable for processing a large flow of exhaust gas and can achieve a high degree of purification; however, when gas flow is very small, further freezing measures have to be performed, and the running cost is greatly increased.

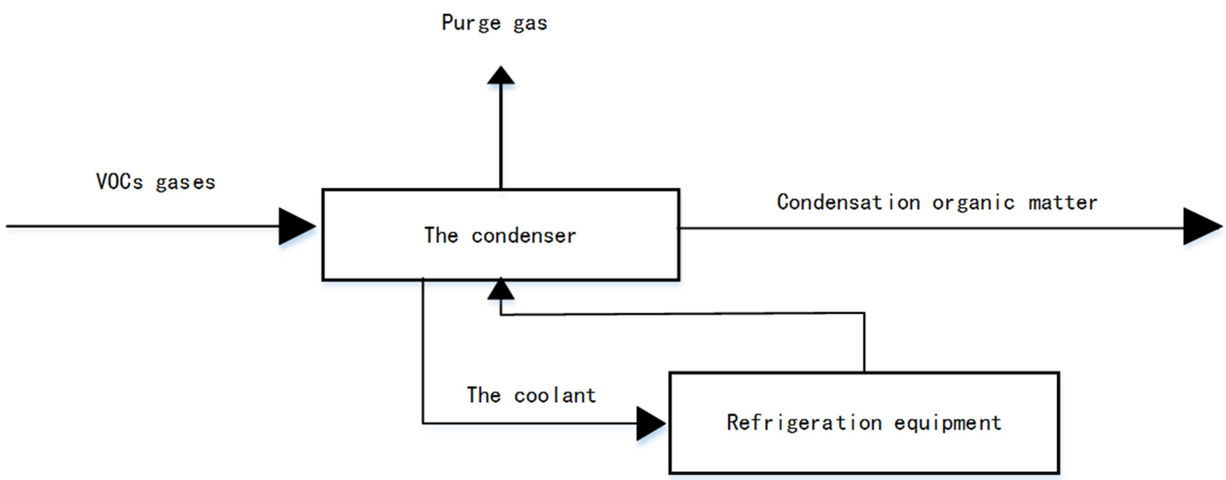

Figure 1. *Condensation system.*

3.1.3. Absorptive Method

Gas absorption is the transfer of solute from the gas phase to the liquid phase. It is the mass transfer process between the difficult to volatilize or volatile solvent absorption of gaseous pollutants from the air, using the difference in physical properties between organic molecules and absorbent separation control technology. Generally when odorous pollutants in water or other liquid solubility is greater, the absorption method can be used. Owing to its simplicity, the absorption technique has been widely used in air pollution control [19].

For certain specific absorption equipment, the selection of absorbent is a key determinant of the treatment effect of organic gas absorption. This is also a widely studied topic among researchers both locally and internationally. A suitable absorbent should have the following properties: (1) low cost; (2) stench in the absorber solubility; (3) stability and strong oxidation resistance is strong, low viscosity, no corrosion to equipment.

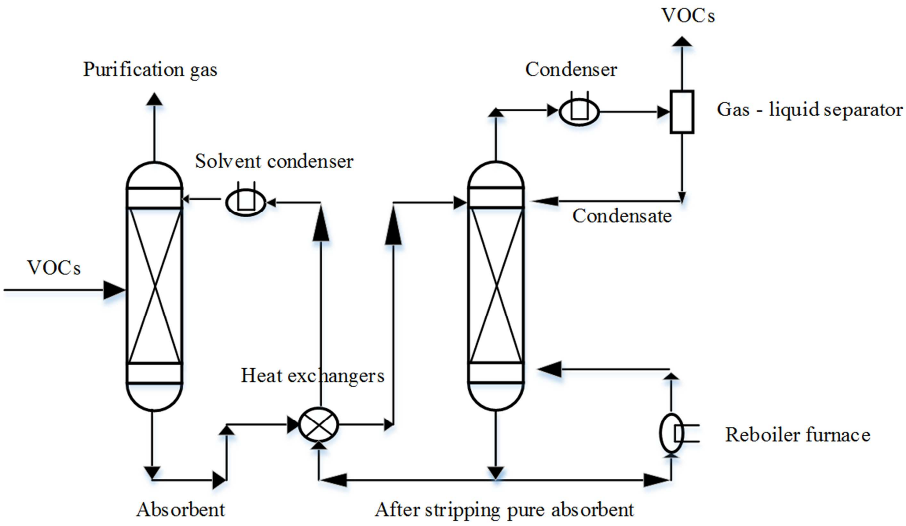

Figure 2. *VOCs absorption process.*

3.1.4. Adsorption Method

The adsorption method refers to the use of porous solid adsorbent adsorption technology in which one or several components is separated from other components. In the general process of removing harmful gas, using the adsorption technology can achieve a high removal efficiency. Compared with other processing technologies, adsorption presents more advantages, including good processing effect, simple equipment, easy operation, and small investment.. Currently, five major types of absorbents are widely used: activated carbon, silica gel, activated alumina, clay, and zeolite molecular sieve [20]. Activated carbon has a packing density, pore size distribution, specific surface area, chemical stability, and thermal stability that are more desirable than other adsorbents;; thus, it is the most commonly used adsorbent in the industry.

Activated carbon adsorbent, according to its shape characteristics, can be divided into powder, granular, and activated carbon fiber. Compared with activated carbon fiber, activated carbon largely differs in structure and its adsorption effect is better [21]. Japan is the first country to study and develop activated carbon fiber. Its large-scale production started in 1970, drawing interest from researchers worldwide. Currently, activated carbon fiber has become a highly researched subject in the modern world. Its development in our country started in 1980—that is, 10 years after the start of mass production—and since then has been applied in environmental protection and other fields.

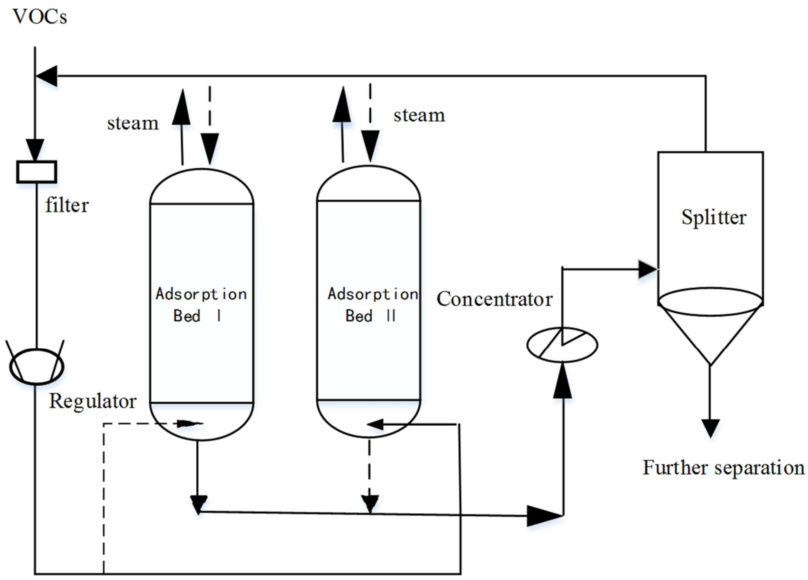

Figure 3. *VOCs Adsorption of Activated Carbon.*

One disadvantage of the adsorption method is that it quickly reaches adsorption saturation. therefore should time replacing adsorbent, or will be renewable adsorbent desorption, use again. Zouali of Xi'an University of Architecture and Technology investigated the adsorption of toluene on activated carbon and the microwave parsing process of active carbon. The results indicated that activated carbon exhibited good adsorption of toluene at microwave irradiation time of 45 min, desorption temperature of 400°C, and carrier gas velocity of 7.3 cm/s; in addition, it showed good desorption.

3.1.5. Membrane Separation

Membrane separation technology is a new separation technology developed in recent years. The basic principle is to use the stench and the abilities of the air through the membrane, driven by the pressure of components. However, the membrane transfer rate varies so that the components have to be selected to achieve separation. General exhaust after compressing and condensing first, again through the membrane component separation [22]. The key step in the membrane separation technology is the selection of membrane materials as the membrane structure significantly influences membrane separation. Membrane materials can generally be divided into symmetric, asymmetric, organic, inorganic, microfiltration, and ultrafiltration membranes, among others.

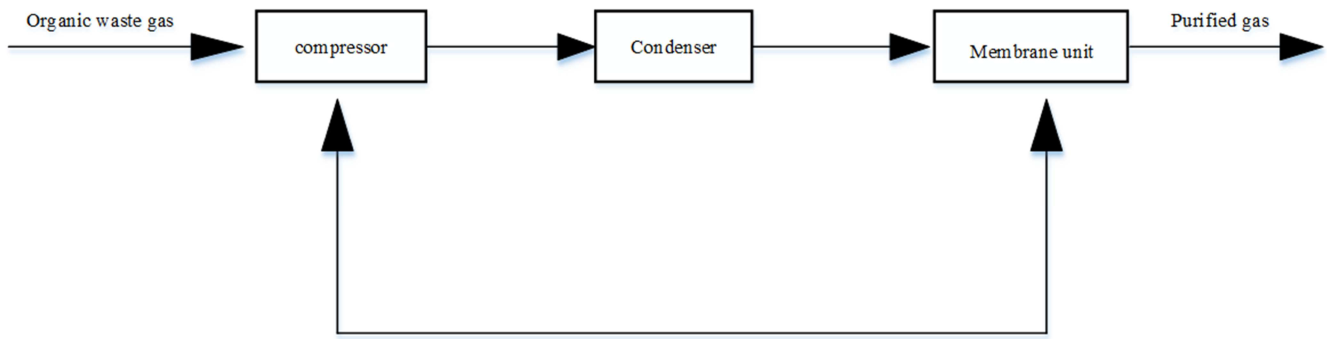

Figure 4. *Membrane separation technology.*

Membrane separation is suitable for the separation and recovery of high-concentration organic gas. Compared with other methods, membrane separation presents certain advantages, including high efficiency, energy economy, simplicity of the process, and high recovery rate; in addition, it does not easily cause secondary pollution. However, it also has disadvantages, such as high cost of film, short service life, and tendency to jam.

3.2. Eliminate the Technology

3.2.1. Chemical Oxidation Method

The chemical oxidation method involves the use of strong oxidants, such as ozone, potassium permanganate, hypochlorite, chlorine, chlorine oxide, and foul-smelling substances such as hydrogen peroxide oxide, which transform chemicals into odorless or mildly malodorous substances. In general, liquid-phase chemical oxidation can also be used in the gas phase, such as in the ozone oxidation process [23]. In chemical oxidation the removal rate of odorous pollutants can exceed 99%; however, the operation involves high costs of about 2 to 3 times that of the burning method.

3.2.2. Photocatalytic Oxidation

Photocatalytic oxidation in recent decades has developed into a new type of advanced oxidation technology in which ultraviolet light is combined with TiO_2 catalyst to degrade pollutants in the solution.

Fujishima used a TiO_2 electrode to study water photolytic decomposition. Frank started applying this technique to degrade the pollutants in the water. In the late 20th century, photocatalytic oxidation technology was applied to control exhaust pollutants [24]. Compared with other processing methods, photocatalytic oxidation is simple, easy to operate, can be used under the atmospheric pressure. The pollutants are decomposed into carbon dioxide, water, and inorganic small molecules. The technology processing tears methylene chloride, methane, and other organic matter has caused extensive concern from environmental workers.

Wan-Kuen Jo, studied the use of TiO_2 photocatalyst for the removal of benzene, xylene, and ethylbenzene in air. Results show that three benzene degradation rates were close to 100% [25]. J Disdie investigated the use of nanometer TiO_2 coated glass fiber processing under UV irradiation; desirable effects were obtained.

Although the existing research results obtained by Cui and Hua indicate that the optical oxidation technology processing pollutants showed a better effect and obvious advantages, many problems have yet t to be solved. These problems include ease of catalyst poisoning; the catalytic efficiency and light utilization rate were not high, recycling was difficult, and so on.

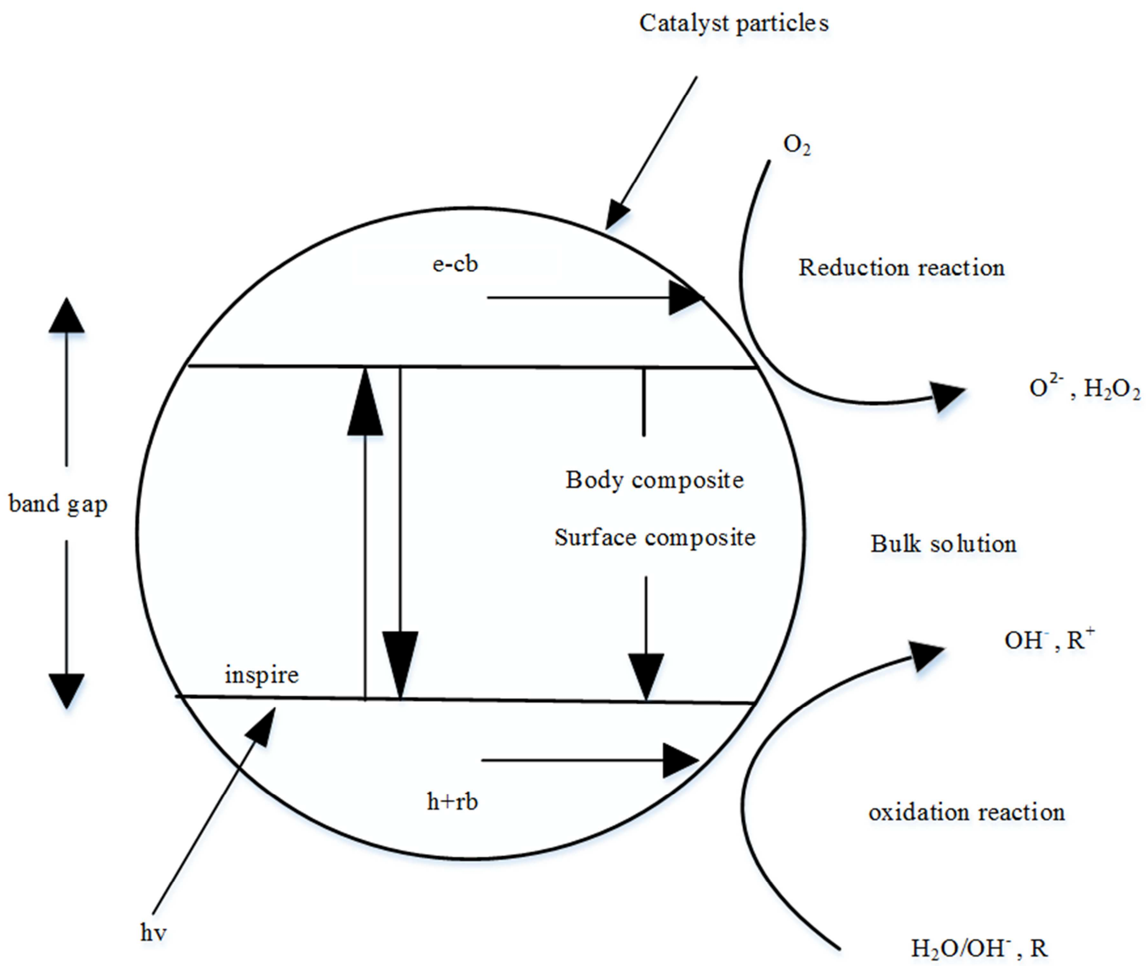

Figure 5. *Photocatalytic degradation.*

3.2.3. Combustion Method

Burning method is usually against harmful gas or smoke, use the method of burning them into low-toxicity or non-toxic substances. The combustion method is applied to purify combustible materials; high-temperature conditions can decompose harmful substances. Widely used industrial combustion method basically has three categories: direct combustion, catalytic combustion, and thermal oxidation [26].

Direct combustion method usually flammable harmful components from the exhaust gas as the fuel combustion directly. The method is suitable for treating of combustible component is larger, or a harmful components of high calorific value gas, because in the combustion, must ensure the temperature of burning area, this would require the harmful gas composition, released by burning calories can compensate the loss of heat, make continuous burning. When the exhaust gases at the same time there are two or more combustible gas, as long as the concentration of calorific value or has reached the requirement of direct combustion method, also can use this method. If the exhaust combustible component concentration higher than the maximum combustion, after can be mixed with air combustion; if below cut-off burning, can add right amount accelerant. Direct combustion usually needs to be controlled at about 1100°C; thus, the temperature of the combustion equipment generally includes a combustion furnace and a kiln. Direct combustion is not suitable for processing low-concentration gas.

Thermal oxidation is suitable for processing some combustible materials with small components or when the combustion exhaust gas has a low calorific value. Generally, combustion technique requires a special burning equipment and can also be carried out daily in the boiler. The process can be divided into the following three steps: (1) auxiliary fuel combustion provides the necessary burning heat; (2) mixing of waste gas with high-temperature gas before full access to achieve the required temperature; and (3) under the appropriate reaction and required temperature, control of waste gas with high-temperature gas contact time, harmful ingredients in exhaust oxidation decomposition to purify gas. This kind of gas often contains a small amount of combustible components in itself; thus, it cannot maintain combustion [27]. The technique often requires adding other fuels (such as coal gas, natural gas, etc.) or increasing the combustion temperature. The waste gas processing technique requires that the pollutants in oxidation be decomposed into CO_2, H_2O, N_2, and so on. Compared with direct combustion, thermal burning requires low temperature and can be carried out at temperatures ranging from 540°C to 820°C.

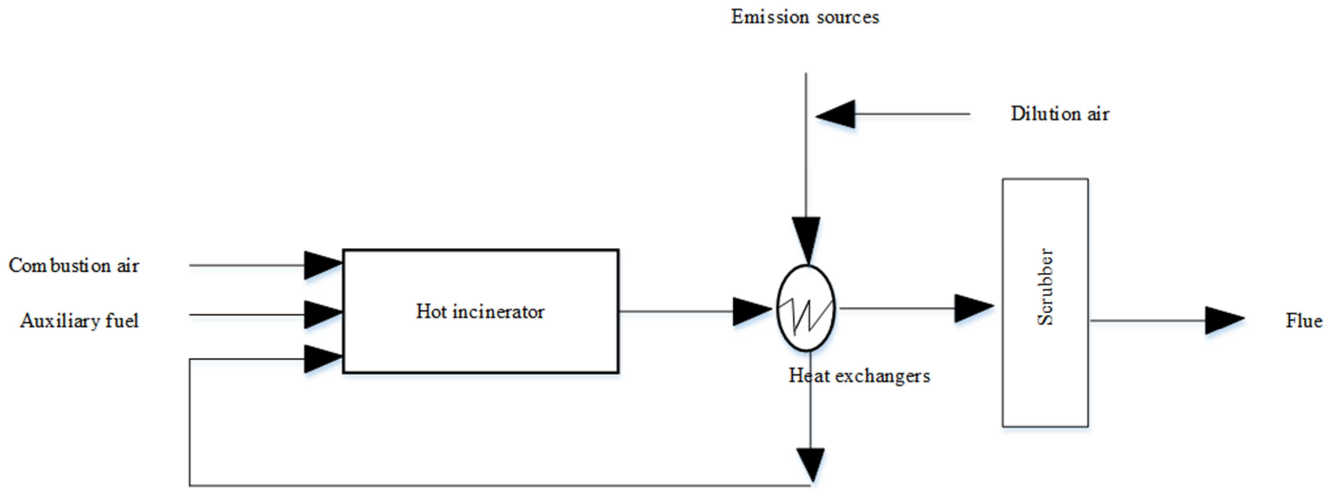

Figure 6. *Thermodynamic combustion.*

Catalytic combustion works under the action of a catalyst; it converts harmful exhaust combustible components that are completely oxidized into CO_2 and H_2O. Therefore, the process is also a type of complete catalytic oxidation. This method is more often used in printing and dyeing industries because exhaust emissions from materials with high organic matter content are advantageous for combustion. Compared with direct combustion and thermal oxidation, catalytic combustion presents more advantages: (1) in general, this method does not produce flame, unlike in direct combustion, thereby improving the safety factor; (2) the required burning temperature is low burning, and the reaction of hydrocarbons and carbon monoxide is completed between 300°C and 450°C; thus, less auxiliary fuel is needed; (3) the concentration of combustible components and calorific value restrictions; (4) little or no treatment of waste gas dust particles and droplets is needed to prolong the lifetime of the catalyst [28].

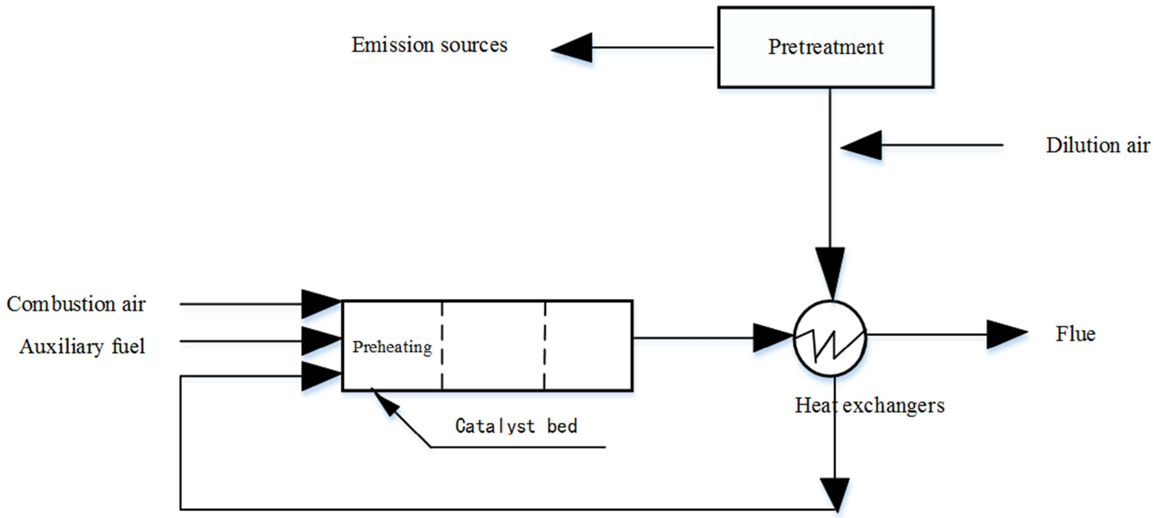

Figure 7. *Catalytic combustion.*

3.2.4. Low-Temperature Plasma Technology

Low-temperature plasma technology is to point to in under the action of high-voltage electric field, through the medium of discharge a large number of free electrons. Free electrons become high-energy electrons after a high-speed movement to gain energy and REDOX reaction with the organic pollutant molecules and to organic pollutants degradation, the purified gas. Low-temperature plasma technology mainly includes corona discharge, dielectric barrier discharge, discharge, and electron beam irradiation of microwave, among others.

In low-temperature plasma technology, the free electrons and ions exhibit high reactivity and high processing efficiency, produces less secondary pollutants, involves a simple process, and is suitable for large-flow, low-concentration organic waste gas treatment. However, the low-temperature plasma technology is still in its early stages of experimental research. Many issues have yet to be addressed, including the occurrence of a spark discharge under high voltage, electric breakdown, electrical clearance, and reduced treatment effect.

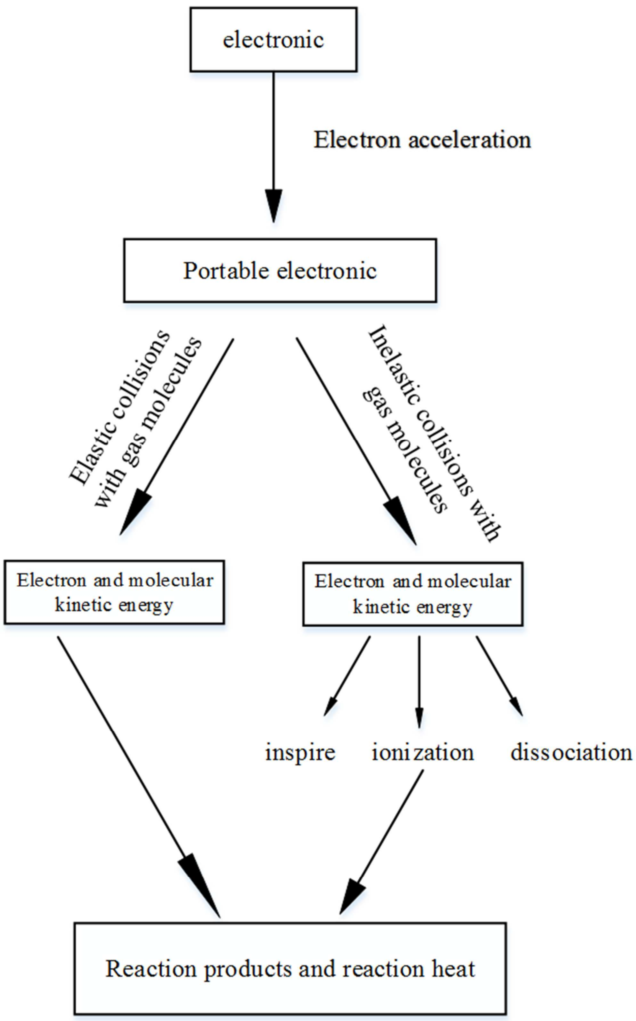

Figure 8. *Plasma energy transfer.*

3.2.5. Biological Method

The biological method of stench gas control was developed in 1950. A new processing technology, it applies the main principle that microorganisms can use organic components as growth factors. Through metabolic oxidation, foul-smelling substances can be converted into odorless and harmless end product (water and carbon dioxide, etc.). Gas emission occurs first, followed by a mass transfer process from the gas phase into the solid/liquid phase. solid/liquid phase can be effective degradation microorganism [29].

In 1970, extensive research in this field has been conducted worldwide, More studies have been reported on biological methods and treatment of H_2S containing ammonia and fetid amine. the achievements of the United States and Japan in the field are considered the most significant and influential. Ottengraf applied the theory of biofilms. The current development and applications of the most widely used biological reactor are mainly biological filter tower, biological filter, and biological scrubber.

Biological filter is a kind of biological reactor for sewage. Its interior is filled with inert filtration material and material surface growth biological community to deal with pollution. There is a single bed open and a filter bed enclosed. Gas moves from the top to the filter tower in the process, and the biological filter material is placed. The membrane contact vaccination is; and after purification, the gas is removed from the bottom. Kiki used xylene in a study of benzene waste gas treatment with biological filter. Results indicated that with xylene concentration of less than 800 $mg \cdot m^{-3}$, the xylene removal rate can reach 86%. The visible when processing object xylene concentration is low. The use of a biological filter can achieve a good degradation effect.

Biological scrubber usually consists of two parts: pool absorption tower and regeneration. In the actual operation, the circulating liquid sprays down from the top of the absorption tower, converting the pollutants from the gas phase into the liquid phase. The circulation fluid flowing into the regeneration of waste gas pool is absorbed and passed into the air with oxygen after regeneration. The absorbed gas through microbial oxidation is recycled in the pool. Activated sludge suspension dropped from the liquid phase becomes recycled [30]. Liu yh, etc by biological washing method containing phenol waste gas processing. The experimental results show that: long-term runtime phenol removal efficiency is about 97%, and the eliminated load is about 30 $g/(m^3 \cdot h)$.

The biological filter in the deodorization mechanism and process of the tower with a biological filter is roughly similar to that of the filter material. It cannot provide nutrients with commonly inert materials. Compared with that of the biological filter, the operating conditions of a biological filter tower are easy to control, and the buffer capacity and operating are is low. The biological filter is integrated with the absorption of the exhaust gas and liquid regeneration tower, tower packing., add attached microbial for microbial growth, the degradation of organic matter. American Huub H j.carol carroll deal with toluene with biological filter tower gas such as ox. The results indicate that at an inlet toluene concentration of 2300 mg/m^3, the toluene removal efficiency is about 60%. Yu-mei sun used the biological filter method to remove toluene and evaluated the effect of volatile organic waste gas. The experimental results suggest that when the inlet toluene concentration is 650–1000 mg/m^3, the load removed is from 24.0–to 38.6 $g/(m^3 \cdot h)$.

3.3. Prospect of Stench Pollution Treatment Technology

At present, the most advanced method of deodorization is biological deodorization. Along with the development of nanotechnology, and using the ratio and strong product, as well as the table and activity of nanometer materials, the effect of deodorization can be further improved [31]. With the combined adsorption and catalytic combustion technology, the concentration of foul-smelling substances can be improved by adsorption, desorption, can reduce exhaust quantity, reduce the volume of catalytic combustion equipment, make full use of calorific value of foul-smelling substances, and reduce energy consumption.

The stench pollution treatment method to use can be selected according to the source, concentration, properties and processing of foul-smelling substances. A particular treatment method or a combination of several processing methods may be applied. At present, the research focuses on the improvement of biological treatment technology, control of reactor operating conditions, and so on to develop more economical, efficient, and environment-friendly treatment technology. The future development trend and research directions include the study of pollutants in the biological process of pollutant mass transfer; efficient biodegradation of bacteria cultivation, domestication and analysis; microbial and environmental relations; reactor internal micro-ecological; development of more Combined process, thereby enhancing the ability to handle complex component gases.

4. Outlook

The purification of foul gas by biological methods has received extensive attention because of its environmental protection and effectiveness. At present, the biological treatment of VOCs problems and research progress mainly focus on the following points:

(1) High load, high air velocity conditions and performance of exhaust gas treatment

At present, the biological method has been successful in dealing with low concentrations of low-speed VOCs, high load, high air speed foul odor treatment. Few studies have been conducted on high load and high air speed foul odor. Research results show that the treatment effect is not ideal. It is necessary to improve the treatment process of odorous waste gas and obtain the optimum process conditions for dealing with high load and high gas velocity exhaust gas, including humidity, nutrition, temperature, and pH, among others, and improve the efficiency of mass transfer. Economically viable waste odor treatment has to be developed.

(2) Control of operating conditions

Temperature, humidity, pH, nutrition, and so on are the main influencing factors affecting the effectiveness of biological methods in purifying VOCs; these factors are important to improve the treatment effect of the system [32]. These operating parameters are not easy to control. Research on the application of the automatic control system has to be conducted to monitor and control these parameters so that the biological treatment of malodor in engineering applications will become feasible.

(3) Biodegradation of composite multi-component exhaust gas

The target of existing biological purification systems is often a single or several simple components. However, malodor is a complex contaminant consisting of a mixture of odoriferous substances. In the actual treatment of malodor, the exhaust gas is composed of complex multi-components, and the competition of each component inhibits the biodegradation of the malodorous exhaust gas, reduces the biological treatment efficiency, and is disadvantageous to the practical application of the biological method. In the future, it will be an important research direction to deal with complex multi-component VOCs emission.

(4) High efficiency colony screening

Biological deodorization plays a leading role in micro-organisms through domestication, separation, screening, and efficient deodorization strains to improve the efficiency of reactor-inoculated microorganisms. However, odor cannot be easily removed by biological treatment of organosulfur substances. At the same time, the biological treatment of H_2S and other malodors to room temperature conditions, low-temperature biological treatment of malodorous gases less, and the results of related studies that treatment is not good. Obtaining the dominant bacteria at low-temperature conditions can help to solve the problem of low biological treatment in winter in northern China.

(5) New biological treatment and the development of a new filler

A biofilter reactor can be efficient, stable, independent, and simple. However, not all malodorous gases are suitable for biological treatment, and solutions to this problem require a combination of treatments or the development of new treatment processes.

In addition, packing clogging, acidification is a common problem in long-term operation. The development of new packing is an effective measure for the further treatment of waste odor, which should focus on the large surface area, hydrophilicity, porosity, high strength, suitability for microbial growth, and reproduction of new packing and packing.

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