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Journal of Inorganic Chemistry and Materials, 2025, 1(1), 16-20
https://www.hillpublisher.com/journals/jicm/
ISSN Online:

Application of Low-temperature Oxidation and Denitrification Technology in Domestic Waste Incineration

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How to cite this paper: Shiqi Zhu. (2025). Application of Low-temperature Oxidation and Denitrification Technology in Domestic Waste Incineration, *Journal of Inorganic Chemistry and Materials*, 1(1), 16-20.
DOI: 10.26855/jicm.2025.12.004

Received: September 6, 2025
Accepted: October 7, 2025
Published: December 19, 2025

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Abstract

With the continuous improvement of people's living standards, the output of household garbage is also more and more. At present, garbage incineration is one of the main treatment methods of household garbage. Under the promotion of environmental protection policies, nitrogen oxides produced by waste incineration have become the focus of air pollution control. Nitrogen oxides are an important part of air pollutants, which seriously harm people's health.

Keywords

Household garbage; Incineration treatment; Low temperature oxidation denitrification technology

1. Introduction

Currently, Chinese cities primarily use three methods for waste disposal: incineration, landfilling, and composting. Municipal solid waste incineration primarily utilizes the heat generated by combustion to fully burn and oxidatively decompose the organic and inorganic substances contained therein. However, incineration of municipal solid waste produces large amounts of pollutants such as dust, dirt, and acidic gases, which can cause certain environmental pollution. Other methods of treating municipal solid waste, due to its typically high water content and low calorific value, and the rapidly increasing waste production, will result in waste of land resources and environmental pollution.

2. Current Status of the Application of Oxidation Denitrification Technology in the Incineration of Municipal Solid Waste

Since my country joined the WTO, China's waste incineration industry has developed rapidly. As of the end of 2020, there were 463 waste incineration power generation projects in my country. With the increase in waste incineration projects, the secondary pollution problem in waste incineration has gradually attracted people's attention, especially the secondary pollution problem of nitrogen oxides. NOx is not only the source of acid rain, but also seriously harms people's lungs and causes photochemical smog. In order to control nitrogen oxides so that they do not cause environmental pollution, it is necessary to remove them from the combustion flue gas. This process is called denitrification.

There are many mature denitrification processes at present, and each process has different characteristics. For example, selective catalytic reduction (SCR denitrification) is suitable for large coal-fired boilers, while selective non-catalytic reduction (SNCR denitrification) is the preferred method for CFB boilers and is relatively more

Note: The article was originally published in *Advances in Resources and Environmental Science*, and this is an authorized translation of it.

economical. In addition, many units are not suitable for the first two methods, but there is also ozone oxidation denitrification as an option [1]. The characteristics of the above three processes are compared below, see Table 1.

Table 1. Comparison of the characteristics of the three processes

Project	Ozone denitrification	SNCR denitrification	SCR denitrification
Basic principles	Ozone is used to oxidize nitrogen monoxide, making it soluble and then absorbed and removed by alkaline slurry in the downstream scrubber.	Using ammonia as a reducing agent, nitrogen oxides are reduced to nitrogen and water at temperatures between 850°C and 950°C.	
Major equipment investment	Oxygen production equipment and supporting power supply equipment	Includes ammonia station, atomizing spray gun and metering module	Including ammonia station, ammonia evaporation system and SCR reactor
Reducing agent/oxidizing agent	O_3	Ammonia, urea	Liquid nitrogen, ammonia, urea
Denitrification efficiency	≥95%	CFB furnace 60%, other furnace types have lower efficiency	≥80%
Reaction temperature	≤190 degrees Celsius, the lower the temperature, the better the effect	850°C to 950°C	300 degrees Celsius to 420 degrees Celsius
Catalyst	none	none	Full-size catalysts mainly composed of TiO_2, V_2O_2 to WO_3
Reductant/oxidant injection position	Scrubber inlet	CFB furnace cyclone inlet	Mostly choose the flue between economizer and SCR reactor
SO_2 /SO_3 oxidation	Very small amount of SO_2 /SO_3 oxidation	Does not cause SO_2 /SO_3 oxidation	Relatively more SO_2 /SO_3 oxidation, the oxidation rate is controlled below 1%
Ammonia slip	none	≤10PPM	≤3PPM
Renovation content	1. Build a new ozone equipment room and liquid oxygen station; 2. Install an ozone reactor	1. Build a new denitrification agent production and storage station; 2. Install a spray gun on the boiler opening.	1. Build a new denitrification agent production and storage station; 2. Renovate and build some boiler flues; 3. Build a denitrification reactor; 4. Replace the low-temperature air preheater to prevent corrosion of the air preheater
Impact on boiler air preheater	none	At low temperatures, NH_3 reacts with SO_3 to produce NH_4HSO_4, causing blockage of the air preheater.	
Fuel requirements	none	none	Ash-abrasive catalysts; Metal oxide-passivated catalysts;
Impact on system pressure loss	none	none	System pressure loss 800Pa to 100Pa
Impact on boiler operation economy	none	The loss of thermal efficiency is small, but the amount of ammonia leakage is large, which has a greater impact on the equipment.	The loss of boiler thermal efficiency is small, which causes the resistance to increase and the power of the induced draft fan to increase.
Service life	Ozone equipment can be guaranteed to avoid major problems within ten years	Mainly affects the service life of the boiler	The service life of the catalyst is 2 to 3 years. Regular replacement
Construction investment	Larger	Smaller	big
Operating costs	Higher, the main cost is the production of ozone	Smaller	High, mainly due to denitrification agent costs, catalyst depreciation, and induced draft fan power consumption
Application performance	More	many	many

Table 1. Continued

Project	Ozone denitrification	SNCR denitrification	SCR denitrification
Difficulty of transformation	Easy, does not affect the normal operation of the boiler	Easier, requires a short stop to open the furnace and install the spray gun	Difficult, requiring shutdown and renovation
Construction period	short	short	Longer
Site requirements	The ozone generator and liquid oxygen station can be set up in other open spaces respectively, with low site requirements.	Takes up no additional space except for the absorbent storage area	It needs to occupy the area between the boiler tail and the dust collector, which requires high

This article mainly discusses the ozone denitrification method. The ozone oxidation denitrification method has the following advantages:

(1) The product operates stably and reliably, does not require anti-corrosion during each overhaul, and has low maintenance costs;

(2) The desulfurization efficiency is over 95%, and the absolute concentration of high-sulfur flue gas can be controlled below 100mg/Nm3. The denitrification removal rate can be set by itself, and the low-temperature ozone denitrification process can accurately reach 50mg/Nm3;

(3) Desulfurization and denitrification share the same absorption tower, which can reduce equipment investment and construction space;

(4) The desulfurization and denitrification process after dust removal does not affect the system operation, avoids internal blockage, and does not affect the operating life, which is conducive to the stable operation of the entire system;

(5) After the desulfurization and denitrification liquids are separated into solid and liquid, the solid matter can be used and the liquid matter can be used to prepare fertilizers. Through the recovery and treatment of the desulfurization and denitrification liquids, the goal of zero emission and resource utilization can be achieved.

The process of ozone oxidation denitrification can be briefly described as follows: The flue gas sent out by the boiler dust collector is about 150 degrees Celsius. The ozone mixer evenly sprays high-concentration ozone into the flue gas mixing device to react with NOx to generate high-order nitrogen oxides that are easily soluble in water, and then enters the washing device for washing and removal. After washing, the wastewater is pumped to the deacidification tower through the slurry discharge pump to evaporate and crystallize together with the lime slurry and then removed, achieving zero wastewater discharge. The technical advantages of using ozone denitrification in municipal solid waste incineration are as follows:

The fuel composition of municipal solid waste incinerators is complex, and ozone oxidation can remove multiple pollutants more synergistically than other pollutants. This method has the following important technical advantages:

(1) It is independent of the combustion process and can be used for various types of flue gas, as long as the flue gas conditions are below 200 degrees Celsius and the required reaction time is sufficient.

(2) It is suitable for low-temperature flue gas treatment and has no effect on combustion and equipment operation.

(3) It can achieve the synergistic removal of various pollutants such as SO2 and dioxins, and remove multiple pollutants in one tower.

(4) It can achieve a denitrification rate of more than 90% and will not cause secondary pollution such as ammonia leakage.

(5) It can achieve zero discharge of denitrified wastewater.

(6) The installation of auxiliary components is all additional equipment, which has little impact on boiler operation and is convenient for future system upgrades to meet ultra-low emission requirements.

3. Principle of Low-temperature Ozone Oxidation Denitrification Technology

To understand the technical principle of ozone denitrification, you need to first understand ozone [2]. Ozone is an extremely unstable allotrope of oxygen with strong oxidizing properties. It can undergo oxidation reactions at low temperatures. It can remove chemical components such as SO2 and nitrogen oxides, and can also purify, disinfect, bleach and deodorize. Ozone is an oxidant without secondary pollution. After decomposing chemical substances, it is reduced to oxygen. Ozone can effectively prevent nitrogen oxide pollution.

The ozone generator can produce ozone in a quantitative manner on site according to the oxygen demand, and then spray it into the flue gas through the ozone grid to react with insoluble nitrogen oxides to produce soluble nitrogen oxides. The ozone generator can also reflect detailed data in a timely manner during the production process, which is conducive to controlling the emission of nitrogen oxides in the flue gas and saving energy at the same time.

The NO is treated with ozone and then sent to the desulfurization tower. There, nitrogen dioxide, nitrogen pentoxide, and other nitrogen oxides quickly come into contact with the alkaline solution, forming nitrates and other substances. These are then sent to the desulfurization treatment equipment along with the desulfurization reaction products. Ozone reacts quickly with nitrogen oxides, providing a degree of operational flexibility. By controlling the time and amount of ozone, the internal oxidation reaction can be controlled, reducing ozone utilization and improving efficiency.

When a large amount of ozone is supplied, NOx is oxidized to nitrogen pentoxide, which then produces nitric acid or nitrates. The basic reaction equation is as follows:

$NO+O_3 \rightarrow NO_2+O_2$

$2NO_2+O_3 \rightarrow N_2O_5+O_2$

$N_2O_5+H_2O \rightarrow 2HNO_3$

Both nitrogen pentoxide and nitric acid are readily soluble in water. Nitrogen pentoxide reacts with water to form nitric acid, which can be mixed with water in any proportion. Therefore, the conversion of nitrogen pentoxide to nitric acid in the presence of water is irreversible.

To ensure economic benefits in actual projects, NOx is typically oxidized to NO2, followed by an acid-base neutralization reaction in a desulfurization tower to produce nitrite. For example, in a wet ammonia desulfurization process, the chemical reaction is as follows:

$NO+O_3 \rightarrow NO_2+O_2$

$2NO_2+2NH_3 \cdot H_2O+1/2O_2 \rightarrow 2NH_4NO_3+H_2O$

In fact, it is not necessary to completely remove all nitrogen oxides in haze. Ozone can be added quantitatively according to the concentration of nitrogen oxides in haze and environmental protection requirements. This helps meet environmental protection requirements while ensuring operational economy.

The denitrification system used in this method can greatly suppress NOx emissions and meet emission reduction requirements. It does not convert sulfur dioxide into sulfur trioxide, and the particulate matter and sulfide contained in the flue gas produced by waste incineration have no effect on ozone depletion and denitrification. This system can not only efficiently remove nitrogen oxides from waste gas, but also effectively remove sulfur dioxide, dust, etc. [3].

4. Components of an Ozone Oxidation Denitrification System

The ozone oxidation denitrification system primarily consists of an ozone production and storage system, an ozone grid, an instrument collection and detection control system, a denitrification scrubbing reaction system, and auxiliary safety systems.

4.1 Ozone Production and Storage System

With the widespread use of ozone in industry, existing ozone production, storage, and transportation technologies have become quite reliable. Ozone is typically produced on-site using an ozone generator, which is safe, reliable, and ensures long-term stable operation.

The main structural components of an ozone generator include a generator, a discharge tube, an electrochemical energy storage circuit, and a high-frequency, high-voltage power supply. Inside, there is a glass tube containing electrodes connected to the power supply. When a large current flows through the plasma discharge tube, a strong corona is generated in the surface electrolyte. When oxygen passes through the surface, oxygen molecules release oxygen atoms, which then combine with available oxygen molecules to produce ozone. Ozone does not escape into the environment and is completely consumed in the nitrogen oxide removal process, thus minimizing environmental impact.

4.2 Ozone Grid (Ozone Distribution Diffusion Reaction System)

Produced ozone is continuously and uninterruptedly delivered to the ozone distribution diffusion reaction system through a uniformly distributed distributor, where it enters the continuous nitrogen oxide flue gas reaction system. The ozone grid ensures uniform ozone distribution and sufficient mixing, accelerating the reaction rate.

The key to the entire denitrification system is ensuring that ozone is evenly distributed within the distributor and fully reacts with nitrogen oxides in the flue gas generated by waste incineration. To ensure the denitrification efficiency of the reaction system, computational fluid dynamics simulation of the system is required in advance. Based on the numerical simulation results and the actual engineering application, the system structure design is adjusted to optimize system performance [4-5]. Flow field simulation software commonly used in engineering projects includes ANSYS, and generally simulates the operation of the project under different operating conditions.

When designing ozone screens, it's important to note that ozone reacts very quickly. It can be assumed that the reaction occurs immediately upon injection and contact with NO. Therefore, when designing the ozone denitrification system, we aim for the most precise design possible to ensure uniform injection.

4.3 Instrumentation, Data Acquisition, and Control System

The instrumentation, data acquisition, and control system utilizes PLC control and a human-machine interface. It performs online monitoring and analysis of various components in the flue gas generated by municipal solid waste incineration, sampling the system's production based on flue gas flow and nitrogen oxide concentration.

4.4 Denitrification Scrubbing Reaction System

Denitrification scrubbing systems typically utilize a wet alkali desulfurization absorption unit. After oxidation, NOx-containing exhaust gas can be directly fed into a wet desulfurization unit, where the scrubber absorbs the high-level nitrogen oxides. This direct absorption process offers high reaction efficiency, is pollution-free, and a large amount of salt generated by the reaction can be recycled into the recycling system.

4.5 Auxiliary Safety Systems

As a toxic gas, the permissible ozone concentration is 0.1 ppm. At a concentration of 0.3 mg/m^3, it can irritate the human senses, such as the eyes and respiratory system. At concentrations between 3 and 30 mg/m^3, symptoms such as headaches and partial paralysis of the respiratory system may occur. Concentrations between 15 and 60 mg/m^3 are harmful to human health. Since its discovery in the 19th century, ozone has been widely used. Because its odor is so strong and easily detectable, no one has died from ozone poisoning to date.

5. Low-temperature Oxidation Denitrification Work Requirements

The technician is the primary safety officer for this position, responsible for on-duty safety and ensuring the proper operation of the denitrification system. Technicians must strictly adhere to safety procedures and regularly check all major components, instruments, sound levels, and oil levels during equipment operation, promptly reporting and addressing any problems. Technicians should conduct regular inspections, conduct thorough and detailed inspections, make regular and dynamic adjustments, and promptly complete records related to automated operations. Technicians should strictly rotate positions and carefully inspect departmental work. Technicians must be familiar with the firefighting equipment in their assigned positions and actively participate in hazard prevention efforts. When encountering a dangerous situation, technicians must implement preventive measures to prevent further accidents and record any such incidents with the team leader and the on-duty supervisor. Technicians must diligently participate in safety training and activities organized for their work, enhance their safety skills, and regularly undergo emergency response training to strengthen their response capabilities.

6. Conclusion

This article discusses the application of low-temperature oxidation denitrification in municipal solid waste incineration in detail, comparing the characteristics of three common denitrification processes. It focuses on ozone denitrification, introducing the basic principles of this technology and its main components. In summary, low-temperature ozone oxidation denitrification has enormous research potential, possesses unique process advantages for denitrification at low temperatures, and offers broad application prospects.

References

[1] Hu HX, Lin CJ, Lu JC. Research on the application of denitrification technology in waste incinerators. Energy Conserv. 2020;(11):39. (In Chinese)

[2] Hou CJ, Tian JL, Wang Q. Application of ozone oxidation denitrification technology in sintering flue gas. Hebei Metall. 2019:71-4. (In Chinese)

[3] Ji RJ, Xu WQ, Wang J, et al. Research progress of ozone oxidation denitrification technology. J Chem Ind Eng. 2018:24-34. (In Chinese)

[4] Zhang YY, Ruan DN, Hu FL, et al. Application of dry denitrification technology in municipal solid waste incineration power plants. Clean World. 2021;37(10):4. (In Chinese)

[5] Wang XM. Discussion on denitrification technology of municipal solid waste incinerators. Environ Dev. 2020;32(9):2. (In Chinese)