Purification System of Domestic Waste Incineration Flue Gas

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Abstract. Flue gas will be emitted during the waste incineration power generation process. The flue gas contains toxic and harmful ingredients. If it is not treated, it will cause serious harm to human health and the environment. Therefore, the incineration flue gas needs to be purified. In this paper, combined with the monitoring of a large-scale waste incineration power plant incinerator flue gas purification treatment project, the combined process of "in-furnace denitrification (SNCR) + semi-dry deacidification + slaked lime and activated carbon (dry process) injection + bag filter". The purification effect of flue gas shows that the process has a good purification effect on domestic waste incineration flue gas. This study can provide reference and basis for the treatment of incineration flue gas in the industry.

1. Introduction
The technology of waste incineration power generation is a new development trend in the field of urban domestic waste disposal in recent years. Compared with the traditional landfill method, the technology of waste incineration power generation has a small footprint, a short treatment cycle, can be processed in large quantities, is harmless, Realize the advantages of resource recycling and so on [1-2]. Waste incineration power generation will emit flue gas, which will contain toxic and harmful components, such as heavy metals; SO₂, HCl, HF and other acid gases; and dioxin. Dioxin is carcinogenic, teratogenic, mutagenic toxic substances [3-4]. If the flue gas is discharged without treatment, it will pose a major threat to the surrounding environment and human health. Therefore, it is necessary to purify the flue gas emitted from the waste incineration power generation process to achieve ultra-low emissions. This paper combines the monitoring of the incinerator flue gas treatment project of a large-scale waste incineration power plant, and studies the waste gas incineration power plant incinerator flue gas treatment situation to provide a certain reference and basis for the treatment of waste gas incineration power plant.
2. Flue gas purification process

2.1. Flue gas purification process
In order to ensure that the flue gas pollutants are discharged up to standard, the waste incineration power plant adopts a combined flue gas purification process of “SNCR + Semi-dry deacidification + Slaked lime and activated carbon (dry method) injection + Bag filter”. Each boiler is equipped with a set of flue gas purification system, which is located behind the waste heat boiler. A rotary spray reaction tower, slaked lime and activated carbon injection system, semi-dry deacidification system, mixer, bag filter, chimney and smoke are arranged in turn. The gas is purified in each process in turn, and finally discharged to the standard. The specific process flow chart is shown in Figure 1 below.

![Flue gas purification process flow chart](image)

**Figure 1.** Flue gas purification process flow chart

2.2. Main process principle

2.2.1. SNCR denitrification. The SNCR denitrification system sprays ammonia water with a concentration of about 10% into the incinerator after being compressed and atomized for denitrification. The suitable temperature range of SNCR denitrification reaction for ammonia is 850 ~ 1100 °C, the actual denitrification efficiency is 30 ~ 50%, and the fine distribution of ammonia water droplets in the corresponding temperature window area in the furnace is an important factor affecting the performance of the system.

2.2.2. Semi-dry deacidification. The semi-dry deacidification process is a slurry digested with lime and water, atomized by an atomizer and sprayed into the reactor to react with acid gas. The semi-dry deacidification system includes: pulping system, reaction tower system and control system. The lime slurry preparation system rotates the conveyed lime slurry (concentration about 15%) at high speed in the sprayer, sprays it into the reaction tower in the form of mist, and at the same time sprays into the temperature-regulated water to remove the acid gas in the flue gas. The reaction equation is as follows:

\[
SO_2 + Ca(OH)_2 = CaSO_4 + H_2O \quad (1)
\]

\[
2HCl + Ca(OH)_2 = CaCl_2 + 2H_2O \quad (2)
\]

\[
2HF + Ca(OH)_2 = CaF_2 + 2H_2O \quad (3)
\]

2.2.3. Slaked lime and activated carbon injection. Since waste incineration tail gas usually contains a certain concentration of dioxins and heavy metals, before the flue gas enters the bag dust collector, spray limestone and activated carbon powder into the mixer. After entering the dust collector, these activated carbon powders are also trapped on the surface of the bag. When the flue gas passes through the bag,
the dioxins and heavy metals in the flue gas are adsorbed by activated carbon and slaked lime to be purified.

2.2.4. Bag filter. Flue gas enters from the outside of the filter bag and is discharged from the top of the compartment. The dust, neutralizers and products generated by garbage incineration, condensed heavy metals, and sprayed activated carbon are all attached to the surface of the filter bag to form filter cake and smoke. The acid gas also reacts with excess reactant here, so that the acid gas removal efficiency is further improved. The activated carbon also further adsorbs on the surface of the filter bag, which not only ensures dust removal, but also de-acidification and slaked lime and activated carbon with semi-dry front end The combination of injection system is conducive to further deacidification, adsorption and removal of heavy metals and dioxins, and the purified flue gas is discharged through the chimney.

3. Study on the results of flue gas treatment

3.1. Smoke source and composition analysis
Domestic waste includes waste paper, plastic waste, waste rubber, kitchen waste and other types of waste. Garbage contains elements such as carbon, chlorine, sulfur, and nitrogen. The flue gas discharged during the pyrolysis and gasification of garbage mainly includes conventional pollutants such as particulate matter, NOx, CO, HCl, and SO2. The garbage also contains heavy metals such as Hg, Cd, Tl, Pb, Cu, Cr, Mn, Zn etc. These heavy metals are easily volatile into the flue gas during the pyrolysis and gasification process. In addition, the flue gas also contains a small amount of dioxins and other substances. The main pollutant components in the flue gas are shown in Table 1 below.

| Table 1. Main components of flue gas |
|-------------------------------------|
| Main components of incinerator flue gas |
| Particulates                        |
| NOx                                |
| CO                                 |
| SO2                                |
| HCl                                |
| Hg and compounds                    |
| Cd/Tl and Compounds                 |
| Sb/As/Pb/Cr/Co/Cu/Mn/Ni            |
| Dioxin                             |
| -                                  |

3.2. Monitoring results
The garbage incineration power plant has 1 #, 2 # and 3 # incinerators, and the auxiliary equipment and environmental protection equipment are operating normally and the working conditions are stable. Monitor the flue gas of the three incinerators, and set up a monitoring section at the entrance of the semi-dry deacidification tower and the vertical flue outlet after the purification system treatment, to monitor the exhaust gas pollutant emission concentration, emission volume and flue gas purification system Acid efficiency and dust removal efficiency. Choose 2 # incinerator flue gas as the monitoring representative, and sample 4 times in four time periods on a working day. See Table 2 for the flue gas monitoring indicators.
Table 2. Incinerator flue gas monitoring results

| Test items          | Import concentration mg/m³ | Outlet concentration mg/m³ | Emission rate kg/h | Removal efficiency | Emission limits* mg/m³ | Compliance |
|---------------------|----------------------------|----------------------------|--------------------|--------------------|-----------------------|------------|
| 1                   | 765                        | 2.7                        | 0.18               | 99.7              | 30                    | Yes        |
| 2                   | 721                        | 0.90                       | 0.54               | 99.7              | 30                    | Yes        |
| Particulates        |                            |                            |                    |                    |                       |            |
| 3                   | 615                        | 1.8                        | 0.21               |                    | 30                    | Yes        |
| 4                   | 452                        | 1.5                        | 0.22               |                    | 30                    | Yes        |
| Mean                | 638                        | 1.7                        | 0.26               |                    | 30                    | Yes        |
| 1                   | 64                         | 43                         | 3.5                |                    | 30                    | Yes        |
| NOx                 |                            |                            |                    |                    |                       |            |
| 2                   | 61                         | 56                         | 8.1                |                    | 300                   | Yes        |
| 3                   | 59                         | 49                         | 6.3                |                    | 300                   | Yes        |
| 4                   | 59                         | 54                         | 6.1                |                    | 300                   | Yes        |
| 1                   | 92                         | <3                         | 0.18               |                    | 300                   | Yes        |
| SO₂                 |                            |                            |                    |                    |                       |            |
| 2                   | 88                         | <3                         | 0.14               |                    | 300                   | Yes        |
| 3                   | 87                         | <3                         | 0.17               |                    | 300                   | Yes        |
| 4                   | 90                         | <3                         | 0.18               |                    | 300                   | Yes        |
| CO                  |                            |                            |                    |                    |                       |            |
| 1                   | <1                         | <1                         | 0.06               |                    | 300                   | Yes        |
| 2                   | <1                         | 1                          | 0.05               |                    | 300                   | Yes        |
| 3                   | <1                         | <1                         | 0.05               |                    | 300                   | Yes        |
| 4                   | <1                         | <1                         | 0.07               |                    | 300                   | Yes        |
| HCl                 |                            |                            |                    |                    |                       |            |
| 1                   | 1.5                        | 5.4                        | 0.63               |                    | 300                   | Yes        |
| 2                   | 1.6                        | 8.3                        | 0.91               |                    | 300                   | Yes        |
| 3                   | 3.8                        | 10.1                       | 1.16               |                    | 300                   | Yes        |
| 4                   | 4.0                        | 10.5                       | 1.05               |                    | 300                   | Yes        |
| Hg and compounds    |                            |                            |                    |                    |                       |            |
| 1                   | 0.140                      | 0.0040                     | 0.0005             |                    | 300                   | Yes        |
| 2                   | 0.061                      | 0.0022                     | 0.0001             |                    | 300                   | Yes        |
| 3                   | 0.065                      | 0.0024                     | 0.0002             | 98.1              | 0.2                   | Yes        |
| 4                   | 0.052                      | 0.0029                     | 0.0004             |                    |                       | Yes        |
| Mean                | 0.079                      | 0.0015                     | 0.0003             |                    | 300                   | Yes        |
| Cd/Tl and Compounds |                            |                            |                    |                    |                       |            |
| 1                   | 1.013                      | <5×10⁻⁶                    | 6×10⁻⁷             |                    | 300                   | Yes        |
| 2                   | 1.125                      | <5×10⁻⁶                    | 6×10⁻⁷             |                    | 300                   | Yes        |
| 3                   | 0.541                      | <5×10⁻⁶                    | 5×10⁻⁷             | 99.9              | 0.1                   | Yes        |
| 4                   | 0.574                      | <5×10⁻⁶                    | 6×10⁻⁷             |                    | 300                   | Yes        |
| Mean                | 0.813                      | <5×10⁻⁶                    | 6×10⁻⁷             |                    | 300                   | Yes        |
| Sb/As/Pb/Cr/Co/Cu/Mn/Ni |                    |                            |                    |                    |                       |            |
| 1                   | 14.7                       | 0.008                      | 0.0003             |                    | 300                   | Yes        |
| 2                   | 11.3                       | 0.017                      | 0.0021             |                    | 300                   | Yes        |
| 3                   | 5.71                       | 0.032                      | 0.0037             | 99.7              | 1.0                   | Yes        |
| 4                   | 6.11                       | 0.023                      | 0.0016             |                    | 300                   | Yes        |
| Mean                | 9.45                       | 0.02                       | 0.0019             |                    | 300                   | Yes        |
| Dioxin (ng I-TEQ/m³) | -                          | 0.016                      | -                  | -                  | 0.1 ng I-TEQ/m³        | Yes        |
| Smoke blackness     | -                          | <1                         | -                  | -                  | 1                     | Yes        |

Remarks: The converted concentration is converted based on the reference oxygen content of 11%; if it is not detected, it is expressed as being less than the detection limit; if it is not detected, half of the detection limit is used for statistics.

Note: The emission limits refer to the standard "Pollution Control Standard for Domestic Waste Incineration" (GB18485-2014).

3.3. Monitoring data analysis

2 # After incinerator purification, all pollutants in flue gas can be stably up to the standard emission. The concentration of particulate matter in the flue gas is less than 10 mg / m³, NOx concentration is less than 300 mg / m³, SO₂ concentration is less than 100 mg / m³, and HCl concentration is less 60 mg / m³,
the concentration of Hg and its compounds is less than 0.2 mg / m³, the concentration of Cd, Tl and its compounds is less than 0.1 mg / m³, the concentration of dioxin is less than 0.1 ng I-TEQ / m³, and the smoke blackness is less than 1. Particulate removal efficiency is above 99.7%, SO₂ removal efficiency is above 98.7%, and heavy metal removal efficiency is above 97%.

From the monitoring data, the concentration of particulate matter, NOₓ, SO₂ and heavy metals in the flue gas generated by waste incineration power generation is relatively high, but after purification, all components can reach the standard emissions. Particulates are mainly fly ash produced by incineration of domestic waste in the incinerator. NOₓ comes from nitrogen in the waste. In addition, the sulfur in the waste mainly exists in the form of organic sulfur and inorganic sulfur. High, the sulfate in the waste gradually decomposes to release SO₂. The heavy metals in the flue gas mainly come from the volatilization of heavy metals during the pyrolysis and gasification of garbage, which is mainly affected by the physical and chemical properties of the metal, the temperature, and the chlorine and sulfur elements in the garbage [5]. The metal Hg is the most volatile, followed by As, Cd, and Pb, which are mainly distributed in the flue gas, and the remaining non-volatile heavy metals are mainly distributed in the particulate matter.

4. Conclusion

(1) The concentration of particulate matter, NOₓ, SO₂ and heavy metals in the flue gas from the incinerator of the waste incineration power plant is relatively high, which is mainly affected by factors such as waste composition, incineration temperature and physical and chemical properties of heavy metals.

(2) After the flue gas of the incinerator of the garbage incineration power plant is treated by the flue gas purification system, the treatment effect is obvious, and all components in the flue gas can achieve ultra-low emissions. In the monitoring data, the value of dioxin is much lower than the emission standard value and the flue gas blackness is less than 1, indicating that the operating temperature and temperature of the furnace of the incinerator, and the domestic waste can be fully incinerated. It shows that the combined flue gas purification process of the "furnace denitrification (SNCR) + semi-dry deacidification + slaked lime and activated carbon (dry method) injection + bag dust collector" configured by the plant has good treatment effect.

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