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Cooperative Treatment and Resource Utilization of Municipal Solid Waste by Industrial Coke Ovens: Effects of Doping Ratio and Management

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For the collaborative treatment and resource utilization of an industrial coke oven on municipal solid waste (MSW), this study used MSW to prepare refuse-derived fuel (RDF). The influence of different mix ratio between RDF and coal on coking products was considered, and technical and economic analyses were conducted. The results showed that under the low mixture ratio (3%), the pyrolytic carbon obtained basically met the class III standard of metallurgical carbon. In the experiment of medium mixture ratio (25%, 30%, 35%), the product contained a certain amount of calorific value, lower than that of the metallurgical coke. It might be that the ash content increased, and such product can be used for civil coke or chemical coke. When the mixture ratio was 100%, the calorific value of pyrolysis carbon was 7.53 MJ/kg, representing 25.7% of the calorific value of ordinary coke. The gas production rate of the discharged gas was 0.35, and the calorific value is 14.0 MJ/kg, reaching 73.6% of the coke oven gas. Under the condition of no coal input, the MSW was converted into usable energy. The results demonstrated that coke oven pyrolysis with 100% RDF addition is the most feasible way to recycle resources and energy.

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INTRODUCTION

Energy shortages and environmental pressures have contributed to making the concept of sustainable development a global consensus. Therefore, it is of significance for the resource utilization and energy recovery from solid waste (Chen *et al*. 2020). In 2019, China's domestic waste treatment volume reached 240 million tons, and the use of conventional landfill and incineration treatment has certain drawbacks (Luo *et al*. 2018; MOHURD 2019). Landfill technology occupies a lot of land area, and its leachate is extremely harmful to soil and groundwater (Rabl *et al*. 2008; Zamorano *et al*. 2008; Grillo 2014). At present, a plenty of research and application have been carried out in combustion technology, energy recovery, and other resource technology. In 2018, the proportion of European plastic recycling energy had reached about 70% (Leal Filho *et al*. 2019). From 2003 to 2012, the final MSW disposal amount of Japan was reduced by 60% (Sun *et al*.

2018). The ash content and moisture content of urban domestic waste in Europe and the United States are relatively low, and the conversion of domestic waste into fuel has been a common method (Chang and Davila 2008). In the case of China's solid waste, the average moisture content can be high as 80%, which reduces the effective heating value to a large extent, and proper pretreatment should be considered for the application of such waste.

Refuse-derived fuel (RDF) is a fuel made by crushing, sorting, drying, adding chemicals, and compressing and forming combustible garbage. In Europe and Japan, it is a viable option to recycle energy and reduce the amount of landfill by converting the waste into RDF and transferring it to treatment facilities such as incineration plants (Garg *et al*. 2007). In the United States, the relevant standards for RDF are complete, which makes the application of RDF very extensive (Gallardo *et al*. 2014). However, in some areas, there are problems with fuzzy RDF standards, poor applicability, or overproduction (Kubota and Ishigaki 2018). At present, the main application of RDF is combustion, but the source of RDF is very complicated, and simple inorganic substances or complex plastics may be present among them (Brás *et al*. 2017). This heterogeneity may increase the content of water and ash in RDF and adversely affect the heat production capacity of RDF.

Pyrolysis is the process of degrading biomass by heating in the absence of oxygen to produce coke, liquid, and gas products (Demirbas and Arin 2002). Pyrolysis of biomass is a suitable means to utilize the energy value of waste, because it can convert waste biomass into valuable products (Arena 2012). Compared with the traditional incineration process, pyrolysis will release less nitrogen oxides and sulfur oxides, which is more environmentally friendly. Veses *et al*. (2020) pyrolyzed domestic waste in a laboratory-scale facility consisting of a fixed bed reactor and a tubular reactor, obtained 16 MJ/Nm3 synthesis gas and solids that can be used as RDF. Agrafioti *et al*. (2013) conducted pyrolysis of sludge and showed that no higher than 300 °C was suitable as a pyrolysis temperature. Yacob *et al*. (2018) conducted pyrolysis of human feces. They showed that methane and carbon dioxide were the main pyrolysis products at medium temperature and provided useful technical guidance for the design of waste pyrolysis system.

Pyrolysis and carbonization of RDF has proved to be a feasible method to improve the application capability of RDF. Nobre *et al*. (2019) conducted pyrolysis on RDF. The energy efficiency was found to be greater than 84.5%. Stępień and Białowiec (2018) measured the kinetic parameters of RDF pyrolysis and investigated the effects of temperature and residence time on the performance of biochar fuels. Tagoe *et al*. (2008) used carbonized RDF for soil improvement, whereas Białowiec *et al*. (2018) studied the densification of RDF after carbonization. In recent years, research on the carbonization of RDF mainly has been carried out at temperatures of about 260 °C. Białowiec *et al*. (2017) studied the appropriate carbonization temperature of RDF from 200 to 300 °C, which paved the way for future generations. Therefore, few people have studied the carbonization effect at high temperature. As a high-temperature (>1000 °C) carbonization device, the coke oven is an important place for converting coal into metallurgical coke. In recent years, there have been related studies on using such ovens to treat solid waste. Kato *et al*. (2003) studied the feasibility of adding plastics in the coking process, and the results showed that the addition of 1% of plastics would not affect the strength of coke. Melendi *et al*. (2011b) added plastics and tar substances in the production of coal blends. They showed that the addition of tar substances can reverse the adverse effects of plastics. Montiano *et al*. (2014) studied the influence of chestnut sawdust addition methods on biomass metallurgy, and the results showed that partial molding addition was a better addition method. In recent years, few people have studied whether RDF was suitable for carbonization in coke ovens.

This article aimed to study the change of coke quality caused by the addition of RDF in the high-temperature coking process and the feasibility of using coke ovens to process RDF. The impacts of low, medium, and high doping levels on the product were evaluated. A 40 kg experimental coke oven was used to simulate the coking process, and the coal properties of pyrolysis charcoal and the value of pyrolysis charcoal and pyrolysis gas were evaluated, providing solutions for areas where RDF is difficult to apply or overproduction, and alleviating the pressure of domestic waste treatment and disposal.

EXPERIMENTAL

Refuse Derived Fuel and Coal

RDF from a certain place in China was used as the raw material for the furnace. The composition of RDF is 70% of municipal solid waste, 15% of wood chips, and 15% of pulverized coal. The coal production ratio of certain coal chemical company was used as the coal allocation ratio in the experiment (11% gas coal, 22% fat coal%, 53 coking coal and 14% lean coal).

The analysis of raw materials was carried out according to the standard GB/T 212-2008 Proximate Analysis of Coal. Results are shown in Table 1. Direct drying method (heating in nitrogen at 105 to 110 °C) was used to determine the moisture content of materials. The sample was fired to a constant weight in a muffle furnace at 850 °C to calculate the ash content. The volatile content of the materials in the porcelain crucible with lid was measured by the insulated air heating method at 900 °C. The results shown in Table 1 reveal that the RDF 100 had a high ash content, and the volatile content was near 70%. The findings showed that the burning characteristics of RDF were good, but to attain a suitable burning performance it is necessary to optimize the mix ratio.

For RDF, the sulfur content was determined by the combustion neutralization method. For coal, the sulfur content was determined using the Escar method.

Table 1. Raw Material Composition Analysis

	Sulfur (%)	Moisture (%)	Ash (%)	Volatile (%)
RDF100	0.35 ± 0.02	11.80 ± 0.53	40.03 ± 1.87	69.85 ± 3.51
Allocation ratio coal	0.76 ± 0.03	-	9.96 ± 0.50	26.71 ± 1.28

Table 2. RDF Ratio and Heating System of Each Experimental Item

	RDF (%)	Coal (%)	Heating system
R0	0	100	When the furnace was installed, the furnace wall temperature was 800 °C. After 16 h, the temperature was raised to 1050 °C, and the furnace was kept at a constant temperature for 3 h.
R3	3	97	
R25	25	75	When the furnace was installed, the furnace wall temperature was 800 °C. After 8 h, the temperature was raised to 1100 °C, and the furnace was kept at a constant temperature for 12 h.
R30	30	70	
R35	35	65	
R100	100	0	When the furnace was installed, the furnace wall temperature was 800 °C. After 8 h, the temperature was raised to 1100 °C, and the furnace was kept at a constant temperature for 7 h.

Experimental Furnace Type and Heating System

In this study, the sample used is named Rx, where x represents the percentage of RDF's substances in the furnace. A 40 kg experimental cokes oven was used for the experiment. The top-loading method was selected for experiments. The normal heating system for the furnace coal was that the temperature of the furnace wall was 800 °C, then temperature would be raised to 1050 °C after 16 h, and the coke inside the furnace would be transported after cooling. The heating system would be adjusted appropriately when the proportion of RDF was changed. The heating system of each item and the ratio of RDF were shown in Table 2.

Characterization

During the experiment, starting from the installation of the furnace, the gas samples were analyzed every 2 h, and the calorific value of the gas was calculated according to the analysis result of the gas. After the furnace was released, the pyrolysis charcoal was analyzed with reference to GB/T 2001-2013 Coke – Determination of Proximate Analysis (GB/T2001-2013). The abrasion resistance and shattering strength of pyrolysis charcoal was detected according to the regulation GB/T 2006-2008 Coke for Metallurgy – Determination of Mechanical Strength. Abrasion resistance refers to the ability of pyrolysis charcoal to resist external friction without causing surface glass to form debris or powder, which is represented by M10. The shattering strength refers to the ability of pyrolysis charcoal to resist external impact without breaking along the cracks or defects of the structure. It is represented by M40. The shattering strength and abrasion strength were calculated as follows:

$$M10 = (m_1/m) \times 100 \tag{1}$$

$$M40 = (m^2/m) \times 100 \tag{2}$$

where m is the mass of coke entering the drum, m_1 is the mass of coke greater than 40 mm after exiting the drum, and m_2 is the mass of coke greater than 10 mm after exiting the drum.

Coke reactivity (CRI) refers to the ability of coke to chemically react with carbon dioxide, oxygen and water vapor, and the coke-reacted strength (CSR) after reaction refers to the ability of the reacted coke to resist fragmentation and abrasion under the action of mechanical and thermal stress.

$$CRI = (m - m_3)/m \times 100 \tag{3}$$

$$CSR = (m_2/m) \times 100 \tag{4}$$

where m is the mass of coke before the reaction, m_3 is the mass of the residual coke after the reaction, and m_4 is the mass of coke after the drum is larger than 10 mm.

The gas production rate was calculated based on the volatile content, and the gas chromatography was used for the overall analysis of the gas.

RESULTS AND DISCUSSION

Effect of Low Addition Amount RDF on Pyrolysis

Conditions R0 and R3 were set to study the suitability of RDF with small doping (3%) in coke ovens. The coal blending used in R0 and R3 was the production blending

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ratio for coke production. The heating system used in the experiment was the same as that of the normal coal loading experiment. Table 3 presents the coke analysis indicators of the products.

Table 3. Coke Analysis Indicators for the Products

	Ash (%)	Volatile (%)	Sulfur (%)	M40	M10	CRI	CSR	Coke Yield
R0	13.02±0.55	1.03±0.04	0.68±0.03	84±1	10.3±0.3	33.5±1.1	50.3±1.5	0.79
R3	13.94±0.62	1.13±0.04	0.72±0.03	80±1	12.3±0.4	35.6±1.3	48.3±1.2	0.77

The addition of 3% RDF increased the ash content from 13.0% to 13.9%. This presumably came from the inorganic content present in the RDF. According to the China's relevant standards, when the coke ash is 13.51 to 15.00, the coke grade is III (GB/T1996-2003). Thus the addition of 3% RDF reduced the grade of coke and the value. Volatile content increased from 1.03% to 1.13%, while the sulfur content did not fluctuate much. The shattering strength (M40) and abrasion strength (M10) of coke dropped from 84 to 80, and it rose from 10.3 to 12.3, respectively. The decrease in the cold strength was due to the increase in ash and volatile content. And the increase of ash content will reduce the shattering strength of coke. Increased volatile content will loosen the material of the coke pore walls, resulting in a decrease in abrasion resistance. The thermal strength of coke also decreased due to the increase of ash and volatile content. Compared with R0, the CRI of R3 increased by 2.1, and the CSR decreased by 2.0.

Therefore, the addition of 3% RDF reduced the quality of coke in all aspects. Melendi *et al*. (2011a) added 2wt% of plastic during the coking process. The mechanical strength of coke did not decrease, and it even increased slightly by 1% to 4%. Under the action of high-density polyethylene, CSR also increased. When the tar residue, acid tar, and coking wastewater biochemical sludge were each 2.5%, and the total amount was 7.5%, the compression resistance of the briquette was maximized (Syenbaatar *et al*. 2014). This shows that the RDF was not suitable for coke production compared with plastic and coking organic waste. In fact, when CSR<50, CRI>35.0, and M10>10.3, the value of coke was generally considered to be low. When the product was positioned as coke, a 3% RDF ratio may reduce the economic value of coke. At the same time, the proportion of 3% did not make a significant contribution to the disposal of RDF.

Taking a small and medium coking plant as an example, its annual consumption of raw coal is about 1.5 million tons. If 3% RDF will be added, the annual consumption of RDF will be only 45,000 tons. In summary, 3% doping amount could only reach a small margin for processing RDF, but the discharged solid could still reach the standard of grade III metallurgical coke.

## Effect of Middle Addition of RDF

To investigate effect of middle addition of RDF on coke production, the corresponding products such as solid, gas, and coke, were studied. The input ratio of RDF was set to 25%, 30% and 35% for the oven. The experiment used fixed carbon and calorific value to measure the potential of pyrolysis charcoal as fuels. The mechanical strength of pyrolysis charcoal was evaluated by combining ash and volatiles with M40 and M10. Gas production rate and calorific value were chosen for the pyrolysis gas. The corresponding analysis of pyrolysis charcoal is shown in Table 4.

Table 4. Analysis Indicators of Pyrolysis Charcoal

	Ash (%)	Volatile (%)	Fixed Carbon (%)	Calorific Value (MJ/kg)	M40	M10
R25	23.98±1.20	1.54±0.04	74.83±1.8	19.04±0.9	62.0±1.7	23.7±1.2
R30	24.08±1.18	1.14±0.04	74.88±1.8	19.33±1.0	52.7±1.6	24.3±1.2
R35	27.23±1.33	1.40±0.04	71.66±1.8	18.27±0.9	27.0±1.1	47.7±1.4

From the perspective of the two indicators of the cold strength of the coke, M40 and M10, the cold strength of R35 was weak, which might be caused by the excessive ash provided by RDF. At the same time, R35 had a lower calorific value than the other two samples. The sharp decline in various indicators of R35 should not only be attributed to the composition of RDF. The heat transfer of the coke oven was from the outer wall to the inside, and the heat would be transferred stably and uniformly from the outside to the inside of the solid in a relatively uniform medium (Lin *et al*. 2015). RDF was found to be a poor conductor of heat, and its thermal resistance was higher than that of coal. The solids in the furnace were not uniform as a whole, and the thermal diffusion coefficients of different substances were different, which would lead to uneven heat transfer. RDF was not crushed before adding, so there would be some gaps in the coke oven. During the heating process, these pores would provide contact resistance for heat transfer (Eidem *et al*. 2009). These factors would reduce the overall degree of carbonization, so that the calorific value of pyrolysis charcoal would decrease more drastically with the increase of RDF content. The composition of the pyrolysis gas and corresponding heat analysis are shown in Fig. 1, and the calculation results are shown in Table 5.
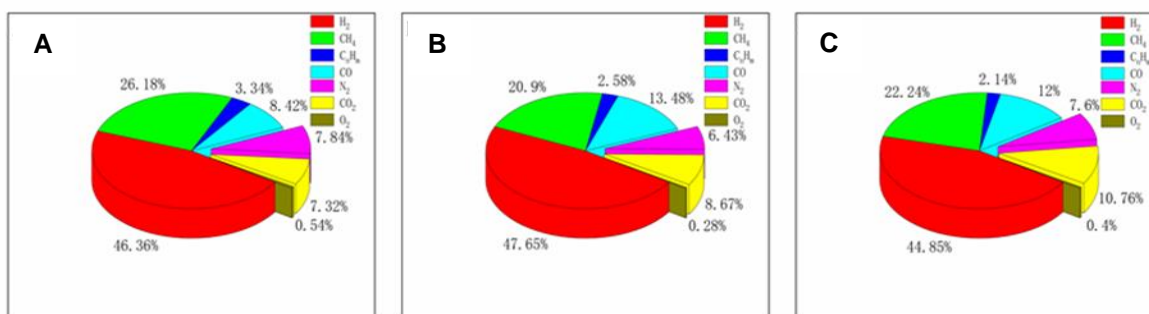
Fig. 1. Pyrolysis gas composition analysis of R25, R30, and R35

Table 5. Pyrolysis Gas Production Rate and Calorific Value of R25, R30, and R35

	Gas Production Rate (m³/kg)	Calorific Value (MJ/kg)
R25	0.31±0.02	17.84
R30	0.31±0.02	16.18
R35	0.30±0.02	15.86

The calorific value of coke oven gas was about 19 MJ/kg. Table 5 showed that all three gases had a calorific value close to that of coke oven gas. The gas production rate of coke oven gas was generally around 0.3 to 0.35 m^3/kg. In this experiment the value was

0.30 to 0.31, which showed ideal gas production potential. Figure 1 shows that the main components of pyrolysis gas were hydrogen and methane, which were close to those of coke oven gas. This showed that the addition of RDF will not affect the composition of pyrolysis gas. R30 pyrolysis gas had the highest proportion of combustible components, reaching 84.61%. The combustible components of coke oven gas were generally around 83%. Fig. 1 showed that the proportion of combustible components of pyrolysis gas after adding RDF was not much different from that of coke oven gas. The gas production rate was close to that of ordinary coking processes. Thus, pyrolysis of RDF produces combustible gas with ideal potential (Razzaq *et al.* 2013).

The most important indicators for the evaluation of pyrolysis charcoal and pyrolysis gas were the calorific value. The result showed the calorific value of pyrolysis charcoal R30 and R25 were obviously more valuable than those of R35. The output of pyrolysis charcoal was much larger than pyrolysis gas, so the comprehensive heating capacity of R30 products was better than that of R25. The calorific value of R30 pyrolysis charcoal was 19.3 MJ/kg, and the calorific value of pyrolysis gas was 16.2 MJ/kg. The calorific values of conventional metallurgical coke and coke oven gas were about 29.3 and 19 MJ/kg. R30 coal consumption was 70% of ordinary coking, the calorific value reached about 66% of ordinary coke, while those of pyrolysis gas reached about 85%, which indicated that the product of R30 had certain application value. Therefore, the 30% RDF ratio was more practical than other ratios. Sampson *et al.* (1991) used high-calorific value coal and biomass for co-firing. When the proportion of wood chips reached 21.9%, the calorific value could reach more than 23.8 MJ/kg, which was much higher than the pyrolysis charcoal calorific value of R30. The proportion of 21.9% also made a great contribution to the treatment and disposal of waste wood chips (Sampson *et al.* 1991). In summary, compared with other studies, pyrolysis charcoal with RDF doping ratio of 25% to 35% had a lower calorific value and could only be used for chemical coke or civil coke. Pyrolysis gas had a certain value, but on the whole it was difficult to make up for the input of coal.

RDF 100% Ratio Experiment

From the perspective of avoiding waste of coal resources and realize the whole resource for solid waste, adjusting the ratio of RDF to 100% was worth studying. R100 was carried out in a 40 kg coke oven. Due to the poor thermal conductivity of RDF, it was loaded into the furnace after crushing to reduce the contact thermal resistance caused by the gap, and the dry distillation time was appropriately extended to ensure an idea carbonization degree.

Table 6. Analysis Indicators of R100

	Ash (%)	Volatile (%)	Fixed Carbon (%)	Calorific Value (MJ/kg)
R100	66.31±2.11	8.65±1.98	30.62	7.53±0.4

The analysis results showed that the ash content in the pyrolysis charcoal was as high as 66.3%, which greatly reduced the mechanical strength and caused the unform of agglomerates. Because R100 did not contain coal, the fixed carbon content was much lower than others. The calorific value of pyrolysis charcoal was 7.53 MJ/kg, 25.69% of the coke produced. Compared with the renewable resource fuel reported by Lin *et al.* (2015), which was up to about 16.7 MJ/kg, R100's pyrolysis charcoal had a lower calorific value, which can be attributed to the ash content. The ash content of RDF before carbonization was

40.0%, and the ash content after carbonization was 66.3%. Götze *et al*. (2016) measured the ash content of food waste fuel as 10.9%. The ash content of garden waste was 8.92%, which were both much lower than those of R100. However, the calorific value of R100's pyrolysis charcoal still reached 46.5% of those for food waste and 41.4% of the garden waste fuel.
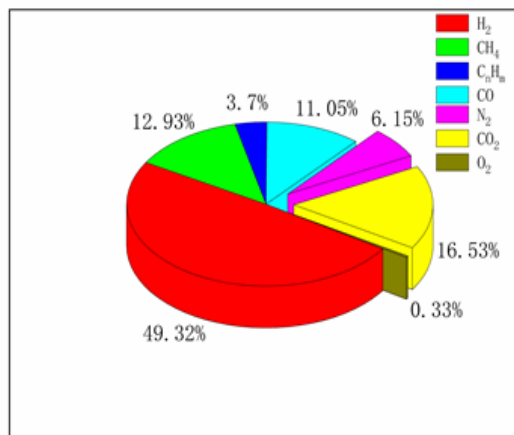
Fig. 2. Pyrolysis gas composition analysis of R100

Table 7. Pyrolysis Gas Production Rate and Calorific Value of R100

	Gas Production Rate (m³/kg)	Calorific Value (MJ/kg)
R100	13.99	0.35

Figure 2 shows the composition of the pyrolysis gas. The calorific value and gas production rate are shown in Table 7. Compared with other experiments, the methane content of R100 decreased, and the hydrogen content increased. RDF contained more abundant organic substances than coal, which gave R100 a higher gas production rate. Dalai *et al*. (2009) steam gasified RDF2 with a volatile content of up to 77.0% at 675°C to 775°C, and its gas production rate fluctuated in the range of 0.29 to 0.35. Although the volatile content of RDF2 was higher than that of RDF, the gas production rate of R100 was higher. This might be caused by the different heating system. The carbonization temperature of the coke oven was as high as 1050 °C and the heating time was longer, so that more components was gasified. RDF2 had the highest calorific value when the steam-to-waste ratio was 0.68 and 2, which was close to 13 MJ/kg. This was lower than the calorific value of R100 pyrolysis gas of 13.99 MJ/kg.

The calorific value of R100 pyrolysis gas was 73.6% of that of coke oven gas under the condition of no coal input. Therefore, R100 had the advantages of high gas production rate and high calorific value. According to the calculation of gas production rate and gas gravity, each ton of RDF could be carbonized by a coke oven to produce about 500 kg of pyrolysis charcoal with a calorific value of 7.53 MJ/kg and 350 m³ of pyrolysis gas with a calorific value of 13.99 MJ/kg. At the same time, the ratio of 100% RDF could also maximize the processing and disposal of RDF, reducing the pressure of handling domestic waste. Taking Shanghai city for example, Shanghai's domestic waste landfill disposal volume in 2018 was 3.934 million tons, and the use of coal was about 8 million tons. With the implementation of the coke reduction policy, if 20% of the coke oven workload of the Shanghai Coking Plant were to be converted into the carbonization of RDF, then about 1.6

million tons of RDF, or 1.12 million tons of domestic waste, could be processed. This is equivalent to 28.5% of the landfill volume. Thus, this would reduce the pressure on Shanghai's domestic waste treatment. At the same time, the coking process produces about 1 million tons of pyrolysis charcoal with a certain calorific value for incineration and power generation. Therefore, the investment of 100% RDF not only can realize the treatment of solid waste, but it also can produce valuable pyrolysis charcoal and gas, which has certain application potential. 100% is a better choice than other doping levels.

Economic evaluation ana management of industrial kiln co-disposal technologies

With the advanced production processes of cement, steel, electric power and other industries, co-disposal of wastes has a remarkable effect on solid waste reduction, harmless and resource utilization, and the application prospect is very broad. However, solid waste components are complex. The S, Cl, alkali metals, heavy metals, and other content varies greatly. High-temperature incineration with the flue gas deposited on the heated surface might exacerbate corrosion, which in turn would create safety problems and increase the cost of operation and maintenance.

From the economic point of view, the process of kiln co-disposal technology in the steel industry are complicated, and the quality of steel products can easily fluctuate in the process of co-disposal, thus affecting the main process. Therefore, there is a need for further research and development of co-disposal projects that could realize long-term operation. Different kilns have their own characteristics. Taking cement kiln co-disposal of fly ash as an example, soluble chlorine salts are removed through a water washing process, and the high-temperature alkaline environment in the cement kiln can be utilized to decompose the residual hazardous substances in the fly ash. The cement clinker formed complied with the national standard GB 30485-2013, which could bring additional benefits to the enterprise at the economic level. When co-disposing high calorific value solid waste in the coal power industry, the solid waste could be utilized as kiln auxiliary fuel, which not only could realize harmless treatment, but also could save fossil energy.

Technical specifications for co-disposal are also a hot research topic. The cement kiln co-disposal technology must conform to the corresponding industry standards. Technical requirements are stipulated for solid waste pollutant control, technology implementation, and other aspects. Co-disposal technology in the steel industry still needs to develop relevant standards to facilitate its implementation into practice. Subsequent research should improve the productization system, increase economic benefits, enhance the willingness and interest of relevant enterprises in the steel industry, and increase the number of co-disposal projects in long-term operation.

CONCLUSIONS

1. In this study, a coke oven was used to pyrolyze and carbonize refuse-derived fuel (RDF) in a certain region of China.

2. When the doping amount of RDF was 3%, the hot and cold strength of the coke would decrease, resulting in a decrease in the quality of the coke and a less treatment ability

for RDF. However, its products could still be used as China's Grade III metallurgical coke.

3. 30% RDF doping for pyrolysis carbonization was shown to be more valuable in case of pyrolysis charcoal and gas. Its solid products could be used as chemical coke or civil coke, and the gas calorific value could reach about 85% of coke oven gas, but overall it was difficult to make up for the loss of coal input.

4. When the doping amount of RDF was 100%, the calorific value of pyrolysis charcoal was 7.53 MJ/kg, 25.7% of the calorific value of ordinary coke, and the calorific value of pyrolysis gas was 14.0 MJ/kg, 73.6% of the coke oven gas.

5. 100% RDF coke oven pyrolysis carbonization could achieve the purpose of processing and disposing of solid waste and alleviating the pressure of domestic waste treatment. Compared with other doping amount, it was a technology with more application potential.

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Author Contributions

Conceptualization, H.M. and P .L.; methodology, J.Z.; software, P.L.; validation, J.Z. and C.W.; formal analysis, H.M. and P .L.; investigation, H.M. and P.L.; resources, J.Z. and H.M.; writing—original draft preparation, P.L.; writing—review and editing, H.M., P.L. and C.W., visualization, H.M.; supervision, H.M. and J.Z.; project administration, H.M.; funding acquisition, J.Z. and H.M. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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