

Indoor Ozone Pollution and the Purification Technologies

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Abstract—An increasing number of air pollutants, like haze, arouse people's great concern about indoor air quality. Ozone is one of key factors influencing indoor air quality. In this paper, combined recent research on indoor ozone pollution at home and abroad, the sources of indoor ozone and indoor pollution were reviewed, and some current methods and technologies of ozone purification were discussed. Based on the above presentation, more efficient and practical multiphase thermal catalysts should be developed.

Keywords—indoor air quality; ozone pollution; purification methods

Air environment is one of the important human survival environment, People living and working in the indoor environment has reached 80–90% of the time throughout the day time, especially the elderly, children and sick people, therefore, indoor air quality is directly impact on people's physical and mental health [1]. Indoor air pollutants include CO, NO_x, O₃, VOCs, etc. [2], which ozone has a strong oxidation, which can be almost any object surface reactions, indoor ozone pollution comes mainly from the outdoor environment and indoor ozone sources (such as printers, copiers, etc.) [1, 3–7]. Exposure to ozone can cause respiratory disease, injury lung function, aggravated asthma, stimulate eyes, noses, weaken the body colds, and other diseases's resistance. Accelerate the aging of lung tissue [8–14]. Meanwhile ozone can react with indoor other chemicals to produce secondary pollution, greater harm to human health. Such as terpenes react with ozone to form ultrafine particles, formaldehyde, hydrogen peroxide, carboxylic acid and other substances, and more likely to stimulate the respiratory and cardiovascular systems [15]. Currently in the indoor environment ozone pollution situation and against the current ozone purification treatment methods and techniques discussed should be further noted that the development of more efficient and practical multiphase thermal and catalytic purification technology.

I. INDOOR AIR OZONE POLLUTION SOURCES

The type of air pollution in China is mainly of particulate matter, sulfur coal-burning pollution, in recent years, with the car ownership increase, nitrogen oxides, and hydrocarbons as the main pollutants automobile exhaust type pollution is gradually serious, ozone is by

nitrogen oxides and volatile organic compounds through a series of complex photochemical reactions important product. At high temperatures, strong sunshine, low humidity and calm wind conditions is the most violent reaction, therefore, ozone pollution problems have become increasingly prominent [1, 16].

Due to traffic congestion in urban areas, oxidized type air pollution problems gradually prominent, photochemical reaction is an important reaction of outdoor ozone formation. Leading to outdoor of near the ground ozone concentrations rises and forms photochemical smog, causing ozone pollution [1], with outdoor environment into the interior.

May be discharged to the indoor ozone the indoor appliances including ionizing type air purifier, negative ion generator and other air purifier equipments, copiers, laser printing equipment and other office equipment and the ozone generator and fault arc terminal devices and transformers [3–5]. U.S. EPA studies show that the incidence ozone of dry type copier is average 40µg/parts, up to 13140µg/copies, the ozone incidence of laser printer is average 43840µg/min. But good maintenance practices can reduce the amount of its ozone [6]; Bai Jing et al [17] found that electrostatic filter at rated wind usage may lead to indoor ozone concentration is increased 0.100mg/m³. Improper use of ozone generator ozone will also be a major source of pollution of the indoor environment, to indoor and outdoor ozone conduct tracer studies have shown that outdoor ozone is the main source of indoor ozone, indoor sources to the contribution of indoor ozone is limited.

Meanwhile, the concentration of indoor ozone is affected by ventilation, temperature, humidity and pollutants in room residence time and other factors [18]. In case of no indoor source, under moderate ventilation conditions indoor ozone concentration for the outdoor concentration about 20–30%; In the case of strong ventilation for about 40–70% [19].

II. DOMESTIC AND ABROAD INDOOR OZONE STANDARD

In recent years, as people focus on ambient air quality continues to improve, every country and every organization to indoor and outdoor air, the ozone concentration limit is also specified, as shown in Table I.

TABLE I. INDOOR OZONE CONCENTRATION RECOMMENDED BY SOME COUNTRIES AND ORGANIZATIONS.

Countries/ Organizations	Concentration Limits (mg/m ³)	Duration/h	Reference Source
China/National Standard	0.16	1	"Indoor air quality standards" (GB/T18883- 2002)
China/National Standard	0.10	1	"ozone in indoor air health standards" (GB/T18202- 2000)
World Health Organization WHO	0.12	8	WHO(1997)
Britain	0.20	8	Liu Jianguo, etc.; 2002 [20]
Japan	0.12	8	Liu Jianguo, etc.; 2002 [20]
Singapore	0.10	8	Liu Jianguo, etc.; 2002 [20]
Hong Kong	0.12	8	Liu Jianguo, etc.; 2002 [20]

As can be seen from Table I of the ambient air quality standards and indoor air quality standards were significantly lower than the standard requirements of other countries and organizations. Meanwhile, China lack of the ozone long-term exposure standards, such as 8h concentration limits. With the worsening environmental pollution, human health requirements should be strengthened of air quality requirements.

III. INDOOR OZONE POLLUTION STATUS QUO AT HOME AND ABROAD

The atmosphere near the ground in the background concentration of ozone in 0.04–0.08mg/m³, average 0.06mg/m³ around. Due to the presence of nitric oxide, urban areas 24 hours generally do not exceed background concentrations of ozone 0.12mg/m³, indoor ozone pollution of various countries and regions are also inconsistent. Summer in North America and Germany's clean area of 7 hours daily average concentration is 0.02–0.05ppm, America's highest-hour average concentration in 0.12–0.20mg/m³; In the Netherlands different urban areas 8-hour average max value 0.20–0.35mg/m³ [16]; 2008 Shanghai, the maximum daily ozone near the ground 8h annual average of 88μg/m³, which the urban is 78μg/m³, City suburb of 96μg/m³[9]; 2006-2008 Suzhou City, the largest concentration of ozone 1 hour, 8-hour average concentration and maximum 24-hour average concentrations were 77.4μg/m³, 57.7μg/m³, 35.7μg/m³ [10]. With car ownership has increased steadily worsening air pollution, ozone pollution problems will be the focus of attention.

In general, indoor and outdoor ozone concentration of ozone concentrations in the region is closely related to outdoor ozone pollution is worsening also makes indoor ozone pollution cannot be ignored [16].

BaiYuhua et al. [21] in1997 monitoring Peking University residential and public places indoor and

outdoor ozone concentration, Indoor ozone between 0.006-0.12mg/m³, outdoor ozone is 0.07-0.14mg/m³, overall, indoor outdoor concentrations of ozone concentration equivalent to 40–80%.

IV. INDOOR OZONE POLLUTION ON HUMAN HEALTH HAZARDS

Ozone exposure (ozone exposure), that is, the concentration of ozone in this ozone concentration multiplied by the residence time, to indicate the amount of ozone applied to the human body, even under normal circumstances, indoor ozone concentration is lower than outdoor ozone concentration, However, due to the indoor time of people is almost of the total time 80–90% , indoor ozone exposure is a major portion of the whole ozone exposure [16]. ozone olfactory threshold is 40μg/m³, when the ozone concentration is less than 100μg/m³, had no effect on measurement of concentration, when the concentration of ozone in the 200–300μg/m³, the susceptible person eye, nose and pharynx mucosa irritation, when the ozone concentration in 300–400μg/m³, less than 30 percent of residents in the mucous membrane irritation, 15% of residents forced expiratory volume in 1 second decline, when the ozone concentration is greater than 400μg/m³, 50% of residents have a stimulating effect, and 25% of the population will one second biggest decline in respiratory gas [22].

At the study of the relationship between ozone short-term exposure and the risk of death in 95 urban communities of United States.

Bell et al. [23] use a variety of concentration measurement. The results showed that the concentration of each additional day 5.1μg/m³ (10ppb), 8h daily concentrations for each additional 7.65μg/m³ (15ppb) and 1h per day increased concentrations 10.2μg/m³ (20ppb), Population the risk of death increased respectively by 0.52% (95%CI: 0.27–0.77%) , 0.64%(95%CI: 0.41–0.86%), 0.67% (95%CI: 0.42–0.92%) . Charles J. Weschler et al. [24] survey America California 600 households, the result showed indoor ozone exposure 1.25 times greater than outdoor. U.S. EPA survey LA 45 households Inhabitation, the indoor ozone concentration was 38% outdoor. Indoor ozone exposure is calculated exposure 1.7 times greater than the outside, a combination of factors, indoor ozone exposure can easily reach the outdoor ozone exposure 3–4 times, the indoor environment of ozone on human health hazards cannot be ignored.

V. OZONE PURIFICATION METHODS AND TECHNIQUES

The ozone which is being in the upper atmosphere is beneficial substances, but when near the ground, ozone's strong oxidizing will produce great harm, for humans and environment It is not only to the human respiratory system and other organisms have a greater harm, but also an important component of urban photochemical smog. The ozone action of threshold concentration that can cause the changes of body's sensitivity to physiological

and biochemical index and people symptoms index is about 0.10–0.14mg/m³. When indoor environment ozone concentration is 0.2mg/m³ above, it will cause harm to humans [25]. So treating ozone, to decompose into harmless substances is very important. The current ozone purification methods include atmospheric ozone purification dilution method, activated carbon adsorption method, catalytic thermal decomposition method, photocatalytic decomposition method [26–30], as shown in Table II.

TABLE II. CURRENT METHODS OF OZONE PURIFICATION.

Technical Methods	Atmospheric Dilution	Activated Carbon Adsorption	Catalytic Decomposition
Principle	Introduction of outside air through the ventilation equipment	Activated carbon adsorption	Catalytic decomposition of ozone
Feature	Lower equipment costs, but if the outside air is contaminated indoor air environment will produce more serious consequences of pollution	Simple and convenient, but it is easy to lose activity of activated carbon, require frequent replacement or regeneration	High decomposition rate, long-term stability, but higher costs

Study of ozone purification are more concentrated in multiphase heated catalysis, relatively few studies of ozone in the photocatalytic elimination, The main catalyst is a manganese-containing catalysts (e.g., MnO₂, MnCO₃, ozone decomposition catalyst), the catalyst containing a transition metal oxide (iron oxide, cobalt oxide, nickel oxide and the like), a catalyst containing a noble metal (Pt, Pd, Rh, etc.), titanium-containing catalyst (titanium silicon oxide, titanium manganese oxides, titanium silver manganese oxides, titanium zirconium oxide, platinum titanium silicon oxide etc.) [27].

Ohtani et al. [31] studied the hot catalytic and photocatalytic decomposition of ozone of different TiO₂ that found after irradiation, ozone decomposition rate is greatly improved and rutile TiO₂ active higher than other crystalline phases. For the semiconductor photocatalyst, metal particles deposited on the surface of the semiconductor light absorption efficiency and the efficiency of the photocatalytic semiconductor can be improved. Liu Dechen et al. [32] took single and double transition metal oxide supported on granular activated carbon, the result show that double metal oxide catalysts, and have a better effect for ozone decomposition.

VI. CONCLUSION AND PROSPECT

(i) The standard of China indoor air quality significantly lower than the standard requirements of other countries and organizations, simultaneously lack of

ozone long-term exposure standards (e.g., 8h concentration limits), with the growing problem of indoor ozone pollution, in order to improve ambient air quality of people's lives standard limits should be promptly revised, providing technical guide for indoor air pollution control.

(ii) Study of ozone purification are more concentrated in multiphase heat catalysis. The catalyst used comprises manganese catalyst, transition metal oxide containing catalysts, noble metal-containing catalysts, titanium-containing catalyst etc., most are staying in the laboratory research stage. Production applications into the market there are still some difficulties. Therefore, that further research into more efficient purification technology, utility and economy to solve the problem of indoor ozone pollution is indeed.

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