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SYSTEM OF WASTE SEPARATION: STATUS AND CHALLENGES IN CHINA

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ABSTRACT

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With the rapid development of China's economic construction and the improvement of people's quality of life, China's MSW generation has reached 215 million tons, which is expected to reach 480 million tons by 2030. The increase in MSW generation put a significant strain pressure on MSW management systems in cities across China. But on September 2019, 46 key cities that need to compulsorily classify garbage have issued their own action plans, implementation rules or local regulations for waste separation, China's compulsory waste separation policy is on the right track.

This thesis begins with a survey of China's waste separation policy and various waste disposal methods, clarifying the meaning of waste separation and introducing China's waste separation system. The impact on two important waste disposal technologies is then investigated through the separation of waste. First, a comparison of incineration technology for separated waste and mixed waste shows that the average water content of separated waste is significantly reduced, carbon content is doubled and combustible components are tripled. This increases the calorific value of the incineration and can reduce dioxin production and emissions of other pollutants. From the perspective of resource utilization, increasing the calorific value can also increase the efficiency of incineration power generation. This was followed by an analysis of the impact of waste separation on anaerobic digestion techniques, which led to the conclusion that waste separation could result in higher quality biogas yields from anaerobic digestion and reduced heavy metal pollution. This confirms the need for waste segregation: both from the environmental point of view and from the point of view of economic benefits and the social effects of waste segregation are considerable.

Finally, the thesis through the research and analysis of the current situation in Japan and combined with the current situation of waste separation in China, two challenges that China may need to face in the future: management challenges and treatment technology challenges.

Key words
Anaerobic digestion, municipal solid waste, waste separation, waste incineration disposal

CONCEPT DEFINITIONS

LIST OF ABBREVIATION

C/N	Carbon-to-nitrogen ratio
CSTR	Continuous Stirred Tank Reactor
HCl	Hydrogen chloride
MSW	Municipal Solid Waste
Nm^3	The volume of gas at 0 degrees Celsius and 1 standard atmosphere.
PET	Polyethylene terephthalate
SO_2	Sulfur dioxide
TEQ	Toxic Equivalent Quantity

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1 INTRODUCTION

The increasing amount of Municipal Solid Waste (MSW) in China poses a massive threat to the environment. The vast amounts of MSW occupy valuable land space. Two thirds of China's cities have a waste siege phenomenon, and MSW management is under great pressure. Waste separation is seen as the only effective way to solve this problem.

In the past, China's waste collection methods have been mixed, which resulted in toxic and hazardous waste such as dry batteries, all kinds of recyclable waste, food waste, without sorting directly into the trash without any separation, which not only increased the burden of waste transportation and landfill, but most importantly, waste disposal was more difficult, requiring more investment to achieve the purpose of harmlessness, and ultimately also resulted in the loss of resources of useful components. If harmless disposal processes are not achieved, mixed landfills, incineration, composting and other disposal methods impose greater environmental costs. (Ye, Anwar, Zhou, Asmi & Ahmad 2020)

At present, waste separation has entered the era of mandatory. Since 2017, the Ministry of Housing and Urban-Rural Development has released a list of 46 key cities that require mandatory classification, marking the beginning of the era of compulsion. In June 2019, on the occasion of World Environment Day, General Secretary Xi Jinping once again gave important instructions on waste separation, pointing out that the implementation of waste separation is related to the living environment and resource conservation of the general public. As of November 2019, a total of 46 key urban settlements across the country have been sorting garbage, with 53.9 % coverage. (Chen 2020)

The scope of research for this thesis is for MSW, the waste that people in the city produce in their daily lives. The purpose of this thesis is to affirm the importance of waste separation by researching and reviewing the current status of waste separation in China, combined with the impact of waste separation on treatment technology and the environment. Finally, the thesis analyzes and predicts the possible challenges to waste separation in China.

2 THE WASTE SEPARATION SYSTEM AND MSW IN CHINA

Globally, the generation of MSW has increased dramatically as a result of population growth, increased economic development, accelerated urbanization and changing consumption patterns. The global generation of MSW is expected to reach 2.2 billion tons by 2025 and 4.2 billion tons by 2050. This has a significant negative impact on the environment. Most countries are currently aware of this serious global environmental problem. (Cudjoe, Han & Nandiwardhana 2020)

Since the reform and opening up, due to the continuous and rapid development of China's economy, people's living standards have been increasing, and a significant amount of urban living waste has also been generated. With the rapid development of industrialization, urbanization and imperfect environmental protection policies in China, environmental pollution has always been a serious social problem. MSW is one of the many problems that affect environmental pollution. The amount of municipal waste generated in China has reached 215 million tons in 2017, and is expected to reach 480 million tons by 2030. The increase in waste generation has put significant pressure on the existing waste management systems in Chinese cities. (Zhang 2017)

China's dictionary of resources and environmental laws defines MSW as "solid waste in the daily life of the city or activities that provide services for the daily life of the city. As well as MSW as a result of laws and administrative regulations, solid waste mainly includes residential garbage, commercial garbage, shopping malls, streets, garbage, garbage in public places, institutions, schools, factories and other waste units (industrial waste and other special garbage other than hazardous solid waste). (Zhang 2017)

The increasing amount of MSW poses a great threat to the environment. The vast amounts of MSW occupy valuable land space. Two thirds of China's cities have a " waste siege " phenomenon, and MSW management is under great pressure. And waste separation is seen as the only effective way to address this problem. (Zhang 2017)

China's waste separation system can be understood as an umbrella term for a series of activities that transform waste into public resources by storing, handling and disposing of waste in separate categories according to certain rules or standards. Waste in this case refers to the municipal waste that people

produce in their daily lives. The purpose of separation is to increase the resource value and economic value of waste and to make the best use of it. (Xiong 2014)

Waste is private property of the public at the stage of separate storage, and becomes a regional quasi-public resource in the community or district where the public is located after it has been separated and deposited, and becomes a non-exclusive public resource after it has been sorted and removed to a waste collection point or transfer station. In terms of the way municipalities at home and abroad classify domestic garbage, the classification is roughly based on the composition and volume of waste generated, combined with the resource utilization and treatment of local waste. (Dong Qing Zhang 2010) Separate waste collection has social, economic and ecological benefits by reducing the volume of waste disposal and treatment equipment, reducing disposal costs and reducing the consumption of land resources. (Li 2013)

China's garbage classification has now entered the era of compulsion, with a series of systems and policies in place and related laws introduced. On June 25, 2019, the revised draft law on the prevention and control of solid waste pollution of the environment was first submitted to the Standing Committee of the National People's Congress for consideration. The draft provides for a specific chapter on "Prevention and control of environmental pollution by domestic waste". (Liu 2019) In September 2019, in order to thoroughly implement the important instructions of General Secretary Xi Jinping Guan on the work of garbage classification, and to promote public institutions across the country to do a good job in the classification of domestic garbage and play a leading role in demonstrating, the State Administration of Organs Affairs issued a notice announcing the "Reference Standards for the Evaluation of Domestic Garbage Classification Work of Public Institutions", and put forward requirements for further promoting the work. (Zhu 2019)

In terms of social impact, garbage classification has also become a key point for all Chinese people to pay attention to. Through vigorous publicity and popularization, at present, the people of China's key cities, such as Beijing and Shanghai, have been able to cultivate an awareness of waste separation, (Liu 2018) improve their understanding of waste separation, abide by the law on waste separation, and achieve the development of waste from the source. (Xu 2019)

2.1 Status and characteristics of MSW production in China

Statistics show that the world generates more than 4 billion tons of solid waste per year (nearly half of which is MSW) and China is the largest developing country with more than 10 % of the world's waste and the world's largest share. As the economy continues to improve, the growth rate of MSW is accelerating, reaching 215 million tons in 2017. (Duan, Li, Wang, Ma, Wenga, Zhong & Chen 2020)

According to China's National Bureau of Statistics in 2018, FIGURE 1 shows that in 2017, China collected and transported 215 million tons of waste, which is equivalent to each municipal resident 0.72 kg per day. (Han 2019) According to the comparison of the data of each country in FIGURE 1, China is now one of the world's largest producers of municipal waste.

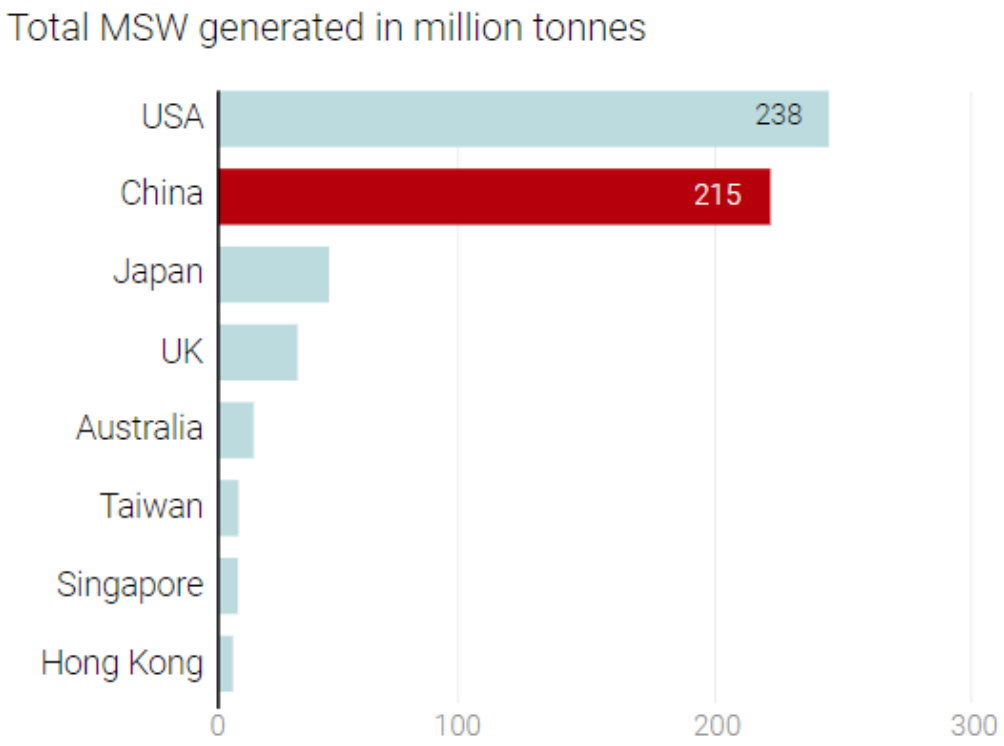


FIGURE 1. Total MSW generated in million tons (adapted from Han Huang 2019)

The research on the characteristics of MSW components is very important for the choice of its follow-up treatment and disposal. Living standards, urban fuel structure and other factors determine the composition and various physical and chemical properties of MSW. (Cheng 2014)Typical MSW in China includes 55.9 % food residues, 8.5 % paper, 11.2 % plastics, 3.2 % textiles, 2.9 % wood chips, 0.8 % rubber and 18.4 % non-flammable materials. (Li 2016)The overall study of MSW in urban areas in

China, it is characterized by a low calorific value of waste, about 4200 kJ/kg, with a higher moisture content, generally 40-60 %, which is 1.5 - 2 times higher than in developed countries. Recyclable content is lower than in developed countries, around 10 - 25 %; a higher proportion is food waste. Waste and various plastic wrappers, which can account for more than 50 % of dry weight; clay masonry will be slightly lower in content. (Lu 2019)

The ash masonry content will be slightly lower, about 10% to 20% of the dry weight, and as the standard of living improves, the proportion of ash will also be down. Municipal solid waste has its own characteristics, the components are variable, long residence time, less diffuse, hazardous. It is characterized by its high sex, which pollutes the environment through the atmosphere, water and soil. (Cheng 2014)

2.2 Waste separation

The concept of municipal waste separation is divided into broad and narrow concepts. The broad definition of municipal waste separation refers to a complete system of waste separation and disposal, including separation at source, collection, transportation and disposal, while the narrow definition of municipal waste separation refers to the classification corresponding to the mixed disposal of MSW, especially urban residents who separate household waste at source, i.e., urban residents who separate household waste into categories according to classification standards. The implementation of MSW classification is a profound and systematic understanding, as a pollution control measure, municipal waste separation draws on the idea of industrial pollution source management, i.e., pollution control in the process of its generation. (Li 2019)

2.3 Historical policies on waste separation

As early as 1996, China's Beijing has started to carry out waste separation in the community, and the Beijing Municipal Waste Management Regulations, which came into effect on March 1, 2012, also put forward the relevant opinions, but there is no clear provision on the method of MSW separation and recycling. (Peng, Li, Peng, Yang & Zhao 2018)

In June 2000, the former Ministry of Construction launched a pilot project to separate garbage in eight cities, including Beijing, Xiamen, Nanjing and Shanghai. In April 2015, the Ministry of Housing and Construction re-established cities (districts) with good experience and technology in waste disposal as a new model region for waste classification, requiring cities (districts) to play an active role in the interests of relevant participants.

In December 2016, General Secretary Xi Jinping, at the 14th meeting of the Central Leading Group for Finance and Economics, stressed the universal implementation of the garbage sorting system and the speedy establishment of the garbage sorting and disposal system. In March 2017, during the "two sessions" of the National Assembly, the government proposed to establish a universal waste separation system to promote comprehensive management of the urban and rural environment, and on March 18, the newly revised "Implementation Plan for the Domestic Waste Separation System" was officially implemented, based on the establishment of an effective resource recovery mechanism and the "mandatory" separation of hazardous waste. (Li 2019)

2.4 Current types of waste separation in China

In order to facilitate waste disposal, waste at the collection stage is broadly classified into four categories: recyclable waste, food waste, hazardous waste and other waste. (Li 2019) Recyclables include five main categories: waste paper, plastic, glass, metal and fabric. This type of waste can be recycled after comprehensive treatment, reducing waste pollution and saving social resources. Waste paper mainly includes newspapers, periodicals, books, various kinds of wrapping paper, etc. However, be aware that paper towels and toilet paper are not recyclable because they are too water soluble. Plastic includes all kinds of plastic bags, plastic foam, plastic packaging (express wrappers are other trash/dry trash), disposable plastic lunch box cutlery, hard plastic, plastic toothbrushes, plastic cups, mineral water bottles, etc. Glass mainly includes various glass bottles, broken glass pieces, warm bottles, etc. (The mirror is other garbage/dry garbage.) Metal mainly includes easy to pull cans, canning boxes, etc. Fabric mainly includes discarded clothes, tablecloths, washcloths, school bags, shoes, etc. (Zhang 2019)

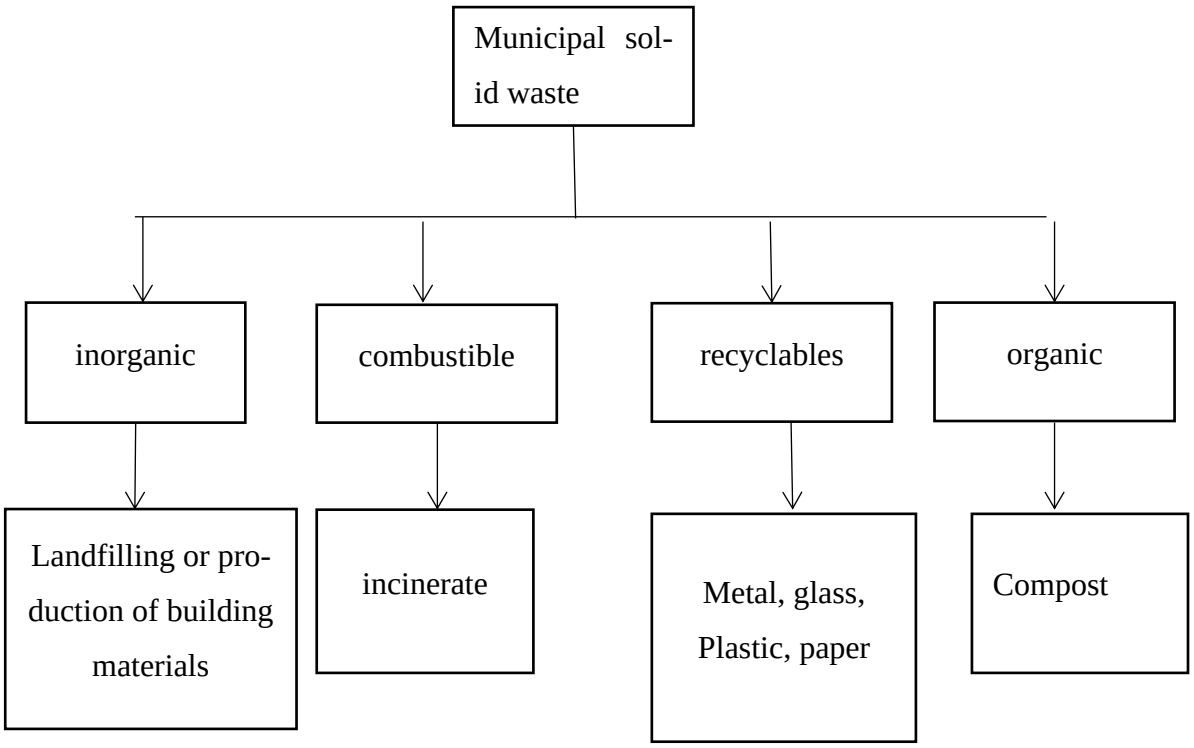
Food waste includes food waste such as leftovers, bones, roots and leaves. Food waste containing: high amounts of water are prone to decay and spoilage, producing irritating gases. This type of waste is mainly composted using biotechnology. In addition, it can produce 0.3 tons of organic fertilizer per ton. Hazardous waste includes used batteries, used fluorescent tubes, waste water thermometers, expired

pharmaceuticals, etc. Hazardous waste cannot be disposed of directly in landfills, incineration, etc., and this type of waste requires special safe disposal. (Xu 2019)

Other waste includes in addition to the above-mentioned types of waste mainly discarded paper towels, discarded bottles and cans, food boxes (bags), dirt, cigarette butts and other waste that are difficult to recycle. Other waste is mostly incinerated for disposal and are the main source of incinerated power generation waste. The ash contained in other waste, as well as the residue from incineration, is disposed of in landfills. (Zhang 2017)

2.5 Waste separation methods of disposal

The most common methods of MSW disposal are landfill, composting, incineration, anaerobic digestion, etc. GRAPH 1 clearly demonstrates this process. Waste has different ingredients and is suitable for different disposal methods. Recyclable waste goes through a series of processes to recycle it, and some of the higher calorific value waste can also be incinerated to generate electricity. Other garbage (or what is known as dry waste) is primarily combustible and is suitable for incineration. Waste incineration is mainly used to treat high calorific value waste, which has the advantage of short treatment cycles, small plant footprint and high efficiency, but incineration power plants have high upfront construction costs and the exhaust gas produced by incineration is complex and requires advanced technology to treat the exhaust gas. Sanitary landfill technology is the most widely used technology in China, and most of the waste can be landfilled in this way, but sanitary landfilling takes up a lot of land, and the leachate from landfills can pollute the groundwater resources, potentially causing great harm to the environment and health, so it must be treated harmlessly. (Zhou, Shun & Yi 2017) Food waste has a high water content and organic separation, which is suitable for waste composting or anaerobic digestion and other technologies, after composting, the organic matter in the waste is transformed into inorganic nutrients, realizing the reuse and recycling of resources. (Cheng 2014)



GRAPH 1. Integrated waste disposal process（adapted from Li Pengfei 2016）

2.6 The significance of waste separation

Separate collection of household waste in cities is conducive to the optimal use of resources. Sorting household garbage shows that people have a deeper understanding of household waste, no longer simply thinking that garbage is waste and useless, but also recognizing that there are recyclable resources in waste. (Lu 2019)

With the acceleration of the urbanization process, household waste as a product of urban metabolism has obviously become an obstacle to urban development, and many cities around the world have been surrounded by waste. It is not difficult to examine people's littering habits to find that most of the early consumer goods were produced by nature or simply processed, coupled with a small population and relatively small consumption, so that the waste produced can basically be absorbed by nature's enormous capacity for consumption. The development of industrial technology has led to rapid economic development, resulting in the population explosion, and the development of the chemical synthesis industry, more and more synthetic products have become consumer products, which may not exist in

nature, or even if they exist only in small amounts, difficult to degrade in the natural environment, then can cause serious environmental pollution. (Li 2016)

Separate waste collection in cities is conducive to more efficient waste disposal. The world's waste disposal technology is diverse, there are landfills, incineration, composting, recycling and so on, but decades of waste disposal practice has shown that every waste disposal technology has its drawbacks that cannot be ignored, no single disposal technology can be both efficient and pollution-free treatment of mixed waste. The reason for this problem boils down to mixed garbage collection without pre-sorted garbage. Due to the complexity of the components in the mixed waste, a single waste disposal method can be overwhelming. Waste separation is implemented, and waste that is suitable for incineration is incinerated, while waste that is suitable for anaerobic digestion or composting is made into organic fertilizer, and waste that can be recycled is recycled, and the final residue in the waste is disposed of in landfills, thus improving the effectiveness of waste disposal. At the same time, separate collection and disposal of hazardous waste also simplifies the process and reduces the cost of waste disposal. (Wang 2015)

Separate waste collection in cities is conducive to the development of a sustainable and circular economy. China's "Seventeenth Great Congress" has called for the building of an ecological civilization. The production of municipal waste remains high and its composition is becoming more and more complex, and if waste is not classified and effectively treated, then the ecological environment and the living environment will be threatened, which is not consistent with the essence of ecological civilization.

3 IMPACT OF WASTE SEPARATION ON THE ENVIRONMENT AND DISPOSAL TECHNOLOGIES

Waste separation can also have a significant impact on environmental protection. The pollution of the environment caused by MSW is huge, occupying land and polluting the soil, accelerating the greenhouse effect and polluting the air, some harmful waste may also enter the body through the food chain, causing harm to the human body. (Cheng 2014)

And in addition to reducing the amount of waste produced, it is the disposal of waste that is the most important aspect of reducing the damage to the environment. Hazardous waste, which is sorted out, is disposed of harmlessly through special departments, reducing pollution to the environment. At the same time, waste sorting helps to improve the quality of waste and allows for better end-of-pipe incineration (or landfill) disposal. For incineration technology, the release of dioxins from the sorted dry waste during incineration will be greatly reduced, reducing pollution to the environment and enhancing the efficiency of the waste incineration plant for power generation and reuse of resources. (Cheng 2014)

Food waste has been the highest proportion of MSW in China, and because of the differences in the lives of our people, food waste has more organic components and water, so it is easy to react with microorganisms and lead to decay and deterioration; the longer it is processed, the more serious the corruption. Particularly in hot summers, high temperatures accelerate their decay and deterioration, making them more susceptible to leachate and foul smell and posing environmental and health risks. (Li, Jin, Borrion & Li 2019)

In the past, most food waste was disposed of by incineration or landfill without sorted, but because of its characteristics. If incineration is used, it is prone to produce air pollutants and cause air pollution. If landfills are used, they are susceptible to contamination by heavy metals and other toxic substances, which can cause illness if they enter the food chain. Compared with other waste, food waste has high moisture content, organic matter content, high salinity and oil content, rich in nutrients and other characteristics, and has great recycling value. The use of anaerobic digestion of waste after sorting, as mentioned below, would be a significant resource if it could be effectively disposed of. (Li, Jin, Borrion & Li 2019) The realization of waste separation will help to improve the quality of civilization and environmental protection for all, as well as the improvement of the environment, while allowing residents will have a greater sense of access and happiness.

3.1 Waste incineration disposal

FIGURE 2 clearly shows the process of incineration technology，the specific disposal technology of incineration. At a high temperature of 850 to 1000 °C, municipal waste is sent to the furnace as fuel for combustion for the chemical reaction, which releases a large amount of heat that can be used to generate electricity. The combustion gas converted to high temperature must be purified before it can be discharged; a small amount of solid residue, which accounts for 10 % to 30 % of the stable nature, is disposed of in landfills. Fly ash contains toxic and hazardous heavy metals, which must be sent to hazardous landfills as hazardous waste. (Ansari 2015) Fly ash flue gas pollution control process is due to that most of the gases produced by waste incineration are harmful gases - acidic gases, dust, dioxins, heavy metals, etc. Bag filters, lime sprayers, activated carbon sprayers and non-catalytic denitrification units are used to remove pollutants from the exhaust gas. (Cheng 2014)

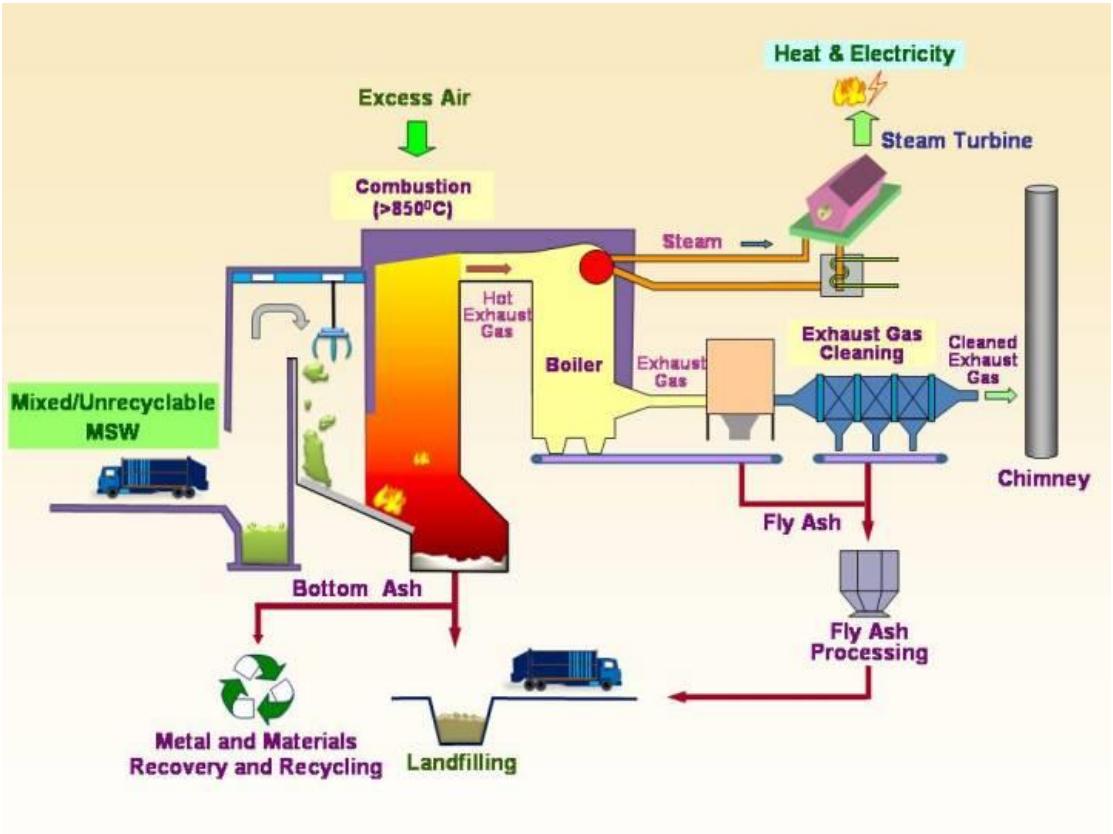


FIGURE 2. Waste incineration process (adapted from Ansari 2015)

According to FIGURE 2, the fly ash collected by the pre-treatment electrostatic precipitator system is not considered hazardous waste and is collected and transferred to cement plants or mixing plants for comprehensive use. The fly ash collected by the semi-dry flue gas purification device is hazardous waste with high content of heavy metals and dioxins, which is transported to the curing workshop and then transported to landfills for safe landfill after cement curing and maintenance. Incineration treatment is characterized by high throughput and good capacity reduction. (He & Lin 2019)

Waste incineration has been growing rapidly in Japan and Europe, where the country is relatively small, for nearly a hundred years. However, the disadvantages of waste incineration, latent pollution to the atmosphere and human health is serious, the unit disposal costs are high, and the operation is complicated. (Xu 2009) The pollution from the incineration of waste lies in the production of 5,000 cubic metres of exhaust gas per ton, leaving about 10 to 30 % of the feedstock as residue. The exhaust gas contains hundreds of pollutants and is difficult to clean up after filtration, washing, adsorption and other processes. These contaminants include harmful gases such as SO_2 and HCl, vaporized heavy metals such as Pb and Cd. The most serious pollutant is dioxin, which is a Class I carcinogen, mainly produced by plastic products, which is thousands of times more toxic than potassium cyanide and 900 times more toxic than arsenic. In addition, dioxins are difficult to control and monitor. (Yuan, Su & Li 2008)

However, with the gradual implementation of the waste separation policy and the continuous updating of incineration technology, China's waste incineration harmless treatment volume is increasing at a great pace every day. Many experts believe that waste incineration technology is an important technology to solve China's waste enclosure, but must ensure harmless treatment, focus on monitoring and control of harmful gas emissions and generation. (Cheng 2014)

3.1.1 Impact of waste separation on incineration

The water content and the calorific value of the burned material determine the impact of disposal for incineration disposal. The lower the moisture content of the waste, the better, the higher the calorific value, and the greater the economic benefits that can be obtained. This project was conducted to analyze the composition of municipal waste in a city in China. (Cheng 2014)

In the case of a municipality in northeastern China, the waste living component is 11.18 % paper, 0.31 % rubber, 0.39 % metal, 0.65 % plastic, 1.27 % glass, 10.24 % textile, 54.54 % residual, 0.19 % toxic and hazardous waste, 3.68 % other waste, 0.86 % wood and bamboo, 1.34 % masonry and ceramics and 5.35 % clay. (Cheng 2014) TABLE 1 shows the components of the combustible waste obtained after waste separation in the city. As shown in the TABLE 1, plastic, paper, and textiles accounted for the main components of the incinerated waste collected after the separation of waste. Plastic accounted for 31.25 %, paper for 32.81 %, and textile for 30.03 %.

TABLE 1. Components of combustible waste in the city (adapted from Cheng Rui 2014)

Components of combustible waste					
Components	plastic	rubber	paper	textile	Wood
Proportion （%）	5.40	0.16	5.67	5.19	0.86
Incineration volume (million tons)	6.78	0.2	7.12	6.52	1.08
Percentage of combustible waste (%)	31.25	0.93	32.81	30.03	4.98

TABLE 2 is a comparison of the components of combustible waste obtained after the city's waste separation with the unsorted mixed waste. TABLE 2 shows that the city's mixed municipal waste has a water content of 58.1 %, and that the high water content leads to a low calorific value, which is very detrimental to the waste incineration. The water content of combustible waste after separation is 33.78 %. The average water content of separated waste is much lower, the carbon content is doubled and the combustible fraction is tripled. This increases the stability of the waste incineration process. (Cheng 2014)

TABLE 2. Component analysis of combustible waste in the city (adapted from Cheng Rui 2014)

	Water content (%）	Solids content (%)						
		C	H	N	O	S	CL	Combustibility (%)
Average of combustible waste	33.78	27.94	1.40	3.96	19.86	0.07	0.36	100
Average of mixed waste	58.10	13.47	0.72	2.02	6.53	0.12	0.37	33.24

After separation, the moisture content and calorific value of municipal waste are more stable than mixed waste, making the incineration system more stable; if mixed waste is incinerated, the composition of domestic waste changes constantly with the region, season, energy structure, etc., making it difficult for waste incineration to operate stably. (Yang 2019) The mixed waste also contains a large amount of food waste, resulting in a high moisture content and low calorific value, which increases the number of auxiliary fuels to be burned, resulting in a waste of energy resources.

The pre-treatment system is very important and decisive for the incineration of mixed waste, it is the guarantee that the incineration process is stable and even generates electricity. The pre-treatment includes the separation and breaking of non-combustible materials, such as glass, bricks and tiles, various metals, etc., to reduce the proportion of non-combustible waste, if the waste is separated and recycled, the waste entering the waste incineration plant is basically combustible waste, so that the temperature of incineration is stable and continuous, and there are no non-combustible materials such as glass bricks. (Yang 2019)

3.1.2 Impact of waste separation on the disposal of pollutants from waste incineration

The chlorine source in waste is a key factor affecting dioxin generation, and the original proportion of plastic components in sorted waste is 5.40 % shown in TABLE 1. If mixed waste is incinerated, the proportion is 10.65 %, and the plastic component is reduced by half by waste separation; there is a

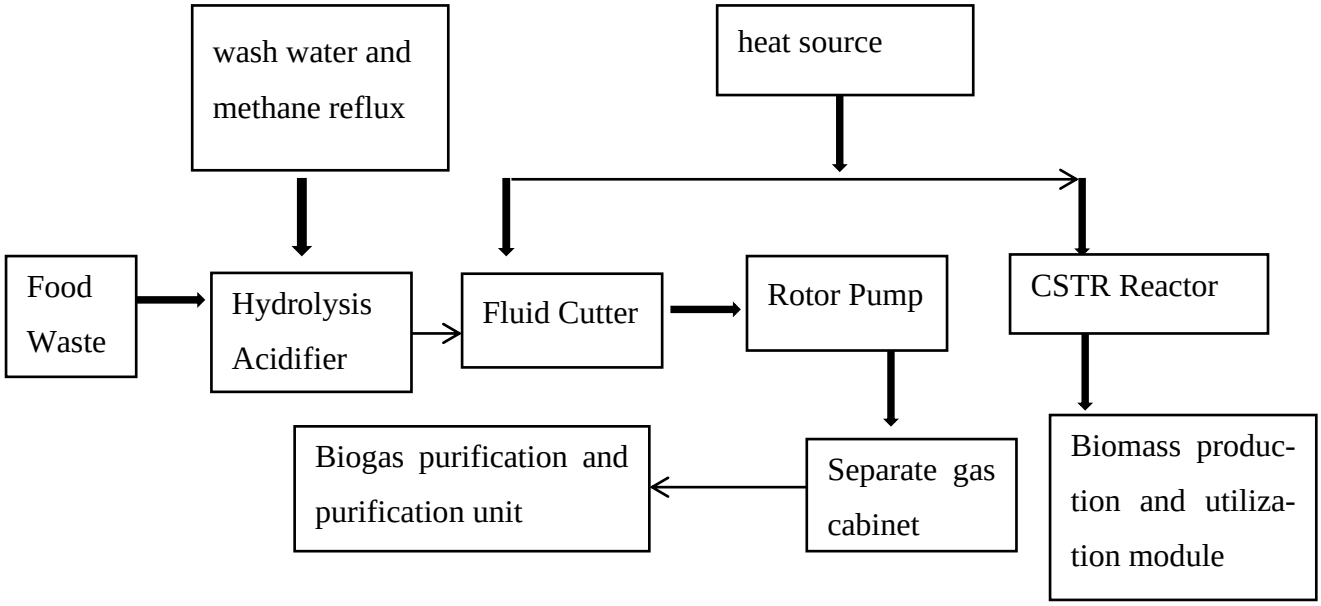
large amount of chlorine salt in food waste, which is used for anaerobic digestion, and the chlorine source is much less than that of mixed garbage, which reduces dioxin production. (Cheng 2014)

The impact of waste segregation on waste incineration slag, the volume of mixed waste incineration residue becomes 50-80 % of the incoming furnace volume, the percentage varies depending on the waste composition, and the combustible waste collected after segregation can even be reduced by 90 % of its original volume. The high ash content of mixed waste after combustion can result in a serious accumulation of ash in the incinerator, reducing the efficiency of heat energy exchange, and ash collapse can also affect safe operation. (H.Fiedler 2007)

Incineration plants that burn dry, wet and hazardous waste directly produce large amounts of dioxin, a notoriously toxic substance with adverse consequences including carcinogenicity, reproductive toxicity and genotoxicity. As hazardous waste and wet waste are now separated from other waste, the remaining dry waste will release significantly less dioxins during incineration and the dry waste will significantly increase the calorific value of the incineration, thereby improving the power generation efficiency of the waste incineration plant. Therefore, the social effects of waste separation are considerable, both from an environmental point of view and from the point of view of economic benefits. (Li 2019)

3.2 Anaerobic digestion technology

Anaerobic digestion is considered to be the best technology for the treatment of the organic part of municipal domestic waste, especially food waste. This is because it helps to recover high quality biogas for energy production and biofertilizer for agricultural purposes. The gas mixture produced by anaerobic digestion of the organic components of MSW is called biogas. (Cheng 2014) The biogas produced by this process consists of 50-70 % methane and 30-50 % CO_2 with high energy (electrical and thermal) content. (Cudjoe, Han & Nandiwardhana 2020) GRAPH 2 provides a clear view of the entire process of anaerobic digestion.



GRAPH 2. Description of the anaerobic digestion process（adapted from Zhang Xuan 2015)

According to the anaerobic digestion process shown in GRAPH 2, the whole process is as follows; the first process is feeding. The food waste anaerobic digestion system can be designed for different types of waste. The food waste is conveyed to the hammer crusher via a screw conveyor, and the crushed food waste needs to be removed by a sand removal system before entering the hydrolysis tank. (Cheng 2014)

The second process is anaerobic digestion. Wet fermentation reactors are fully hybrid cylindrical reactors with vaulted tops and inclined bottoms. The reactor is of steel construction. The concrete foundation of the reactor is the common tendency bottom center structure. Depending on the minimum temperature difference between the design temperature and the atmospheric temperature, the reactor needs to be insulated, and the mixing of the reactor with insulated insulation on the outside of the tank is done using a deflector tube located in the center of the interior to allow the gas to circulate. The density difference between the two stages of anaerobic digestion, inside and outside the conduit, combined with the pumping action, produces a vertical circulation flow of biogas in the reactor (internal circulation reactor). The slurry rises in the central conduit and falls outside the tube to form a circulation. Circulating biogas is injected at a certain location below the liquid surface, producing a vertical two-phase flow of gas and liquid. The pneumatic mixing system allows the reactor to be operated on a flat bottom. Anaerobic digestion system is the core of kitchen waste treatment, using wet medium temperature two-phase anaerobic digestion. The Continuous Stirred Tank Reactor (CSTR) process, using mechanical

stirring, can achieve homogeneous mixing of materials, avoiding the rise of oil and grease, crusting, can make the anaerobic reaction stable, and at the same time improve the gas production rate. (Cheng 2014) The resource utilization system is started by hydrolysis acidification, through wet medium temperature two-phase anaerobic digestion to produce biogas, after purification and purification treatment into vehicle natural gas, then compressed and loaded into the skid-mounted vehicle for sale, the remaining fermentation residue dehydration into the fertilizer utilization unit. (Zhang 2015)

The third process is biogas systems. The hydrogen sulphide in the biogas is first removed from the bioreactor by a chemical desulphurization system, which is required to protect the cogeneration system due to its very corrosive nature. The purified biogas goes first to the biogas storage tank. The tanks are equipped with a high pressure protection system and also have a condensate collection system. The biogas in the biogas storage tank is partly transported to the cogeneration system by fans and partly compressed and returned to the bioreactor for use as agitation gas. (Zhang 2019) The resource utilization system is started by hydrolysis acidification, through wet two-phase anaerobic digestion of medium temperature to produce biogas, after purification and purification treatment into vehicle natural gas, then compressed into skid-mounted vehicles for sale, the remaining fermentation residue dehydration into the fertilizer utilization unit. (Zhang 2015)

The advantages of anaerobic digestion are high organic load carrying capacity, recovery of biomass energy, no homology problems, organic matter is turned into methane, carbon dioxide and methane is better sold. The disadvantage is that the project investment is large and the resulting methane needs to be reprocessed. (Yuan, Cao, Niu & Zhao 2016) The conditions for anaerobic digestion are as follows; the anaerobic digestion system is capable of treating organic flue gases with a solid content of 10 % to 25 %, and the temperature range at which anaerobic digestion can take place is (40 °C to 65 °C). The pH of the system should be controlled between 6.5 and 7.5. Anaerobic digestion of organic matter, which requires concentrations of organic matter generally greater than 1000 mg/L or more, is higher than aerobic treatment. (Yuan, Cao, Niu & Zhao 2016)

3.3 Impact of food waste obtained after waste separation on anaerobic digestion treatment

Anaerobic digestion technology is suitable for treating waste with high organic content in domestic waste, most of which are food waste. Because of the large population, the proportion of food waste in domestic waste in China is relatively high. TABLE 3 is a comparison of the content of each component between food waste and mixed waste in a city of China studied in this thesis. (Li, Jin, Borrion & Li 2019)

TABLE 3 shows that food waste has the characteristics of higher water content, higher organic content and richer nutrition. If the food waste is not separated from the mixed waste, the waste is very perishable and deteriorates, emits a foul smell, and spreads bacteria and viruses. In the past, most food waste has not been classified as waste, and most of it has been disposed of by incineration or landfill. If not separated, because of its characteristics, if incineration is used, it can easily produce air pollutants and cause air pollution. If landfills are used, they are susceptible to contamination by heavy metals and other toxic substances and can cause disease if they enter the food chain. (Cheng 2014)

TABLE 3. Component analysis of food waste in the city (adapted from Cheng Rui 2014)

	water content（%）		solids （%）							
	solids content（%）		C	N	H	O	S	C/N	organic	inorganic
Average amount of food waste	69	31	43.25	2.19	4.37	35.80	0.44	19.57	84.25	15.75
Average amount of mixed waste	58.1		13.47	0.72	2.02	6.53	0.12	15.70	—	—

TABLE 4 is the analysis of heavy metal elements in municipal waste. From the comparison of heavy metal elements in TABLE 4, the contents of heavy metal elements such as copper, zinc, chromium and cyanide in mixed municipal domestic waste are high, which will not only inhibit the anaerobic diges-

tion treatment. At the same time, the mixed collected waste is easily polluted by toxic substances such as heavy metals. Composting for soil will further pollute the soil. If it enters the food chain, it can cause cancer after being eaten to a certain extent. By contrast, the content of heavy metals in food waste is much lower than that of mixed waste, and the environmental risk of anaerobic digestion of food waste obtained after strict waste separation is much lower than that of mixed waste. The C/N ratio of kitchen waste is 23.76 %, the C/N ratio of mixed waste is 15.70 % in TABLE 3, and the increase of C/N ratio will increase the amount of methane. Therefore, the gas yield and quality of food waste after separation are higher. (Cheng 2014)

TABLE 4. Analysis of heavy metal elements in the City's waste (adapted from Cheng Rui 2014)

Element	unit	mixed waste	food waste
Hg	mg/Kg	0.04	undetected
Cd	mg/Kg	0.36	undetected
Cr	mg/Kg	74.97	9.61
Cu	mg/Kg	65.83	5.98
Ni	mg/Kg	23.43	2.40
Pb	mg/Kg	29.03	1.36
As	mg/Kg	6.79	undetected

4 WASTE SEPARATION IN CHINA AND ABROAD

For the time being, some developed countries, such as Japan, have sound and mature policies and systems, and people can consciously waste separation. The concept of waste segregation is deeply rooted in people's minds. At the same time, the technical treatment is at the world leading level, such as incineration, recycling. These methods and approaches are worth learning from other countries. (Li 2016)

For some developing countries, such as China, waste separation is still in its infancy. It is necessary to adjust the policies and laws of waste separation in light of national conditions, and to constantly popularize the concept and methods of waste separation. At the same time, in the aspect of waste treatment, the waste treatment plant should try to achieve 100 % of waste harmless treatment, reduce environmental pollution while pursuing greater resource reuse with new technologies.

4.1 Status of waste separation in Japan

In the 1960s, severe industrial pollution caused by Japan's rapid economic growth made the Japanese people aware of the importance of environmental protection. Therefore, starting in the 1970s, Japan has spent more than 40 years progressively refining the method of waste separation to reduce environmental pollution from the source and further improve resource utilization. Japan's waste separation is "extreme" and even "harsh" in the eyes of many foreigners. (Xiong 2014)

In Japan, waste is carefully sorted and disposed of in different ways, for example, different components of a plastic beverage bottle are divided into different waste categories. Local governments in Japan develop their own waste separation and recycling methods according to their own circumstances. In Shinjuhama City, for example, household waste is divided into the following eight categories: combustible waste, non-combustible waste, plastic containers and packaging, bottles and cans, plastic bottles marked with PET (polyethylene terephthalate), waste paper, hazardous waste and large waste. (Yu 2019) For example, combustible, non-combustible, plastic containers and packaging must be placed in clear or semi-clear bags of up to 45 litres; bottles and cans and plastic bottles marked with PET must be placed in designated net pockets; and large garbage must be collected at home.

The smooth implementation of such a detailed and even somewhat cumbersome garbage separation process is inseparable from Japan's legal norms, persistent education and awareness of the public. The main measures can be summarized in the following three. The Government of Japan has promptly amended and enacted relevant laws and regulations in response to the problems encountered in waste management and the current social situation. In Japan's waste disposal legislation, the implementation of specific aspects of the law has been made practical, making it highly operational. (Yu 2019)

In Japan, penalties for non-compliance with the rules and requirements for waste separation are very strict, and a mechanism for evaluation and punishment has been gradually established to clarify the penalties for non-compliance with waste disposal and to strengthen the responsibilities and mandatory authority of the State agencies. (Liu 2019)

In addition to improving laws and regulations, Japan has also increased its efforts to publicize and educate its citizens on the kinds of classifications, forming a "government-led, socially-responsive" system of public information and education, in which education and public information are carried out in a detailed and systematic manner and in a variety of forms. Japan's waste separation campaign covers all aspects of society, including the government, businesses, communities, families, associations, schools, office buildings. In the classification promotion, both standard norms for waste classification and correct classification demonstration guidance are included, as well as corrective education for wrongdoing. The Japanese people's awareness of classification is very high, and the level of knowledge of classification has increased rapidly through more than a decade of persistent classification education and promotion. (Yu 2019)

In Japan, as the concept of waste separation has become more and more popular, people have made it an important criterion for judging the moral and social responsibility of citizens, such as whether or not to separate waste according to regulations, put it away, and use waste bags correctly. Waste is collected on a community basis, etc. If there is a mistake in separation, location or time of drop-off, the waste will usually not be collected and will have to be picked up. In some areas, there is also a person who helps check that the waste that is thrown out is up to standard and will send it back if there is a problem. (Li 2019) Although littering is not completely eradicated in Japan, Japan's waste separation policy is one of the world's leading policies, thanks to the influence of long-term laws, awareness-raising, self-regulation and public opinion monitoring. (Yu 2019)

4.2 Waste disposal technology and current status of waste disposal in Japan

At present, in Japan, incineration and landfill are the main methods of waste treatment and disposal. The amount of waste incineration is as high as 75 %. Dioxin is easy to be produced by incineration, and the incineration plant in Japan is close to the residential area. The government aims to ensure the health of residents. Therefore, the unit cost of waste incineration in Japan is relatively high. (Li 2019)

Japan's waste disposal method is mainly incineration, which is mainly related to urban population, area and urban natural conditions of the location are closely related. Waste incineration treatment occupies a small area, allowing for maximum waste reduction, and is well suited to the basic principles of Japan, where land resources are tight and population density is high. When selecting a site for a waste incineration plant in Japan, the following two aspects are usually taken into account: first, the distance away from the residential area and the optimal distance beyond two times the maximum distance from which the smoke and dust will fall according to the height of the smoke and second, the cost of transportation. Japan's expansion of waste collection and the adjustment of waste incineration plants in terms of incineration capacity are intended to address the problem of the emission of the toxic gas dimethyl ether and the poor utilization of waste heat. In terms of incineration technology, Japan's rotary furnace pyrolysis technology and fluidized bed gasification technology are among the most advanced in the world in terms of waste-to-energy generation. (Mu Yu 2014)

The grate-fired incineration technology is used in many countries because it does not require very fine waste separation, is mature, stable, reliable and adaptable, and most of the solid waste can be burned directly in the furnace without any pre-treatment. The most common fluidized bed technology in Japan, however, requires the breakdown of waste fuel, which is based on specific materials to achieve efficient combustion. Therefore, there is some justification for Japan's strict waste separation. (Fei Mayi 2019)

There is also the fluidized bed pyrolysis melt furnace waste treatment technology, which has become popular in recent years and can operate steadily while at the same time achieving a dioxin concentration of 0.1 ng TEQ/Nm^3 or less in the flue gas outlet. (Mitsubishi heavy industries co. LTD 2001)

In order to make it easier to store and transport waste, Japan has also invented a method of solid waste fuel, in which combustible waste is crushed, hoof-selected, dried, lime is added, and a solid waste product is compressed and shaped, which is then sent to a waste incineration plant for use as fuel. In

Japan, waste from small-scale cities, streets, villages and towns is collected and centralized for disposal, which is first produced as solid waste fuel and then transported to incineration plants in nearby large cities for incineration, which not only reduces environmental pollution but also saves the cost of incineration. (Wang, Lv, Gu, Yang & Guo 2020)

In Japan, the recycling rate of waste disposal has been increasing, and incineration for efficient power generation has been gaining more and more attention and utilization. The use of incineration to treat domestic waste requires a significant amount of capital to maintain infrastructure and operating costs, so many environmental companies are beginning to focus on the ability to reduce costs by recovering energy from the incineration process.

In 2018, Japan's total waste disposal was 42.72 million tons, with a daily per capita discharge of 918 grams. (Japan's environment ministry government 2020) The following are various disposal methods of waste; Landfill disposal was 0.6 % lower than the previous year, with a slight decrease in recycling rates. Landfill disposal was 3.84 million tons and the waste reduction rate was 98.9 % and the direct landfill disposal rate was 1.1 %. The total amount of waste recycled is 8,530,000 tons, with a recovery rate of 19.9 %. (Japan's environment ministry government 2020)

Waste incineration disposal; the number of waste incineration plants has decreased, but the amount of electricity generated per plant has increased slightly. The number of plants with power generation equipment increased to 35.0 %, increasing the total generation capacity. As of March 31, 2019, the number of waste incineration plants is 1082. The capacity of incineration plants is 178,336 tons / day, the number of waste heat utilization plants is 748. The number of plants with power generation facilities is 379, and the total power generation capacity of waste incineration is 2.069 million kW. (Japan's environment ministry government 2020)

4.3 The current status of waste separation in China

At present, waste separation has entered the era of compulsory. Since 2017, the Ministry of Housing and Urban-Rural Development has released a list of 46 key cities that require mandatory classification, marking the beginning of the era of compulsion. In June 2019, on the occasion of World Environment Day, General Secretary Xi Jinping once again gave important instructions on waste separation, stating that the implementation of waste separation has a bearing on the living environment and resource con-

servation of the general public. It is also an important manifestation of the level of civilization of society. (Zhu 2019)

According to research, by September 2019, each of these 46 focus cities had issued its own action plan, implementing bylaws or local regulations for waste separation. As of November 2019, a total of 46 key urban settlements across the country have been sorting waste, with 53.9 % coverage. Thirty cities have issued laws and regulations on waste separation, 16 cities have incorporated waste separation into their legislative plans, and 237 prefecture-level cities have started to separate waste.

According to the National Annual Report on the Prevention and Control of Environmental Pollution from Solid Waste in Large and Medium-sized Cities in 2019, In 2018, 200 large and medium-sized cities nationwide generated a total of 2,147,000 tons of household waste and disposed of 2,128,000 tons of waste, a disposal rate of 99.4 %. Among them, Shanghai had the highest domestic waste generation at 9.843 million tons, followed by Beijing, Guangzhou, Chongqing and Chengdu at 9.294 million tons, 7.453 million tons, 717,000 tons and 6.231 million tons respectively. The top 10 cities generated 62.56 million tons of waste, or 29.6 % of the total amount of waste in all cities where information was released. (National Bureau of Statistics of China, 2019) The amount of waste generated and disposed of in specific municipalities can be found in Appendix (1).

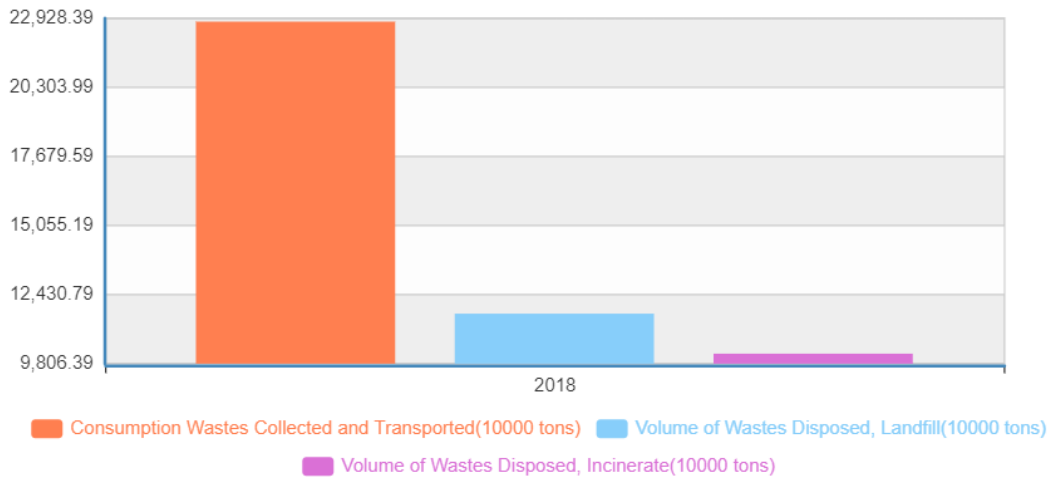


FIGURE 3. China's Total Waste Disposal and Incineration and Landfill Disposal in 2018 (adapted from National Bureau of Statistics of China 2019)

In the area of waste disposal; according to the data of the National Statistical Office, FIGURE 3 shows that the volume of MSW treated in a sound manner was 228 million tons in 2018. The sanitary landfill

treatment capacity is 117.06 million tons; incineration treatment capacity is 101.849 million tons; other treatment methods treatment capacity is about 9 million tons.

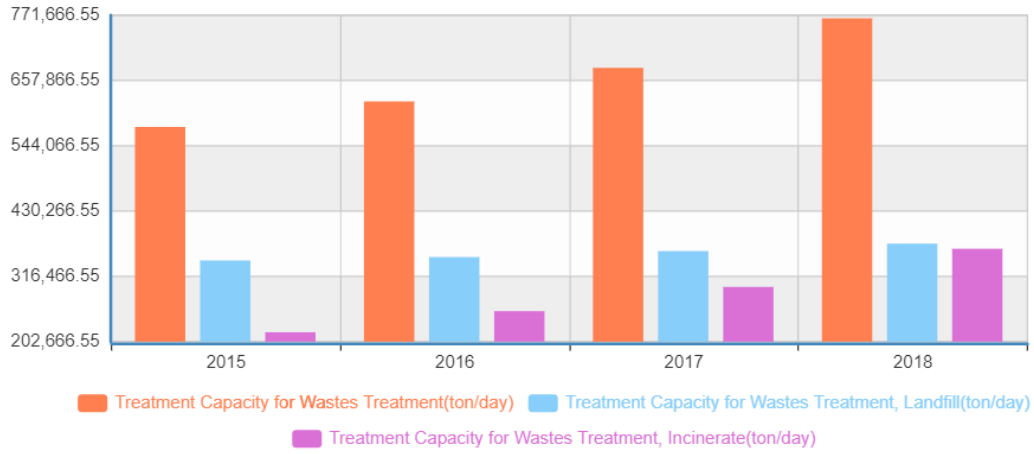


FIGURE 4. Daily emissions from waste disposal methods in recent years (adapted from National Bureau of Statistics of China 2019)

The FIGURE 4, which shows that at present, the national capacity of household waste incineration and treatment facilities is 365,000 tons per day. The proportion of waste incineration and waste treatment that is harmless has been growing year. With the gradual advancement of the national waste separation policy, waste incineration and waste treatment can better meet the needs of MSW education and harmless development, and incineration and waste treatment will become the mainstream mode of industry development. (Wang, Lv, Gu, Yang & Guo 2020)

According to FIGURE 5, China's municipal waste disposal rate is steadily increasing every year, which means that China's waste disposal is causing less and less harm to the environment, but is still not perfect. The problem of irregular emissions and substandard treatment continues to exist in rural or small urban areas throughout the country. By the end of 2018, the national urban garbage disposal rate was 99 %; eight provinces, including Beijing, Tianjin, Shanghai, Jiangsu, Shandong, Guangxi, Hainan and Sichuan, had passed the acceptance of rural household waste management. Among the 100 rural household waste separation and resource utilization demonstration counties (cities and districts). 75 % of townships and 58 % of administrative villages had initiated waste separation; 47 % of the 24,000 informal waste dumps identified nationwide had completed the rectification task. (National Bureau of Statistics of China 2019)

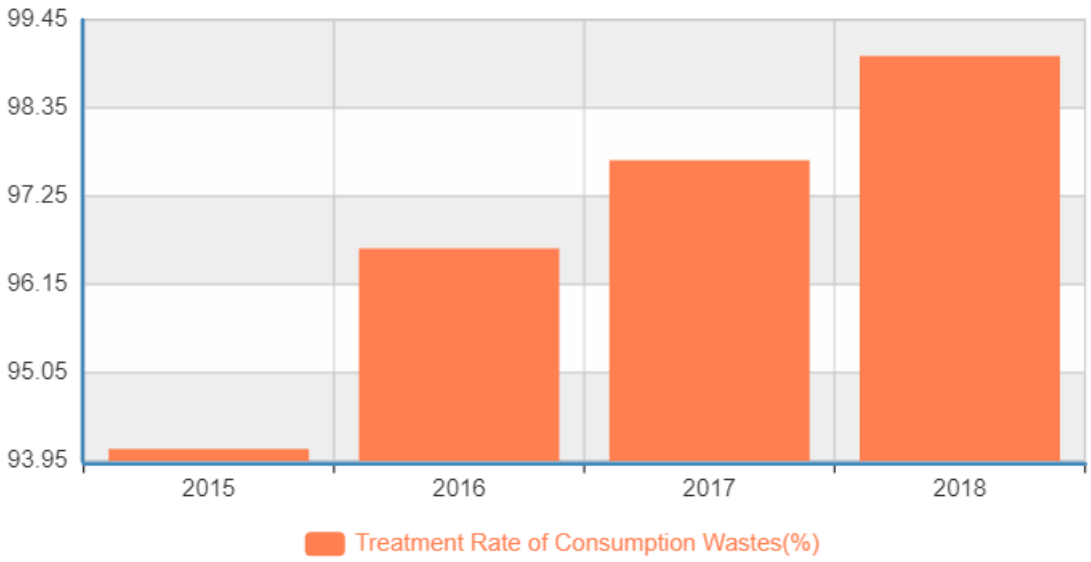


FIGURE 5. Treatment Rate of Consumption Waste in recent years (adapted from National Bureau of Statistics of China 2019)

4.4 The challenges of waste separation in China

Combining the above, the challenges of waste separation remains twofold: the challenge of management and the challenge of disposal technology. In the past, experts and scholars have generally agreed that the management challenge of waste separation is greater than the technical challenge. This is due to the inability to implement past policies, the inadequacy of the legal system. At present, China has entered the era of mandatory waste separation. With the improvement of policies and systems in key cities, the popularization and promotion of waste separation has been deeply rooted in people's minds. The general policy direction of waste separation in China can already be determined. Although China still face the challenges of waste separation management, such as the need to improve the coverage of waste separation, more cities need to develop a sound system and legal provisions based on the characteristics of local waste and people's living habits, how to make residents develop a good awareness of waste separation, awareness of the importance of waste separation, etc. (Li 2016)

In the future, as systems and policies get better, we will need higher-end waste disposal technology. From the point of view of resource utilization, it is important to select the most targeted and resourceful technology for disposal, so that the utilization rate of waste is higher. From the point of view of environmental protection, the search for healthier and better waste disposal methods and the pursuit of minimal harm to the environment. It is possible to try to link several existing mature waste disposal methods to form a complete waste disposal system. Finally, it is also important to consider how to reduce the generation of waste at the source, including pollution during transport or collection. (Li 2016)

5 CONCLUSION

In the past, China faced the problem of waste siege at the same time as MSW caused serious pollution to the environment due to the failure to separate waste and only mixed collection and disposal. But now, the start of compulsory garbage sorting in China marks the start of China's garbage sorting on the right track. By September 2019, each of the 46 focus cities has issued its own action plan, implementing bylaws or local regulations for waste separation. China's MSW disposal rate has steadily increased each year, reducing secondary pollution to the environment.

With regard to the improvement of waste separation for waste treatment technology and environmental protection, the study in this thesis shows that for incineration technology, the water content and calorific value of separated waste are more stable than mixed waste, resulting in a more stable operation of the incineration system, doubling of carbon content and tripling of combustible components. The separated waste is very conducive to incineration, while also reducing the generation and emission of pollutants and dioxins. For anaerobic digestion technology, this results in higher quality biogas yields and less heavy metal pollution. Overall, the impact of waste segregation, both from an environmental point of view and from the point of view of economic benefits, is considerable, as is the social impact of waste separation.

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APPENDIX 1

Instructions for appendices

Collection, Transport and Disposal of Consumption Wastes in Cities by Region 2018

8-18 Collection, Transport and Disposal of Consumption Wastes in Cities by Region (2018)

Region	Consumption Wastes Collected and Transported (10 000 tons)	Number of Factories for Wastes Treatment (unit)				Treatment Capacity (ton/day)				Volume of Wastes Disposed (10 000 tons)				Treatment Rate of Consumption Wastes (%)
			Landfill	Incinerate	Others		Landfill	Incinerate	Others		Landfill	Incinerate	Others	
National Total	**22801.8**	**1091**	**663**	**331**	**97**	**766195**	**373498**	**364595**	**28102**	**22565.4**	**11706.0**	**10184.9**	**674.4**	**99.0**
Beijing	975.1	28	13	7	8	28591	10991	12050	5550	975.1	393.8	399.7	181.6	100.0
Tianjin	294.8	9	4	5		10600	5100	5500		278.5	142.0	136.5		94.5
Hebei	755.7	53	39	10	4	25342	13942	10650	750	754.2	386.1	343.3	24.8	99.8
Shanxi	478.9	27	19	6	2	13887	10012	3577	298	478.1	345.5	122.6	10.1	99.8
Inner Mongolia	349.3	28	25	3		12954	9604	3350		348.6	255.5	93.1		99.8
Liaoning	872.2	38	32	3	3	26622	22442	2780	1400	868.4	734.3	67.2	67.0	99.6
Jilin	470.6	30	22	6	2	15234	9154	5500	580	410.5	270.3	132.2	8.0	87.2
Heilongjiang	524.9	35	28	6	1	18831	13888	4600	343	456.4	349.3	100.5	6.6	86.9
Shanghai	784.7	15	5	9	1	29150	15350	13300	500	784.7	394.3	386.0	4.4	100.0
Jiangsu	1718.0	72	28	35	9	60665	14935	44210	1520	1718.0	348.9	1328.7	40.5	100.0
Zhejiang	1474.6	72	22	38	12	63626	16626	44585	2415	1474.6	454.8	981.3	38.5	100.0
Anhui	612.0	39	16	18	5	24595	8735	15110	750	612.0	179.5	420.3	12.2	100.0
Fujian	874.9	30	11	14	5	24896	6246	16350	2300	873.9	254.3	585.3	34.3	99.9
Jiangxi	448.8	24	17	7		17318	12356	4962		448.8	335.0	113.8		100.0
Shandong	1700.8	88	34	40	14	57515	18653	36100	2762	1700.8	499.4	1116.4	85.0	100.0
Henan	1019.6	45	37	7	1	25265	17865	7350	50	1016.6	807.7	207.5	1.4	99.7
Hubei	954.2	49	32	11	6	31397	14847	12350	4200	954.0	501.6	409.3	43.1	100.0
Hunan	824.5	37	29	6	2	26647	16222	10300	125	824.1	508.9	311.5	3.7	100.0
Guangdong	3035.4	99	54	37	8	107304	51668	53872	1764	3031.6	1739.4	1241.7	50.4	99.9
Guangxi	466.5	27	19	8		15896	9796	6100		466.5	313.0	153.5		100.0
Hainan	222.4	13	6	5	2	6438	2230	3908	300	222.4	80.7	133.7	8.0	100.0
Chongqing	549.2	25	18	6	1	17697	7047	10500	150	549.1	292.1	256.9		100.0
Sichuan	1013.1	48	29	16	3	25441	9731	14810	900	1006.0	439.7	558.2	8.0	99.3
Guizhou	338.5	25	13	10	2	15821	7656	7750	415	325.3	184.8	130.4	10.0	96.1
Yunnan	435.8	30	20	10		12409	4479	7930		427.8	175.2	252.6		98.2
Tibet	53.9	6	5	1		1501	801	700		51.8	23.3	28.5		96.0
Shaanxi	650.2	25	24		1	19388	19288		100	644.1	642.8		1.3	99.1
Gansu	281.2	27	22	4	1	10244	6294	3600	350	280.5	159.4	109.0	12.1	99.8
Qinghai	113.5	8	7		1	1779	1659		120	109.0	90.7		18.3	96.0
Ningxia	117.7	13	9	2	2	4830	2670	2000	160	116.9	64.4	49.9	2.6	99.3
Xinjiang	390.7	26	24	1	1	14312	13212	800	300	357.2	339.3	15.5	2.5	91.4