The Life Cycle Assessment on Mixed Incineration of High Heating Value Industrial Solid Waste with Municipal Solid Waste

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Abstract. The industrialization process of China has achieved remarkable economic and social development in recent decades, which companies with excessive production of industrial solid waste (ISW). It took up a large amount of land and led to potential environmental problems such as air, water, soil pollution. With the increasing awareness of environmental protection and the better vision to build a pattern of sustainable economy, the comprehensive utilization of ISW is becoming a challenging and promising research field. In this work, a waste incineration power plant in Guangdong Province, China was selected as the research object. Its novel incineration scheme by mix ISW and MSW was evaluated, which aims to improve power generation efficiency. The comprehensive environmental impact assessment of this refuse incineration-power generation technology was also carried out by life cycle assessment. Results show that for waste incineration power generation system, the numerical order of all normalization indicators is Waste Solids>EP>NOx>ADP>AP>CADP>RI>CADP (fossil fuel) >CO_2> SO_2>GWP>PED>COD>IWU> Water Use > NH_3-N. It shows that the ash reduction and denigration system are the most worthy of optimization. And the contribution of flue gas purification to ECER index reaches 38.98%, which is the most influential link and significantly ahead of other links, as well as the most needed optimization link.

1 Introduction

In recent years, both developed and developing countries are faced with serious waste discharge and disposal problems caused by the high degree of industrialization, rapid economic development and population growth, and the severity of environmental problems are becoming increasingly prominent [1]. With the increasing awareness of governments around the world on environmental pollution and resource shortage, people have paid more and more attention to environmental protection and sustainable development [2]. To achieve this ambitious goal, countries around the world by making international regulations and provisions to strengthen international cooperation and build a community of human destiny, for example, the *Kyoto protocol* has been replaced by the *Paris agreement*, this is very important not only to solve the problem of carbon emissions, and for the sustainable development of economy

China's decades of industrialization have produced enormous economic and social development. But at the same time, it also causes serious environmental pollution, such as waste pollution, dust pollution, water pollution, etc. [5]. Especially, the excessive production of industrial solid waste (ISW) occupies a large amount of land and leads to ecological, environmental problems such as air, water and soil pollution, which has become an important cause of environmental pollution in China [6].

ISW is characterized by large output, wide source and large fluctuation of components, so it is difficult to achieve large-scale treatment with a unified method. At present, landfill treatment is the most widely used method. However, it has a low degree of resource recovery and occupies too many land resources, which is not in line with the trend of environmental protection [8]. Despite a great deal of research in recent years, the comprehensive utilization of ISW is still a serious problem in the sustainable development of developing countries. Some researchers have applied ISW to building materials such as cement, baking-free bricks and concrete [10-12], as well as the preparation of porous materials and sintered glass-ceramics [13-15], but these studies are still at the laboratory level, and it is difficult to treat ISW on a large scale and realize the industrial application. Municipal solid waste (MSW) which has a similar situation with it has achieved large-scale incineration power generation treatment, and the effect is very significant, which is a treatment mode worthy of reference [16-17]. The feasibility of using ISW for incineration power generation needs to be evaluated. Different components of ISW may have different impacts on pollutant emission, energy consumption and power generation in the process, and the life cycle assessment (LCA) can include all the -

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above indicators, which is a suitable assessment method for the process.

This work attempts to analogize the treatment mode of MSW. The relevant experiments on ISW are made in a waste incineration power plant, which aims to explore the possibility of using large quantities of ISW with the complex components for incineration power generation, Then the comprehensive indicators of life cycle assessment are estimated to evaluate from the perspective of environmental impact.

2 LCA modeling and results

2.1 Introduction to waste incineration power generation system

This work selects a large waste incineration power plant in Guangdong Province, China as the research object. The plant consists of three branch factories and a total of 8 incinerators. The mature technology based on grate furnace is adopted, which has an excellent representation. It incinerates about 4500t mixed solid waste (ISW and MSW) every day and generates about 450kWh of electricity per ton of solid waste. We select the second factory for ISW mixed with the MSW incineration power generation experiment, the whole process is made up of waste feed system, incinerator system, steam turbine power generation system, flue gas purification system and fly ash solidification system, besides raw materials and industrial by-product ash transportation system. The mixed waste is dumped into the waste storehouse by the transport truck and then captured by the waste crane into the incinerator for full combustion. After that, the steam turbine converts the heat energy generated by the combustion into electricity, and the high-temperature flue gas produced by the incinerator enters the flue gas purification system after denitrification in the incinerator. Then Using deacidification tower, denitration system outside the incinerator, cloth bag dust collector and activated carbon injection system for removal of the harmful material in flue gas, and the purified flue gas is discharged by reaching the national standard. The removed fly ash will form bottom ash by chelating stable solidification system, which will be transported out the factory area together with the slag produced by incinerators and safely landfill.

2.2 Goal and scope definition

The research scope of the life cycle assessment should be according to the purpose of the research content, this work used eBalance software for the operation of the waste incineration power plant in the environmental impact assessment, and the scope of evaluation objects is set to from waste collection of transportation process to the all forms waste emissions, namely the main body of waste incineration power plant operation, and the specific scope boundaries are shown in Figure 1. Due to the immeasurable nature of equipment manufacturing and plant construction and the small degree of environmental impact, they are not considered in this work.

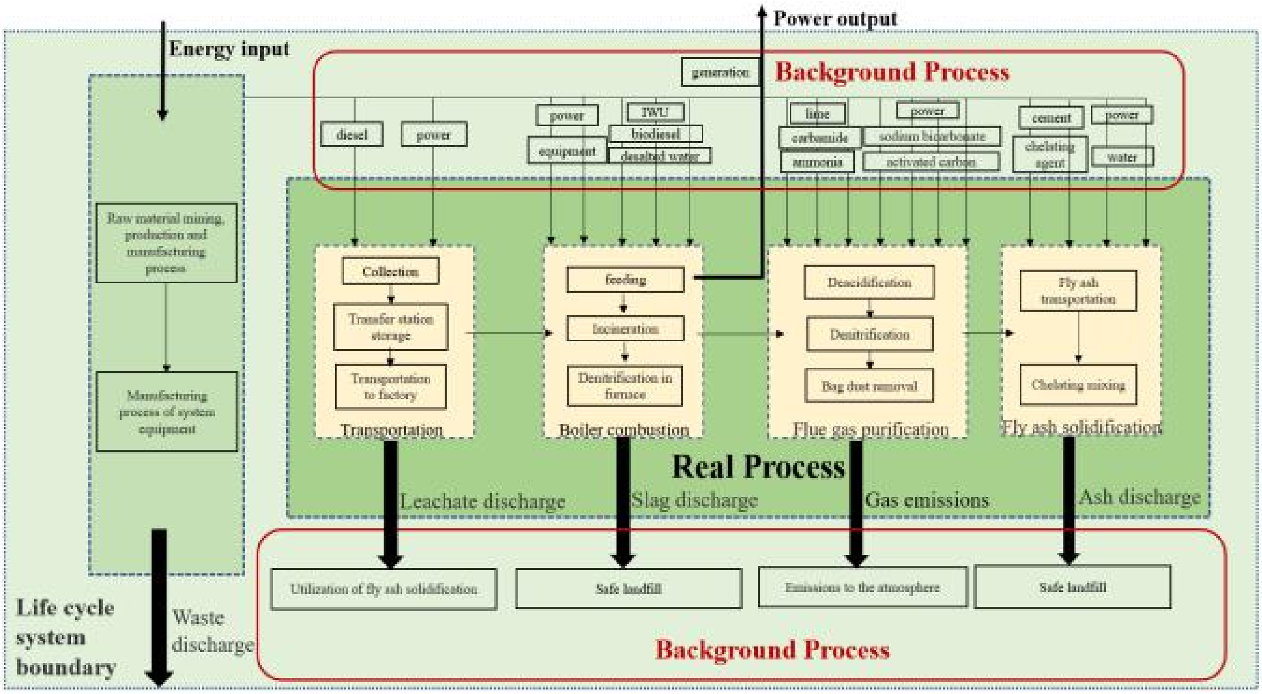

Fig. 1. The boundary of LCA in waste incineration power generation system

To facilitate the subsequent quantitative analysis, it is necessary to establish an appropriate calculation benchmark in the LCA evaluation model and calculate the input and output data in the modeling process. This work sets up a dual function unit reference flow from the perspective of waste treatment and power generation. (1) With waste treatment as the benchmark flow, the functional unit is set as the system processing

1t of mixed waste. (2) With power generation as the reference flow, the function unit is set as 1kWh electric energy produced by the system.

According to the system boundary, the real process and background process are divided. The data of the real process mainly come from the actual investigation of the factory and the results of large-scale experiments, while the data of the background process are selected from the database in the eBalance software and related papers. The database used in this model includes the built-in database of eBalance software: Chinese life cycle database (CLCD) and Ecoinvent, which follows the principle of giving priority to the local database in China.

2.3 Life cycle inventory

The waste incineration power generation process of this plant is divided into six major links: transportation and feeding - boiler combustion - steam turbine power generation - flue gas purification - fly ash solidification – ash and slag landfill. The plant operation data and the experimental data are selected to establish a material list database for each major link. All the power consumption and water consumption of the plant come from the real-time meter reading data, and all the substances added in the process also come from the accurate data records.

2.4 Environmental impact assessment

2.4.1 Classification

This work selects two types, namely resource consumption type and material emission type, with a total of 15 environmental impact indicators to comprehensively evaluate the energy consumption and environmental pollution performance of the system in low-carbon path planning.

2.4.2 Characterization results

Since different pollutants have different contributions to the environmental impact of their classification and do not meet the same dimension, they cannot be directly accumulated. Therefore, it is necessary to introduce the characteristic factor representing the impact degree with the reference pollutant as the coordinate. The characterization results can directly reflect the quantitative values of different environmental impact indicators, and facilitate the comparison of multiple indicators among different process systems.

2.4.3 Normalization results

The characteristic results of different dimensions of environmental impact indicators cannot be directly compared, but the normalization of the characteristic results can be realized. In this work, eBalance built-in normalization scheme -- China 2010 Normalized Total (CN2010) was used. The utilization background of this scheme is to collect the proportion of the total emission or consumption of the main functional substances of various environmental impact indicators in China in 2010, which is the normalized base value to illustrate the contribution. Table 1 shows the normalization results of various environmental impact indicators in the life cycle of the waste incineration power generation system for consuming 1t mixed waste.

Table 1. Normalization results of waste incineration power generation system

Indicator	Normalization result
ADP	3.47E-11
AP	3.43E-11
CADP (fossil fuel)	1.23E-11
CADP	2.30E-11
PED	6.79E-12
CO_2	8.27E-12
COD	5.48E-12
EP	5.61E-11
GWP	6.87E-12
IWU	5.30E-12
NH_3-N	1.13E-12
NOx	4.53E-11
RI	1.68E-11
SO_2	7.35E-12
Waste Solids	1.91E-09
Water Use	1.28E-12

According to the results in Table 1, the normalization value of Waste Solids ranks first among all indexes, and its magnitude is much higher than other indexes. This is because the incineration of waste still produces about 25% slag and bottom ash for landfill treatment, which is still a huge number, so it is a very necessary and meaningful technical breakthrough direction for ash reduction. The second and third indexes are EP and NOx, which fully illustrate the importance of denitration in the waste incineration power generation system. How to reduce the amount of ammonia, urea and other substances while maintaining or even reducing NOx emissions is a technical difficulty that needs to be overcome. The order of all indexes is Waste Solids>EP>NOx>ADP>AP>CADP>RI> CADP (fossil fuel) > CO_2> SO_2>GWP>PED> COD>IWU> Water Use > NH_3-N.

2.4.4 Comprehensive evaluation index calculation

Normalization results of environmental impact indicators do not combine indicators and reduce the number of indicators. When there are multiple indicators, they often conflict with each other, which makes the analysis results of LCA inconclusive. To further consolidate the indicators, in this work, two integrated evaluation calculation schemes built into eBalance are used for calculation. The first scheme is the Index of sustainable consumption and production (ISCP), which includes eight environmental impact indicators (GWP, EP, AP, COD, RI, CADP, Water Use and Waste Solids). The weight is calculated by the expert scoring method and the analytic hierarchy process. The second scheme is the energy conservation and emission reduction comprehensive index (ECER), which includes seven environmental impact indexes (PED, SO2, NOx, COD, CO2, NH3-N and IWU). ECER is a policy indicator, which is selected according to the policy target clause "reduction rate per unit GDP" in China's "14th Five-year Plan" for National Economic and Social Development. Therefore, ECER plays a strong role in process comparison, enterprise evaluation and policy suggestions. The Pareto diagram analysis of the ECER index of the waste incineration power generation system is shown in Figure 2.

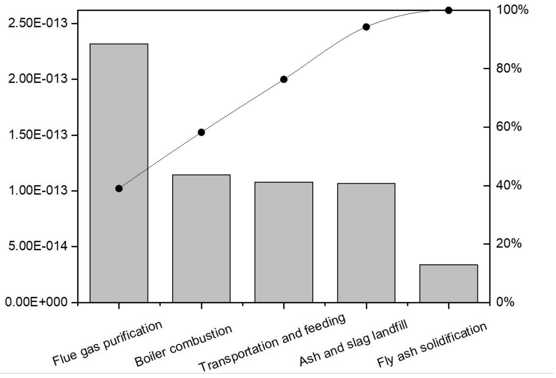

Fig. 2. Pareto chart in different links of ECER indicator of waste incineration power generation system

As can be seen from Figure 2, the contribution of flue gas purification to ECER index reaches 38.98%, which is the most influential link and significantly ahead of other links. The contribution ratio of boiler combustion, transportation and feeding, ash and slag landfill is nearly the same, and the contribution ratio of fly ash solidification is the smallest. The steam turbine power generation link is not included in the statistics because it is the link that produces income to the index. The flue gas purification link has a huge impact and needs to be further analyzed. Therefore, the ECER contribution ratio of related products in this link is statistically analyzed as shown in Figure 3. Products with a contribution ratio of less than 0.1% are not included in the statistics.

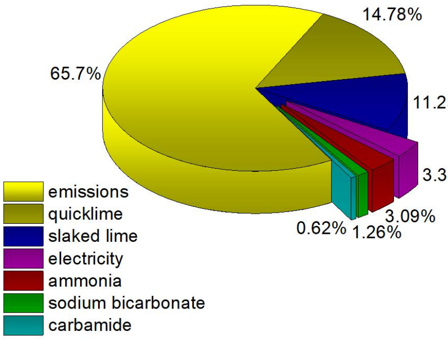

Fig. 3. Proportion of ECER indicator contribution of related products in flue gas purification

According to the contribution ratio of related products in the flue gas purification link in Figure 3, it can be seen that the flue gas directly emitted after treatment accounts for the largest contribution ratio, reaching 65.7%, which is much higher than the contribution of other products. Therefore, the direct emission of flue gas is the key factor affecting the overall environment. However, in the waste incineration power generation system, all flue gas can be discharged only after being strictly treated to meet the requirements of the national standard, and the impact on the environment is already relatively small, thus indicating that the environmental impact caused by other links of the system is smaller, and the specific numerical comparison of the environmental impact of different processes in the next part can further illustrate the superiority of the waste incineration power generation system.

3 Discussion and suggestions

The results of LCA show that, from the comparison of environmental impact indicators, the value of EP indicators is very prominent, far exceeding other indicators, and it should be optimized most. Incomplete denitration will cause a certain amount of NOx to be discharged into the atmosphere in the form of gas. Meanwhile, a large amount of ammonia water, urea and other substances are added in the denitration process, which are the contribution sources of EP indicators. Therefore, the processing system should establish a more stringent emission control system, optimize denitration technology, and carry out the double handle from the input side of additives and NOx emission side to reduce the environmental load.

4 Conclusions

This study was conducted at a large waste incineration power plant in Guangdong Province, China as the studied. And it aims to explore the possibility of using a large proportion of ISW for incineration power generation from the perspective of environmental impact assessment. Firstly, the waste mixed with ISW and MSW is taken as the research object, and the LCA model with the boundary from waste collection and transportation process to all kinds of waste discharge process is established by selecting a variety of environmental impact indicators, and the calculation results of the system are characterized, normalized and weighted comprehensively calculated. Results show that for waste incineration power generation system, the numerical order of all normalization indicators from largest to smallest is Waste Solids, EP, NOx, ADP, AP, CADP, RI, CADP (fossil fuel), CO_2, SO_2, GWP, PED, COD, IWU, Water Use, NH_3-N. It shows that the ash reduction and denitration system is most worthy of optimization, which can be carried out by the ash recycling system. And the contribution of flue gas purification to ECER index reaches 38.98%, which is the most influential link and significantly ahead of other links, as well as the most needed optimization link.

This paper is one of the phased achievements of the National Natural Science Foundation of China (general project), "Study on the Mechanism of Low-Temperature Cascade Pyrolysis of Medical Waste Based on Interaction and Secondary Reaction Enhancement" (52076092).

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