Summary of Flue Gas Purification and Treatment Technology for Domestic Waste Incineration

LI Hao-ming1,2, ZHANG Ning3, GUO Xuan3, DOU Ming-yuan1,2, FENG Qing1,2, ZOU Shuai1,2, and HUANG Fu-chuan1,2*.

1 College of Mechanical Engineering, Guangxi University, Nanning, 530004, Guangxi, China.
2 Guangxi Key Laboratory of Petrochemical Resource Processing and Process Intensification Technology, Guangxi University.
3 Guangxi Nongken Yongxin animal husbandry group Jinguang Co., Ltd
*Corresponding author’s e-mail: huangfuchuan@gxu.edu.cn

Abstract. Incineration technology is widely used in the world as a domestic waste treatment technology. The reason is that the incineration technology can reduce the weight of the treated domestic waste by 80% and the capacity by more than 90%, which is of great significance to the realization of the management goal of domestic waste treatment. However, the problem of flue gas pollution will occur when the waste incineration technology is used to treat the waste. The main harmful substances in the flue gas generated by waste incineration include: smoke, dioxin, SO2, NOx, heavy metal and other pollutants. Therefore, the flue gas can only be discharged into the atmosphere after proper technical treatment and meeting the national emission standards. This paper summarizes the domestic and foreign technologies of waste incineration flue gas purification and treatment, and puts forward suggestions for the development of domestic waste incineration flue gas purification and treatment technology.

1. Preface
At present, the annual production of domestic garbage in China is growing at an average rate of 10%[1]. In 2015, the domestic waste output of 246 large and medium-sized cities in China totaled 186 million tons[2]. Therefore, the treatment of domestic waste is increasingly becoming the focus of people's attention. At present, the main ways to deal with garbage at home and abroad are as follows: Composting, landfill and waste incineration power generation[3]. Among them, waste incineration technology is widely used in the world due to its characteristics of harmless, reduction and resource utilization, and it gradually becomes the main way of domestic waste treatment[4]. At present, it is necessary to analyse the flue gas purification technology in the process of waste incineration at home and abroad to ensure that the waste incineration is harmless.

2. Purification and treatment technology of domestic waste gas

2.1. Pollutant composition of flue gas
The main components of the flue gas generated by waste incineration are composed of four harmless substances such as N2, O2, CO2 and H2O[5], which occupy most of the volume of flue gas. However, due to the uncertainty of waste type and combustion process, there are still a small amount of air...
pollutants in the flue gas, mainly including: Particles (PM2.5 and PM10)[6] with strong adsorption[7]; acid gases such as SO$_2$, NO$_x$, HCl and HF; heavy metals such as Hg and Cd and their corresponding compounds; dioxins and other residual organic compounds[8].

2.2. Flue gas treatment and purification technology

2.2.1. Particulate matter purification technology. In order to meet the requirements of the laws and regulations on the discharge of particulate matter, there are three types of dust collectors used in the waste incineration treatment facilities: cyclone dust collector, bag dust collector and electrostatic precipitator. Combined with the current situation of waste incineration technology in China, the bag dust removal technology with mature technology, wide application range and good economy is more suitable.

The bag filter operates continuously in the way of filtration / ash removal[9]. Its dedusting effect is related to the factors such as flue gas flow, temperature, moisture content, dust content and filter material, and its efficiency is generally over 90%[10]. Hao Yanhong et al. [11] conducted experimental research on the bag type dust removal experimental device, and obtained the change rule of the efficiency of bag filter. Kang Dayou [12] proposed to use the ECS-100 distribution system of Zhejiang central control technology Co., Ltd. to realize the real-time monitoring and remote control of the whole bag dust removal system. This technology is of great significance to the innovation of particle purification technology. In the aspect of filter material research, Pang Jie [13] has carried out the test and Research on the temperature resistance of a new type of filter material, and found that its temperature resistance has outstanding advantages. Zhang Liang [14] proposed a new type of filter material technology, which uses a variety of fiber materials for composite and post finishing, and develops a low-cost and high-performance filter material for waste incinerator.

2.2.2. Acid gas purification technology. The flue gas from MSW incineration contains SO$_2$, NO$_x$, HCl, HF and other acid gases. These gases are mainly removed by washing, and the acid gas in the flue gas is removed by physical adsorption and chemical reaction. The common control technology of acid gas can be divided into three methods: wet method, dry method and semi dry method[15]. NO$_x$ removal method in flue gas is special, which will be introduced separately in section 2.2.3.

Wet flue gas purification technology was widely used in some developed countries in the early stage. Based on the uniformity of flue gas flow, Qu Jiangyuan [16] proposed a structural optimization scheme for the spray area of the desulfurization tower and a component design scheme for enhancing the collection of liquid drops by the demister. Song Naiying [17] carried out the research on the influence of the configuration parameters of the nozzles in the desulfurization tower on the desulfurization effect, which provided the theoretical basis for the configuration design of the nozzles in the desulfurization tower and had important application value for improving the desulfurization efficiency. Huang Yueqi et al. [18] conducted a numerical simulation of the removal process of particles in the desulfurization system. The removal characteristics of particulate matter under different working conditions (such as spray intensity, flue gas velocity and slurry spray layer) were solved. Liu Bin [19] studied the automatic control system and its optimal control in the process of pH value control of desulfurization slurry. Hu Ting [20] took a waste incineration power plant as an example to analyze the design of desulfurization wastewater treatment and reuse system. Lu Suoqiang [21] took a desulfurization wastewater treatment system of a coal-fired boiler with wet desulfurization as an example, and carried out process optimization design to ensure the efficient and stable operation of the desulfurization wastewater treatment system.

Dry flue gas purification technology refers to the removal of acid gas in flue gas by solid absorbent through pipe spraying, and the cleaning work in the latter section combined with high-efficiency dust remover. Li Chunhua [22] concluded that the sulfur dioxide in the flue gas of municipal solid waste can be effectively absorbed by using the plant ash as the additive through theoretical analysis and specific experiments. Li Yan et al. [23] used process simulation software to simulate the fixed bed activated carbon dry flue gas desulfurization process, and studied the influence of different factors on SO$_2$ removal.
rate. Liu Xi [24] carried out numerical simulation calculation on the adsorption process, analyzed the flow field distribution in the adsorption process and the influence of different operations on desulfurization. Wang Haiou [25] established a numerical simulation model of wet activated carbon flue gas desulfurization. This study provides a reference for the improvement and development of flue gas purification technology. Wang Xiaoming [26] summarized the process principle, reaction process, influencing factors and application scope of dry desulfurization technology. Burgess Conforti Jason R et al. [27] conducted relevant research on by-products of flue gas desulfurization (FGD), and evaluated the impact of land use of by-products of high calcium dry FGD on aboveground biomass and microelements in soil. Dry flue gas purification technology for acid gas removal efficiency is relatively low and absorbent consumption is relatively large[28].

Semi dry flue gas purification technology is a combination of wet flue gas purification technology and dry flue gas purification technology[29]. Jixin [30] studied the structure optimization and flow field numerical simulation of semi dry deacidification tower by establishing mathematical model. The research results can provide quantitative basis and theoretical reference for the design and calculation of deacidification tower as well as the actual working conditions. Jia Zhennan [31] used the semi dry rotating spray deacidification tower widely used in refuse incineration plant as the simulation object, and studied the influencing factors of flow field and deacidification efficiency of deacidification tower. The optimal operation condition is obtained, which lays a theoretical foundation for the design of deacidification tower. Shi Yingjie [32] proposed the integrated way of deacidifying agent ash transportation, digestion and activation to solve the problem of low deacidifying efficiency and low deacidifying agent utilization. Liu Yang [33] studied the swirling pressure nozzle for the internal circulation two-stage spray semi dry desulfurization process. The structure of the pressure nozzle is optimized by the method of computational fluid dynamics. Fu Yinglei et al. [34] studied the oxidation and transformation of calcium sulfite in semi dry FGD ash, and obtained a composite catalyst through experiments, which was successfully used in the modification of semi dry FGD ash.

2.2.3. NO\textsubscript{x} purification technology. The production of NO\textsubscript{x} in the process of MSW incineration is inevitable. At present, there are two main technologies for NO\textsubscript{x} purification at home and abroad: selective non catalytic reduction (SNCR) method and selective catalytic reduction (SCR) method[35]. A large number of scholars at home and abroad have studied the application of these two technologies in the flue gas purification technology of MSW incineration. Liu Zhanbin et al. [36] analyzed the SNCR system of Taiyuan TongZhou circulating fluidized bed MSW incinerator, and thought that the SNCR system of ammonia injection for MSW incineration power generation is a kind of flue gas denitrification technology worthy of promotion, with its simple, efficient, safe and reliable system, which has a good market prospect. Zhang Hui [37] introduces the working principle of SNCR technology and puts forward some problems that should be paid attention to, taking an operating waste incineration power plant in Shenzhen as an example. Zou Jinsheng [38] discussed the experience of design scheme selection and design optimization in the process of revamping the selective non catalytic reduction flue gas denitrification system of a domestic waste incineration power plant, which provided reference for relevant technical revamping. Huang Xin [39] used CFD technology to optimize the denitrification technology of flue gas from a 750 t / d boiler in a waste incineration plant in Guangzhou, and used numerical simulation method to simulate the optimal design of the denitrification technology. The results show that SNCR technology is the best choice. Wang Qian [40] took a 400t / d MSW incinerator as the research object, and put forward the optimized transformation scheme of flue gas denitrification of MSW incinerator by using CFD software. Li Yanli [41] used computational fluid dynamics software (CFD) to model and analyze the MSW incinerator with a capacity of 400t / d, and provided a reference for the design of SNCR Denitration Process in the MSW incinerator transformation. Xu Haitao [42] carried out experimental and industrial verification and Application Research on the development of low temperature SCR catalyst, zero discharge technology of desulfurization wastewater, and new biological process for simultaneous desulfurization and denitrification.
2.2.4. Purification technology of heavy metals and dioxins. Many scholars at home and abroad have studied the purification technology of heavy metals produced by MSW incineration. Peng Xi [43] systematically studied the basic characterization, environmental toxicity and bioavailability of the fly ash from a municipal solid waste incineration plant in Chongqing. Through the experimental study on the electric removal of heavy metals in the fly ash, the feasibility of the electric removal of heavy metals in the fly ash was discussed. The results show that it is feasible to remove heavy metals from the incineration fly ash by electric technology. However, the removal efficiency of heavy metals needs to be further improved. Zhang Yuewei [44] studied the three-dimensional electrode electric removal of heavy metal pollutants in MSW incineration fly ash, and discussed a more effective harmless treatment method for fly ash. The results show that the three-dimensional electrode method has a better effect on the removal of heavy metals in the incineration fly ash. Hu Junfei [45] studied the bioleaching process of environmental protection and mild conditions, used bioleaching to remove the heavy metals in the municipal solid waste incineration fly ash, and optimized the bacterial system, explored the better technological conditions for the bacterial culture process and leaching process, carried out the research on the recycling and regeneration process of leaching liquid, and developed a set of new technology for the treatment of heavy metals in the municipal solid waste incineration fly ash. Art. Liu Kexiang [46] focused on the production of activated carbon and its application in the electric removal of heavy metals from fly ash.

There are many researches on dioxin purification technology at home and abroad. Han Liangjun [47] thinks that we should take targeted prevention and control technology according to the source of dioxin in the incineration of domestic waste, classify the domestic waste from the source, consider the furnace type selection, material composition and waste treatment capacity in the incineration process, and take comprehensive treatment technology and standardized high-level management at the end to realize the effective control of dioxin in the domestic waste. Chen Tong [48] conducted a series of basic experimental studies on the formation mechanism and control technology of dioxin produced in the process of waste incineration, which provided a reference for the selection of dioxin purification technology. Su Shanshan [49] takes four kinds of environmental receptors in a typical region of Guangxi, an economic underdeveloped region of China, as the research object, makes an in-depth study on the distribution of PCDD/Fs, and through the qualitative/quantitative comprehensive analysis of the model, expounds the sources of dioxin pollution in environmental multi-media and the risk assessment of human health in this region. Shi Dezhi [50] in view of the nature and change trend of domestic garbage in China, aiming at resource recovery and pollution control of incineration, a new type of garbage source classification collection and transportation system was established. Under the comprehensive technical system of garbage classification collection and transportation and incineration treatment, the system operation regulation of garbage incinerator, the formation and pollution control of dioxins and polycyclic aromatic hydrocarbons were studied. The research results are of great practical significance to the improvement of the management system of MSW classified collection and the adaptation to the control technology of incineration pollutants.

3. Conclusion and Prospect
Incineration is not only the mainstream way of garbage treatment at home and abroad, but also an important way to reduce, recycle and make the domestic waste harmless. It has a very broad development prospect, but due to the wide range of garbage sources, complex components and diverse properties, the combustion process will produce a variety of pollutants that are harmful to the environment and human body, so the pollutant concentration reduction technology is increasingly valued. The waste incineration shall be in strict accordance with the relevant standards such as the pollution control standard for domestic waste incineration to control and treat the flue gas, sewage, slag, fly ash, odor and noise, so as to prevent environmental pollution.

The emission standards of waste incineration pollutants in China are becoming increasingly strict, and the gap between the emission standards of waste incineration and those of EU is gradually narrowing, which promotes the improvement of the technical level and equipment level of waste incineration and
pollutant control, and ensures the sustainable development of domestic waste incineration treatment in China. Although the purification process of MSW incineration flue gas in China has entered the stage of market operation and tends to be mature, there is still a large space to optimize the research on the ultra-low emission route of MSW incineration flue gas. Including the optimization design of the purification process of particles, acid gas, heavy metal and dioxin, and the structural transformation of the required equipment.

In order to realize the harmless, resource and industrialization of garbage incineration, it is necessary to strengthen the basic theoretical research of MSW incineration flue gas purification, learn from foreign mature and high-quality process and equipment, and comprehensively improve the economy and rationality of MSW incineration flue gas purification process in combination with China's national conditions. At the same time, all working units and colleges and universities should strengthen the training of relevant talents and improve the theoretical level and professional ability of employees. Actively promote the innovation of ultra-low emission technology of MSW incineration.

Acknowledgments
Thanks for the foundation of Guangxi Petrochemical resources processing and process Strengthening Technology Key Laboratory, contract No.: Guike AB16380249 project, contract No.: 20183106 project.

References
[1] Zhang, Z.Y. (2020) Study on environmental management of municipal solid waste collection and treatment. J. Resource conservation and environmental protection, 01: 135.
[2] Jiao, X.D., Du, H.Z. (2019) Study on the current situation, problems and management strategies of urban waste treatment in China. J. Renewable resources and circular economy, 12 (01): 18-22.
[3] Zhang, Y.L. (2015) Study on the design of flue gas purification system for a municipal solid waste incineration project. D. Zhejiang University of technology.
[4] Su, P., Wang, G.H., Liu, Y.Z., et al. (2002) Development status of municipal solid waste incineration technology. J. Energy research and information, 3: 143-149.
[5] Wang, W.G., Fu, X.H., Wang, X.Z. (2014) Process selection for control of pollutants in flue gas from MSW incineration. J. China population, resources and environment, 24 (S1): 87-91.
[6] Su, Y.M. (2019) Analysis of flue gas purification technology of domestic waste incineration plant. J. New technology and new products of China, 14: 103-104.
[7] Wu, T., Cao, Y., Xu, C.T., Luo, Y.H. (2014) Summary of emission control of air pollutants from waste incineration. J. Industrial boiler, 05: 28-32.
[8] Chen, P., Cheng, J.G., Chen, J. (2006) flue gas pollution and its control in waste incineration. J. Environmental science and management, 5: 116-118,133.
[9] Zhou, S.D. (2017) Analysis and selection of purification process of flue gas pollutants from MSW incineration. J. Environment and development, 29 (03): 57-59.
[10] Liu, X. (2018) Analysis and Research on emission reduction technology of flue gas pollutants from municipal solid waste incineration. J. Environmental science and management, 43 (06): 97-100.
[11] Hao, Y.H., Qiu, L.X., Sun, N. (2010) Experimental study on dust removal performance of bag filter. J. Power station system engineering, 26 (05): 11-12 + 42.
[12] Kang, D.Y. (2008) Study on bag filter system of waste incineration power generation. D. Chongqing University.
[13] Pang, J. (2011) Experimental study on performance of polysulfonamide fiber composite filter material for high temperature flue gas dedusting. D. Donghua University.
[14] Zhang, L. (2007) Experimental study on bag filter material for flue gas purification of MSW incinerator. D. Donghua University.
[15] Zhou, S.D. (2017) Analysis and selection of purification process of flue gas pollutants from MSW incineration. J. Environment and development, 29 (03): 57-59.
[16] Qu, J.Y. (2018) Numerical simulation of flow field optimization in wet FGD tower. D. North China Electric Power University (Beijing).
[17] Song, N.Y. (2017) Study on optimal configuration of multiple nozzles for wet FGD. D. China University of Petroleum (East China).
[18] Huang, Y.Q., Zheng, C.H., Li, Q.Y., Zhang, J., Guo, Y.S., Zhang, Y.X., Gao, X. (2020) Numerical simulation of the simultaneous removal of particulate matter in a wet flue gas desulfurization system. J. Environmental science and pollution research international, 27(2).
[19] Liu, B. (2018) Optimal control of pH in flue gas desulfurization process. D. Shanghai Jiao Tong University.
[20] Hu, T. (2019) Design of wet desulfurization wastewater treatment and reuse system in waste incineration power plant. J. Guangdong chemical industry, 46 (18): 117-118 + 129.
[21] Lu, S.Q. (2016) Study on wet desulfurization wastewater treatment system and process optimization. J. Chemical management, 29: 251 + 253.
[22] Li, C.H. (2006) Experimental study on fixed bed dry desulfurization of municipal solid waste incineration flue gas. D. Kunming University of technology.
[23] Li, Y., Zhao, J.G., Fan, M., Tao, W.L. (2016) Simulation study of fixed bed activated carbon dry flue gas desulfurization process. J. Chemical environmental protection, 36 (03): 317-320.
[24] Liu, X. (2012) Experimental study and numerical simulation of flue gas desulfurization by activated carbon. D. Dalian University of technology.
[25] Wang, H.H. (2015) Study and application of adsorption characteristics of flue gas SO2 on activated carbon. D. Beijing University of science and technology.
[26] Wang, X.M. (2018) Dry and semi dry desulfurization technology. J. Electric power technology and environmental protection, 34 (01): 45-48.
[27] Burgess-Conforti Jason, R., Brye Kristofor, R., Miller David, M., Pollock Erik, D., Wood Lisa, S. (2018) Dry flue gas desulfurization by-product application effects on plant uptake and soil storage changes in a managed grassland. J. Environmental science and pollution research international, 25(4).
[28] Liu, X. (2018) Analysis and Research on emission reduction technology of flue gas pollutants from municipal solid waste incineration. J. Environmental science and management, 43 (06): 97-100.
[29] Wang, S.J., Zhang, Y.Q. (2009) Application of semi dry flue gas purification system in municipal solid waste incineration. J. Shanghai electric technology, 2 (04): 48-51.
[30] Ji, X. (2010) Structural optimization and numerical simulation of flow field of semi dry deacidification tower with waste incineration flue gas. D. South China University of technology.
[31] Jia, Z.N. (2018) Numerical simulation of semi dry flue gas deacidification process in deacidification tower. D. North China Electric Power University.
[32] Shi, Y.J. (2004) Study on flue gas purification process of semi dry and semi wet waste incineration. D. Chinese Academy of Environmental Sciences.
[33] Liu, Y. (2014) Study on the characteristics of pressure atomizing nozzle for semi dry FGD. D. Harbin University of technology.
[34] Fu, Y.L., Mu, Y., Zhang, Z.G., Guo, B., Zhao, F.Q. (2013) Modification and application of semi dry FGD ash. J. Environmental science and technology, 36 (02): 155-158.
[35] Liang, Z.Y. (2011) Study on SNCR denitrification technology of municipal solid waste incinerator. D. South China University of technology.
[36] Liu, Z.B., Liu, Q., Zhang, Z.G., Cai, Z.G. (2016) Study on the application of SNCR technology in flue gas denitrification of waste incineration power plant. J. Green building materials, 11: 203-204.
[37] Zhang, H. (2016) Application of selective non catalytic reduction flue gas denitrification technology in waste incineration power plant. J. Huadian technology, 38 (01): 62-63 + 67 + 78.
[38] Zou, J.S., Wang, Z.Q. (2012) Application of selective non catalytic reduction flue gas denitrification technology in waste incineration power plant. J. Huadian technology, 34 (05): 71-73 + 76 + 80.

[39] Huang, X. (2010) Numerical simulation of optimization and optimal design of denitrification technology of MSW incineration flue gas. D. South China University of technology.

[40] Wang, Q. (2017) Simulation of denitration of MSW incineration flue gas and its application in operation optimization. D. Harbin University of technology.

[41] Li, Y.L. (2013) CFD numerical simulation study on denitrification of waste incineration flue gas. D. Harbin University of technology.

[42] Xu, H.T. (2016) Research and development of key technologies and engineering application of flue gas desulfurization and denitrification. D. Southeast University.

[43] Peng, X. (2012) Experimental study on the characteristics of municipal solid waste incineration fly ash and the electric removal of heavy metals. D. Chongqing University.

[44] Zhang, Y.W. (2017) Study on the treatment of heavy metals in municipal solid waste incineration fly ash by three-dimensional electrode method. D. Chongqing University.

[45] Hu, J.F. (2016) Bioleaching of heavy metals from municipal solid waste incineration fly ash. D. Beijing University of technology.

[46] Liu, K.X. (2017) Study on electric removal of heavy metals from municipal solid waste incineration fly ash by self-made activated carbon. D. Chongqing University.

[47] Han, L.J. (2018) Dioxin control technology in the process of domestic waste incineration. J. Light industry technology, 34 (11): 95-96.

[48] Chen, T. (2006) Study on formation mechanism and control technology of dioxin in municipal solid waste incineration. D. Zhejiang University.

[49] Su, S.S. (2012) Study on the distribution, incineration release and reduction control of dioxin in environment. D. Huazhong University of science and technology.

[50] Shi, D.Z. (2009) Study on pollutant control and mechanism of MSW incineration process based on new classification and collection system. D. Zhejiang University.