Topic 4. Waste Management Technologies

Contents

1. Waste Discharge, Collection and Transport

1.1 Transition of Waste Collection and Transport Methods

Since the 1950's, when Japan entered a period of rapid economic growth after postwar reconstruction, the increase in generated waste and related sanitation issues made it necessary to collect the growing waste amounts discharged from each household. To ensure reliable waste collection and transport systems the related technologies continued to progress. At the initial stage of waste collection, hand carts were used. Due to the requirements for more efficient and sanitary collection, the transport method shifted from manual collection to the introduction of mechanical collection by compactors - vehicles for waste collection with the function of compressing waste, often referred to as packers in Japan. With changes in the social conditions including economic growth and urbanization, issues such as waste collection in large amounts, sanitary collection, and efficiency arose and these issues have been handled with technological innovations for waste collection and transport vehicles as well as collection forms and methods.

Waste collection had been in place prior to the enactment of the *Public Cleansing Act*. In the 1950's when the *Public Cleansing Act* was established, waste collection was introduced to address the problems of the increase in waste amount and related sanitation issues. At the initial stage, waste was collected from each household by using a hand cart. The waste collected in the hand cart was then transferred to a vehicle and transported to a landfill site or an incineration plant.

Due to the subsequent continuous increase in the amount of waste combined with population concentration in urban areas due to urbanization, the collection of waste in urban areas became a serious issue. To resolve this issue, collection vehicles were introduced to ensure more efficient and sanitary waste collection.

With the introduction of waste collection compactor vehicles (packers) and shifting from manual collection by hand carts, there were improvements in the safety of collection operations (e.g., accidents involving workers), sanitary conditions during transportation (e.g., countermeasures of odor and waste liquid leakage), and collection efficiency (e.g., collection route planning). At the same time, in order to operate an efficient waste collection and transport system various types of vehicles were developed for waste collection and transport, low-pollution emissions, and transport of recyclable materials.

Photo 4-1 Collection of Kitchen Waste from Households by Handcart - circa 1957

Photo 4-2 Transfer of Household Waste from Handcart to Transport Vehicle - circa 1961

Photo 4-3 Transport Vehicle that were Often Used- circa 1961

Photo 4-4 Pilot Project for Introducing Mechanized Waste Collection by Compactor - circa 1957

Source: Tokyo Metropolitan Government Bureau of Environment

Photo 4-5 Waste Collection by Compactor

Photo 4-6 Example of Low Pollution Type of Waste Collection Compactor

Source: Ministry of the Environment “Solid Waste Management and Recycling Technology of Japan” (2013)

1.2 Collection Methods

Waste discharge methods are classified into two major methods, door-to-door collection and station collection. In Japan, both methods have been adopted for a long time and the selected method in a certain region is determined by the actual conditions of that region or the preference of the residents. For upgrading, it is important to introduce a practical and effective collection method suitable for the actual conditions of the region - for example if it is a built-up area or a suburb, the population density, and land utilization status, etc. - after examining the advantages and disadvantages of each method.

(1) Storage and Discharge of Waste

Waste is generated every day from each household and it is important to collect the waste generated effectively and efficiently to secure the sanitary condition of each household and its surrounding area. For this reason, in principle, it is important for residents to collect the waste that is generated in each household, and store the waste inside the house until it is time to discharge it to the designated location at the specified time according to the predetermined collection plan.

Source: Tokyo Metropolitan Government Bureau of Environment

Photo 4-7 Fixed Waste Box in Front of each Household

In most cases, plastic bags are used to discharge waste at designated locations. For recyclables, paper is tied up with string, or special containers are used.

Photo 4-8 Waste Discharged to Collection Points Using plastic Bags

Source: Yachiyo Engineering Co., Ltd.

Photo 4-9 Corrugated Cardboard Discharged Tied with String

(2) Door-to-door Collection and Station Collection

Waste collection services that are provided by the municipality (not only directly managed services but also by subcontracted collection services operators,) are mainly carried out by door-to-door collection or station collection methods. Depending on the type of waste being discharged, there may be a direct delivery system whereby a resident of the household directly delivers the waste to the specified waste management facility (transfer station, intermediate treatment facility, or landfill site).

In the door-to-door collection method, waste is discharged in front of each household which is then collected. In Japan, not many municipalities adopt door-to-door collection as the standard collection method. However, this method is partially used in many municipalities for certain circumstances such as collection of bulky waste and to support elderly residents in their waste discharge. Since each household discharges its own waste in front of the residence under its responsibility, this method has certain features such as clarity of the responsibility for the waste discharged and some degree of freedom for each household. Door-to-door collection is effective for districts with low population densities - districts containing large residences of high-income earners and districts in local areas where residences are scattered over a large area. On the other hand, since waste discharged needs to be collected from many collection points, the workload of the collection operators increases, which becomes a disadvantage for the municipality.

Source: Tokyo Metropolitan Government Bureau of Environment

Photo 4-10 Station Collection (1964)

In the station collection method, a specific location is set as a waste discharge station and a number of households discharge their wastes there for collection. In Japan, many municipalities adopt station collection. In station collection, since a station is shared by a number of households, the unique features of this method are that the station location needs to be determined by all the residents who share the station and the stations needs to be managed. Therefore, in long-established districts where there usually are residents associations, it is possible to examine the introduction of station collection method there since it is comparatively easier for the residents to cooperate together. Furthermore, since less waste collection points are required than those of door-to-door collection, waste can be collected more efficiently, reducing the workload of operators, which is an advantage for the municipality. Station collection is efficient in districts where many households are concentrated such as apartments and terrace houses. Table 4-1 shows the features of door-to-door collection and station collection.

Another effective collection method is the container collection method, although this method is not widely adopted in Japan. Container collection is a method in which containers of 4 to 10 m^3 are set up to collect waste from surrounding households. Residents can discharge their waste at any time, and a large amount of waste can be collected at one time. On the other hand, if container is not emptied at an appropriate frequency, the waste may overflow from the container and deteriorate the sanitary environment in the area where the container is set up.

Photo 4-11 Station Collection - 1

Photo 4-12 Station Collection - 2

Photo 4-13 Door-to-door Collection - 1

Photo 4-14 Door-to-door Collection - 2

Source: Yachiyo Engineering Co., Ltd.

Table 4-1 Advantages and Disadvantages of Door-to-door Collection and Station Collection

Item	Door-to-door collection	Station collection
Advantages	✓ The responsibility of the location of discharge and the waste discharged is clearly defined (the owner of the waste discharged is identifiable). ✓ Highly convenient for residents as the waste discharge point is nearby, and there is a certain degree of freedom in how and when to dispose of the waste. ✓ Awareness of the residents is raised. They have better waste discharge manners. There is less waste scattering caused by dogs and crows. ✓ Sorting of waste is improved.	✓ Collection operation can be implemented efficiently since there are less collection points (number of stations). ✓ Collection cost is reduced. ✓ Collection time is shorter and operator burden is reduced. ✓ Awareness on waste discharge can be shared within the regional community. ✓ Less impact on the traffic conditions.
Disadvantages	✓ A longer collection time is required due to the large number of collection points involved. ✓ Increase in collection cost due to the large number of collection points involved. ✓ Lower operation efficiency due to the large number of collection points involved, thereby causing an increase of the operator's work burden. ✓ Consideration is necessary for privacy since the waste can be easily traced to the discharging household	✓ Selection of collection stations may be difficult. ✓ The responsibility for the waste discharged is unclear. Awareness of individual households on their own discharged waste is lowered. ✓ The handling of inappropriate discharge by any of the households sharing the station is difficult. ✓ The collection station needs to be managed. Inappropriate management creates a situation similar to open dumping at the station.
Remarks (Examples of countermeasures against disadvantages)	✓ Efficiency of waste collection is improved by examining collection plans in detail such as establishing the most efficient routes. ✓ Sufficient collection vehicles and workers are secured to reduce the burden on workers. ✓ The discharged waste is promptly collected.	✓ In selecting collection stations, it is important to consult in advance with the residents who will be using the stations. ✓ If a new residential district is to be developed, it is desirable to decide on the location of the collection station at the stage of development. ✓ If there is an understanding among residents, and considering privacy concerns, it is possible to reduce the decline in resident's awareness by having them write their names on the waste bags they discharge. ✓ A manager or assistant should be assigned to each collection station to provide regular monitoring and advice.

Column: Measures for Handling Birds and Animals

Birds, particularly, crows are natural enemies of waste collection as they scavenge waste collected for food. In some regions, damage is caused by animals such as monkeys and boars. In particular, in developing countries, it is necessary to prevent waste scavenging by stray dogs.

In Japan, each region takes some measures to prevent birds from tearing waste bags such as covering the waste at the station with nets. In some cases, waste is covered by simple nets and in other cases, waste is placed inside of a meshwork cage. Where waste is to be placed on the roadside, residents are asked to discharge their waste on the scheduled collection day, instead of the previous day to reduce the time the waste is susceptible to damage caused by birds and animals.

Prevention of waste scavenging by birds and animals contributes to smooth and improved collection operations as well as prevention of deterioration of the sanitary environment and maintenance of local beauty of the region.

Photo 4-15 A Crow Rummaging through the Waste

Photo 4-16 Waste Collection Bag Torn by Crows

Photo 4-17 Countermeasure Using Net at Collection Station

Photo 4-18 Countermeasure Using Wire Frame Box for Door-to-door Collection

Source: Yachiyo Engineering Co., Ltd.

(3) Source Separation and Separate Collection

It is extremely important to separate waste at the source of generation (commonly referred to as source separation) in order to promote recycling. Through source separation, positive effects such as waste amount reduction, collection efficiency improvement, and improvement of recyclables quality (cans, bottles, plastic, paper, kitchen waste, etc.) can be expected. The cooperation of residents is essential to realize source separation. In addition, it is necessary to secure collection equipment and personnel required for collection as well as recyclables businesses. While source separation is an effective measure, it is important to establish and implement a feasible plan, giving some consideration to the degree of cooperation from the residents and the funds available in the municipality.

Source separation and separate collection is expected to contribute to the promotion of recycling, as waste generated is separated at an early stage. In addition, many municipalities are implementing this as an effective measure at the waste discharge stage, since it leads to raising public awareness on waste management among residents and to reduction of waste. On the other hand, since an increase of the number of categories for waste materials separation requires development of a system for sorting and increases the burden on the residents, further cooperation of residents becomes necessary. In each municipality, the categories for separation are determined according to the characteristics and actual condition of the region.

Effects of source separation and separate collection:

- More types of waste to separate and recycle reduces the waste amount.
- Recycling is facilitated, leading to a reduction of the recycling cost and improvement of the quality of recyclables.
- Awareness of residents towards waste discharge improves through the work for separating waste, which in turn has an effect on the reduction of waste generation.

Considerations on source separation and separate collection:

- It is essential for the municipality to be able to develop a collection system through securement of personnel and equipment and the funds required.
- Set the number of categories for separation and the separation items such as plastic bottles so that waste can be separated easily to gain the understanding of the residents.
- In order to secure receivers (takers) for the separated items, the growth of the venous industry for recycling is important.

Photo 4-19 PET Bottle Separated and Discharged by Residents in Tokyo

Photo 4-20 Bins and Cans Separated and Discharged by Residents in Tokyo

Source: Yachiyo Engineering Co., Ltd.

Separate collection is actively implemented to promote both prolonging the life of landfill sites and recycling. Table 4-2 shows the waste separation status in Japan. All the municipalities have adopted waste separation and in 32 municipalities (2% of total municipalities) waste is separated into over 26 categories. There are 646 municipalities where waste is separated into 11 to 15 categories (38% of total), accounting for the highest proportion, followed by 418 municipalities where waste is separated into 16 to 20 categories (24% of total). The waste in more than half of all the municipalities is separated into 11 to 20 categories.

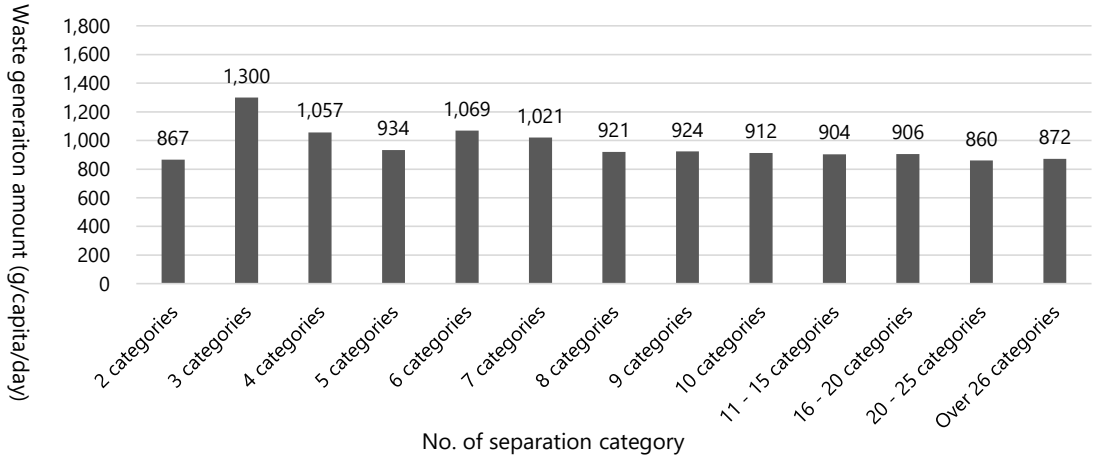
Table 4-2 Waste Separation in Japan

No. of separation	No separation	2 categories	3 categories	4 categories	5 categories	6 categories	7 categories	8 categories	9 categories
No. of municipalities	0	7	8	11	33	67	58	92	97
		373							
(%)	0	22%							
Waste amount (g/capita/day)	0	867	1,300	1,057	934	1,069	1,021	921	924

No. of separation	10 categories	11 - 15 categories	16 - 20 categories	20 - 25 categories	Over 26 categories	Total
No. of municipalities	113	646	418	137	32	1,719
(%)	7%	38%	24%	8%	2%	100%
Waste amount (g/capita/day)	912	904	906	860	872	-

Source: Ministry of the Environment “Waste Management in Japan (FY2019)” (2021)

Figure 4-1 shows the numbers of categories of waste separation and the amount of waste discharged per day per person in grams. Separation of waste into 3 categories falls into the category of the highest amount of waste discharged, which is 1,300 grams/person/day. Starting from the separation of waste into 3 categories with the highest amount discharged, as the number of categories for separation increased, the amount of waste discharged per person per day decreased. This indicates that the number of categories applied for separation of waste contributes to the reduction of the amount of waste.



Source: Ministry of the Environment "Waste Management in Japan (FY2019)" (2021)

Figure 4-1 Relation between Number of Separation Categories and Unit Generation Rate

(4) Establishment of Collection Form

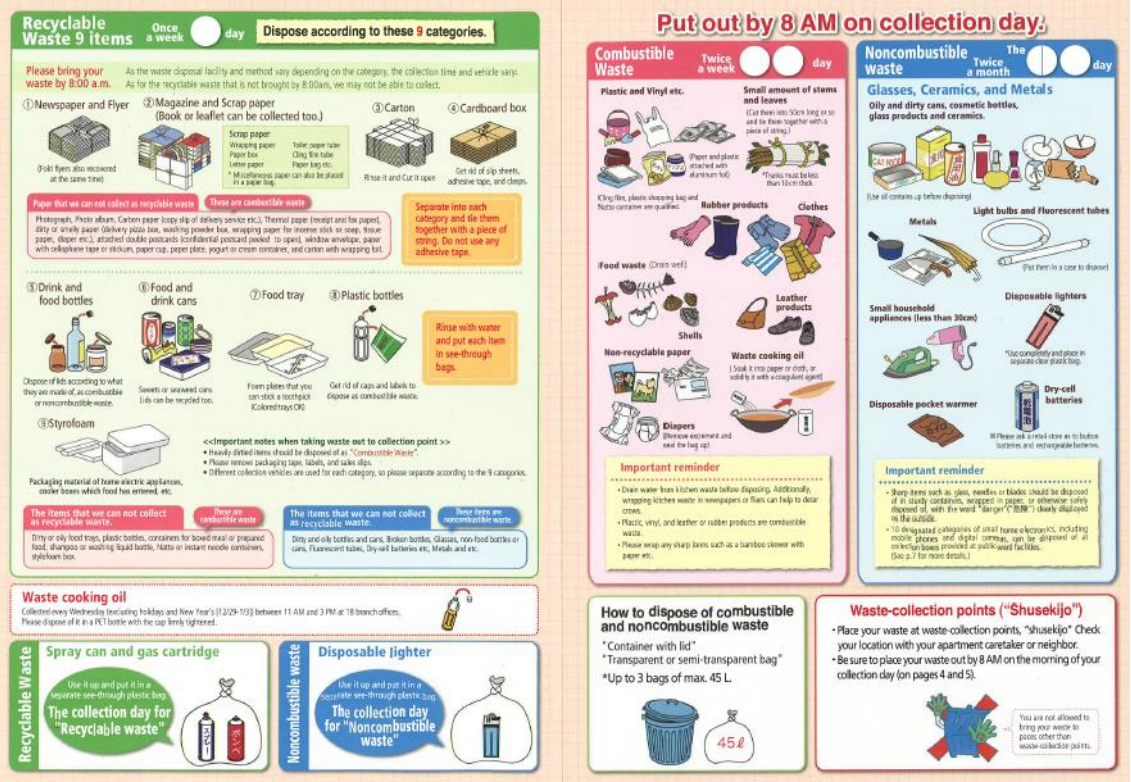
Local governments have always positioned gaining the understanding and cooperation of local residents as an important issue in the implementation of waste management in each region, and are actively disclosing and disseminating information such as plans and data related to waste management.

In particular, the collection and transport stage is the best opportunity to make contact with local residents, and it is extremely important for municipalities to build relationships of trust with them. Therefore, in order to ensure the smooth implementation of collection and transport, the local governments need to continuously disseminate information on how to discharge waste and collection services provided to local residents.

Each municipality actively discloses information on waste management projects and activities planned and implemented by the municipality through the municipality website and other means in order to gain local residents' understanding of waste management. In addition, each municipality continuously conducts various activities such as environmental education and facility tours related to waste management in order to promote the residents' proactive participation in waste management.

Each municipality is responsible for providing services related to waste collection and transport, and the proactive participation and cooperation of residents are indispensable for the smooth operation of these services. For this reason, many municipalities provide information on how to dispose of waste and the collection schedule through pamphlets and municipal websites.

The pamphlets and other information include not only the types of waste to be separated and the collection days, but also the size of waste, procedures to discharge waste (putting it in bags, tying it up with string, etc.), draining food scraps, and other points to keep in mind as a reference for residents when disposing of waste.



*: Pamphlet is available in Japanese, English, Chinese, Korean, Tagalog, Nepali and Vietnamese.
http://www.city.ota.tokyo.jp/honnyaku/index.html

Source: Ota City "How to dispose and separate your waste and recyclables" (2021)

Figure 4-2 Leaflet on How to Discharge and Separate Household Waste in Ota City, Tokyo

(5) Resource Recovery

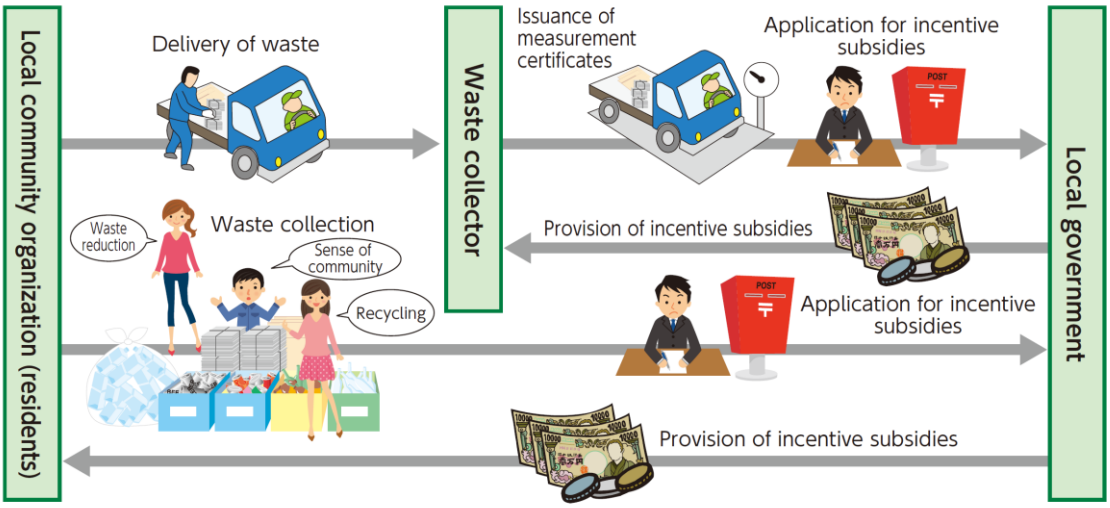
In Japan, group collection has been adopted since a long time ago, where a voluntary association of community residents voluntarily collects recyclables and delivers it to recycle business operators. The adoption of group collection contributes to the effects of not only an increase in the amount of recyclables, but also enhancement of awareness of community residents towards waste management and the environment, as well as creation of opportunities for children to learn about the environment and for residents to communicate with the administration.

In addition to source separation and separate collection that are implemented by municipalities, community group collection is exercised as a recycling activity, where a voluntary association of community residents such as a neighborhood association and a children's group voluntarily collects recyclables and delivers it to a recycle business operator. Many municipalities support voluntary associations that implement community recycling activities through group collection, by providing subsidies to cover expenses for the activities and introducing them to recycle business operators. Group collection can directly contribute to the improvement of the recycling rates. More significant effects that can be expected are improvement of awareness of community residents towards recycling and the reduction of the amount of waste and improvement of their understanding on waste management.

Source: Yachiyo Engineering Co., Ltd.

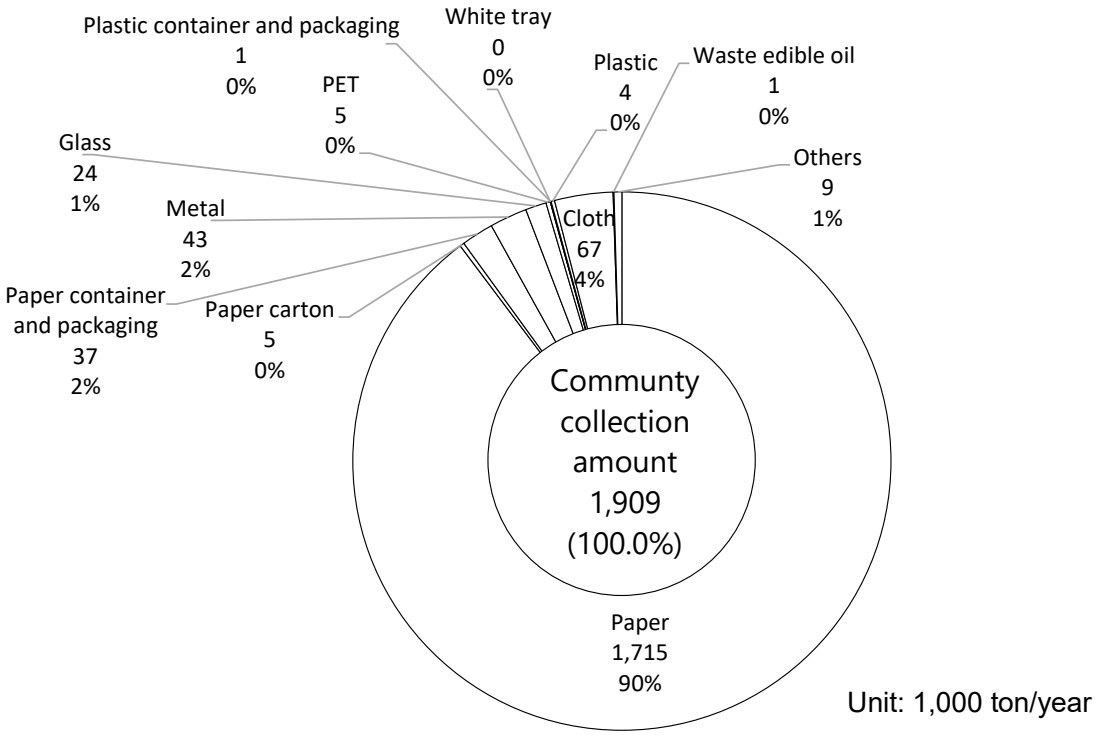
Photo 4-21 Group Collection (in Tokyo)

The main recyclables categories targeted for group collection include paper, bottles/cans, and fabrics. The performance records of 2019 show that paper category accounts for the majority at the overwhelmingly high amount of 1,715,000 tons (89.8%).



Source: Ministry of the Environment "History and Current State of Waste Management in Japan" (2014)

Figure 4-3 Group Collection System



Source: Ministry of the Environment "Waste Management in Japan (FY2019)" (2021)

Figure 4-4 Status of Residential Community Collection (FY 2019)

1.3 Features of Vehicles and Equipment for Waste Collection and Transport

Various types of vehicles have been developed for waste collection and transport to improve the collection efficiency. In Japan, compaction vehicles (often referred to as packers in Japan) that compress the waste during collection are widely used as they can collect and transport a large amount of waste in one trip. However, suitable vehicles need to be assigned according to the characteristics of the vehicles and the usage method, including normal dump trucks.

Various types of vehicles are used for waste collection and transport to cater for various purposes, collection plans, and collection modes. Table 4-3 lists the collection vehicles.

Recently, introduction of low gas exhaust vehicles and low fuel consumption vehicles is becoming widespread and in the future, electric vehicles are expected to be widely used for waste collection and transport. The battery power required for electric vehicles for waste collection and transport can be charged at waste treatment facilities and this power can also be shared with the households during times of disaster. Such usage methods are also examined.

Examples of considerations on selecting waste collection and transport vehicles

- In principle, select waste collection and transport vehicles that can be repaired and maintained. In particular, vehicles with readily available spare parts are preferable.
- Select the type and size of a vehicle considering the amount of waste to be collected and transported, road conditions in the collection route (width of the road and pavement conditions), and the topography (slopes).
- A compactor vehicle is suitable when a large amount of waste is to be collected and collection efficiency is the priority.
- For a residential area that generates a comparatively low amount of waste and does not require frequent collection, a container is effective for collection. For a market that also discharges a sizable amount of waste regularly, a container is also effective for collection.

Table 4-3 List of Vehicles Used for Waste Collection and Transport

Vehicle type	Feature
Dump Truck  Source: Yachiyo Engineering Co., Ltd	✓ It is an ordinary dump truck. ✓ Because it is not a special vehicle, maintenance is comparatively easy. ✓ Since it does not have the ability to compact waste, it is not highly efficient in transportation. ✓ In the case of high vehicle height, it is not easy for workers to load waste into the truck.
Compaction Vehicles (Packers)  Source: Sapporo City "Waste Disposal Administration/ 3R Policy in Sapporo City (JICA training text)" (2019)	✓ This vehicle is designed for efficient collection of waste and collects waste while compressing it with a compactor (press type, turntable plate type, or rotary type) that is installed in the container compartment. ✓ Since the waste can be collected while compressing the loaded waste, a packer can transport more waste than a normal truck. ✓ As this is a special vehicle, routine maintenance is important for the vehicle's stable and long-term use. ✓ As this is a special vehicle, it is not easy to maintain and repair (including parts replacement).
Container vehicle with arm type removable unit  Source: Yachiyo Engineering Co., Ltd.	✓ Vehicle equipped with a steel arm and hock that can mount or dismount a transport container on or off the vehicle. ✓ The whole process such as storage, collection, transport, and discharge of waste to facility can be operated as a system flow. ✓ As this is a special vehicle, routine maintenance management is important for the vehicle's stable and long-term use. ✓ As this is a special vehicle, it is not easy to maintain and repair (including parts replacement).

Vehicle type	Feature
Container vehicle  Source: Yachiyo Engineering Co., Ltd.	✓ With one dedicated vehicle and multiple containers, it is possible to place containers at appropriate locations to collect waste at multiple locations, thus increasing collection efficiency. There is no need for loading work, reduced waiting time due to loading, etc. ✓ As this is a special vehicle, routine maintenance management is important for the vehicle's stable and long-term use. ✓ As this is a special vehicle, it is not easy to maintain and repair (including parts replacement).

1.4 Maintenance Management of Waste Collection and Transport Vehicles

To carry out waste collection and transport stably and continuously, regular inspection and maintenance of collection vehicles are essential. In Japan, annual inspection, monthly inspection, and regular voluntary inspection before starting operation are regulated by technical standards such as Safety Management Guideline. Implementing such periodic inspections and taking preventive maintenance measures not only contributes to the stable and continuous use of the vehicle, but also contributes to its long-term use.

Collection vehicles must be constantly kept in good condition to operate them stably and continuously according to the collection plan. For this reason, regular and appropriate vehicle inspection and maintenance is very important.

To maintain vehicles in good condition, it is desirable to apply the concept of preventive maintenance and inspection that prevents faults occurring during operation, and that not simply takes measures swiftly to rectify the faults that are detected as a result of inspection or occur during collection operation. In developing countries, it has been observed that mechanized parts, especially hydraulic and loading equipment, often become defective and result in the related vehicles to be out of service for long periods due to the large amount of time required to purchase the necessary replacement parts and make repairs.

In Japan, for general vehicles daily routine inspection is required by the *Road Vehicles Act* and also implementation of regular inspection and maintenance are regulated. It is required to keep a record book containing the details of the inspection and maintenance - including information on the date, method, section inspected, result, executer, and contents of measures taken for the inspection result. Waste collection vehicles need to be inspected and maintained based on the “Safety Management Guidelines for Mechanical Garbage Trucks” (1987). These management guidelines specify the implementation of annual inspection, monthly inspection, and regular voluntary inspection at the start of operation. The outline of each inspection is provided in Table 4-4 and Table 4-5. Thus, proper implementation of the voluntary periodic inspections will enable the vehicles to be used for longer periods, as well as ensure the safety of workers and prevent accidents.

Table 4-4 Annual Inspection Items for Collection Vehicles

No.	Inspection items
1	Motor, motor transmission device, running gear, controlling gear, and braking system
2	Rotating plate, push-in plate, compression board, and other loading equipment
3	Hydraulic pump, hydraulic motor, cylinder, hydraulic piping, hydraulic hose, safety valve, and other hydraulic devices
4	Electric system
5	Emergency stop switch, emergency stop unit, interlock unit to prevent tailgate power dive, safety rod, and other safety devices
6	Loading operation switch
7	Discharger
8	Tailgate, body, alarm unit, direction indicator, lighting system and gauge
9	Power unit for the waste collection vehicle that has a dedicated power unit for lifting a tailgate
10	Other accessories

Source: Ministry of Labor "Safety Management Guidelines for Mechanical Garbage Trucks" (1987)

Table 4-5 Monthly Inspection Items for Collection Vehicles

No.	Inspection items
1	Controlling gear, braking system, and wheels
2	Loading unit and hydraulic device*
3	Safety device
4	Loading operation switch
5	Alarm unit
6	Power unit for the waste collection vehicle that has a dedicated power unit for lifting a tailgate
7	Device for automatically mounting a safety rod for the waste collection vehicle that has such a device

*: Refer to following Figure 4-5 for the location of each equipment.
Source: Ministry of Labour "Safety Management Guidelines for Mechanical Garbage Trucks" (1987)

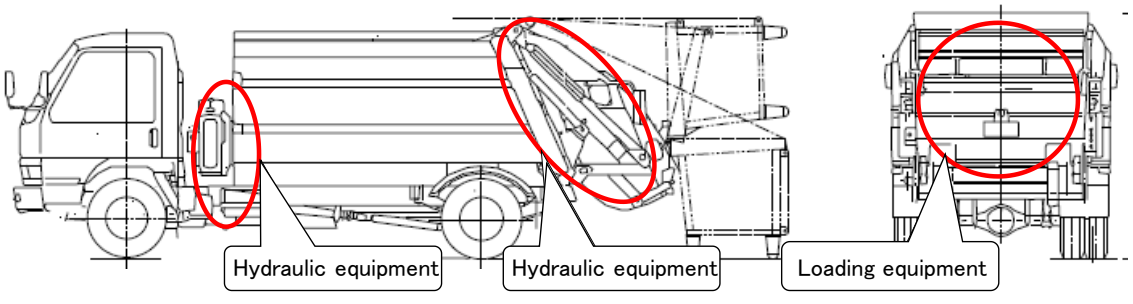


Figure 4-5 Equipment of Waste Collection Vehicles

Table 4-6 Check List for Periodic Inspection of Waste Collection Vehicle - example 1

Inspection items		Inspection points	Span of inspection		
Part	Items		Before starting operation	Monthly	Yearly
Vehicle	Engine	Noise, rattle, looseness, heat generation, oil leakage, etc.	✓	✓	✓
	Power transmission	Noise, rattle, looseness, heat generation, oil leakage, etc.		✓	✓
	Driving unit	Noise, rattle, looseness, heat generation, oil leakage, etc.	✓	✓	✓
	Steering unit	Noise, rattle, looseness, heat generation, oil leakage, etc.	✓	✓	✓
	Braking system	Noise, rattle, looseness, heat generation, oil leakage, etc.	✓	✓	✓
Hydraulic system	Hydraulic pump	Noise		✓	✓
		Oil leakage		✓	✓
		Loosening of mounting bolts			✓
	Hydraulic Cylinders	Rod damage			✓
		Oil leak		✓	✓
		Presence of abnormalities in the mounting part			✓
	Hydraulic motor	Noise		✓	✓
		Oil leak		✓	✓
		Loosening of mounting bolts, sprockets, etc.			✓
	Hydraulic oil	Oil content in the tank	✓		✓
		Stains (color)			✓
		Clean the strainer in the tank			✓
		Replace filter			✓
	Rubber Hose	External damage due to contact, impact, etc.		✓	✓
		Oil leakage, surface deterioration and cracking, etc.		✓	✓
		Loose tightening			✓
	Hydraulic pipe fittings	Oil leakage, loosening of tightening		✓	✓
		Loose pipe clamps, contact with other parts, etc.			✓
	Hydraulic pressure	Confirmation of predetermined pressure			✓
	Hydraulic valve	Oil leak		✓	✓
		Loose mounting bolts			✓
		Operation			✓
Electrical and control equipment	Switches for Loading	Check the operation of the rear switch.	✓		
		Damaged or loosely attached waterproof rubber cover		✓	✓
	Loading Control	Loose cam mounting bolt		✓	✓
		Loose limit switch mounting bolt		✓	✓
		Loose relay timer			✓
	Discharge Control	Loose tailgate lock, limit switch, etc.			✓
		Loose lift control limit switch			✓
		Loose damper limit switch			✓
	Wiring	Contact damage, connector ground corrosion, etc.			✓
	Rotary solenoid (Engine constant speed device)	Loose arm wire			✓
Safety devices and functions	Emergency stop switch	Checking operation, looseness of switch attachment, etc.	✓	✓	✓
	Emergency stop device	Check operation, damage, etc.	✓	✓	✓
	Garbage input device prevention device	Checking operation	✓		✓
		Adjustment		✓	✓
	Interlock when tailgate is lowered	Checking operation	✓	✓	✓

Source: The Waste Management Society of Japan “Waste Handbook” Ohmsha (1996)

Table 4-7 Check List for Periodic Inspection of Waste Collection Vehicle - example 2

Safety devices and functions	Safety bar	Check for abnormalities and normal operation. Confirmation of alarm buzzer.	✓	✓	✓
	Confirmation of loading cycle time	Confirmation of predetermined cycle time	✓		✓
		Confirmation of sealing		✓	
	Back buzzer	Back buzzer emit an alarm sound when the vehicle is backing up	✓		✓
	Tailgate up, down Alarm buzzer in operation	Tailgate emits an alarm sound when it is operating up or down	✓		✓
	Contact buzzer	Proper operation	✓		
	Dump drop protection device	Inspection check	✓	✓	
	Tailgate lock	Engagement condition	✓		✓
Conduction control	PTO and control	Smooth and reliable switching of disconnection, and good feeling of operation	✓		✓
		Are there any abnormalities such as abnormal noise	✓	✓	✓
		Oil leakage, looseness of mounting bolts		✓	✓
		Adjust the wire.			✓
	Drive shaft and UJ	Abnormal noise, runout, oil supply, etc.		✓	✓
		Looseness of mounting bolt		✓	✓
Loading and discharging	Loading operation	Operation of the loading plate		✓	✓
		Bending or cracking of plate links, etc.			✓
		Rattling of the bearing, loosening of the pin stopper			✓
		Tension of chain, abnormal noise, etc.		✓	✓
		Wear of the reverse rotation prevention pin.			✓
		Can the reversing prevention pin be easily removed?		✓	
	Tailgate open/close operation	Tailgate up/down operation			✓
		Bending, cracking, looseness, etc., of cylinder mounting part *			✓
		Bending or cracking of the tailgate lift stopper *	✓		
		Does the tailgate not rise when it is not in the normal position, such as when it is caught in debris?			✓
		Tailgate lock rattles in pin, adjust often.			✓
		Tailgate lock. Are the nuts on the U-bolts unloose and are they tightened evenly on both sides?			✓
Direction indicators	Direction indicators	Confirmation of normal operation	✓		
	Lighting devices	Confirmation of normal operation	✓		
	Gauges	Confirmation of normal operation	✓		
Other equipment	Tailgate	Bend, crack, rust			✓
	Bodies	Bending, cracking, rusting			✓
	Subframes and bracing	Looseness of tightening bolts to chassis			✓
	Spare tire carriers	Looseness of mounting nut, looseness of fixing	✓		
	Wastewater leak prevention	Damage to the wastewater packing			✓

*: For loading and lifting cylinder car

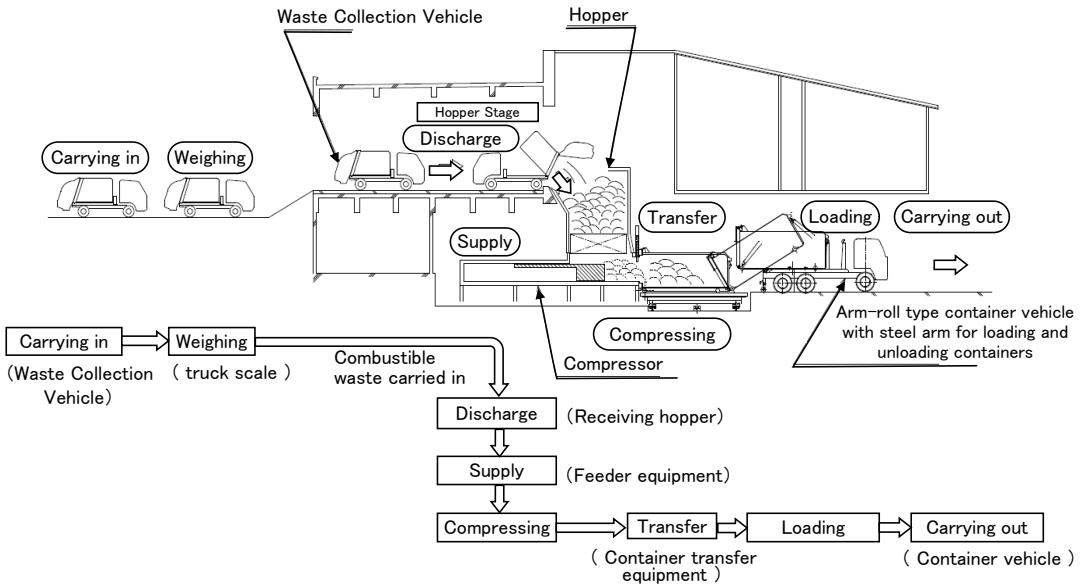
Source: The Waste Management Society of Japan “Waste Handbook” Ohmsha (1996)

1.5 Transfer Station

A transfer station is useful for efficient waste collection when waste is to be collected from a wide area or the distance to the treatment plant or final landfill site is far. In Japan, there are not many transfer stations in operation because many municipalities have their own necessary facilities and the targeted collection areas are not large.

At a transfer station, waste is transferred from the collection truck to a larger transport vehicle, referred to as a secondary transport vehicle, with or without compression depending on the transfer station. This allows the collection truck to speedily return to the waste collection area and thereby improves the collection truck operation efficiency. A transfer station may have shredding equipment and provide a function of a recycling facility, depending on the waste that is received.

A transfer station is a facility where waste is transferred from a small or a medium-size collection vehicle to a large transport vehicle, either with or without compression of the waste, in order to allow the collection truck to speedily return to its collection activities. The transfer station operation thereby enhances the efficiency of waste collection and transport for urban areas where waste is to be collected across wide areas. Figure 4-6 shows an example of a transfer station processing flow (compactor/container type). In the compactor/container type, waste fed from collection vehicles into the loading facility is compacted by a compressor and transferred into a large container. The container is then mounted on a container vehicle for transport to the next destination, either treatment facility or landfill site.



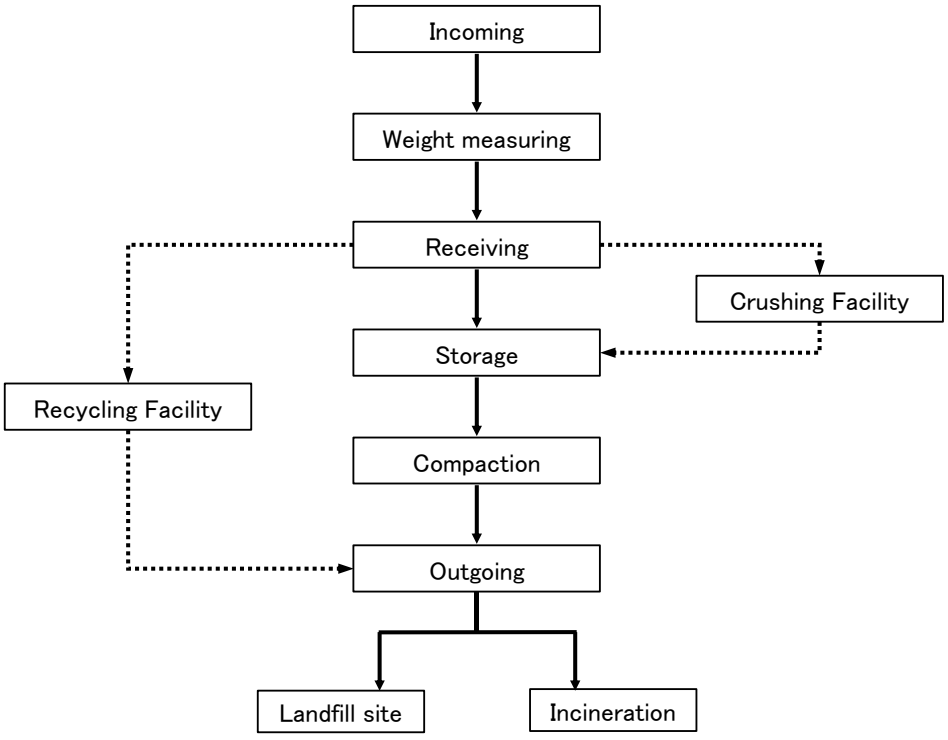
Source: Ministry of the Environment "Guidance for application for subsidy for establishing a Sound Material-Cycle Society (For Facility)" (2021)

Figure 4-6 Example of Process at Compactor/Container Type Transfer Station

Source: Yachiyo Engineering Co., Ltd.

Photo 4-22 Transfer Station in Kuala Lumpur, Malaysia

Figure 4-7 and Table 4-8 respectively show the structure and outline of the main facilities of a transfer station. After the incoming waste is weighed, it is reduced in volume by compression and crushing, etc. and then carried out.



Source: Japan Waste Management Association "Planning and Design Guidelines for Waste Treatment Facility Maintenance, 2017 Revised Version" (2017)

Figure 4-7 Structure of Transfer Station Facility

Table 4-8 Main Facilities of a Transfer Station

Main facility	Outline of the facility
Unloading/ loading facility	This facility comprises a weighing machine for managing receiving and transporting waste, entry/exit roads for collection/transport vehicles, a platform for unloading waste in a storage pit/storage site, an unloading hopper for temporarily storing the incoming waste, and loading equipment for loading the waste that is stored in the incoming hopper on to a compression facility.
Shredding facility	This facility shreds combustible bulk waste that is received at the station.
Compression facility	In a compactor/container type transfer station, this facility is used for loading the waste that is supplied on to a container by compressing it. The facility comprises a compactor and a hydraulic system. Other devices include a storage discharger that cuts out waste into a fixed amount continuously and loads it in a large transport vehicle, and a packing machine that compresses waste that was delivered to the hopper and packs it by strapping or baling.
Recycling facility	This facility processes recyclables as required to facilitate transportation and recycling. The facility must be suitable for processing the targeted recyclables. Recyclables include iron, aluminum, refillable bottles, glass cullet, plastic bottles, paper, fabric, and plastics. The equipment units of the facility include metal press, plastic bottle compressing and packaging machine, plastic container compressing and packaging machine, plastic material compressing and compacting machine, paper binding machine, bottle shredder, and styrene foam compactor.
Transport facility	In a compactor/container type transfer station, this facility is used for transporting containers between a compactor connection position and a position for loading/unloading containers on to a container vehicle. This facility comprises standalone equipment or a combination of a trolley, a conveyer, and so on. A container storage facility temporarily stores containers inside the facility. Containers and arm-roll type container transport vehicles equipped with steel arm device to load and unload containers on to the vehicle bed, are used in this facility.
Dust collection/ deodorization facility	This facility is used to maintain the integrity of the surrounding environment and the work environment of the facility. It comprises hoods, ducts, a dust collector, ventilators, and a deodorizer.
Water supply facility	This facility is used to supply cooling water and washing water, spray water for dust prevention, and water for extinguishing fires.
Wastewater treatment facility	This facility is available for treating wastewater or for transporting it with a vacuum vehicle when various types of water are assumed to be generated. The handling varies depending on the plan. If the condition allows, such as that the peripheral sewage treatment facility has an extra capacity, collected wastewater may be discharged to sewage after being diluted and stirred.
Electrical facility	This facility receives power required for all these facilities and distributes power to the required sections (motor, and so on) of each equipment.
Instrumentation facility	The instrumentation facility is necessary for operation and control of the facilities.

Source: Created based on Japan Waste Management Association “Planning and Design Guidelines for Waste Treatment Facility Maintenance, 2017 Revised Version” (2017)

1.6 Waste Collection and Transport Technical System necessary for Efficient Collection

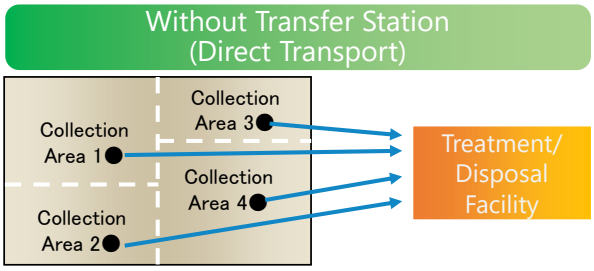
At the waste collection and transport stage of the waste management many persons are engaged in collection and transport and maintenance of vehicles and facilities and accordingly a large amount of labor costs is incurred. Therefore, implementation of efficient collection is extremely important not only to ensure a good collection service, but also in order to reduce the associated costs.

To achieve efficient waste collection and transport, it is necessary to consider the use of collection stations and transfer stations, by examining the time and cost associated with waste collection and transport according to the characteristics and actual conditions of the region.

In order to provide efficient waste collection and transport it is necessary to exert efforts in preparing collection and transport plans that carefully consider the current conditions of the region and any advantages of using transfer stations. In particular, for developing countries, the plans should carefully determine suitable vehicle specifications for large-size trucks and trailers considering the local traffic conditions (traffic congestion, accidents, etc.) and road conditions (unpaved roads, sloping roads, etc.). In addition to comparing transport times and costs, it is important to develop and implement collection and transport plans that take safety into consideration.

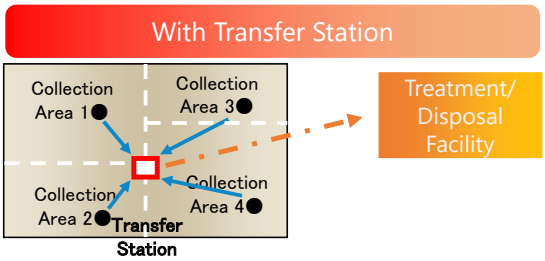
Table 4-9 Considerations for Achieving Efficient Waste Collection and Transport

Item	Description
Use of collection stations	Use waste collection stations as appropriate considering the characteristics and actual conditions of the region (population, land use, location, etc.).
Preparation and implementation of a detail collection plan	Develop a collection plan and a detailed operation plan for collection (collection route, collection schedule, etc.) to gain the residents' cooperation and increase collection efficiency
Use of a transfer station	In cases when the target collection area is widespread or when large vehicles can be easily utilized, the introduction of transfer stations should be considered. When checking cost effectiveness, compare the cost of collection and transport of the waste to the treatment/disposal facility with and without a transfer station, as shown in Figure 4-8. If the distance of collection and transport from the collection area to the treatment/disposal facility is far, although the construction costs for introducing a transfer station are required at the initial stage, over the long term the costs of collection and transport may be reduced. However, with regard to the use of large-size transport vehicles from transfer stations to treatment/disposal facility, it is necessary to avoid subjecting roads and bridges to excessive loads, etc. Appropriate vehicles should be selected based on local traffic and road conditions.



Total Collection Cost (case ①)

Costs	Contents
Cost 1	Collection from Collection Area 1 to Transfer Station
Cost 2	Collection from Collection Area 2 to Transfer Station
Cost 3	Collection from Collection Area 3 to Transfer Station
Cost 4	Collection from Collection Area 4 to Transfer Station
Total Collection Cost (=Cost 1+Cost 2+Cost 3+Cost 4)	**Collection from Collection Areas 1~4 to Treatment/disposal facility**



Total Collection Cost (case ②)

Costs	Contents
Cost 1	Collection from Collection Area 1 to Transfer Station
Cost 2	Collection from Collection Area 2 to Transfer Station
Cost 3	Collection from Collection Area 3 to Transfer Station
Cost 4	Collection from Collection Area 4 to Transfer Station
Cost 5	Collection from Transfer Station to Treatment/disposal facility
Cost 6	Cost for transfer station (Construction cost, operation and maintenance cost)
Total Collection Cost (=Cost 1+Cost 2+Cost 3+ Cost 4+Cost 5+Cost 6)	**Collection from Collection Areas 1~4 to Transfer Station Collection from Transfer Station to Treatment/disposal facility Cost for transfer station**

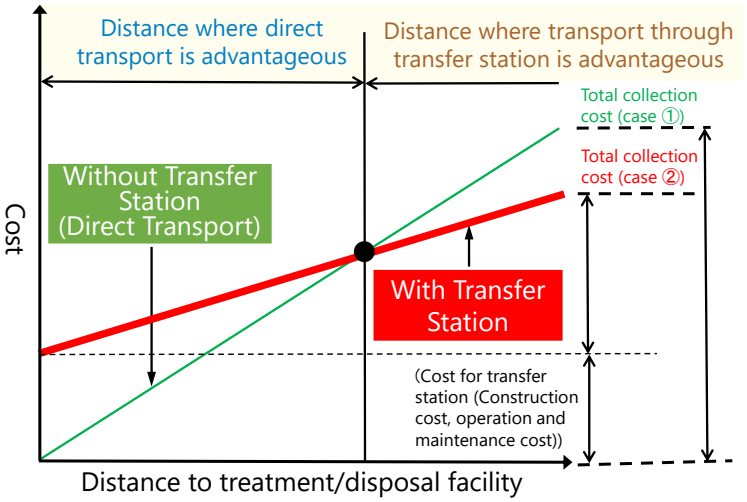


Figure 4-8 Comparison between with and without Transfer Station Options

Colum: Formulation of Efficient Collection and Transport Plan

Establishing efficient waste collection and transport routes will result in increased work efficiency, reduced costs, and reduced accident rates. To improve the efficiency of collection routes, the routes need to be studied by collection workers and staff members responsible to formulate routes based on actual data. A summary is presented here of the elements necessary to study efficient refuse collection based on the example of Yokohama City.

Table 4-10 Benefits from Formulating an Efficient Collection Plan

Benefit	Contents
Work efficiency improvement	Analyzing traveling routes, minimizing travel distance
Decrease in cost	Minimizing costs of personnel, vehicles, fuel consumption, etc.
Reduction of accident rate	Identify dangerous areas in advance so that collection crews can take sufficient care when working in those areas
Work environment improvement	Set clear working hours and reduce staff burden

Data Collection

The data needed for route formulation are shown in Table 4-11. Data on collection areas, waste amounts, and working hours are used to establish routes.

Table 4-11 Examples of Data Collection

<table>
<tr><th>Items</th><th>Data to be collected</th><th>Example</th></tr>
<tr><td>Collection sites</td><td>・Number of households
・Estimated discharge amount for each collection site
・Coordinates on the map</td><td>1. Collect data from citizens on collection sites
Station area: 2.03 m^2
Waste storage method: Net is used
Date to start using: 30th March 2022 etc.
2. Calculate the number of households per collection site
<table>
<tr><th>Items</th><th>Area A</th><th>Area B</th></tr>
<tr><td>Number of households</td><td>128,328</td><td>117,957</td></tr>
<tr><td>Number of collection site</td><td>6,473 sites</td><td>4,252 sites</td></tr>
<tr><td>Household/collection site</td><td>19.9</td><td>27.6</td></tr>
<tr><td>Time required to collect at each location</td><td>Short</td><td>Long</td></tr>
</table></td></tr>
<tr><td>Waste amount</td><td>・Collection results for each vehicle/each trip
・Seasonal changes in the waste amount
・Facility treatment amount results</td><td>IC cards are installed in each collection vehicle to control the amount and time of waste collection. (See Table 4-12)
By recording detailed work conditions, it will be easier to predict the waste amount and working hours when formulating routes.</td></tr>
<tr><td>Working hours</td><td>・Breakdown of each work activity</td><td>15 seconds: Get off the vehicle
x seconds: Load (Calculated as 1 household = 1 bag)
y seconds: Confirmation* (Calculated as 1 seal = 15 seconds)
10 seconds: Tidying up (Tidying up nets, etc.)
10 seconds: Get on the vehicle
18 seconds: Move (0.1km (between collection sites ÷ 20km/h (speed per hour))</td></tr>
</table>

*: Confirmation is the process of placing a sticker on the discharged waste if it is found not to be eligible for collection as per the collection schedule and to notify the correct discharge date based on the waste category

Table 4-12 Examples of Data Records Related to Waste Collection

No.	Vehicle Size	1st Trip	2nd Trip	3rd Trip	4th Trip	Waste Amount	Work Start	Work End	Mileage
1	Medium	9:36 2.25 t A area	11:46 2.28 t A area	14:20 2.02 t A area		6.55 t	8:15	15:05	32 km
2	Small	9:18 1.62 t B area	10:23 1.47 t B area	11:42 1.78 t B area	13:40 1.44 B area	4.87 t	8:20	14:35	46 km
⋮									
Total						205.20 t			1,529km

Preparation of Collection Maps

The procedure shown in Table 4-13 is used to divide the district into blocks, which are further subdivided according to the number of collection vehicles. In each of these areas, waste discharge points are plotted on a map and collection routes are developed.

Table 4-13 Process of Creating Collection Maps

No.	Process
1	In order to designate the collection days, consider the waste amount generated and divide it into blocks with roughly equal waste amounts
2	Divide each block further by the number of vehicles allocated. The size of the area varies depending on the topography, road conditions, distribution of housing, and the capacity of the fleet.
3	Based on the divided area, create a route considering the collection amount and work time

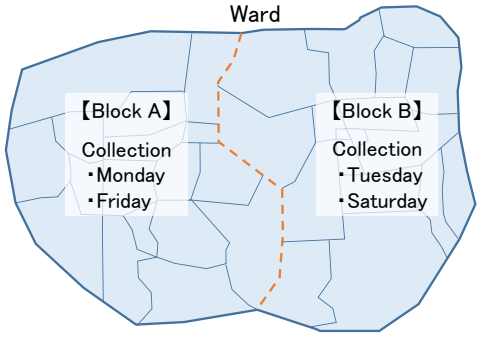
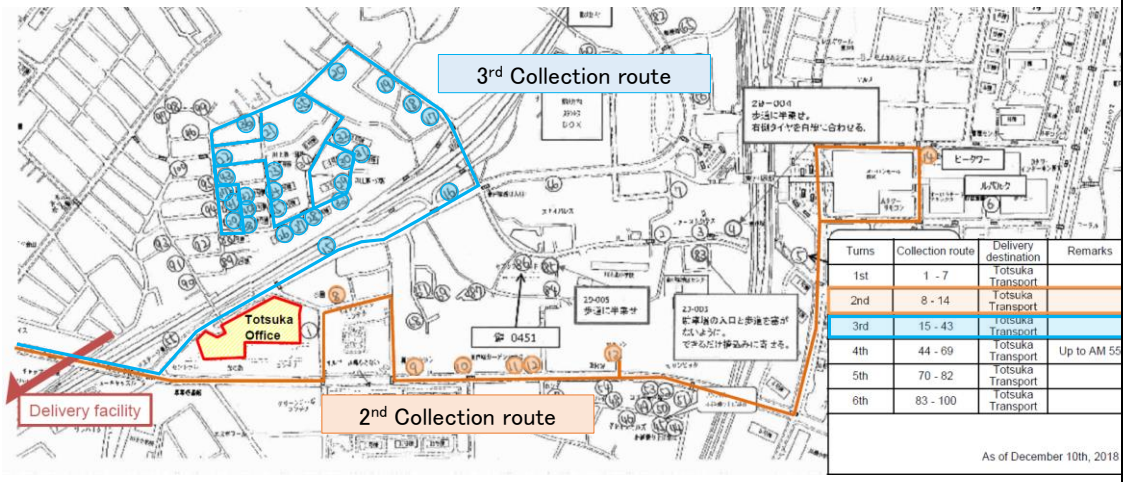


Figure 4-9 Conceptual Figure of Dividing Blocks



*: ○number is waste collection site

Figure 4-10 Example of Actual Collection Map for Totsuka Ward in Yokohama City

Source: Yokohama City "JICA Training Materials Formulation of Efficient Collection Plan" (2019)

2 Intermediate Treatment

2.1 Transition of the Intermediate Treatment Technologies

For Japan, which has a small land area, effective use of the limited land area has been an extremely important issue. Since deterioration of the living environment caused by waste has become a serious problem, incineration treatment has been widely adopted from the hygienic viewpoint.

In addition, since incineration is a well-versed waste treatment method in terms of sanitary treatment and amount reduction, waste treatment systems based on incineration treatment are being built in many local communities.

At the same time, due to the realization of a sound material-cycle and the pressure on final disposal sites, intermediate treatment technologies have been developed and reformed to suit the types of waste and the Japanese technologies are playing a part for setting targets and taking measures to solve the issues associated with recycling and amount reduction.

Since Japan has a small land and the usable land area is limited, reduction of waste amount is extremely important. Therefore, incineration has historically been considered an effective treatment method and was mandated under the amendment of the *Waste Cleaning Act*, in 1930. However, even with this mandate the burning of waste in open fields and the dumping of waste into rivers continued to be frequent occurrences, and in reality incineration technologies were not introduced as centralized intermediate treatment.

From the period of the 1960s', the treatment of the increased waste amount that was associated with the rapid economic growth, the improvement of the living environment, and enhancement of public sanitation became serious issues. In order to resolve these issues and from the perspective that incineration of waste is very effective in sanitary treatment of waste and reduction of the waste amount, the development of intermediate treatment facilities using incineration technology was promoted.

Under this development policy, the introduction of a waste incineration facility was promoted in all urban areas through the provision of technical and financial support based on the laws and plans established by the central government, and promising results were achieved for sanitary treatment and amount reduction of waste. At the same time, in response to the pollution issues caused by waste incineration, the central government established the Facility Technical Standards Including Exhaust Gas Treatment (1971) for proper waste treatment by intermediate treatment facilities. Since then, the incineration technology has significantly progressed to become a highly reliable waste treatment method, through the process of responding to new and updated standards, regulations, and structural guidelines (1979) and performance guidelines (1998) which ensured the necessary countermeasures against dust, dioxins, organic pollutant, and mercury.

In conjunction with the progress of the incineration technology, new technologies including RDF, gasification melting, and ash melting were developed and introduced. Since then the development and introduction of recycling technologies including organic waste recycling and the technology for generating power by using waste for thermal recovery (also referred to as thermal recycling) have been actively promoted in order to bolster the national policy of establishing a sound material-cycle society.

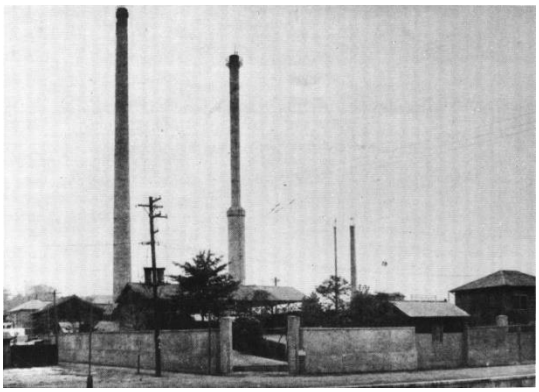


Photo 4-23 Osaki Incineration Plant - First Incineration Plant in Tokyo (Completed in 1924)

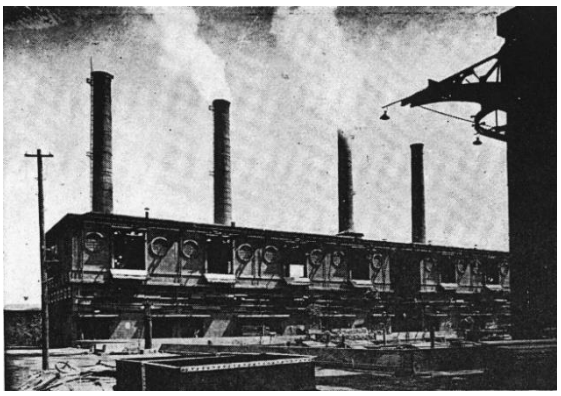


Photo 4-24 Fukagawa Incineration Plant – Technology of the Time did not Provide Adequate Exhaust Gas Treatment (Completed in 1933)

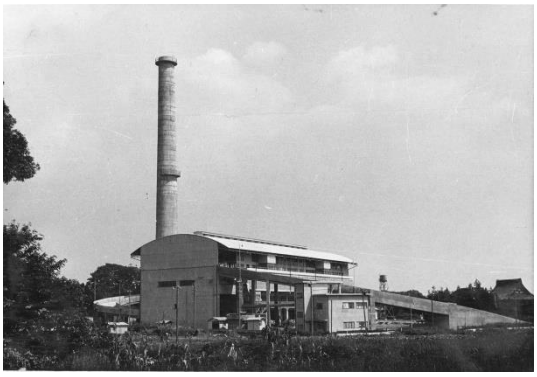


Photo 4-25 Waste Incineration Plant (Completed in 1958)

Photo 4-26 Koto Incineration Plant (Completed in 1974)

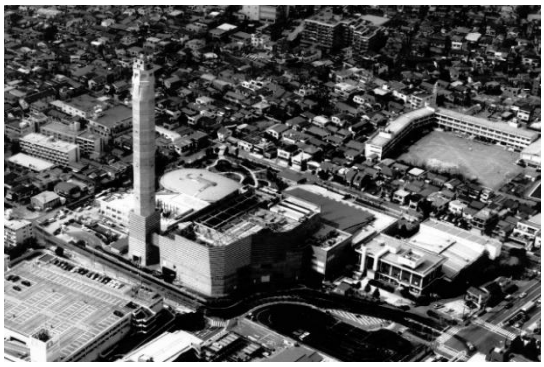


Photo 4-27 Kita Incineration Plant (Completed in 1988)

Photo 4-28 Shin-Koto Incineration Plant (Completed in 1998)

Source: Tokyo Metropolitan Archives (Photo 4-23, Photo 4-24)
Source: Tokyo Metropolitan Government Bureau of Environment (Photo 4-25, Photo 4-26, Photo 4-27, Photo 4-28)

Column: Waste Incineration Facility in Shibuya City, Tokyo

Source: Ministry of the Environment "Japanese Waste Treatment and Recycling Technology" (2013)

Photo 4-29 Shibuya Incineration Plant

Central Government Agencies are located in the 23 special cities of Tokyo, the capital of Japan. These special cities are the center of politics and the economy and have about ten million residents (about 15,000 persons/km^2).

Within these 23 special cities, commercial and residential zones coexist, generating a large amount of waste. Under these conditions, a waste incineration facility (treatment capacity: 200 ton/day) was constructed in July 2001 at the center of a highly dense populated city area near Shibuya railway station.

Even for Tokyo, under the principle of treating the waste within the special city it is generated in, it was necessary to construct this facility in such an urban district. In Tokyo, waste facilities are constructed and operated even in heavily populated urban areas by obtaining the understanding of the residents through discussions with them from the planning stage and by developing a facility that sufficiently satisfies the environmental regulations such as exhaust gas.

Source: Ministry of the Environment "Japanese Waste Treatment and Recycling Technology" (2013)

Photo 4-30 Outer View of Incineration Plant

Photo 4-31 Green Exterior Walls

Photo 4-32 Facility Entrance for Waste Collection Vehicles

Photo 4-33 Green Buffer zone between Incinerator Plant and Residential Area

Source: Yachiyo Engineering Co., Ltd.

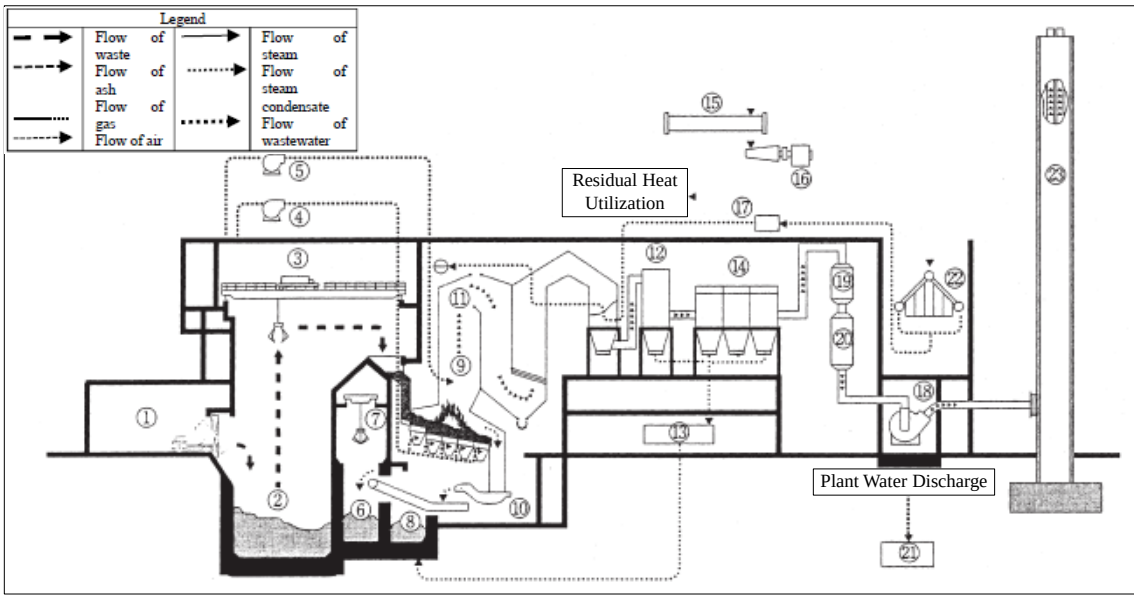
2.2 Incineration Technologies

(1) Overview and Types of Technologies Associated with Incineration

An incineration facility is a special facility comprising various facilities including an incinerator for treating waste in a sanitary manner by burning the waste as the main unit, a facility for receiving waste, a facility for properly treating exhaust gas after burning, and a facility for collecting and transporting ashes. Therefore, incineration facilities are required to satisfy many standards including the exhaust gas standards and the wastewater quality standards.

In Japan, the stoker type technology is most widely applied and when an incineration facility is installed in a municipality, the type to be installed is determined through comparison and examination of each type.

Figure 4-11 shows an example of the structure of an intermediate treatment facility that utilizes stoker-type incineration technology. Waste that is unloaded into a waste pit is transferred to the loading/unloading facility, stably placed into an incinerator, and burnt. Exhaust gas that is generated as a result of burning waste is discharged from a stack after harmful substances such as dioxins are removed by treatment facilities such as a dust collector and a catalytic reaction. Ashes generated by combustion are collected and transported after being sorted into incinerated ash and fly ash, and a facility for treating wastewater is also provided.



(1) Platform	(9) Incinerator	(17) Steam condensate Tank
(2) Waste pit	(10) Ash extruder	(18) Induced draft fan (IDF)
(3) Waste crane	(11) Boiler	(19) Steam type gas re-heater
(4) Forced draft fan (FDF)	(12) Cooling tower	(20) Catalytic reaction tower
(5) Secondary positive blower	(13) Fly ash treatment device	(21) Wastewater treatment facility
(6) Ash pit	(14) Filter type dust collector	(22) Steam Condensers
(7) Ash crane	(15) Steam receiver	(23) Stack
(8) Induced fan at ash pit	(16) Turbine generator	

Source: JICA “Guideline for Promoting Waste to Energy Facility Projects” (2017)

Figure 4-11 Example of Waste Incineration Plant with a Stoker Furnace

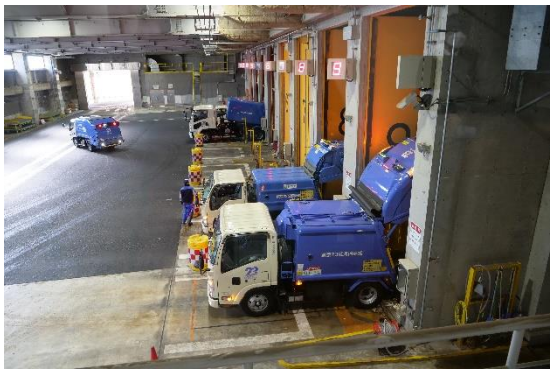


Photo 4-34 (1) Platform

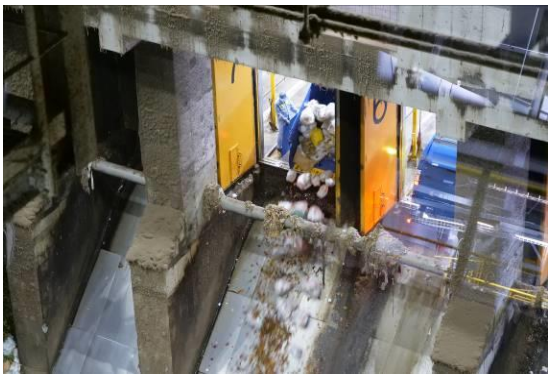


Photo 4-35 (1) Platform (Waste Pit)

Photo 4-36 (2) Inside the Waste Pit

Photo4-37 (2) Inside the Waste Pit

Photo 4-38 (3) Waste Crane

Photo 4-39 (9) Waste Incineration inside Stoker Furnace

*1: Numbers (1), (2), (3) and (9) match the respective number in Figure 4-11
*2: The Photos were taken in Suginami Incineration Plant
Source: Yachiyo Engineering Co., Ltd.

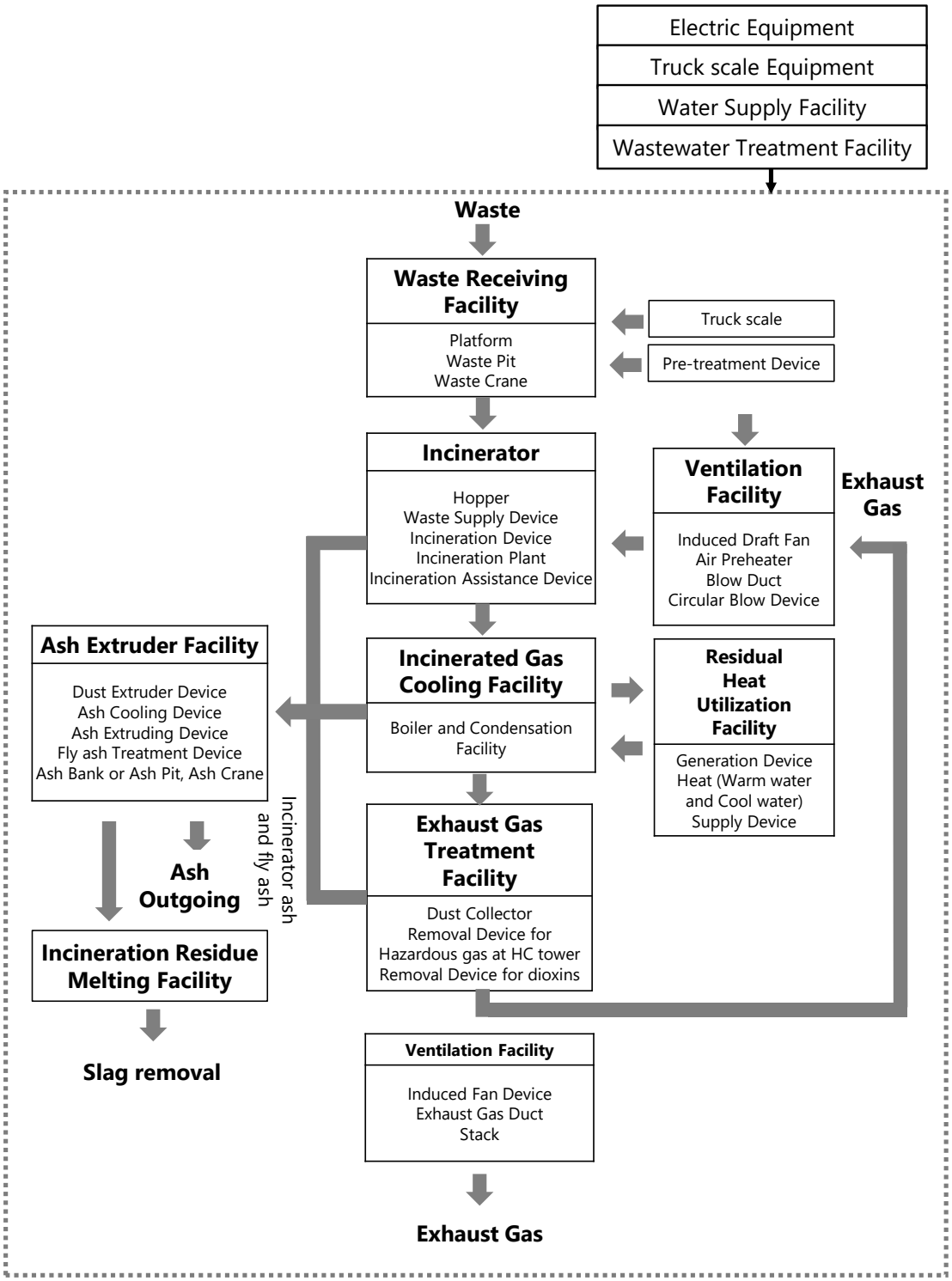
Source: Yachiyo Engineering Co., Ltd.

Photo 4-40 Funabashi North Incineration Plant

Source: Tokyo Metropolitan Government

Photo 4-41 Shin-Koto Incineration Plant

The structures and outline of the main facilities of waste incineration facilities are shown in Figure 4-12 and Table 4-14.



Source: Japan Waste Management Association "Planning and Design Guidelines for Waste Treatment Facility Maintenance, 2017 Revised Version" (2017)

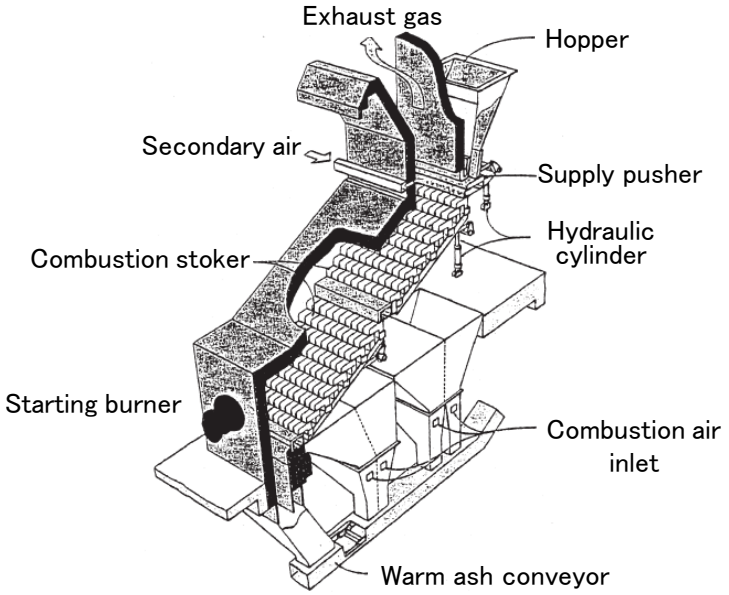
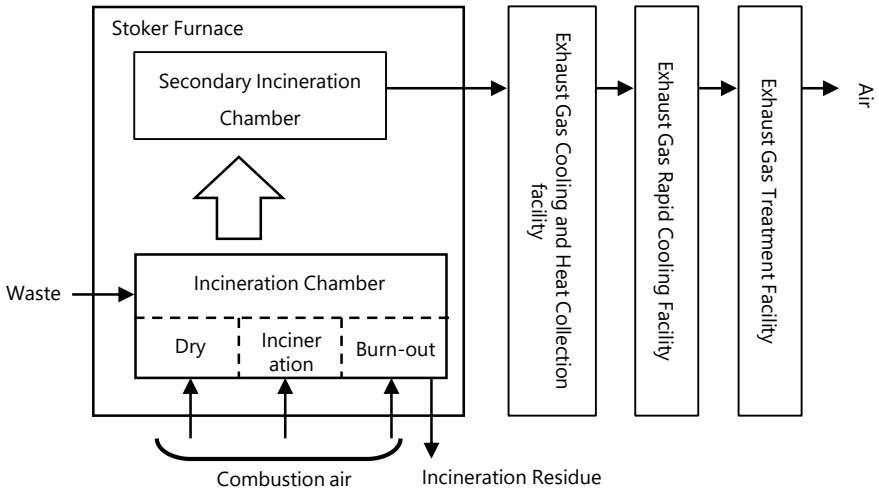
Figure 4-12 Structure of Facility of Waste Incineration Plant

Table 4-14 Outline of Major Waste Incineration Facilities

Major facilities	Facility outline
Unloading/loading facility	This facility comprises a weighing machine for weighing the amount of waste to be unloaded, entry/exit roads, a platform for a waste collection vehicle to unload to a waste pit, a dumping door for controlling access between a platform and a waste pit, a bunker or a waste pit for adjusting the waste amount to be collected and amount to be incinerated by storing the waste temporarily, and a crane for delivering the waste to a hopper. Equipment such as shredding and bag ripping may also be available for incineration pre-treatment depending on the quality of the waste and the type of the incinerator.
Combustion facility	This facility comprises a waste hopper for receiving the waste to be delivered to a furnace, a waste feeding facility for smoothly feeding the waste to a furnace, combustion equipment for incinerating waste, an incinerator main unit comprising refractory lining and so on to enable smooth combustion.
Combustion gas cooling facility	This facility is used for cooling a high-temperature combustion gas that is generated by burning waste. Available types are a waste heat boiler type and a type designed by combining a boiler and a water sprayer.
Exhaust gas treatment facility	This facility comprises a dust collector and dust removal equipment for removing dust and harmful gases such as hydrogen chloride (HCl) and dioxin that are contained in the exhaust gas that is generated as a result of combustion.
Waste heat utilization facility	When a boiler is installed, hot water can be made available by using a wastewater utilization facility (power generation facility, hot water equipment, heating and cooling system) and a hot water generator by using waste heat of combustion gas.
Ventilation facility	This facility comprises a pressure fan and air duct (airway) for sending air necessary for burning waste to the combustion equipment, an air preheater for heating air for combustion, an induced draft fan for discharging exhaust gas that was generated by burning, an exhaust gas duct (flue) for sending exhaust gas from a combustion facility to a stack, and a stack for releasing exhaust gas to the atmosphere.
Ash discharge facility	This facility comprises a dust transport and storage facility for properly transferring the dust discharged from the exhaust gas treatment facility and gas cooling facility, an ash cooling facility for extinguishing and cooling the incinerated ash that has been generated by completely incinerating waste by the combustion facility, as well as an ash conveyor for transferring falling ash, and an ash bunker or an ash pit for temporarily storing ash.
Incineration residue melting facility	Incineration residue is placed in a melting furnace after pre-treatment such as drying, screening, and magnetic separation as required and is turned into molten material in liquid state. Inorganic substances that make the most part of the incineration residue turn into a molten slag material. Some of the heavy metals enter in the matrix, preventing elution and at the same time, reducing the amount to one third or a half.
Water supply facility	This facility supplies water from a water supply source within the facility premises to each device and it has plant water supply pumps and equipment cooling water pumps. This also includes water supply for construction facilities.
Wastewater treatment facility	This facility treats wastewater that is discharged from the waste incineration facility and consists of a combination of various types of facilities to be able to handle recycling and meet the conditions of the discharge destination.
Electrical facility	This facility receives power required for all these facilities and distributes it to the required sections (motor, and so on) of each equipment. An instrumentation control facility is necessary for operating and controlling the facility.
Others	Common facilities such as various types of water supply pumps, hydraulic pumps, and compressors are installed as well as a vehicle washer and deodorizing equipment as required.

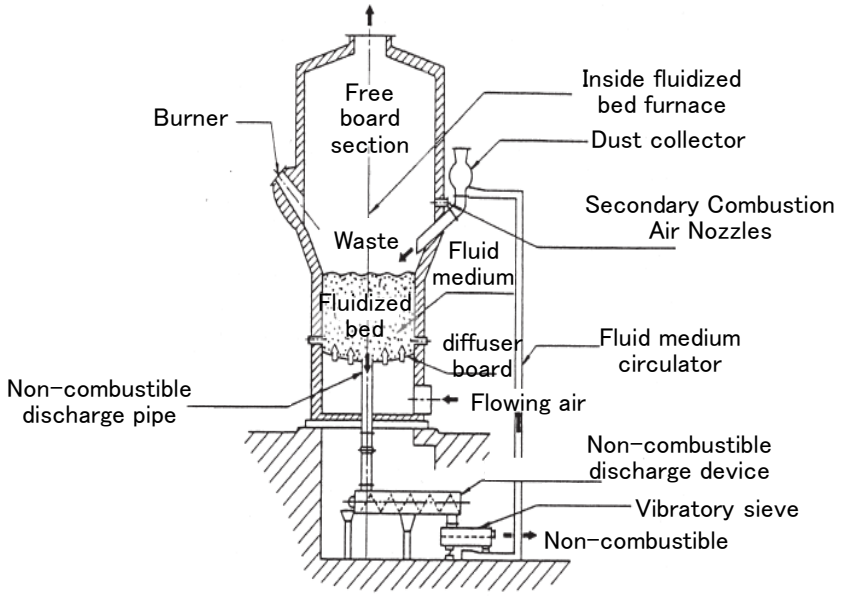
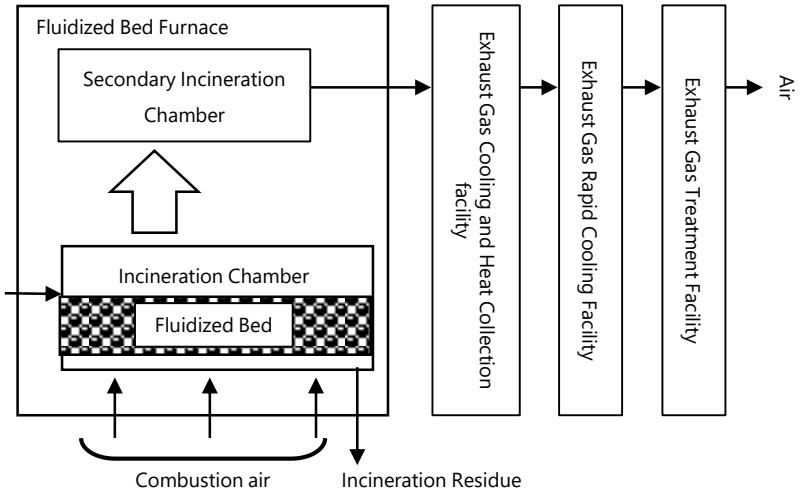
Source: Created based on Japan Waste Management Association “Planning and Design Guidelines for Waste Treatment Facility Maintenance, 2017 Revised Version” (2017)

Incineration (Stoker Furnace)

Conceptual Figure	
Flow	
Principle	A stoker furnace is a thermal treatment facility that dries waste with hot air and treats waste by using oxygen in the air inside of the furnace at a temperature higher than the combustible material ignition temperature. Elements that make up the organic matters in the waste such as C, H, and O are oxidized by thermal treatment and are stabilized by transforming them to low molecular chemical compounds such as CO_2 and H_2O. The basic principle of thermal treatment by a stoker furnace is the same as that of incineration furnaces such as fluidized bed furnace and rotary kiln.
Features	In this thermal treatment system, waste is placed on a metal fire grate for efficient combustion in large amounts and is dried and burnt by the combustion air that is supplied from the bottom of the grate by a fan. By actuating a fire grate mechanically, the waste is mechanically supplied and transferred and the incineration residue is discharged. Urban waste is treated over a wide range of amounts from a daily incineration capacity of several tons to 1,000 tons per furnace.

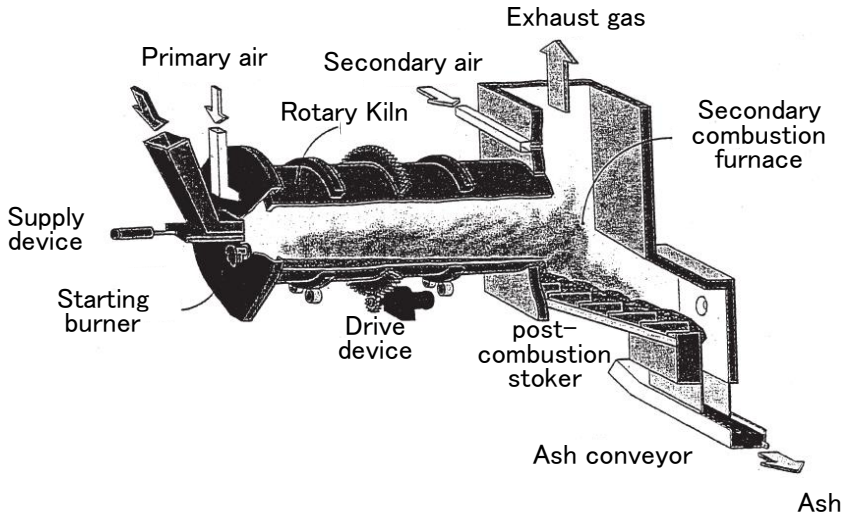
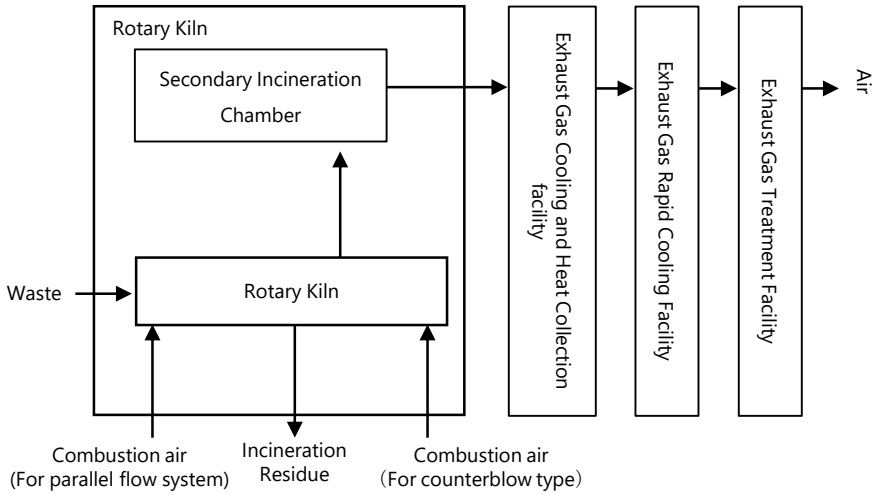
Source: Central Environment Council "Outline of Incineration Plant and Melting Facility" (2013)

Incineration (Fluidized Bed Furnace)

Conceptual Figure	
Flow	
Principle	In this thermal treatment system, waste is delivered in a fluidized bed comprising inactive particles such as silica sand, which is maintained at a high temperature and is completely burnt in a short time with oxygen in the air that is supplied from the bottom of the furnace. Inorganic materials including metals and silica sand are discharged from the bottom of the furnace and incineration residue with low apparent specific gravity is captured by a dust collector in the form of fly ash.
Features	Since this system does not use a metal stoker, unlike a stoker furnace that is limited in heat resistance, the system can treat waste of high heat value and can handle a wide range of physical properties. It can treat low heat waste such as dewatered sludge, waste plastic, viscous substances such as oil mud, and substances of high heat values. Inorganic substances are discharged in a dry state. Since most of the combustion residue becomes fly ash, a vast amount of fly ash is discharged in the fluidized bed furnace compared to stoker furnace and rotary kiln furnace.

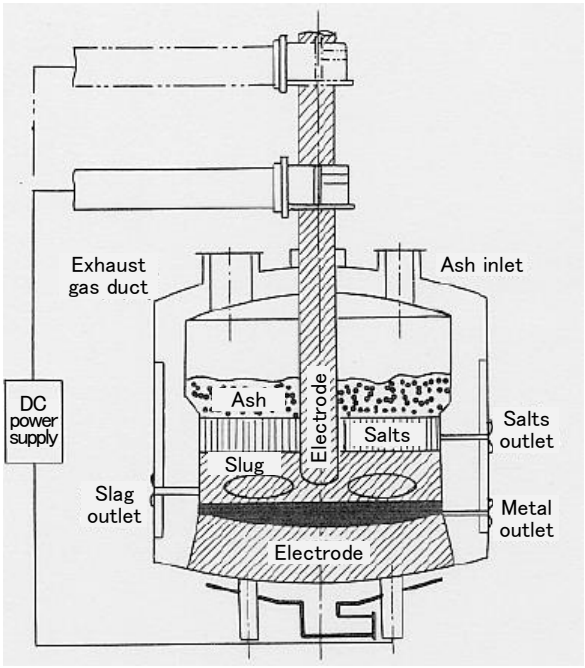
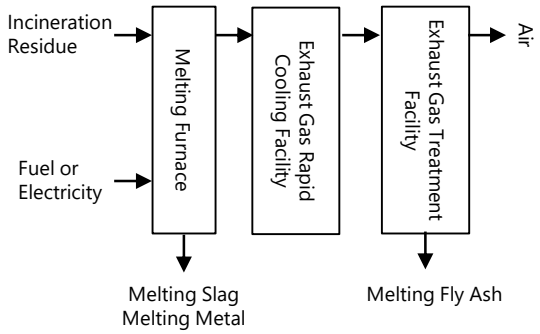
Source: Central Environment Council “Outline of Incineration Plant and Melting Facility” (2013)

Incineration (Rotary Kiln)

Conceptual Figure	
Flow	
Principle	Waste is delivered to a rotary kiln that is installed with a gentle descent towards the discharge side. The kiln is lined with a refractory material and maintained at a high temperature. Waste is stirred and transferred by rotation of the kiln. In the case of a parallel flow system, combustion is completed by the oxygen in the air that is supplied from the waste input side and in the case of a counter flow type, combustion is completed by the oxygen in the combustion air that is supplied from the incineration residue discharge side.
Features	Since this system does not use a metal stoker, unlike a stoker furnace that is limited in heat resistance, it can treat waste of high heat value and can handle a wide range of physical properties. It can treat low heat waste such as dewatered sludge, waste plastic, viscous substances such as oil mud, and substances of high heat values. To handle a variety of waste types, a kiln stoker designed by combining a rotary kiln stoker and stoker furnace in parallel and a kiln stoker designed by using a stoker furnace for after-burning are both available.

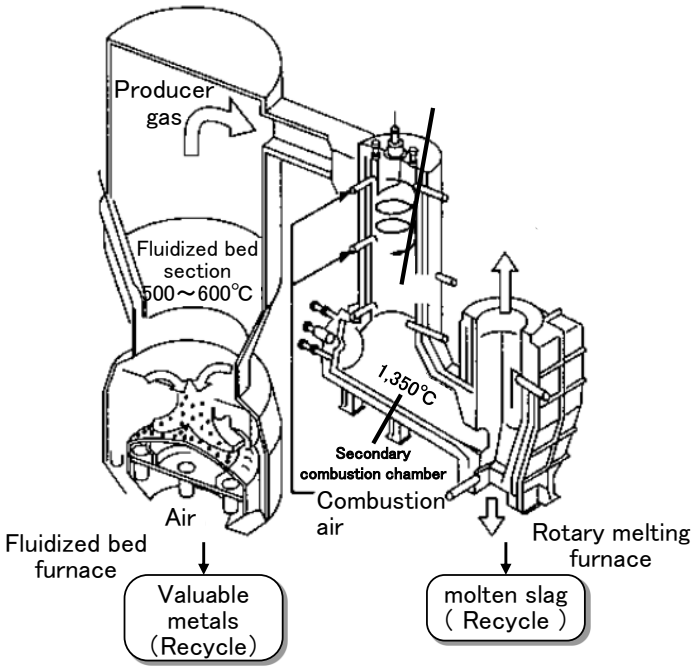
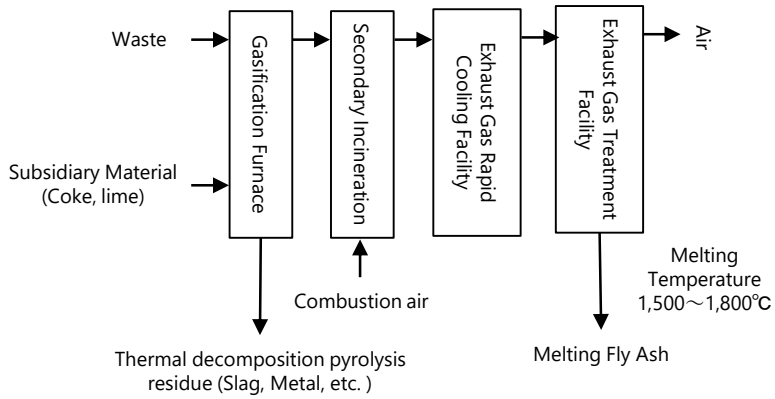
Source: Central Environment Council “Outline of Incineration Plant and Melting Facility” (2013)

Ash Melting

Conceptual Figure	
Flow	
Principle	If incineration residue is heated to a temperature above the inorganic substance melting temperature by using fuel or electricity and then is cooled rapidly, unburned residue is mineralized and at the same time, silicon components in the inorganic substances bring heavy metals into the crystal structure and as a result, stabilized molten slag can be obtained. This melting furnace performs this process.
Features	Incineration residue and an incombustible portion can be separated into metals with iron as the main component and molten slag by melting and then cooling them. Metals can be recycled as metal resources and molten slag can be recycled as construction materials through some other processing. Depending on the cooling method applied to molten slag, the slag forms a different crystal structure such as water granulated slag formed by rapidly cooling with water, air cooled slag formed by naturally cooling in a container, and cold removal slag formed by cooling under a controlled temperature in a container. These types of slags can be used for different applications due to the differences of crystal structures.

Source: Central Environment Council “Outline of Incineration Plant and Melting Facility” (2013)

Gasification Furnace

Conceptual Figure	
Flow	
Principle	This treatment system resolves the waste that was roughly shredded in the previous treatment facility into char of high carbon content and volatile pyrolysis gas by applying a temperature ranging from about 450℃ to 600℃ under oxygen-free atmosphere. Ash may be melted by burning at high temperature by supplying air to the pyrolysis gas.
Features	Since waste is gasified at a high temperature, the amounts of dioxins that are generated are low. As a whole, the amount of exhaust gas is low due to the low excess air combustion.

Source: Central Environment Council “Outline of Incineration Plant and Melting Facility” (2013)

(2) Advantages and Disadvantages of Technologies Associated with Incineration

Incineration and gasification melting technologies are extremely effective for the sanitary treatment and amount reduction of waste. In addition, after having overcome various issues, Japan is now in possession of well-developed incineration technologies with performance records covering a long period of time.

On the other hand, facilities using technologies such as incineration require both technical and financial attention. Facility improvements require substantial cost and at the same time, the facility's operation and maintenance management requires securement of higher expenses and more advanced management than those of disposal sites.

In Japan, there are many waste treatment facility construction companies with a rich experience of established performances. There are also many private operators that are well qualified to manage the operation and maintenance of incineration facilities. Therefore, incineration technologies are being adopted by many municipalities in Japan for intermediate treatment of waste. In considering introduction of incineration, a detailed examination is conducted covering aspects of viability, necessity, and sustainability of incineration technologies, and considering the advantages and disadvantages of the types of incineration technologies, based on essential installation preconditions.

1) Incineration Technology

The following preconditions need to be satisfied for introduction of incineration technology:

Installation preconditions for incineration facilities:

- ✓ A fee collection system such as a tipping fee system has been established to ensure regular income. It is extremely difficult to fund the cost for the entire operation and maintenance management with only the revenue from power generation.
- ✓ It is possible to secure continuous and stable financial resources, including income from tipping fees, in order to cover the expected large costs that will be incurred in the operation management and regular maintenance of the facility.
- ✓ It is possible to secure the necessary engineers and provide training for them on operation management in order to ensure that they will possess the advanced technological skill that is required for the facility operation management.
- ✓ A site planned for the construction has either been already secured or it is certain that a site for construction may be secured on public land or the like.
- ✓ It is possible to obtain the understanding of residents living in the vicinity of the construction site on the facility development.

Table 4-15 shows the advantages and disadvantages of introducing waste incineration. In Japan, the stoker system is widely used due to its stable combustion. When considering the introduction of an incineration facility, it is necessary to understand the characteristics of each incineration method and compare the advantages and disadvantages based on past performance records.

Table 4-15 Advantages and Disadvantages of Incineration Technologies

Technology	Advantages	Effects
Incineration	✓ Waste can be treated sanitarily by burning at a high temperature (mineralization, sterilization, and stabilization). ✓ The amount of waste can be reduced. ✓ Power can be supplied by installing a power generation facility.	✓ Sound hygienic environment can be maintained by applying sanitary treatment, thereby ensuring that the occurrence of infectious diseases can be controlled. ✓ Since the amount of waste is reduced to one tenth, the amount at the final disposal is reduced dramatically, thereby reducing the strain at the disposal site. ✓ The facility can contribute to the region as a power generation facility.
	Disadvantages	**Issues**
	✓ The operation and maintenance management are costly in comparison to landfill. ✓ Advanced technical skills are required for operation and maintenance management of the facility.	✓ Secure funds, continuously and stably to cover the high operation and maintenance costs. ✓ Obtaining the technical skills necessary for the facility operation and maintenance management.

2) Gasification Melting Technology

The preconditions for installing the gasification melting technology are almost the same as for the incineration technology. Gasification melting has excellent heat recovery, and effective utilization of slag, but its operation is more complicated than that of incineration.

Table 4-16 Comparison between the Incineration and Gasification Melting Technologies

Technology	Features
Incineration	✓ Has performance records over a long period of time and has developed technically. ✓ Can be more easily operated than gasification melting.
Gasification melting	✓ Surpasses in thermal recovery as this technology treats waste at high temperature. ✓ Slag can be used effectively, and further reduce waste disposed in landfill sites.

(3) Other Uses of Incineration Technology

In Japan, in order to effectively utilize the energy generated by waste incineration treatment, many incineration facilities utilize residual heat and generate power. Waste heat is recovered and distributed to surrounding local communities as well as within the facility as a heat source. Regarding incineration power generation, the improvement in power generation efficiency brought about by technological progress has encouraged the promotion of power generation facilities and the utilization of the generated power.

1) Use of Waste Heat

The thermal energy that is generated by combustion in an incineration facility is used for heating, and hot water supply within the facility in the forms of air, steam, and hot water. The energy is stored and distributed to the local residents as an energy source for hot water for swimming pools in recreational centers, social welfare facilities, and community centers of the region, in addition to heating inside the incineration facility.

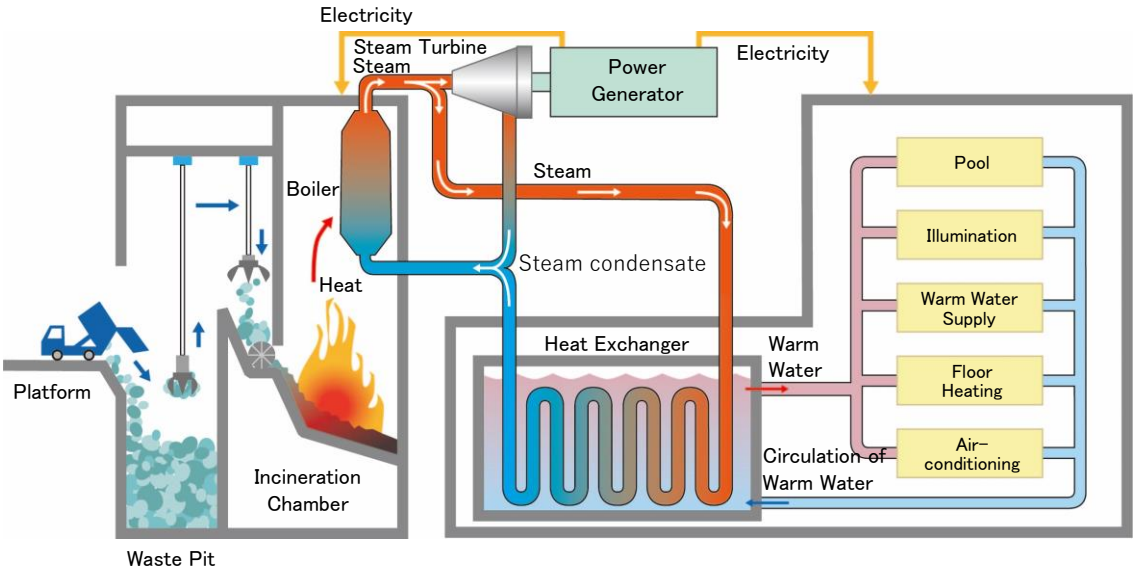


Figure 4-13 Schematic Diagram Showing Residual Heat Utilization

2) Incineration Power Generation

Steam is created by the waste heat that is generated during the incineration of waste. The steam is then utilized to turn a turbine, a device that converts thermal energy into kinetic energy and uses it as power to generate electricity. This is the process referred to here as incineration power generation. When considering the introduction of incineration power generation and developing the facility as a waste treatment plant with an additional function of electric power generation,

various social, technical, and financial aspects need to be examined. These include understanding the development status of the power transmission line for connecting the generated power to the electricity grid and power selling unit prices, amongst others.

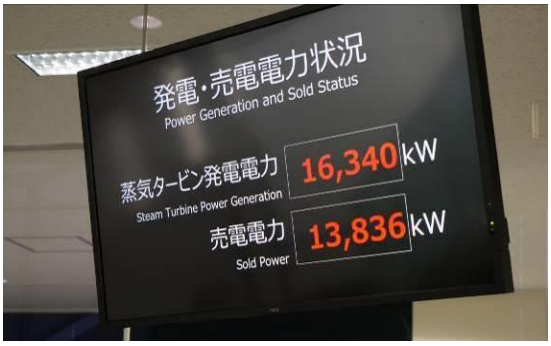


Photo 4-42 Monitor of Suginami Incineration Plant Showing Amounts of Power Generation and Sold Power

Photo 4-43 Steam Turbine in Suginami Incineration Plant

Source: Yachiyo Engineering Co., Ltd.

As a reference, Table 4-17 shows the pre-checklist for deciding on introduction of waste incineration power generation facilities indicated in the Guideline for Promoting Waste to Energy Facility Projects. The items on this list are important for gauging the requirements of the region before considering the introduction of waste incineration facilities with power generation facilities (i.e. waste to energy facilities).

Table 4-17 Pre-Checklist for Feasibility Study of Waste Power Generation Plant (WtE)

Classification	Importance	Item	Content
1) Social conditions	Most important	(1) Target city population	The target city population is 100,000 or more.(Or plant capacity is 70 ton/day or more).
	Inportant	(2) Social needs	There are high social needs, such as "The remaining capacity of final disposal sites is limited.", "Sanitary waste treatment is highly required."
	Recommended	(3) Development status of social infrastructure pertaining to environmental sanitation	Administrative services of energy, waterworks and sewerage works are provided in the target city without problems.
	Recommended	(4) Integration of environmental and social considerations	Laws with regards to pollution prevention and environmental impact assessment (environmental laws etc.) have been developed and enacted in target countries and target areas.
2) Understanding of residents	Most important	(1) Cooperation of residents in waste sorting	Cooperation of the residents concerning the sorting of wastes can be obtained. (Delivery of wastes not suitable for WtE can be controlled.)
	Most important	(2) Understanding of residents about WtE	Understanding of the residents about WtE has been obtained.
3) Institutional aspect	Most important	(1) Development of laws, enforcement orders and rules	In addition to laws with regards to solid waste management, enforcement orders and rules have been developed.
	Important	(2) Stability of administrative organization	There is an administrative organization in charge of the project for construction and operation of WtE and the organization is stable. Also, there is a personnel management system enabling long-term employment (for 3 years or longer) of the core staff.
	Important	(3) Adequacy of construction site	Construction site in which WtE can be built is available.
4) Governance capability of the government	Most important	(1) Positioning of WtE in upper level plan	WtE has its position in the upper level plans (comprehensive plan, regional development strategy, etc.).
	Most important	(2) Stance of the head of local government	The head of local government is positive towards WtE.
	Important	(3) Performance capability of the government	The government is able to leverage committees comprised of external experts and external specialist organizations, such as consulting firms, to perform the project appropriately.
	Important	(4) Technical standards and operation pertaining to selling electricity	By energy department and electric power company, technical standards and operation pertaining to selling electricity, and selling price of electricity are set forth.
5) Financial aspect	Most important	(1) Securing of financial resources	Project cost (construction cost and operating cost) of WtE can be secured. The government is prepared to bear the cost such as tipping fee (fee for outsourcing disposal) and reliable investors are expected to participate in the project.
	Important	(2) Tipping fee	It is possible to set the tipping fee at a stable price over a long period by contract.
	Important	(3) Revenue by selling electricity	It is reasonable to assume selling price and the amount of electricity and recyclable waste.
	Recommended	(4) Project scheme	Project schemes (DB, DBO, BTO, etc.) are being discussed among stakeholders.
	Recommended	(5) Project risks	Major project risks are confirmed and the difference of responsibility division points according to project schemes are understood.
5) Technical aspect	Most important	(1) Collecting basic data concerning waste	Basic data and information concerning waste (amount and composition of waste, waste treatment process etc.) have been clalified.
	Important	(2) Technical capacity of manufacturers	Reliable manufacturers (of stoker incinerators) are expected to participate in the project.
	Important	(3) Proper disposal of incineration residue (incineration ash)	Proper disposal of incineration residue (incineration ash) is possible. (For example, measures for preventing the outflow of leachate have been taken at the final disposal site.)
	Recommended	(4) Environmental monitoring system	Laboratories for analysis of exhaust gas, wastewater, noise, vibration, odor, etc. exist and enable perform appropriate monitoring.
	Recommended	(5) Track record of similar facilities	Similar facilities, such as thermal power plants, exist and are managed appropriately.
	Recommended	(6) Securing of engineers	It is possible to secure engineers (personnel with skills equivalent to technical high school graduates).

Importance of evaluation indicators

Most important: It is considered extremely difficult to introduce WtE if this criterion is not fulfilled.

Important: The criterion should be fulfilled for and is expected to be fulfilled if assistance is provided.

Recommended: This criterion should desirably be fulfilled.

Source: JICA "Guideline for Promoting Waste to Energy (WtE) Facility Projects" (2017)

2.3 RDF/RPF Conversion Technology

(1) Overview of the Technology Associated with RDF/RPF Conversion

RDF (Refuse Derived Fuel) / RPF (Refuse derived Paper and plastics densified Fuel) is a solid fuel that can be obtained by forming combustibles into cylinders through shredding or sorting. RDF/RPF conversion ensures not only the proper treatment of waste, but also provides a fuel with high heat value and stable combustion which can be used as a heating and energy source in paper mills, cement factories, and public facilities.

On the other hand, while RDF/RPF is suitable for use in various facilities, in order to prevent troubles and accidents due to heat generation and ignition, sufficient attention should be paid to manufacturing, storage, and safe operation management at the facilities where the fuel will be used.

RDF (Refuse Derived Fuel) is a solid fuel that is produced from combustible waste - kitchen waste, paper waste, plastic waste, and so on. The combustible waste is solidified through the processes of shredding, sorting, drying, and molding. RDF can be stored for a comparatively long period of time due to its low biodegradability and can be transported more easily than waste due to its reduced amount and molding into more usable shapes.

Stable combustion is another major feature of RDF because of its generally constant shape and heat value.

Table 4-18 General Properties of RDF

Item	Quality
Shape	Cylindrical: Around 10mm to 50mm in diameter
Unit weight	0.3 tons to 0.7 tons/m^3
Low-level heat value	3,000 kcal/kg（12,500 kJ/kg） or more
Composition	Moisture content: 10% or less, Ash content: 20% or less

Photo 4-44 RDF

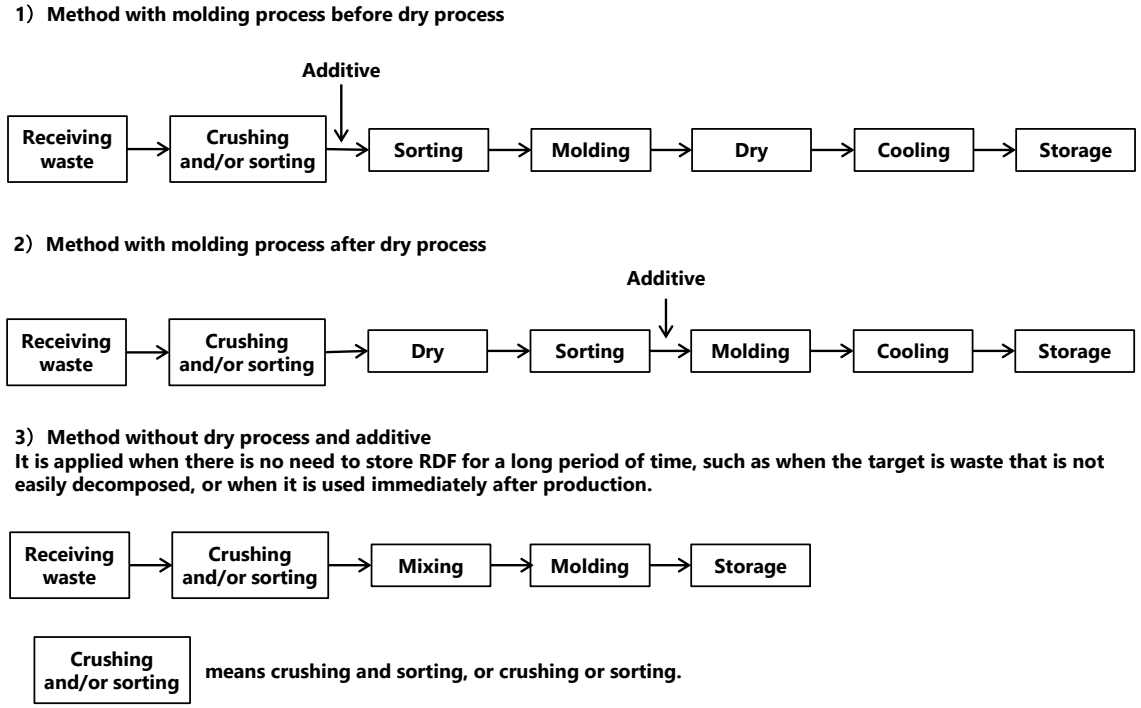
Photo 4-45 RPF

Source: Study Group on Appropriate Management of RDF “Report of Study Group on Appropriate Management of RDF (2003)” (RDF) (Photo 4-44)

Source: Japan RPF Association Website “What is RPF?” https://www.jrpf.gr.jp/rpf-1 (accessed January 10, 2022) (Photo 4-45)

RPF (Refuse derived Paper and plastics densified Fuel) is a solid fuel that is manufactured mainly from paper and waste plastics discharged in industrial waste and specifically selected municipal waste, that are difficult to recycle as raw materials. RPF can be used as a fuel in the same way as RDF, however, since RPF is produced from selected waste, it is characterized by having less foreign matter content, lower moisture content, and higher heat value (5,000kcal/kg or more).

Figure 4-14 shows the treatment methods at the intermediate treatment facility where RDF/RPF conversion technology is applied.



Source: Japan Waste Management Association "Planning and Design Guidelines for Waste Treatment Facility Maintenance, 2017 Revised Version" (2017)

Figure 4-14 Treatment Process of RDF Facility

Table 4-19 Outline of Major Equipment of an RDF Facility

Major equipment	Equipment outline
Unloading/loading equipment	This equipment comprises a weighing machine, a delivery door, a receiving hopper, a receiving conveyer, a waste pit, and a waste crane.
Shredding equipment	This equipment comprises a bag ripping machine for ripping the bags that are unloaded and a shredder that shreds waste of specified amount and quality into intended sizes.
Sorting equipment	This equipment is used for sorting waste into combustibles that are suitable for converting to a solid fuel and waste unsuitable for conversion to a fuel.
Drying equipment	This equipment is used for producing RDF of a target moisture content or lower by drying waste of planned quality in a specified amount.
Solidification equipment	This equipment is used for solidifying waste to a specified quality and shape. It comprises a molding machine, adding equipment, a reactor, and a cooler that adjusts the temperature of the solidified material to the temperature suitable for storage and transport. Adding equipment is used for adding lime to prevent decay during storage or as a chlorine removal measure when RDF is used as a fuel. This equipment can supply add-in materials in a fixed amount.
Transfer equipment	This equipment transfers municipal waste, shredded waste, dried waste, RDF, and waste unsuitable for fuel conversion.
Pooling/transport equipment	A pooling equipment is used for temporarily storing waste for transport and a storage equipment is used for storing waste for a certain period of time. Each equipment is used according to the amount of RDF or waste unsuitable for fuel conversion to be transported.
Deodorization equipment	This equipment is used for treating malodorous gases that are generated from the facility.
Dust collector	A dust collector is used for removing dust from the facility. To maintain the work and surrounding environment, dust collection measures are taken at the dumping section, shredding section, sorting section, storage section, and transfer/transport section.
Others	A water supply equipment and a wastewater treatment equipment are available as basic facilities of the RDF conversion facility.

Source: Created based on Japan Waste Management Association “Planning and Design Guidelines for Waste Treatment Facility Maintenance, 2017 Revised Version” (2017)

(2) Advantages and disadvantages of technologies associated with RDF/RPF conversion

In Japan, the use of RDF/RPF has been promoted as one of the appropriate waste treatment methods and at the same time considering the advantage of being able to be used as an energy source in other facilities. While RDF/RPF contributes to the effective use of energy, issues concerning safety need to be addressed in the operation management and storage of RDF/RPF.

In addition, since RDF/PRF is produced using waste that is discharged daily as the raw material, it is necessary to secure continuous supply destinations. In order to secure supply source for RDF/RPF, it must also be noted that development of a network of RDF/PRF supply destinations over a wide area is required.

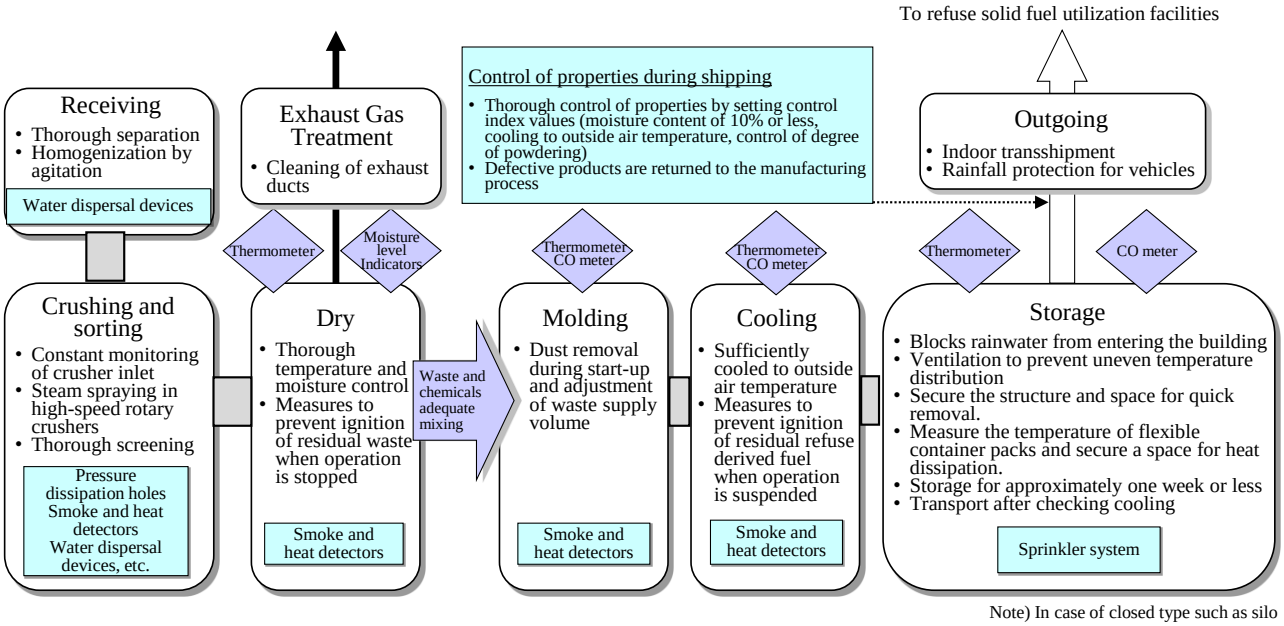
Table 4-20 shows the advantages and disadvantages of introducing RDF/RPF conversion technology. In particular, caution should be taken not to fall into a situation where stable supply destinations cannot be secured after RDF/RPF production and there are no sales destinations.

Table 4-20 Advantages and Disadvantages of RDF/RPF Conversion Technology

Technology	Advantages	Disadvantages
RDF/RPF	✓ Can be handled easily due to its stable quality. ✓ The quality can be adjusted according to the application. ✓ Can be used efficiently as an energy source due to its high heat value in comparison with waste. ✓ Burns stably due to its low moisture content and homogeneous properties in comparison with waste. ✓ Can be used according to a fixed schedule since it is dry and can therefore be stored for a long period of time.	✓ Development of a separate RDF/RPF facility is necessary. Development cost is required. ✓ Securement of stable and continuous supply destinations (markets) of RDF/RPF is required. Need to balance between demand and supply. ✓ Consideration is necessary for the storage of RDF/RPF.

Source: Created based on the Japan Waste Management Association "Planning and Design Guidelines for Waste Treatment Facility Maintenance, 2017 Revised Version" (2017)

Figure 4-15 and Table 4-21 show the items to be noted in operation management of an RDF/RPF conversion facility. Adequate measures are necessary for the production process and storage of RDF/RPF due to the high fire risk of RDF/RPF.



Note) In case of closed type such as silo

Source: Study Group on Proper Management of Refuse Derived Fuel "Proper Management Measures for Refuse Derived Fuel" (2003)

Figure 4-15 Countermeasures in RDF/RPF Facility

Table 4-21 Measures to be Taken for an RDF/RPF Conversion Facility

Process	Measure
Receiving process	Thoroughly sort waste into dangerous substances and incombustibles. Stir waste well to ensure uniform properties as much as possible. Place sprinklers and fire hydrants appropriately in case of fire breakout.
Shredding/sorting process	Constantly monitor the conditions around the inlet of the shredder. When using a high-speed rotary shredder, take fire prevention measures such as steam spraying. Install a fire extinguisher together with a heat sensor inside the chamber.
Drying process	Monitor constantly and properly the dryer exhaust temperature and the dried waste moisture content indicator. Take measures to prevent the waste remaining inside the drying furnace from being ignited when the operation stops. Clean the inside of the exhaust duct regularly. Install a heat sensor inside the chamber.
Chemical agent adding process	Design and control properly so that waste and additives can be mixed thoroughly.
Molding process	Measure the temperature and the concentration of carbon monoxide continuously. Before starting the machine, remove dust and check the amount of waste to be supplied. Install a heat sensor inside the chamber. Mold the RDF/RPF to an appropriate hardness.
Cooling process	Cool the solid fuel down to a temperature in the range of the outside air temperature by checking that fuel is adequately cooled up to the center of the fuel. Measure the air temperature of the cooler continuously and control the cooler. Take measures to prevent the waste remaining inside the drying furnace from being ignited when the operation stops. Install a heat sensor inside the chamber.
Storage/transport process (measures when storing a small amount)	Prevent rainwater from getting into the facility by wind and rain. Ventilate the tank and chamber to prevent the temperatures inside the tank and chamber from deviating. When storing in a closed type facility, measure the carbon dioxide and temperature continuously and design the structure of the facility so that solid waste fuel can be removed quickly. The permissible storage period is up to one week and take heat accumulation prevention measures when a fuel is stored for a long period of time. After checking that the fuel is cooled down to a temperature in the range of the outside air temperature, transfer it.
Property management at transport	Determine control index values of moisture content, temperature, and so on and measure and monitor them daily. Control the process thoroughly by returning the solid fuel that did not satisfy the index values to the production process.

Source: Study Group on Appropriate Management of Solid Waste Fuel “About Appropriate Management Measures for Solid Waste Fuel” (2003)

Column: Examples of Accidents Associated with RDF

1. Outline of Examples of Accidents/Troubles

Example A

On December 12, 2002, an accident occurred in the solid fuel power generation plant owned by a municipality. A part of the solid fuel was ignited at the bottom of the silo containing solid waste fuel and the fire was extinguished by spraying inside the silo.

As a result, the use of the silo was suspended and the solid waste fuel was removed from the tank and was inspected. At the same time, measures to improve properties of the solid waste fuel to be delivered were taken to prevent accident recurrence, and the use of the silo for storage resumed from February, 2003.

However, heat generation/ignition from the solid waste fuel inside the silo was confirmed in July 2003. Although removal of the solid waste fuel that generated heat or was ignited and cooling of the silo were attempted, satisfactory results could not be achieved. In the meantime, an explosion occurred within the silo in August 2003, causing injuries to four workers. Furthermore, the silo exploded in the process of extinguishing the fire, and the roof was blown out, causing death and injuries to three persons.

Example B

In September, 2003, an abnormality was confirmed from a private power plant. The temperature around the center cone (protruding equipment at the center of the bottom of the silo storage tank) inside the silo storage tank (same type as the silo of Example A) for storing solid waste fuel increased by about 2℃.

When the inspection panel of the conveyor at the bottom of the storage tank was opened, the presence of white smoke together with a discharge of a carbonized solid fuel from the delivery conveyor were confirmed. Consequently, the solid waste fuel was removed from the tank while injecting nitrogen gas from the bottom of the silo storage tank.

Example C

In October, 2003, an abnormality was confirmed at the RDF center that was built by a local union. An increase of the temperature by several degrees Centigrade was detected at the upper section of the silo storage tank (same type as the silo of Example A) storing solid waste fuel. When the surface temperature of the solid waste fuel at the top was measured, it was confirmed to be around 40℃ (normally, it should be around room temperature).

Therefore, while injecting nitrogen gas, the refuse solid fuel was taken out. It was found that during the discharge of solid waste fuel, smoke was being generated from refuse solid fuel at the delivery conveyor at the bottom of the tank in October 2003. Subsequently, the removal operation was suspended and after continuous injection of nitrogen gas, the removal was resumed after confirming the decrease of the oxygen concentration and temperature and their stabilization.

2. Insights Obtained from the Accidents

(1) Heat Generation/Ignition in the Storage Tank (silo)

It is assumed that the heat generation/ignition in the storage tank (silo) was caused by the following process: Due to the causes from 1) to 4) below, localized concentration of moisture occurred due to inflow of moist air or condensation, the solid waste fuel absorbed the moisture, and heat was generated as a result of the fermentation of organic substances.

In addition, solid waste fuels of at least from 600 tons to 700 tons were stored inside the storage tank,

making it extremely difficult for heat to escape. Therefore, the solid waste fuel that generated heat as a result of fermentation became hotter through self-heating by chemical oxidization of organic substances (low-temperature oxidization), thereby causing ignition.

<Main Cause of Heat Generation/Ignition>

1) The structure of the storage tank allowed in-flow of air.
2) Since the sweep device had not been operated, possibly a solid waste fuel remained in the dead space for a long period of time.
3) Fuel was input again without completing the removal of the solid waste fuel at the regular inspection.
4) The solid waste fuel that had been stored in another warehouse for a long period of time was input.

(2) Explosion in the Storage Tank (silo)

The concentration of carbon monoxide at the top of the storage tank showed an abnormal value exceeding 300 ppm before stopping the delivery of fuel to the storage tank. Although fire break-out was confirmed, the inside of the storage tank was kept at high temperature for a long period of time without taking sufficient measures.

Consequently, a combustible gas was generated by various reactions such as thermal decomposition, and the cavity created by removal of solid waste fuel and the upper space were filled with the gas. Combined with air inflow and water discharge, the mixture reached the explosion limit and an explosion occurred from some sort of fire source.

(3) Heat Generation/Ignition in the Storage Facility

As for the cause of the heat generation and ignition, an accident in the storage facility was assumed. Alternatively, after heat, such as frictional heat generated from the molding machine of the facility was accumulated, a solid waste fuel that had not been completely cooled was delivered inside the storage facility and the heat was accumulated by low temperature oxidization of organic substances, ultimately leading to ignition. Such possibility was suggested.

Source: Study Group on Appropriate Management of Solid Waste Fuel “About Appropriate Management Measures for Solid Waste Fuel” (2003)

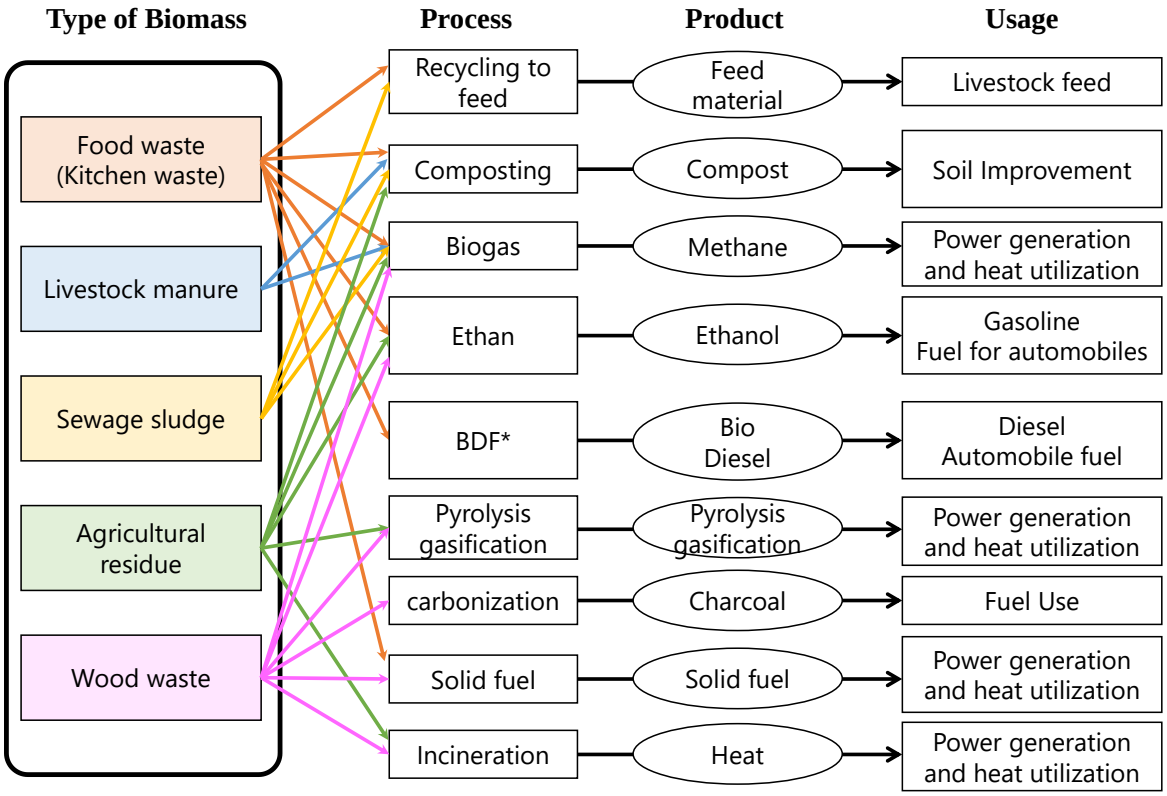
2.4 Organic Waste Recycling Technology

(1) Overview and Types of Technologies Related to Organic Waste Recycling

Kitchen waste from homes accounts for about 40 percent of the total organic waste and a large portion of the rest is the residue from the food processing sector and leftovers from restaurants. This situation highlights the issue of how to effectively recycle this waste stream in order to reduce the waste amount at final disposal. Conventionally, composting and manufacturing livestock feed have been used to promote the recycling of organic waste. In order to cope with this problem, new technologies are being developed, such as conversion of organic waste to methane gas for effective utilization which is a global warming countermeasure because it helps reduce emissions of greenhouse gases. Japan is not only using these diverse technologies to revitalize local communities and create a sound material-cycle society, but is also developing biomass (organic waste) recycling to create a low carbon society.

Biomass refers to organic resources from animals and plants, excluding fossil fuels. It is a sustainable and renewable resource that can be utilized as renewable energy and may be produced as long as there is life and solar energy.

To realize a sound material-cycle and low carbon society and to escape from the dependency on fossil fuels, it will be necessary to utilize organic waste. To that end, the spotlight is on green energy that uses biomass that is both renewable and carbon neutral. In 2009, Japan enacted the *Basic Law for Promotion of Utilization of Biomass* to revitalize rural areas and realize a sound material-cycle society through policies that promote the utilization of biomass. Biomass is a sustainable and renewable energy resource. In Japan, utilization of biomass is being promoted according to the regional characteristics, and promoting the utilization of biomass included in organic waste is part of Japan's efforts to construct a sound material-cycle society. Figure 4-16 shows the different ways to recycle organic waste. This section mainly deals with the recycling methods of converting organic waste to methane gas (biogasification), composting, and turning waste into livestock feed.



*: BDF : Bio Diesel Fuel

Source: Ministry of the Environment Website "Types and Uses of Waste Biomass"
http://www.env.go.jp/recycle/waste/biomass/biomass.html (accessed January 27, 2022)

Figure 4-16 Types and Uses of Waste Biomass

Table 4-22 shows two methods to collect the biomass (kitchen waste, etc.) for use as raw material: The first methods is source separation and separate collection of food waste that has been separated by citizens at source, and the second methods is mixed collection and mechanical sorting of food waste that has been discharged together with other waste without separation, and then is mechanically sorted at an intermediate treatment facility. The decision on whether to use separate collection or mixed collection should be determined by considering the local characteristics of the collection area.

Table 4-22 Comparison of Biomass (Kitchen Waste, etc.) Collection Methods

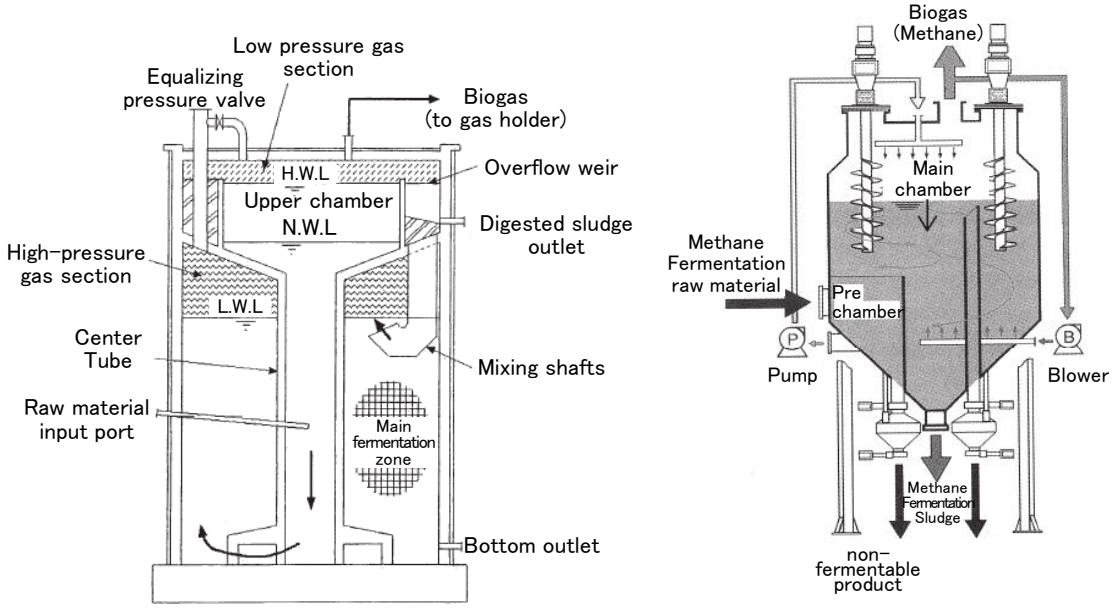
Classification	Source separation + separate collection	Mixed collection + Mechanical sorting
Methane fermentation	Either wet or dry fermentation	Dry fermentation that has fewer requirements can be adopted because of the high probability of the presence of materials not suited for methane fermentation in the waste.
Composting	High quality compost can be produced.	A mechanical sorting process is added. It will be necessary to purchase and operate the necessary equipment. Quality is problematic because foreign matter may be mixed in with the compost.
Cooperation of citizens	It is necessary to acquire the citizens understanding and cooperation for source separation and separate discharge.	There is no need to acquire the cooperation of citizens for separation.
Changes in collection containers	It is necessary to prepare dedicated kitchen waste bags. In some cases special collection containers are allocated at the collection stations.	Regular collection containers can be used.
Changes in collection frequency	In some cases the frequency of collection times is increased.	The frequency of collection times does not change.
Reuse of by-products	Wastewater generated in the treatment process can be converted to liquid fertilizer and fermentation residue can be converted to compost.	Utilization of generated wastewater as liquid fertilizer and compost is difficult because there is a high probability of the presence of materials not suited for fermentation. Incineration followed by thermal recovery are more appropriate.
Fermentation residue	Relatively low	Relatively high
Waste collection and transport costs	Tend to be high. It may be necessary to increase collection days to collect the separated waste.	No change from the present.
Required area	Small	Relatively large. Area for mechanical sorting is necessary.

Source: Ministry of the Environment Website "Waste and recycling measures"
http://www.env.go.jp/recycle/waste/biomass/supportinformation.html (accessed December 15, 2021)

(2) Overview of Methane Gasification Technology

Methane gasification is a technology in which methane fermentation is used to basically produce and recover methane. Not only is biogas usable, but the fermentation residue can also be used as fertilizer, material for cement, etc. Therefore, introduction of methane gasification not only helps to reduce the quantity of waste that is incinerated, but it can also support the establishment of a local sound material-cycle society by producing energy from the methane gas and using the residue locally as fertilizer.

Methane gas facilities ferment the organic waste that is acquired by separate collection and from mechanical sorting of collected mixed waste, and recover the biogas from the produced methane. Figure 4-17 shows an example of the structure of a methane fermentation tank and Figure 4-18 shows the process.

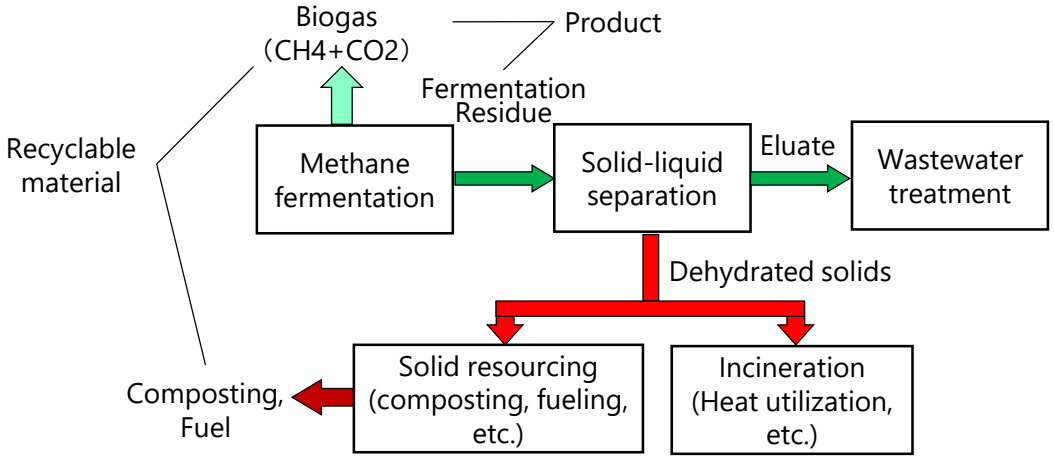


Example 1 Example 2

Source: Created based on Japan Waste Management Association "Planning and Design Guidelines for Waste Treatment Facility Maintenance, 2017 Revised Version" (2017)

Figure 4-17 Examples of the Structure of a Methane Fermentation Tank

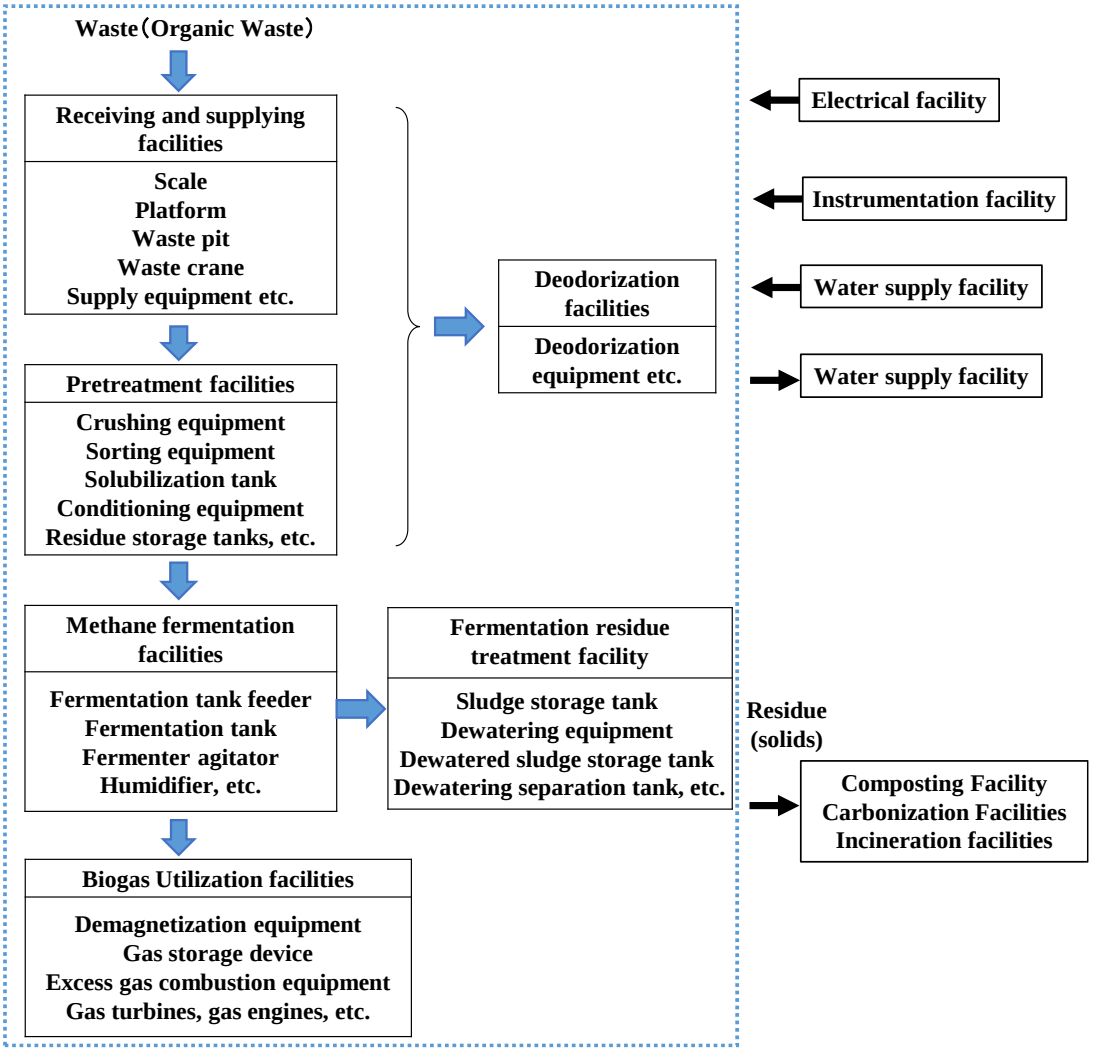
1. Biogas and fermentation residue are produced from methane gasification.
2. Dehydrated solids are used as fertilizer, etc. Or, after drying into solids, they can be incinerated.
3. Fermentation residue is used as liquid fertilizer, after disinfection. Or, after dehydration, the eliminated liquid is treated as wastewater.



Source: Ministry of the Environment Website "Methane Gasification Technology"
https://www.env.go.jp/recycle/waste/biomass/technical.html (accessed January 20, 2022)

Figure 4-18 Process of Methane Fermentation

Figure 4-19 shows the configuration and overview of the main facilities and equipment at a methane gasification facility. In general, a methane gasification facility is made up of receiving and supplying facilities, pretreatment facilities, methane fermentation facilities, and the biogas utilization equipment. The fermentation residue is also processed at the facility.



Source: Ministry of the Environment "Guidance for application for subsidy for establishing a Sound Material-Cycle Society (For Facility)" (2021)

Figure 4-19 Components and Equipment in a Methane Gasification Facility

Photo 4-46 Methane Gasification Facility in Nagaoka City, Niigata Prefecture

Photo 4-47 Methane Gasification Facility in Hofu City, Yamaguchi Prefecture

Source: Ministry of the Environment Website "Examples of Methane Gasification Facilities" https://www.env.go.jp/recycle/waste/biomass/example.html (accessed January 20, 2022)

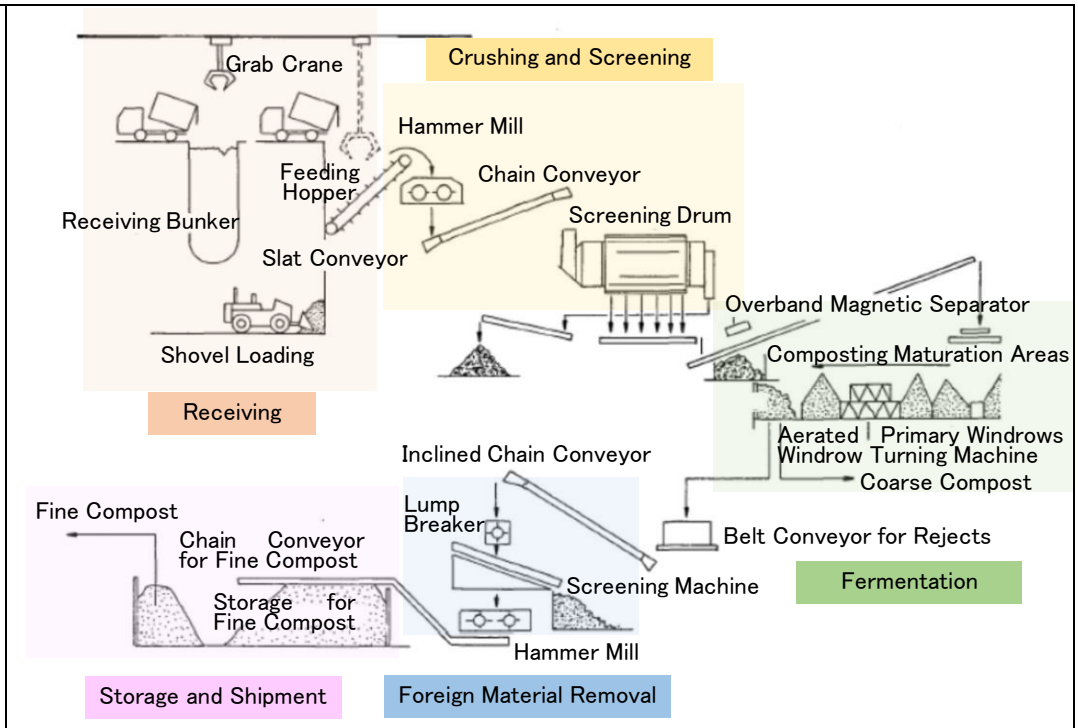
(3) Overview of Composting Technology

Composting is a technology that uses microbes to convert organic waste into compost. This technology has been used in Japan for ages, and in modern society composting is often used in rural areas because it is relatively easy to find buyers there for the compost that is produced. In order to produce good quality compost, it is important to make sure that incompatible wastes, plastics, and other non-organic matter are not mixed in the collected kitchen waste.

In composting, the organic waste in kitchen waste and the like is broken down and made into compost by microbes under aerobic conditions. This technology has been used for recycling kitchen waste in Japan for ages. In composting, the raw material used is kitchen waste and agricultural residue, livestock manure, branches and leaves, etc. It is necessary to understand that citizens will have to cooperate in separating kitchen waste at source and that buyers must be found for the compost that is produced. In developing countries, the key points are whether there is demand from local farmers and if the price is low enough for them. Before introducing composting technology, it is important to make sure that there will be continuous buyers for the compost and to secure them beforehand. For reference an example of the compost center built at Shibushi City is provided in "Topic 6, 4. Activities at Shibushi City, 4.3 Current Waste Treatment Activities, (2) Compost".

Composting

Flow



Source: JAPAN ENVIRONMENTAL SANITATION CENTER "Waste management technology in Japan (JICA training text)" (2017)

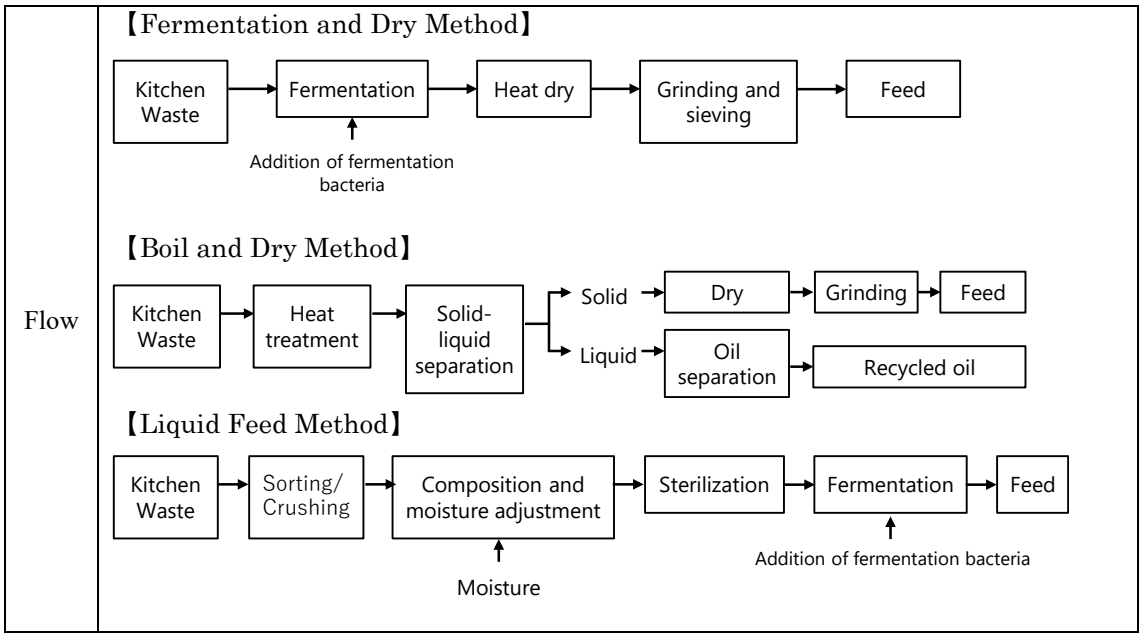
Figure 4-20 Flow of Composting

(4) Overview of Technology Related to Turning Waste into Livestock Feed

Turning waste into livestock feed is a technology that involves thermal treatment and drying of kitchen waste and agricultural residue, adjusting the oil and fat content, then producing livestock feed pellets. This technology has also been used for some time. As is the case with composting, it is important to take precautions in the production process and to ensure that there are buyers for the produced feed.

Under this technology livestock feed is produced from kitchen waste and other organic waste. As is the case with composting, this is a food recycling technology that has been used in Japan for ages. The main technologies involved in turning waste into livestock feed are reducing the water content through thermal treatment and drying, and adjusting the oil and fat content.

Livestock feed



Source: Ministry of the Environment Website "Types and uses of waste biomass"
http://www.env.go.jp/recycle/waste/biomass/biomass.html (accessed January 27, 2022)

Figure 4-21 Flow Chart of Recycling to Feed

Column: The History of Utilizing Kitchen Waste in Japan

In Japan, kitchen waste has been returned to farmland since ancient times as fertilizer by incinerating it and spreading the ashes. After World War II and when there was little plastic and metal mixed in the waste in the 1950s, a large amount of the waste from urban areas was used in rural areas as fertilizer. However, the growth of urban areas, the increased use of chemical fertilizers, and the sudden deterioration of rural areas due to the aging of the populations there, led to major changes in waste treatment in urban areas.

Geographically, Japan has few locations suitable for landfill sites and seasons with high temperatures and humidity. Due to these conditions and additionally from the viewpoints of reducing waste and maintaining sanitary conditions, incineration became the mainstream waste treatment method in the 1960s. However, there were some municipalities that built composting facilities to make compost from kitchen waste and return it to rural areas. However, most of the composting projects that used urban kitchen waste, especially that from households, confronted the problems described below. As a result, there were no users for the compost that was produced and it ended up in landfill sites. Therefore, most of the composting projects faded away except in some cities near farming areas.

1) Issue of Foreign Matter

From the 1950s to the 1960s, the standard of living improved rapidly. With many different consumer products becoming available, many different types of foreign matter were discharged together with kitchen waste, such as glass from bottles and jars, metals from cans, and plastics from containers and daily goods. At that time, there was no concept of waste separating at source and as a result the produced compost included contaminants. It therefore became impossible to assure the quality necessary for farm usage and farms stopped using the compost that was being produced.

2) Issue of Odor

Because of Japan's high temperatures and high humidity, kitchen waste rots easily and composting requires sufficient countermeasures to reduce the resulting odor. However, these measures were not sufficient at the composting facilities at the time so local residents considered these facilities troublesome.

3) Issue of Farm Labor

From the 1950s to the 1960s, young workers moved from rural to urban areas which lead to a gradual growth in the age of rural farmers. While farmers knew that using organic fertilizers was more effective for continued farming, it became increasingly impractical to use organic fertilizers due to the related hard work required. The result was that chemical fertilizer usage spread because it was easier for the aging farmers to supply just the necessary components.

Source: Based on the Ministry of the Environment “White Paper on the Environment” (2008)

Column: Takakura Composting Method that Spread in Developing Countries

The Takakura composting technology was part of the overseas aid activities conducted by Kitakyushu City in 2004. The technology was established as part of the studies to reduce and reuse the waste in Surabaya, Indonesia. The technology was named the Takakura Composting Method after the specialist, Kohji Takakura.

In the Takakura Composting Method, local natural materials are used to increase fermenting bacteria to make composting more efficient. Special fermenting bacteria are not needed and only locally available fermenting bacteria (indigenous bacteria) are used. Fermenting bacteria can be acquired from (1) food fermenting bacteria (yogurt, mushrooms, yeast, etc.), (2) leaf mold, (3) soil from organic farms, and (4) other natural items (rotting trees, hay, rice husks, etc.). It is more effective to collect as many types of bacteria as possible.

The process for making compost is shown in Figure 4-22. First, fermentation liquor is made, the fermentation liquor and bacterial bed are mixed to make bacterial colonies, and the bacterial colonies and kitchen waste are repeatedly mixed or agitated, then dried to make compost.

The Takakura Composting Method has been accepted by developing countries for the following reasons.

1) Ease of Introduction

It was easy for the receiving country to accept composting technology because it is familiar in developing countries. Additionally, by carefully explaining this technology from the basic theory through to the entire process, the composting of kitchen waste was successful.

2) Production is Easy Using Local Items

Due to the fact that the Takakura Composting Method is easy to implement using local materials, the hurdles to introduction and continuation of composting were low. Another feature of this method is that the composting period is about one or two weeks which is much shorter than usual composting periods of about three months.

3) Adaptability to Various Scales

The basic theory behind the Takakura Composting Method is not limited to small-scale kitchen waste composting in households. It can also be applied to large-scale composting facilities. If the local needs are not for household composting but for relatively large-scale composting projects that encompass communities or entire regions, the Takakura Composting Method may be effectively used for that purpose as well.

4) Developing Human Resources for Local Expansion

In the Surabaya project attempts were made to increase understanding of the basic theory by assigning community leaders to lead the way in improving the environment in their communities. Locally developed human resources have helped to spread the adoption of the Takakura Composting Method in the area.

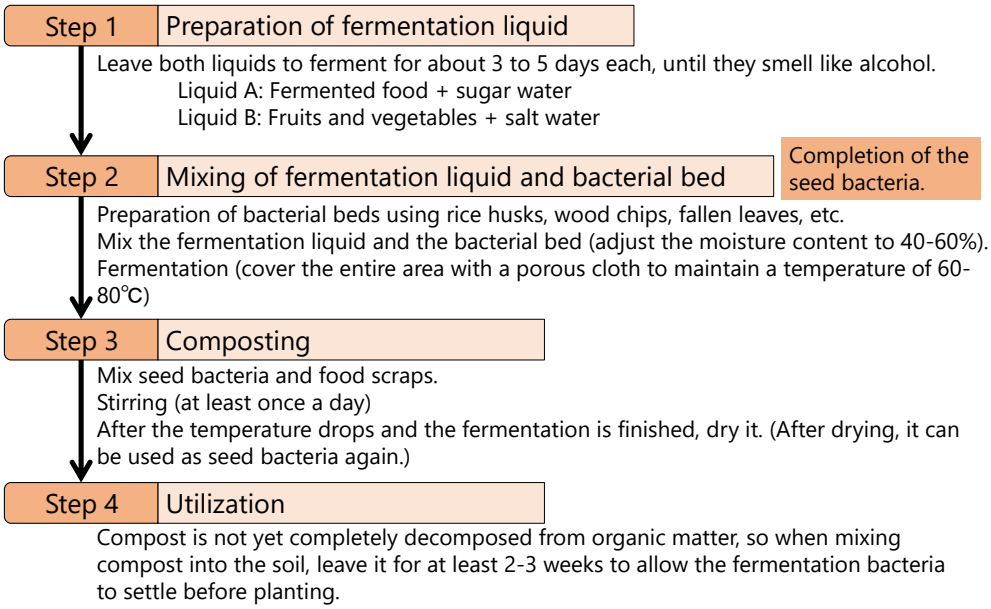


Figure 4-22 Steps of Takakura Composting Method

*: For more information on the Takakura composting method, please refer to the Takakura composting Manual.
English version: （https://kitakyushu.iges.or.jp/publication/Takakura/Takakura_Method_Full.pdf）

Photo 4-48 Fermentation Liquid Left (A), Right (B)

Photo 4-49 Mixing of Fermentation Liquid and Bacterial Bed

Photo 4-50 Inside the Compost Center

Photo 4-51 Home Composting

Source: Yachiyo Engineering Co., Ltd.

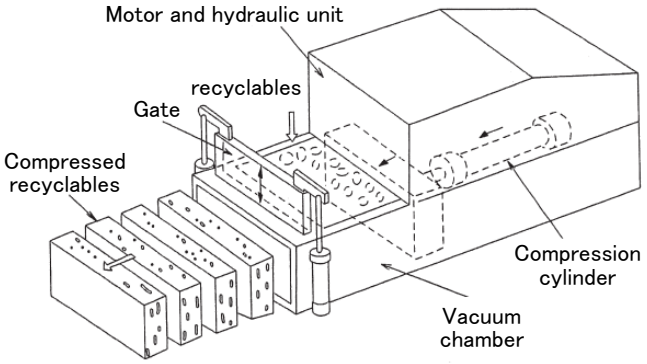
Example of Takakura Composting in Ecuador

2.5 Recycling Technology

(1) Overview and Types of Recycling Technologies

Facilities for recycling use technologies such as sorting, shredding, compression, drying, and solidifying to promote recycling of waste materials as resources. The methods and equipment used differ depending on the material that is to be recycled. Recycling is an effective technology to promote material reuse and create a sound material-cycle society.

In order to create a sound material-cycle society, the effective use of resources and recycling is very important. In Japan, various recycling laws have been enacted to promote recycling. It is necessary to economically and safely process waste using methods suitable for source separation and separate collection. The main technologies related to recycling are sorting, shredding, compression, drying, and solidifying. For reference the recycling center built at Shibushi City is provided as an example in "Topic 6-4.3 (3) Sorting Waste for Recycling".



Source: Japan Waste Management Association "Planning and Design Guidelines for Waste Treatment Facility Maintenance, 2017 Revised Version" (2017)

Figure 4-23 Metal Press Machine

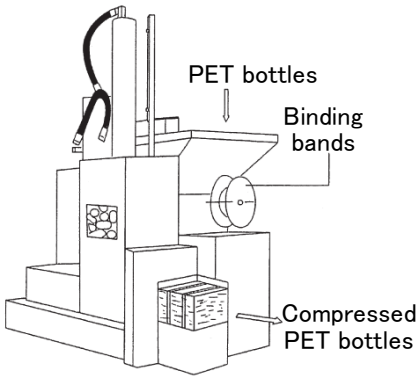


Figure 4-24 PET Bottle Compaction and Baling Machine

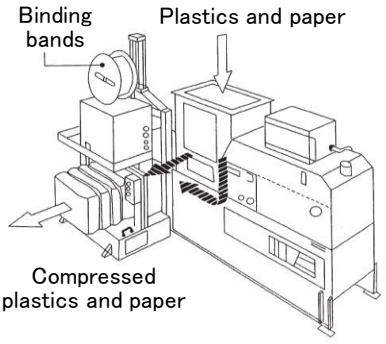
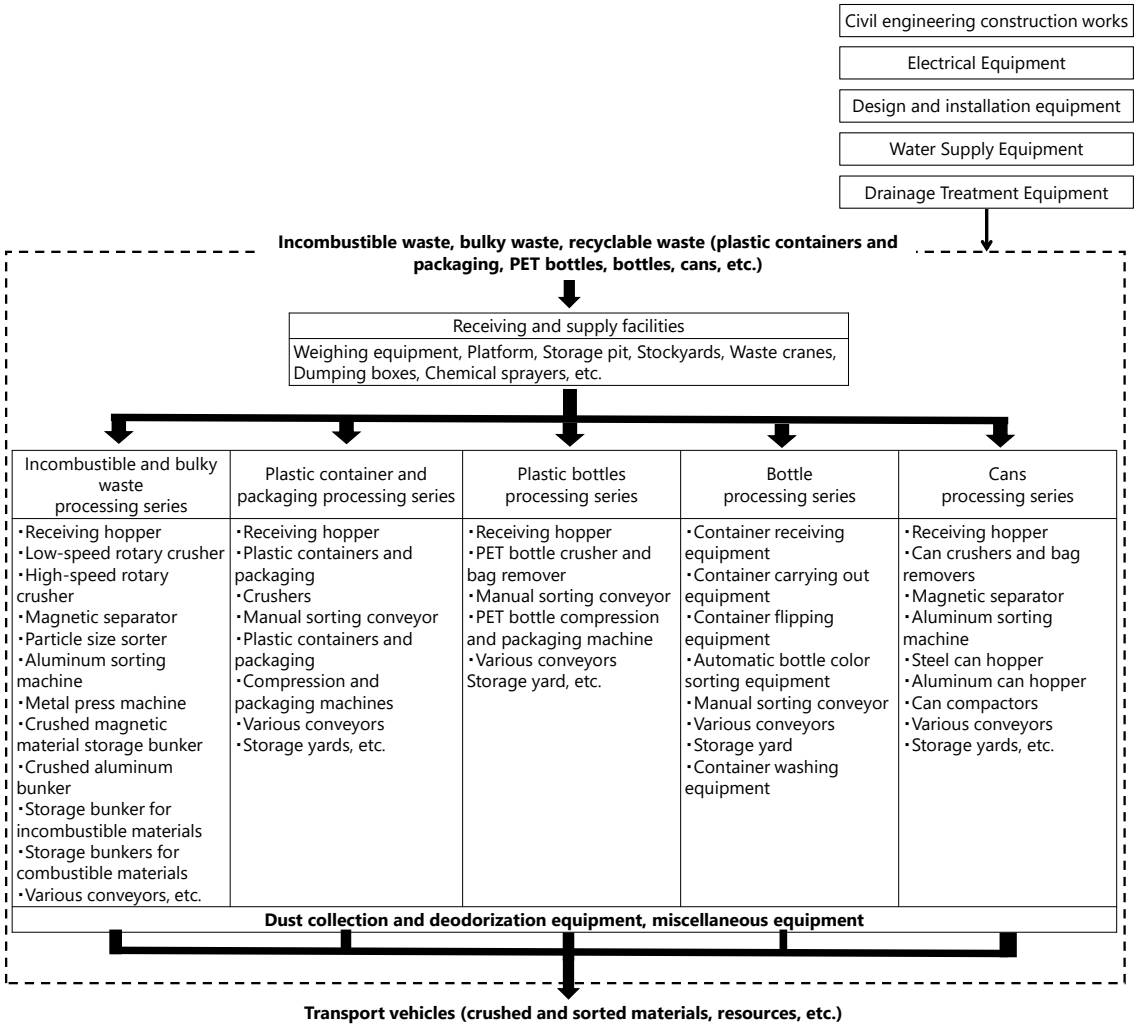


Figure 4-25 Plastic Container Packaging Compaction and Baling Machine

Source: Japan Waste Management Association "Planning and Design Guidelines for Waste Treatment Facility Maintenance, 2017 Revised Version" (2017)

Figure 4-26 and Table 4-23 provide overviews and configurations of the main equipment used at recycling facilities.



Source: Ministry of the Environment "Guidance for application for subsidy for establishing a sound material-cycle society (Facility)" (2021)

Figure 4-26 Components of Recycle Facility Equipment

Table 4-23 Overview of the Main Equipment at Recycling Facilities

Main equipment	Equipment overview
Receiving and supplying equipment	Made up of the following: Weighing machines to weigh incoming waste and outgoing recycled materials; entrance and exit roads; platforms for receiving waste from collection trucks for the storage pits and stockyards; waste input doors to separate the platforms and storage pits; waste crane to feed waste from the storage pit into the receiving hopper; dumping boxes for sorting of hazardous waste, difficult-to-process waste, and recyclables; chemical spraying equipment to prevent stench at the platforms; etc.
Incombustible and bulky waste treatment systems	Made up of the following: Receiving hoppers that receive the incombustible and bulky waste from waste cranes and excavator loaders; low-speed rotating shredders that make it easier to transport and sort incombustible and bulky waste; high-speed rotating shredders; magnetic sorters that recover iron from the shredded waste; granular separators that recover incombustible waste after scrap iron is removed from shredded waste; aluminum separators that recover aluminum scraps from the shredded waste; metal compressors or storage that compress recovered iron and aluminum scraps for reuse and storage; shredded magnetic material storage bunkers for shipping out; shredded aluminum bunkers; incombustible waste storage bunkers and combustible material storage bunkers for storage and shipping out incombustible and combustible material.
Plastic container and packaging treatment systems	Made up of the following: Receiving hoppers that receive the plastic containers and packaging from waste cranes and excavator loaders; plastic containers and packaging bag openers that make it easier to separate plastic containers and packaging; manual sorting conveyor belts to remove foreign matter from the opened bags; recycling the recovered plastic containers and packaging; plastic containers and packaging compressing and bailing machines to compress for storage; storage for compressed bails; and storage yards for shipping.
PET bottle treatment systems	Made up of the following: Receiving hoppers that receive the PET bottles from waste cranes and excavator loaders; bag openers to make it easier to separate the PET bottles; PET bottle bag openers to remove them from the bags; manual sorting conveyor belts to remove foreign matter from the opened bags and their contents; recycling of recovered PET bottles; compressing and bailing machines to compress PET bottles for storage; storage for compressed bails; and storage yards for shipping.
Bottle treatment systems	Made up of the following: Container receiving unit to receive bottles collected in containers; container conveying unit to convey the containers with bottles inside; container inverting units to invert the containers with bottles inside; automatic bottle color separators to automatically separate the inverted bottles by color or manual sorting conveyor belts for manual sorting; storage yards for storing and shipping recovered bottles; and container washing machines to clean the containers that were used when receiving the bottles.
Can treatment systems	Made up of the following: Receiving hoppers that receive the cans from waste cranes and excavator loaders; can bag opening and debagging machines to make it easier to sort the cans; can separating machines to recover the steel cans from the waste from the bags; aluminum can separator machines to recover the aluminum cans; steel can hoppers and aluminum can hoppers to store the recovered steel and aluminum cans; can compressing machines to compress the steel and aluminum cans for recycling; storage yard for storing and shipping compressed materials.

Main equipment	Equipment overview
Dust collection and deodorizing equipment	Made up of the following: Cyclones, bug filters, and blowers for dust collecting; deodorizers for deodorizing; blowers for deodorizing; ducts connecting the various equipment.
Water supply equipment	Made up of the following: Water tanks to supply city water, industrial water, well water, etc. for use in the plant and regular use; pumps; etc.
Wastewater treatment equipment	Made up of the following: Wastewater screens to process the floor washing water and daily wastewater from the platforms and shipping rooms; water tanks; pumps; sludge treatment units.
Electric equipment	Receives power for all of the above and distributes it to the necessary sections of the various equipment (motors, etc.).
Instruments	Instruments, control equipment, ITVs, data processing, and other equipment necessary for operation control.
Miscellaneous equipment	General air compressor, car washing machine, and other equipment necessary to maintain the work environment within the plant.
Other	Buildings and building equipment are necessary for the installation of equipment, the administration building, and various access roads. Rooms and spaces for the purpose of improving public awareness on the 3Rs by holding seminars and disseminating information related to waste and recycling, locating equipment to recycle used and discarded items, equipment necessary to store, display, and replace things in the recycling process.

Source: Ministry of the Environment "Guidance for application for subsidy for establishing a sound material-cycle society (Facility)" (2021)

(2) Roles of Technologies Related to Recycling

Recycling technologies such as sorting, shredding, and compressing can also perform the following roles for promoting efficient recycling.

Roles of recycling technology

- Shredding combustible bulky waste into sizes that can be incinerated.
- Shredding organic waste into sizes suitable for intermediate treatment.
- Shredding and sorting incombustible waste and bulky waste to enable recovery of recyclable materials.
- Reducing waste disposal by shredding and compressing waste.
- Reducing final disposal amount by recovering recyclable materials.
- Reducing waste generation amount.
- Resources recovery.

2.6 Standards Related to Intermediate Treatment Facilities and Their Maintenance

To assure that operators can prevent air and water pollution, they must have facilities that can satisfy the various regulatory standards and maintain suitable operations and maintenance. The various standards related to intermediate treatment facilities are regulated by laws and ordinances.

The construction and operation of a waste treatment facility must consider the surrounding environment. As Figure 4-27 and Table 4-26 show, standards have been developed for a variety of items. Table 4-24 shows the differences between environmental standards and regulatory standards.

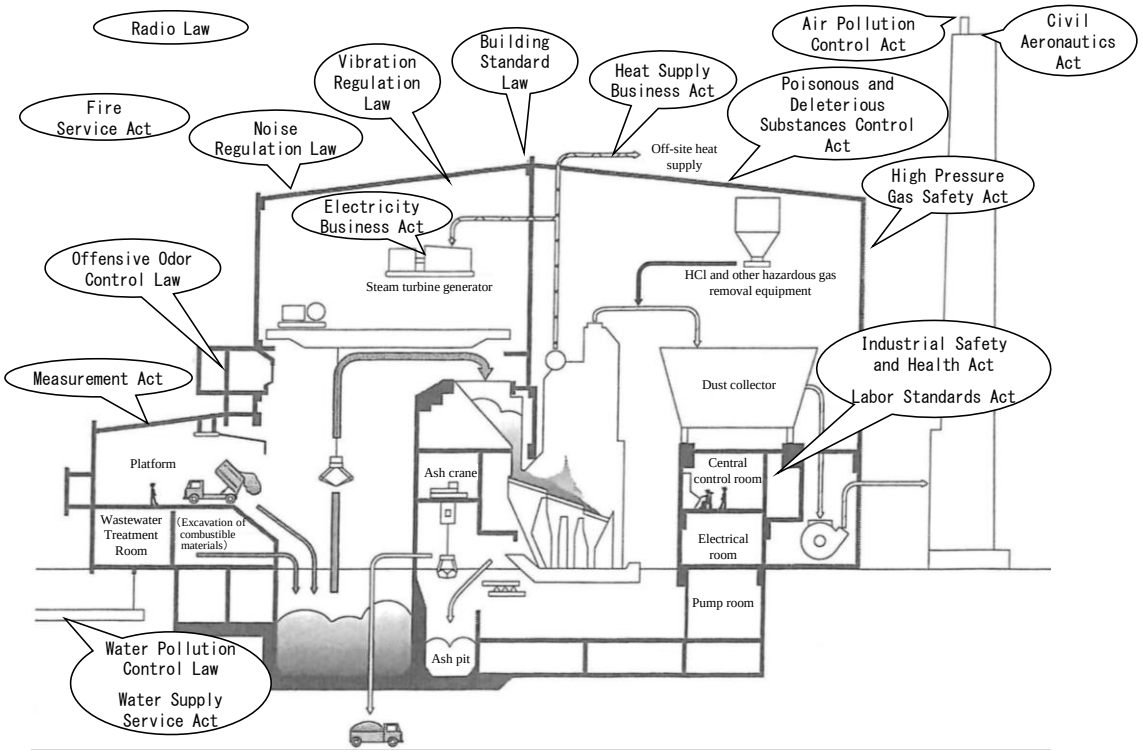
These are especially important for incineration plants because the gases they emit can be a major cause of pollution to the surrounding environment. Moreover, they can cause issues of odor and noise in the surrounding community.

Table 4-24 Difference between Environmental Standards and Regulatory Standards

Standards	Contents
Environmental standards	As standards that should be maintained to protect human health and maintain the environment, these have the ultimate goal of determining to what levels of quality air, water, soil, and noise must be maintained. These are only environmental standards that should be maintained, and there are no penalties when they are not met. .
Regulatory standards (tolerance limits)	In order to prevent pollution, these standards must be met to regulate the emission concentrations and quality of air and water from plants. If the standards cannot be met, then notifications or guidance will be issued by the relevant administration agencies, and if improvements are not made, then penalties will be applied.

Table 4-25 Summary of Relevant Laws and Regulations Relating to the Planning of the Facility

No.	Laws	Enactment Year	Outline
1	Fire Service Act	1948	Law to prevent and mitigate damage caused by disasters such as fires and earthquakes.
2	Offensive Odor Control Law	1971	Law to protect health by imposing necessary regulations on odors generated by business activities in factories and workplaces in regulated areas.
3	Measurement Act	1992	Law to establish standards for measurement and to ensure proper implementation of measurement.
4	Water Pollution Control Law	1970	Law to regulate water discharge and underground penetration from factories and business sites into public water bodies and to prevent pollution of public water bodies and groundwater.
5	Water Supply Service Act	1958	Law to establish standards for the installation and other management of sewage systems and to improve the healthy development of cities and public health, as well as to protect the quality of water.
6	Radio Law	1950	Law to ensure the fair and efficient use of radio waves and to promote public welfare.
7	Noise Regulation Law	1968	Law to protect the living environment by regulating the noise generated by business activities and construction work at factories and workplaces, and by regulating automobile noise.
8	Vibration Regulation Law	1976	Law to protect the living environment by regulating vibration and road traffic vibration caused by business activities and construction works in factories and workplaces.
9	Electricity Business Act	1964	Law to ensure public safety by regulating the proper operation of electric utilities and the construction, maintenance, and operation of electric facilities.
10	Building Standard Law	1950	Law to protect health and property by establishing standards for building sites, structures, facilities, and uses.
11	Heat Supply Business Act	1972	Law to ensure public safety by regulating the proper operation of heat supply businesses and the construction, maintenance, and operation of heat supply facilities.
12	Poisonous and Deleterious Substances Control Act	1950	Law to control poisonous and deleterious substances as necessary for health and hygiene.
13	Air Pollution Control Act	1968	Law to protect health and the environment by regulating air pollutant emissions from business activities at factories and workplaces and by setting required limits for automobile emissions.
14	High Pressure Gas Safety Act	1951	Law to prevent fires caused by high-pressure gas by regulating the manufacture, storage, sale, import, transfer, consumption, and disposal of high-pressure gas.
15	Industrial Safety and Health Act	1972	Law to protect workers' health and safety and promote the formation of a comfortable work environment by promoting comprehensive and systematic measures to prevent industrial accidents.
16	Labor Standards Act	1947	Law to protect workers' rights by establishing standards related to labor, such as employment regulations, working hours, and wages.
17	Civil Aeronautics Act	1952	Law to ensure the safety of aircraft transportation by prescribing methods to ensure the safety of aircraft navigation and the prevention of obstructions caused by aircraft navigation.



Source: Japan Waste Management Association "Planning and Design Guidelines for Waste Treatment Facility Maintenance, 2017 Revised Version" (2017)

Figure 4-27 Relevant Laws and Regulations Pertaining to the Planning of Facilities

Table 4-26 Standards Related to the Construction and Maintenance of Facilities

Item	Standard	Subject	Applicable laws
Air quality	Environmental standard	・All areas*1	・Basic Environment Law ・Act on Special Measures concerning Countermeasures against Dioxins, etc.
	Emission standard (regulatory standard)	・Gas emissions from waste incinerators, etc.	・Waste Management Act ・Air Pollution Control Act ・Act on Special Measures concerning Countermeasures against Dioxins
Noise	Environmental standard	・Areas that are not facing roads. ・Areas that are facing roads.	・Basic Environment Law
	Regulatory standard	・Plant noise pollution ・Construction noise pollution, etc.	・Noise Regulation Law
Vibrations	Regulatory standard	・Plant vibrations ・Construction work vibrations, etc.	・Vibration Regulation Law
Odors	Regulatory standard	・Site boundaries ・Gas outlets ・Drainage outlets	・Offensive Odor Control Law
Water quality	Environmental standard	・Rivers, lakes, seas ・Groundwater, etc.	・Basic Environment Law ・Act on Special Measures concerning Countermeasures against Dioxins
	Drainage standard (regulatory standard)	・Drainage from plants and facilities	・Waste Management Act ・Water Pollution Control Law ・Act on Special Measures concerning Countermeasures against Dioxins
Soil pollution	Environmental standard	・All areas*2	・Basic Environment Law ・Act on Special Measures concerning Countermeasures against Dioxins
	Specified hazardous substances	—	・Soil Contamination Countermeasures Act

*1: Not applicable to dedicated industrial areas, or roads, general areas, and locations which the general public usually does not use.

*2: Not applicable to the soil of locations where it is clear that the pollution is from a natural source, and the soil of areas where raw materials are deposited, waste landfills, and other areas where the items listed in the separate table are used or processed and actually stored.

*3: The ordinances of various local governments can also be the basis of standards for all items.

(1) Standards Based on the Waste Management Act

The technical standards related to the operation and maintenance management of municipal waste treatment plants are regulated by the *Waste Management Act*. There are detailed standards that specifically regulate incineration plants which must be met. (for more details on the *Waste Management Act*, refer to "Topic 2-2.2 (3) Wastes Management and Public Cleansing Law".

(2) Maintenance and Control of Plants

Meeting the established standards will protect the surrounding environment and help gain the trust of residents. Therefore, executing a planned operation and maintenance program for the plant and stopping operation for even the slightest problem are important actions for safety.

Waste treatment plants must be operated and maintained under the strictest control to satisfy the related standards. The operation controls to reduce dioxins at incineration plants are described in Figure 4-28. It is extremely important to have a combustion chamber that can meet the conditions for perfect combustion to reduce dioxins, cooling equipment that can cool the gas after incineration, and to maintain the functionality of exhaust gas treatment equipment including dust collector that removes dust. If any of the equipment indicates a problem that could lead to operation interference, the operation must be stopped immediately to solve the problem. Once an accident occurs, the trust of residents will be lost, so operators must always act on the side of caution.

Another important way to gain the trust of the surrounding residents is to monitor exhaust gas concentration in real-time and publicize the results on a website or at the plant.

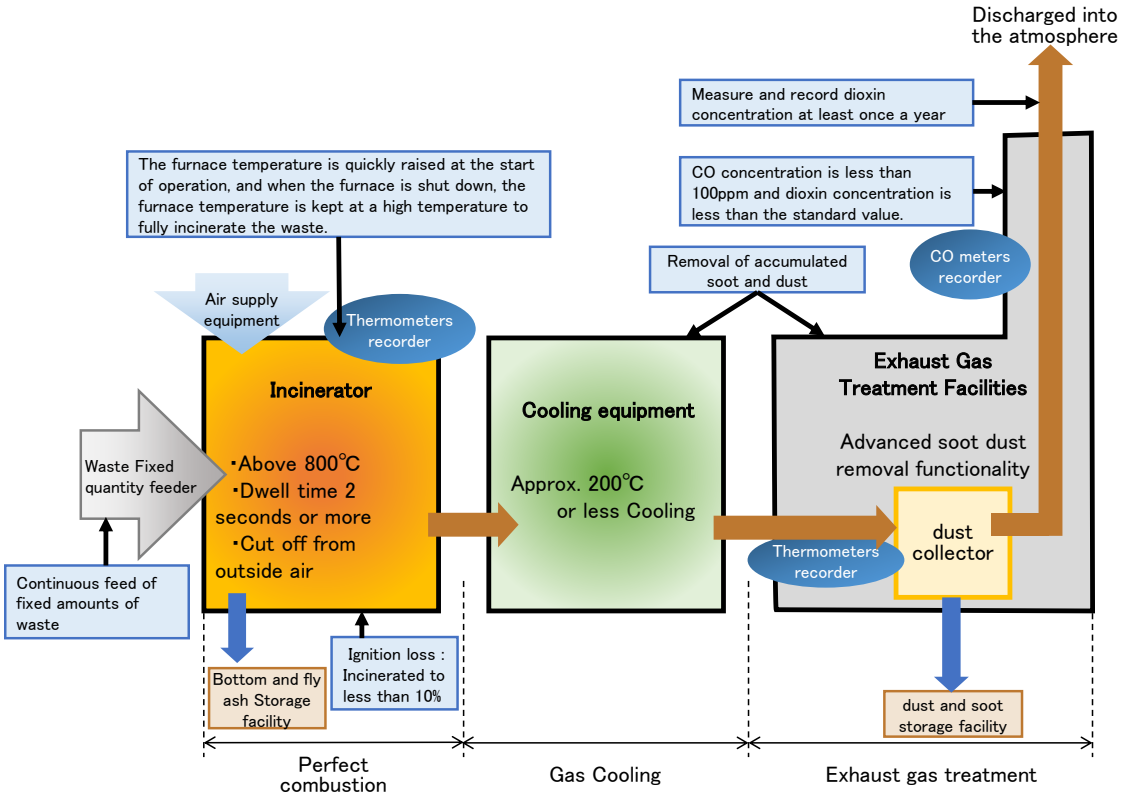


Figure 4-28 Proper Operation and Maintenance of Incineration Plant

Photo 4-52 Disclosure of Exhaust Gas Status at Suginami Incineration Plant

Photo 4-53 Disclosure of Exhaust Gas Status at Shibuya Incineration Plant

Source: Yachiyo Engineering Co., Ltd.

3 Final Disposal

3.1 History of Disposal Sites

Various types of disposal sites were developed depending on the background of each period, the realities of the local society and the types of waste being disposed - organic waste, inorganic waste, hazardous waste, etc. Technical standards and guidelines were established to assure suitable disposal site management and to reduce the effects on the surrounding environment. Due to these guidelines and the strict operations followed by local municipalities, it has become possible for them to build suitable disposal sites and operate and maintain them in a sanitary manner. As a result, these facilities have been accepted by the local residents.

Before the introduction of intermediate treatment, kitchen waste and other types of waste were disposed of at designated locations. However, this caused problems for the surrounding environment such as the generation of odor, pests (mosquitos, flies, etc.), and spontaneous fires caused by gas produced from the disposed waste.

During the period of high economic growth in the 1960s, waste increased, the remaining capacity of landfill site was shortened and it became necessary to promote the reduction of waste disposal amount at landfills by incineration.

In the 1970s, the *Waste Management Act* was revised and technical standards for disposal sites covering construction, operation and maintenance, and decommissioning were established. Disposal sites were divided into three categories, namely inert landfill sites, controlled landfill sites, and isolated landfill sites and standards were established for each.

Then, the “Structural Guidelines for Final Waste Disposal Sites” were established in 1979 and the “Performance Guidelines for Final Waste Disposal Sites” were established in 2000. These guidelines dealt with the issues of suitable landfill control, and helped to alleviate the shortage on landfill sites and solved the problems related to the surrounding environment, such as the generation of hexavalent chromium and hydrogen sulfide.

The shortage of landfill sites furthered the need for more sites which was one problem, but on the other hand it was becoming more difficult to gain the understanding of surrounding residents to construct new sites. Therefore, local harmonized landfill sites were proposed, underpinned by the operation and maintenance being strictly controlled and implemented with the understanding of residents. As a result, closed system landfills were adopted as landfill sites for municipal waste. There were 1,620 municipal waste final disposal sites in FY2019, and 83 closed system landfill sites in FY2018.

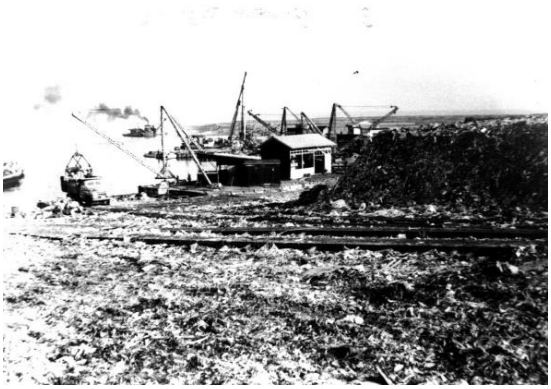


Photo 4-54 A landfill Site in Tokyo where Spontaneous Combustion was Occurring Because the Waste was Directly Disposed with no Intermediate Treatment and no Soil Cover Application – circa 1957

Photo 4-55 Stress on Landfills due to Increase in Waste Amount and Diversification of Waste quality (1965)

Photo 4-56 Previous Conditions of a Landfill in Tokyo that was Swarming with Wild Birds (1989)

Photo 4-57 Shortage of Landfill Sites due to Increasing Amount and Diversification of Waste Quality (1992)

Source: Tokyo Metropolitan Government Bureau of Environment (Photo 4-54, Photo 4-55)
Source: Tokyo Metropolitan Government (Photo 4-56, Photo 4-57)

Column: Open Dumping in Developing Countries

Open dumping is the uncontrolled dumping of waste at a disposal site and is practiced in many disposal sites in developing countries. Table 4-27 and Figure 4-29 describe the concerns of open dumping. In order to reduce the risks of open dumping, proper management at the disposal site is important, including the development of appropriate facilities, leveling and compaction of dumped waste, and soil covering.

Table 4-27 Concerns Related to Open Dumping

Risk	Content
Landfill Gas (Fire and air pollution)	Methane gas and other gases produced in landfills cause fires which generate toxic substances.
Scattering	There are concerns about the impact on the surrounding environment due to the scattering of waste.
Water Leaching	Since leachate is discharged outside the landfill without any treatment, there is concern about the impact on the surrounding aquatic environment, such as rivers and groundwater. There is also concern about land pollution as leachate percolates into the soil.
Sanitary Environment	The stagnation of water in the landfilled area generates large numbers of mosquitoes and flies, which worsen sanitary conditions.
Stench	The stench generated from the decomposing waste at the disposal site affects the surrounding residents.
Waste collapse	If disposal works of leveling and compaction, landfill height control, and mild slopes of the disposed waste are not implemented, there is a risk of collapse of the landfilled waste, which may cause injuries or casualties to workers and other personnel.
Waste pickers	The poor sanitary conditions in the landfilled area are a health hazard for waste pickers active at the site. Of particular concern is infectious waste, such as injection needles, when mixed with medical wastes.

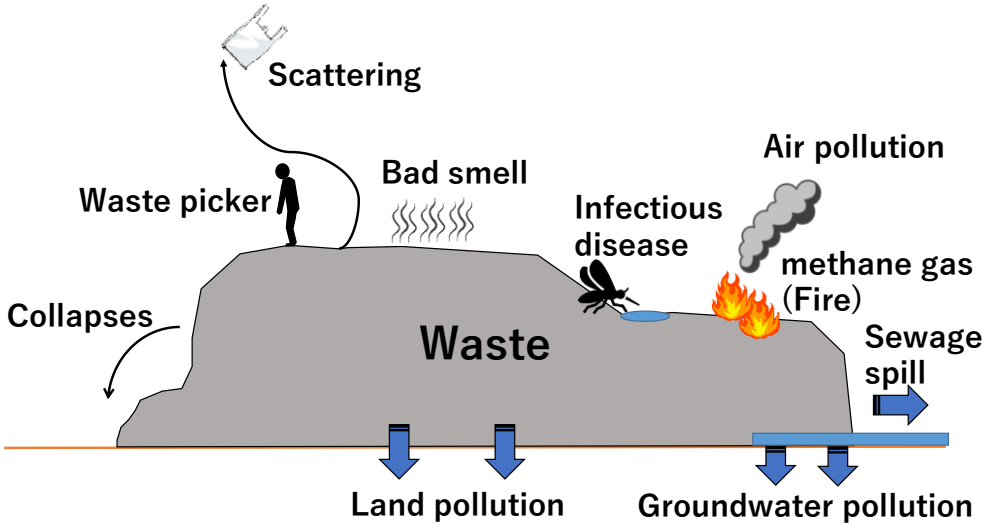


Figure 4-29 Concerns Related to Open Dumping

Photo 4-58 Open fire - Nigeria, 2016

Photo 4-59 Waste Scattering - Nigeria, 2016

Photo 4-60 Piling of Waste - Indonesia, 2019

Photo 4-61 Waste Pickers - Cambodia, 2000

Photo 4-62 Stagnant Water Puddles - Cuba 2002

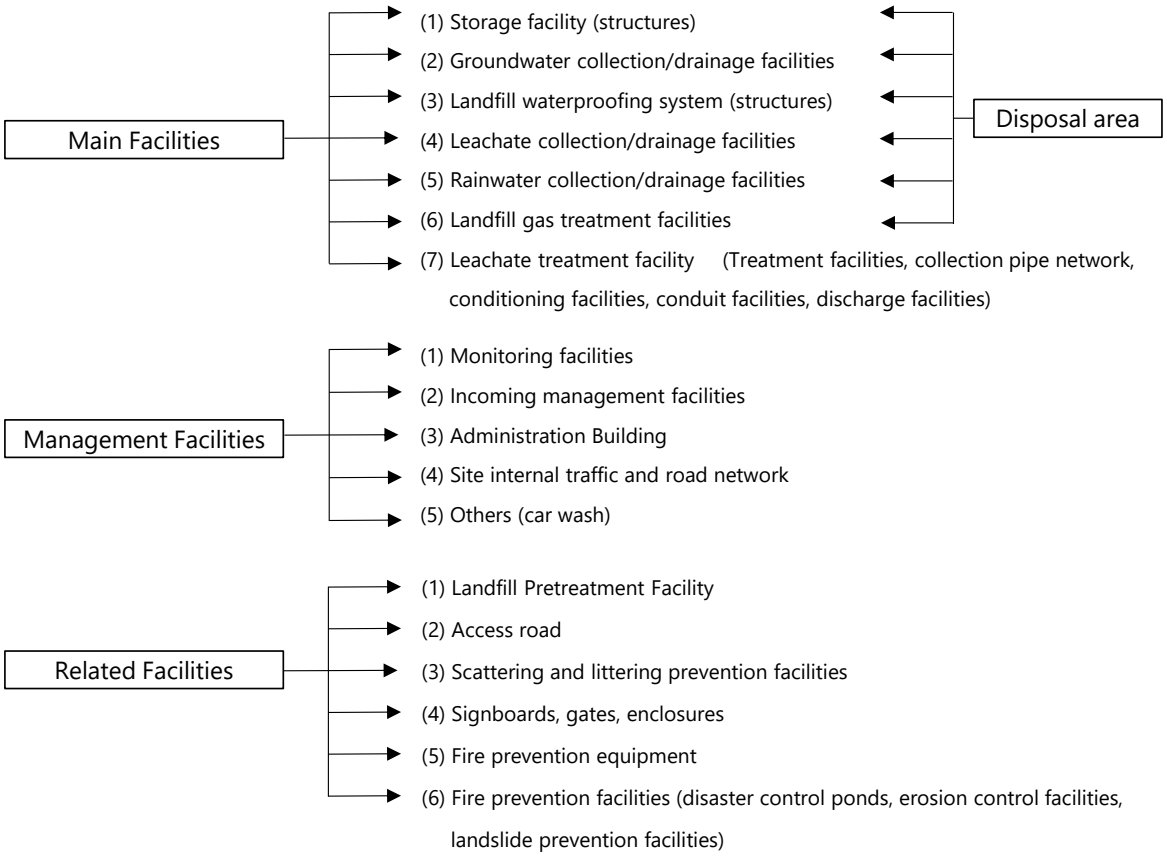
Photo 4-63 Water pollution - Myanmar, 2000

Source: Yachiyo Engineering Co., Ltd.

Examples of Concerns in Open Dumping Sites in Developing Countries

3.2 Functions and Features of Landfill Site Facilities and Equipment

The main functions required of landfill sites are as follows: waste storage function to stably store the waste in the landfill; water sealing functions to prevent groundwater from entering the landfill site, and prevent water from the waste in the landfill from being discharged outside the disposal area; and cleaning functions to facilitate the decomposition of organic waste and washing out contaminated matter. The main facilities are storage structures, waterproofing liner system construction, leachate treatment facilities, monitoring facilities, and generated gas treatment facilities. Figure 4-30 and Table 4-28 show the main facilities of landfill sites.



Source: Based on the Japan Waste Management Association "Planning, Design, and Management Procedures for Preparing Waste Landfill Sites, Revised 2010 Edition" (2010)

Figure 4-30 Outline and Flow of Main Facilities of Landfill Sites

Table 4-28 Overview of the Main Facilities of Landfill Sites

Main facilities	Equipment overview
Storage structures	These structures, often referred to as waste disposal cells, contain the waste layers within designated disposal areas and prevent collapsing, and are used to safely store waste.
Groundwater collection/drainage facilities	These facilities effectively collect groundwater and spring water, and quickly drain them. In general, there are upstream and downstream main lines connected to horizontal branches.
Water waterproofing construction	These are a series of facilities used to prevent water pollution caused by leachate. There are mainly two types: Surface sealing construction (impermeable liner membranes construction, impermeable soil liner construction, etc.) and vertical sealing construction.
Rainwater collection/drainage facilities	These are facilities to collect and drain rainwater. They prevent rainwater that falls outside the landfill site from entering the site and rain that falls on active disposal sections of the site before they are covered from penetrating into the waste layers.
Leachate collection and drainage facilities	These are facilities used to collect the moisture content of the waste disposed in the landfill and the leachate that has seeped through the waste layers and discharge the collected leachate to the leachate treatment facility.
Leachate treatment facilities	These are facilities used to treat the leachate collected by the leachate collection/drainage facilities so that the liquid does not pollute public waters and groundwater after being discharged.
Landfill gas treatment facilities	These are either vertical or inclined ventilation facilities installed in the landfill to collect and vent any gas produced in the landfill site.
Covering facilities	These are facilities such as roofing that cover the surface of landfill sites so that rainwater cannot enter.
Incoming waste control facilities	These facilities are used to weigh the waste delivered to the landfill site, analyze the quality, conduct deployment inspections, manage records, etc.
Environmental monitoring facilities	During and after final completion of waste filling operations, these facilities monitor water quality, landfill gas, the quantity and quality of delivered waste during operation, groundwater quality, noise and vibrations, scattering of waste, etc.
Administration building	This building is used to do all of the following work in a systematic manner: environmental monitoring; assuring safety; inspecting and weighing the delivered waste to assure economically efficient site operation; confirming the compliance of the landfill conditions with the landfill plans; securing coverage materials; installing section embankments; operating and maintaining leachate treatment facilities; monitoring; etc.
Controlled roads	In addition to daily management, inspection, and maintenance of the various facilities, fire prevention, and safety management, these roads are also used for the delivery of materials, etc.
Pre-landfill treatment facilities	These are facilities used for pre-treatment before landfill treatment and include shredding and sorting of waste, melting treatment, crushing of waste, etc.
Delivery access road	This is a road used to deliver waste and soil cover materials to the landfill site. It is made up of a public road that is also used by general vehicles as well as the entrance from the public road to the landfill site.

Main facilities	Equipment overview
Scattering prevention facilities	These are facilities used to prevent the waste from being scattered by strong winds and birds and polluting the surrounding environment. In general, scattering is prevented together with daily management, such as by covering with soil and by sprinkling water.
Signage, gates, and enclosure facilities	In addition to a sign and gate at the entrance of the landfill site, there is an enclosure around the landfill site to mainly ensure site access control.
Fire prevention facilities	Availability of fire extinguishers, fire prevention water and soil (which can also be used as cover soil), construction of fire break zones, and using sprinkler trucks and bulldozers in place of fire trucks are all effective.
Disaster prevention facilities	These facilities and equipment are used to prevent possible landfill site disasters.

Source: Based on the Japan Waste Management Association “Planning, Design, and Management Procedures for Preparing Waste Landfill Sites, Revised 2010 Edition” (2010)

3.3 Types of Disposal Sites

Disposal sites are categorized according to the site location where they will be constructed, their structure, the types of waste they will be receiving, and the environmental conditions in the landfill site. In addition, since the appropriate shape of the disposal site is dictated by the site location, surrounding environment, presence of residents, waste disposal conditions in the relevant area, etc., it is important to consider the plan for the disposal site after fully understanding the current situation of the planned site.

Landfill sites are facilities for disposing of wastes that are difficult to undergo intermediate treatment - such as incineration, recycling, etc., waste items that are difficult to reuse, and the residue from intermediate treatment. They are facilities where waste is appropriately stored without negatively impacting the surrounding environment. The number of landfill sites in Japan and their remaining capacities are discussed in "Topic 1. 1.2 Waste Management Condition (5) Final Disposal of Waste".

This section will introduce the types of disposal sites according to the various categorization methods.

(1) Categorizing by Location: Disposal Sites in Mountainous areas, in Plains Land, and in Land Reclamation Sites at Sea

Generally, landfill sites are constructed in mountainous terrain by adopting the topographical features there or by excavation in plains. In Japan due to limitations of finding sites for constructing landfills, the method of constructing a seawall in a coastal area and constructing a landfill at sea, i.e. land reclamation, is also implemented. Table 4-29 shows examples of disposal sites categorized by location.

(2) Categorizing by Facility Structure: Open and closed Systems

In Japan, learning from past experience that construction of landfills was difficult due to opposition from local residents, in recent years closed system landfill sites in which waste is disposed of in enclosed structures have been constructed as regional-friendly facilities that are accepted by the residents. Moreover, operation and maintenance of closed system landfill sites are not affected by the weather and has the advantage of being able to effectively minimize leachate generation as intake of rainwater can be controlled. Tables 4-30 and Table 4-31 show the features of open and closed systems of landfill sites.

Table 4-29 Features of Disposal Sites Categorized by Location

Photos	Types and Features
 Tsuruoka City, Yamagata Prefecture	Disposal sites in mountainous terrain: These are disposal sites built in the valleys between mountains. Their advantage is that they can be built far from urban areas. About 70 percent of all disposal sites in Japan are of this type.
 Nigata City, Nigata Prefecture	Disposal sites in plains: Where construction in mountainous areas is difficult, disposal sites are constructed in plains on level ground by excavating spaces for waste disposal. These can be near urban areas and one important consideration point is how the land will be used in the future after the completion of disposal activity there.
 Ube City, Yamaguchi Prefecture	Disposal sites by land reclamation: These are disposal sites that were constructed by land reclamation at sea because of the limited land area in Japan. Their construction requires advanced marine civil engineering technology. A feature compared with disposal sites on land is that the area per disposal site is large.

Source: Tsuruoka City Website “Tsuruoka City Municipal Waste Landfill”
https://www.city.tsuruoka.lg.jp/kurashi/gomi-seikatsu/shorishisetsu/saishushobunjou.html (accessed March 1, 2022)
Niigata City Website “Fourth Akatsuka Landfill”
https://www.city.niigata.lg.jp/smph/nishi/shisetsu/seikatsu/dai4akatuka.html (accessed March 1, 2022)
Utsunomiya City Website “When landfill waste is brought to a processing facility”
https://www.city.ube.yamaguchi.jp/kurashi/gomi/dashikata/1001977/1001994/1001998.html (accessed March 1, 2022)

Table 4-30 Features of Open System Landfill Sites

Item		Content
Overview		・Disposal sites are constructed according to the site geography and geology. ・Rain and snow that fall on a disposal site generate leachate. ・Many facilities of this category have been constructed.
Environment	Natural environment	Daily soil cover application is necessary to mitigate the effects of rain and wind on active disposal cells in the site.
	Effect on living environment	Operation and maintenance must be thorough. Measures such as leak detector systems must be installed to prevent against water leak risks.
	Landfill facilities environment	In order to prevent scattering of waste, daily, intermediate and final soil covers need to be applied
Facilities planning	Stabilization of landfill site	In principle there is natural stabilization. Natural rain and semi-aerobic landfills promote stability.
	Landfill capacity	Large landfill capacity can be assured by effectively utilizing the terrain. Additionally, it is relatively easy to make structural changes in order to expand disposal capacities.
	Storage structures	Depending on the site geography and geology, storage spaces are prepared by constructing dams, excavating pits or utilizing retaining slopes. Many storage facilities are of soil structure so they are relatively inexpensive to construct and maintain.
	Waterproofing construction	Waterproofing is often provided through laying of a double layer of impermeable membrane sheets as liner.
	Leachate treatment facilities	The scales of these facilities is determined by the amount of rain and snow falls, and are large when compared to the closed system landfill sites.
	Landfill work	The space inside landfills is open and there are few obstacles and limiting conditions while working there.
Economy	Construction costs	While the scale of the leachate treatment facilities (treatment equipment, adjustment tanks, etc.) will be large, in terms of construction costs they are cheaper than for closed systems.
	Maintenance and control costs	There is more leachate treatment than for closed systems, so the operation and maintenance expenses are high during the facility operation period.
Summary		Open system landfill sites are affected by storms, typhoons, and other weather conditions. Leachate generated from rain falling on the site cannot be reduced. However, there are few limiting conditions at these sites, and expanding the site and changing the structure are relatively easy. There is an established track record with these sites and the technology for construction, operation and maintenance, and safe closing are all established.

Source: Sagamihara City, "Sagamihara City Basic Concept Plan for the Next Municipal Waste Final Disposal Site" (2021)

Photo 4-64 Landfill of Minami-Ashikaga City

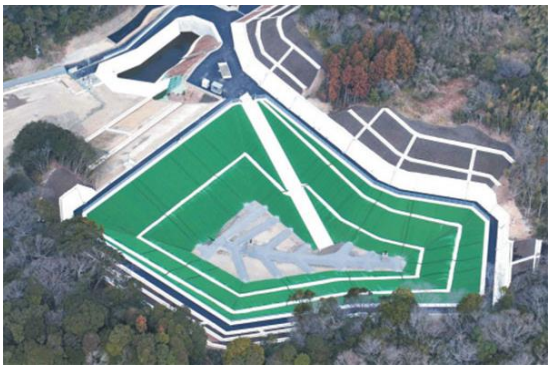


Photo 4-65 Landfill of Minami-Chita Association

Photo 4-66 Landfill of Sagamihara City

Source: Minami-Ashikaga City Website “Landfill”
https://www.city.minamiashigara.kanagawa.jp/shisetsu/kankyou/saisyusyobunjyou.html (accessed March 1, 2022)
Minami-Chita association Website “Landfill for Municipal Waste”
http://chitananbu.com/%E4%B8%80%E8%88%AC%E5%BB%83%E6%A3%84%E7%89%A9%E6%9C%80%E7%B5%82%E5%87%A6%E5%88%86%E5%A0%B4/ (accessed March 1, 2022)
Sagamihara City “Landfill site for municipal waste in Sagamihara City” (2019)

Table 4-31 Features of Closed System Landfill Sites

Item		Content
Overview		・ The landfill is covered by installation of roofs. ・ Landfills are not affected by rain or snow and can be stabilized with scheduled water sprinkling. ・ The technology was developed to obtain the residents' consensus.
Environment	Natural environment	Because sites are closed spaces they are not affected by rain, and scattering of waste and other problems can be controlled.
	Effect on living environment	Operation and maintenance must be thorough. Measures such as leak detector systems must be installed to prevent against water leak risks.
	Landfill facility internal environment	The possibility of waste scattering is low because the site is covered so in many cases the soil cover is not applied daily on the waste. Because the space is closed, ventilation, lighting, and odor countermeasures are necessary to maintain the internal work environment.
Facilities planning	Stabilization of site location	Stabilization is artificially promoted. Stabilization can be promoted by water sprinkling and either aerobic or semi-aerobic operation.
	Landfill capacity	Covered facilities tend to be less economical with larger landfill areas and therefore many of them are constructed with small areas and therefore limited landfill capacities. However, with the emphasis on mitigating the effects on the living environment in recent years outweighing the economic concerns, more of these facilities with large disposal capacities are being constructed. Because these facilities have covering structures, there is a limit to the available space and structural modifications, such as increasing landfill capacity are not easy.
	Storage structures	This is similar to open systems in that because the landfill area is small, in many cases the slopes of pit type and the like are steep. Therefore, there is a tendency for construction costs to increase due to the installation of concrete structures, etc.
	Waterproofing construction	Waterproofing sealing is often provided through laying of a double layer of impermeable membrane sheets as liner.
	Leaching treatment facilities	Because the covered facilities are not affected by rain and snow, the leachate produced is limited, so these facilities are smaller when compared to the open system.
	Landfill work	Because the space is closed, caution must be taken in maintaining the work environment. Disposal works require careful attention not to damage the roof, pillars and walls, in addition to many other limiting conditions.
Economy	Construction costs	Covered facilities increase construction costs. Although leachate treatment related facilities (treatment equipment, adjustment tanks, etc.) may be smaller in scale compared to those of open systems, their construction costs are higher than those of open systems.
	Maintenance and control costs	Because the quantity of leachate treated is small when compared with open systems, the operation and maintenance costs during the landfill operation period are lower.
Summary		These facilities are hardly affected by storms and typhoons so stable operation and maintenance management is possible. However, there are many limitations in operating in the landfill site so special care is required during landfilling work. In addition, it is difficult to expand the sites and make structural changes.

Source: Sagamihara City, "Sagamihara City Basic Concept Plan for the Next Municipal Waste Final Disposal Site" (2021)

Source: Yugawara-cho Manazuru Sanitary Association, “Municipal Waste Final Disposal Facility Pamphlet” (2021)

Photo 4-67 Outside View of the Landfill **Photo 4-68 Inside the Landfill**

Landfill of Yugawara and Manazuru Towns Association

Source: Tokachi Environmental Complex Office Association, “Municipal Waste Final Disposal Facility Ume-ru Center Mikato Pamphlet” (2021)

Photo 4-69 Outside View of the Landfill **Photo 4-70 Inside the Landfill**

“Ume-ru Center Mikato” Landfill of Tokachi Environmental Complex Office Association

(3) Categorizing by Facility Structure and Functions: Inert, Controlled and Isolated Landfills

Landfill sites are categorized into landfill sites for municipal waste and landfill sites for industrial waste. Landfill sites for industrial waste are categorized into inert, controlled and isolated landfill sites. Landfill sites for municipal waste are almost identical to controlled landfill sites for industrial waste.

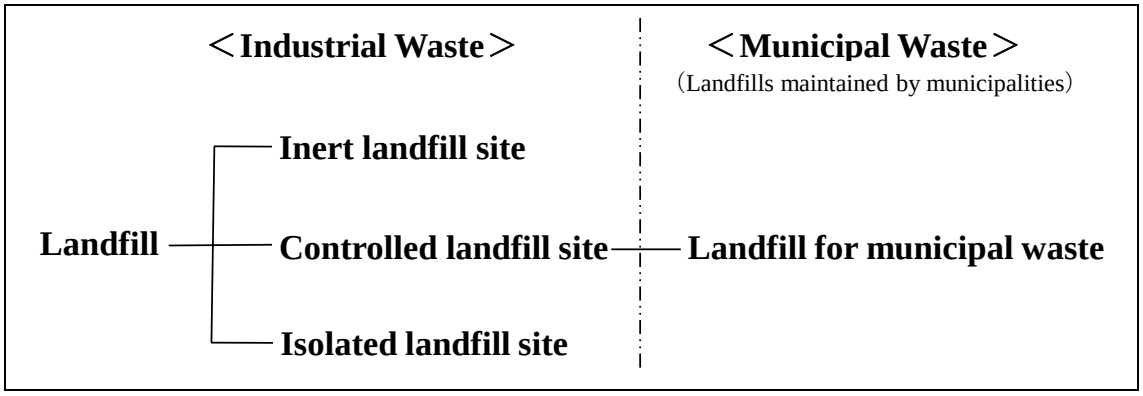


Figure 4-31 Types of Landfill

1) Inert Landfill Sites

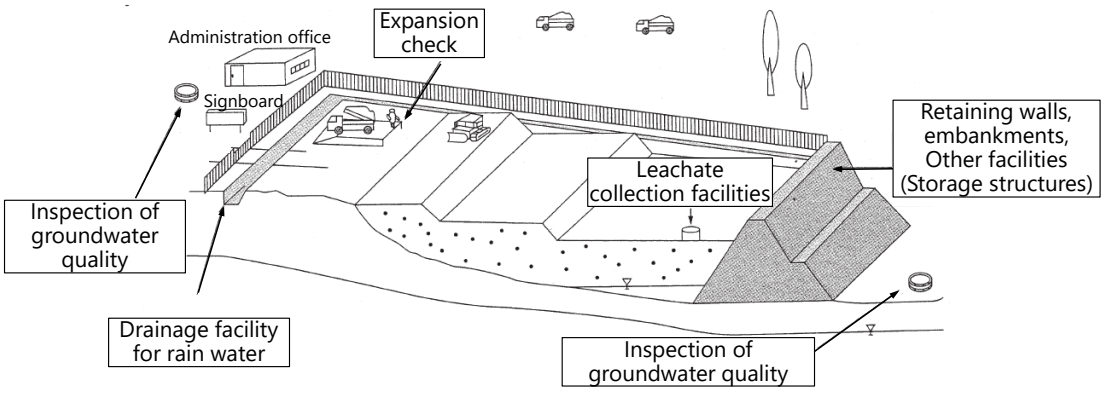
Inert landfill sites are landfill sites where only waste that cannot affect the surrounding environment can be filled. The materials include general debris, broken glass, concrete debris, waste plastics, metal scraps, rubber scraps, and other materials that do not contain harmful or organic matter.

Therefore, inert landfill sites do not have leachate treatment and water collection facilities, such as waterproofing liner construction.

Table 4-32 Waste that can be Disposed of in Inert Landfill Sites

Type	Details
Waste plastics (excluding automobile shreds, discarded printed circuit boards, and discarded containers and packaging)	Must be pretreated with one of the following methods. (1) Must be shredded or cut so that they are solid and with a maximum circumference of 15 cm or less, or they must have been melted at a melting facility. (2) Incinerate at an incineration plant or decompose with heat at a thermal decomposition facility.
Rubber scraps	Must be pretreated with one of the following methods. (1) Must be shredded or cut so that the maximum circumference is 15 cm or less. (2) Incinerate at an incineration plant or decompose with heat at a thermal decomposition facility.
Metal scraps (excluding automobile shreds, discarded printed circuit boards, the poles of lead batteries, lead pipes and plates, and containers and packaging.)	
Glass, concrete, and ceramic debris (excluding automobile shreds, discarded CRTs, discarded plasterboard, and containers and packaging).	
Debris	

Source: Enforcement Order of the Waste Disposal and Public Cleansing Act (Cabinet Order No. 300 of 1971)



Source: Ministry of the Environment "Annual Report on the Environment and the Sound Material-Cycle Society in Japan 2007" (2007)

Figure 4-32 Example of Inert Landfill Site Structure

2) Controlled Landfill Sites

Controlled landfill sites can accept the following waste materials in industrial waste: combustion residue, sludge, paper scraps, tree scraps, and other organic waste that meet the standards for harmful materials.

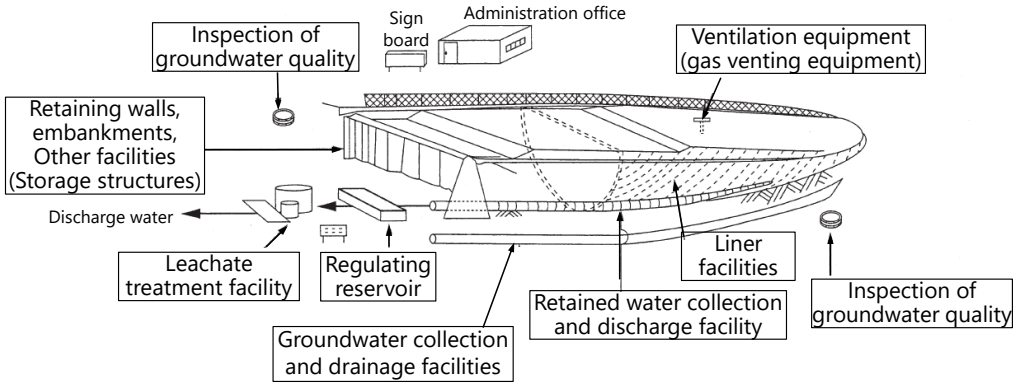
They can also be used to dispose of municipal waste that can be decomposed to produce leachates and gas.

Leachate is produced at controlled landfill sites because of the decomposition of the waste, so waterproofing liner construction and leachate treatment facilities are mandatory.

Table 4-33 Waste that can be Disposed of in Controlled Landfill Sites

Type	Details
Sludge	Must be pretreated with one of the following methods. (1) Incinerate at an incineration plant or decompose with heat at a thermal decomposition facility. (2) Treat until the water content is 85% or less.
Combustion residue, ash, etc.	Must be pretreated with one of the following methods. (1) Do not spread around in a specific part of the disposal site. (2) Apply soil cover or take other measures so that residue and ash are not scattered either inside the disposal site or to areas outside the site. (3) Add moisture, solidify, bail, or take other measures so that residue and ash are not scattered into the air. (4) Wash vehicles and take other necessary measures.
Animal residue, animal related solid waste, animal manure, animal bodies	Must be pretreated with one of the following methods. The thickness of a layer of industrial waste should be about 3 m or less (about 50 cm or less if 40% or more is decomposing matter), and the surface of each layer should be covered with about 50 cm of soil.
Paper waste, tree waste, textile waste, slag, plasterboard (Combustion residue, sludge, slag, and ash must be equal to or less than the standards for each.)	

Source: Enforcement Order of the Waste Disposal and Public Cleansing Act (Cabinet Order No. 300 of 1971)



Source: Ministry of the Environment "Annual Report on the Environment and the Sound Material-Cycle Society in Japan 2007" (2007)

Figure 4-33 Example of Controlled Landfill Site Structure

3) Isolated Landfill Sites

Isolated landfill sites are used to dispose of industrial waste that must be sealed from the outside because of including harmful matter that has not met the legal standards.

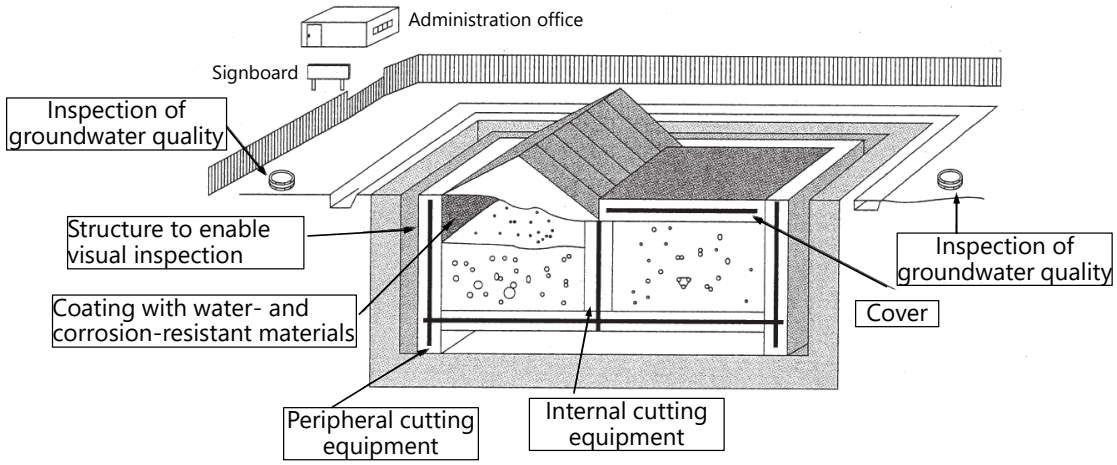
Therefore, isolated landfill sites are sealed in concrete structures and roofs and isolated from their surroundings.

Table 4-34 Waste that can be Disposed of in Isolated Landfill Sites

Type	Details
Combustion residue, sludge, slag, ash	Matter that exceeds the standards. Industrial waste (combustion residue, sludge, ash, etc.) that contains a certain level or more of harmful substances (heavy metals).

*: Disposal of PCB waste, waste that contains dioxins, infectious waste, liquid waste, waste acid, and waste alkali are prohibited.

Source: Enforcement Order of the Waste Disposal and Public Cleansing Act (Cabinet Order No. 300 of 1971)



Source: Ministry of the Environment "Annual Report on the Environment and the Sound Material-Cycle Society in Japan 2007" (2007)

Figure 4-34 Example of Isolated Landfill Site Structure

(4) Categorizing by Microbe Environment: Anaerobic, Semi-aerobic, and Aerobic Landfills

The behavior of microorganisms within a disposed waste layer varies depending on the environment inside the landfill. Under aerobic conditions, where oxygen is supplied within the disposed waste layer, aerobic microorganisms are more active. On the other hand, under conditions of limited oxygen supply, the disposed waste layer becomes an anaerobic environment, and anaerobic microorganisms that do not require oxygen become active.

Disposal sites can be categorized into anaerobic, semi-aerobic, and aerobic landfill sites depending on condition of oxygen supply, in other words, the microbe environment in the disposed waste layers.

The features of landfill sites by the differences in microbe environment are shown below. Aerobic landfill is expected to improve the quality of leachate by promoting the decomposition of landfill waste and reducing the generation of methane gas because the environment of the waste layers inside the landfill site become aerobic. However, the blowers used to supply air to create this aerobic environment require financial resources for operation and electricity, and if the moisture content of the soil is high, the blowers come under pressure leading to failures.

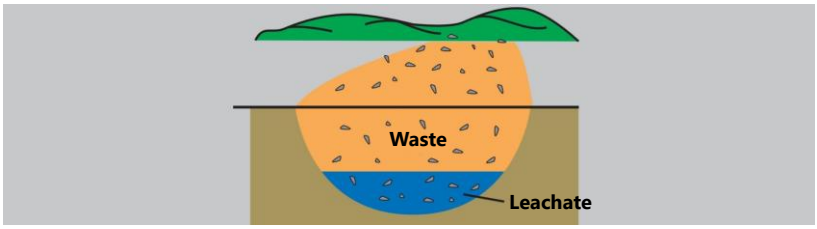
Anaerobic landfills can reduce construction and maintenance costs because no equipment is required to maintain an anaerobic environment within the disposed waste layers. On the other hand, the anaerobic environment within the disposed waste layers prevents the speedy decomposition of the disposed waste, resulting in long-term operation of the landfill. In addition, the activity of anaerobic microorganisms produces more methane gas than aerobic ones.

Table 4-35 Features of Landfill Sites by Microbe Environment Differences

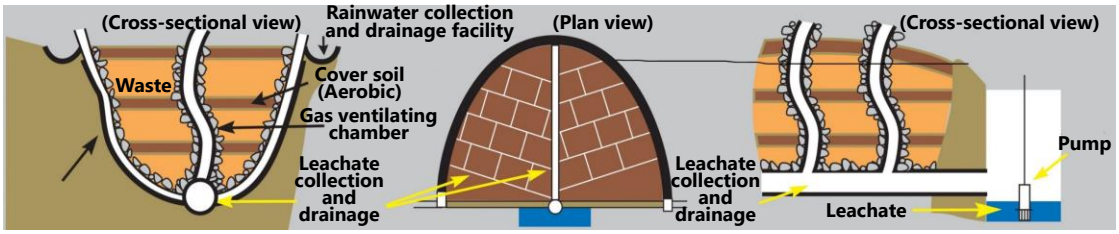
Landfill type	Anaerobic	Semi-aerobic	Aerobic
Overview	General method used in Europe	Method developed in Japan	-
	Waste is disposed of in excavated flat ground or valleys, and the waste has a high moisture content and is anaerobic.	These landfill sites have perforated gas release pipes and leachate collection pipes and as water is drained through the pipe network fresh air is supplied to the waste layers creating an aerobic environment.	Blowers and air pipes are used to force air into the waste layer interior to make it more aerobic.
Construction and operation /control costs	Inexpensive	Normal	Expensive
Methane gas emissions	High	Low	Low*
Precautions	The pollutants in the waste do not decompose and may remain in the soil for decades.	-	If the water content in the soil is high during rainy periods, pressure will be placed on the blowers leading to malfunctions.

*: Although aerobic landfills produce less methane than anaerobic landfills, the operation of blowers can lead to a significant generation of carbon dioxide.

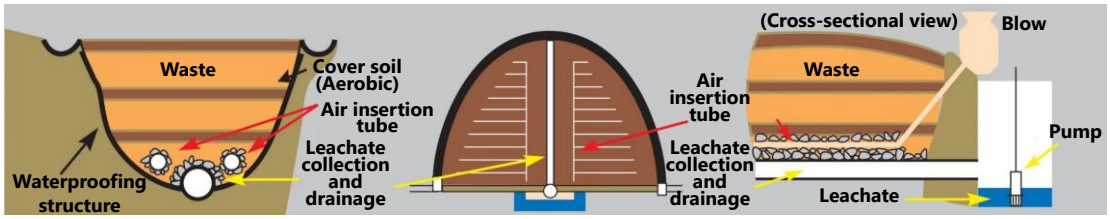
Anaerobic Landfill



Semi-aerobic Landfill



Aerobic Landfill



Source: Fukuoka City "What is the Fukuoka method of semi-aerobic landfill construction?" (2013)

Figure 4-35 Structural Diagram of Landfill System with Different Microbial Environments

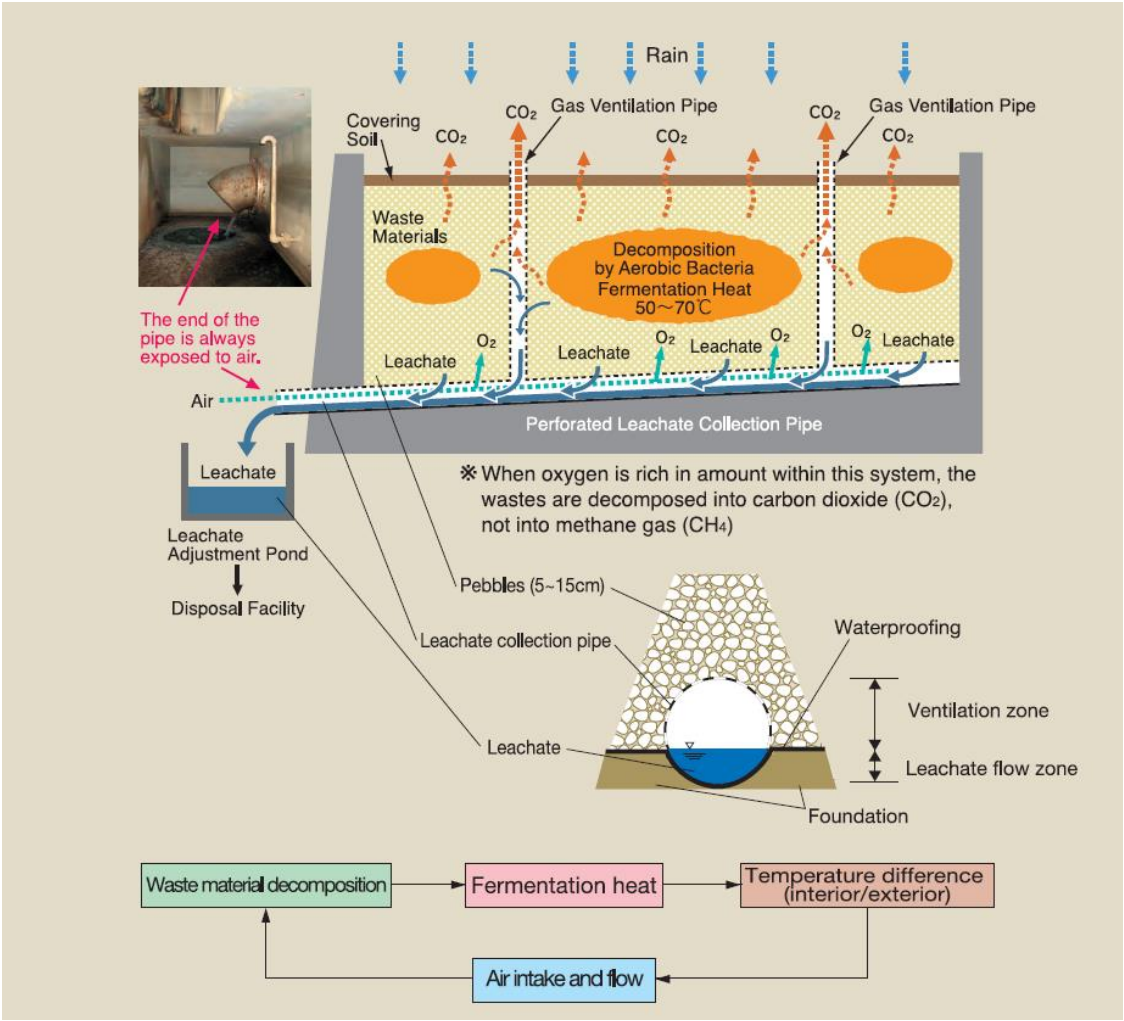
Fukuoka Method (Semi-aerobic Landfill Construction)

The Fukuoka Method is a semi-aerobic landfill type that was developed when Japan was still disposing of kitchen waste in landfills. Therefore, at the time there was no intermediate treatment. As these conditions were similar to those present in developing countries that mainly use direct landfill disposal, this technology is very suitable for those countries. Moreover, due to the fact that the construction of Fukuoka Method landfill sites can use locally available alternative materials, it has spread widely among developing countries.

The semi-aerobic landfill construction method was researched and developed by professor emeritus Hanashima of Fukuoka University with the cooperation of Fukuoka City. At the time, Fukuoka City was confronted with pollution issues from landfill sites used for kitchen waste that caused water pollution, odor, gas, and pests. Therefore, professor Hanashima and Fukuoka City jointly conducted a study for three years from 1973 to improve the leachate quality and in turn the landfill sites. As a result of these experiments, the basic concept of semi-aerobic landfill construction that uses leachate collection pipes to supply air to the interior of landfill sites was proposed. In 1975, the first semi-aerobic landfill site was constructed at the Shinkamata landfill site. Then, the semi-aerobic landfill construction method was adopted throughout Japan under the name of the Fukuoka Method.

Because the Fukuoka Method technology was developed when intermediate treatment was not sufficient and kitchen waste was being directly disposed of in landfills, at present there are only limited uses of this technology in Japan because intermediate treatment, such as incineration, has greatly developed since then. However, this technology is effective in developing countries which are in circumstances similar to those faced by Japan in the past when it did not have intermediate treatment. These countries are confronting problems of leachates, odor, etc. Therefore, this technology has been adopted in many locations in Asia, Africa, and Oceania.

In July 2011, improvements to existing landfills by using semi-aerobic landfill construction (Fukuoka Method) were certified as a new method by the Clean Development Mechanism (CDM) stipulated by the United Nations Framework Convention on Climate Change. By promoting the decomposition of waste in landfills by maintaining aerobic conditions, this technology can improve the water quality of leachates and reduce the production of methane gas so it can help to reduce emissions of greenhouse gases.



Source: Fukuoka Prefecture “Guide to Introducing The Fukuoka Method” (2020)
English: https://www.pref.fukuoka.lg.jp/uploaded/life/613855_61086159_misc.pdf
Vietnamese: https://www.pref.fukuoka.lg.jp/uploaded/life/613855_61086163_misc.pdf
Thai: https://www.pref.fukuoka.lg.jp/uploaded/life/613855_61086164_misc.pdf

Figure 4-36 Conceptual Figure of Semi-aerobic Landfill Construction

Column: Introduction of the Semi-aerobic Landfill Method (Fukuoka Method) Landfills in Developing Countries

The semi-aerobic landfill method (Fukuoka Method) that is being introduced in developing countries is a Japanese technology (refer to "Topic 7-4.2 (1) Construction and Proper Maintenance, Management and Expansion of Sanitary Landfill Sites Using the Fukuoka Method" for an example of a Fukuoka Method landfill in El Salvador).

The main reasons that the Fukuoka Method spread in developing countries are described below.

(1) Utilization of Locally Available Materials

Developing countries cannot acquire sufficient materials, so they cannot construct landfill sites according to their blueprints and maintain them. The basic system in the Fukuoka Method is simple and there is a high degree of flexibility for the materials that can be used, so locally available materials can be adopted.

Source: Yachiyo Engineering Co., Ltd.

Photo 4-71 Example of Beer Bottle Case Usage

For example, when the gravel needed for encircling the gas ventilation pipes were not available, cases used for carrying beer bottles were utilized instead. When soil for coverage was not available, old waste was excavated and used as cover. There are other examples of working together with local administrators and workers to find alternatives through trial and error. From the viewpoint of protecting waterproofing liner sheets from heavy construction equipment, liner sheets were only used in the downstream leachate adjustment pond where there is a high risk of polluting the outside water environment by the leachates collected in the pond. Simple sheets or clay were used in other sections. In this way, it is possible to reduce the construction and maintenance costs depending on the innovations used.

Note that the gradient of leachate collecting and drainage pipes is about 1 to 2 degrees, so the speed of the leachate is slow. This will require a careful design because the pipe diameter will have to be two or three times that of sewage pipes.

(2) Improving the Motivation of Landfill Operators Personnel by Making Visual Improvements

The construction of Fukuoka Method landfill sites has changed the appearance and environment of the working place when compared with open dumping, and this has improved the motivation of operators personnel. Additionally, this improved the understanding of the theory behind the Fukuoka Method as well as its operation and maintenance methods among operators in developing countries, which contributed to the spreading of this technology within the country.

Photo 4-72 Appearance of the Landfill

Photo 4-73 Gas Venting Pipes

Source: Yachiyo Engineering Co., Ltd.

Fukuoka Method Landfill in Macas City, Ecuador (2016)

3.4 Operation and Maintenance Management of Landfill Sites

In Japan, an operation and maintenance plan stipulated by law must be attached to the notification of establishment of a landfill to be submitted before starting operation of the landfill site. This plan should include the relevant details agreed upon with local residents. By formulating and implementing a plan that includes the agreed items, it is possible to obtain the understanding of local residents regarding the necessity of the facility.

When local governments need to develop landfill sites, they must apply to their prefectural governments. Together with their application, they must submit an operation and maintenance management plan. The understanding and cooperation of local residents are extremely important to facilitate the operation and maintenance of the facility, and the prepared operation and maintenance plan should carefully consider local conditions and aspirations and the plan contents need to be thoroughly discussed with local residents. Once commissioned, the facility should be operated and maintained in accordance with the prepared plan.

Waste Delivery Control

In order to manage and operate a landfill site according to plans, it is important to understand the types, quantities, and characteristics of the waste that will be delivered to the landfill. Therefore, when daily waste is delivered, in addition to the types and quantities of the waste and the amount and material of the covering soil, the following items should also be recorded. Appropriate delivery management will make it possible to confirm variations in the amounts of waste disposal and estimate the remaining capacity of the landfill and remaining years of operation at any given time. These estimates will be very important for determining future landfill construction requirements and preparing the necessary development plans.

Table 4-36 Daily Recording Items Related to Waste Delivery Control

No.	Recording item	No.	Recording item
1	Delivery time and date	6	Type of waste
2	Vehicle number and type	7	Source of the waste (collection area, intermediate treatment facility, business, generating region, etc.)
3	Vehicle empty weight		
4	Gross weight	8	Delivering vendor, driver name
5	Quantity of delivered waste		

Source: Based on the "Planning, Design, and Management Procedures for Preparing Waste Landfill Sites, Revised 2010 Edition," (2010), Japan Waste Management Association.

Landfill Work Management

Carrying out landfill work as planned is necessary not only for securing disposal capacity at the landfill site, but also for stabilizing landfill waste and managing leachate and landfill gas generated from the landfill. Information on the types and amounts of waste disposed in each landfill disposal cell is also necessary from the perspective of long-term landfill management, including the prevention of environmental pollution during the period after completion of disposal operations and abolition of the landfill and consideration of the land use after abolition.

Facility Operation and Maintenance Management

If the functions of each facility are not fully utilized, the disposal site will become unsanitary, causing problems such as environmental pollution to the surrounding area and negative impacts on the health of workers. In addition, since it takes a long time, in some cases several decades, from the completion of disposal operations to the abolition of the landfill, it is necessary to keep in mind that each facility will be operated for a long period of time.

Table 4-37 shows the important items for the suitable long-term operation and maintenance management of landfill sites.

Table 4-37 Items to be Recorded for the Operation and Maintenance Management of Landfill Sites

<table>
<tr><th colspan="2">Item</th><th colspan="2">Recording content</th></tr>
<tr><td rowspan="4">Plan/ operation</td><td>Type and quantity of waste (Daily recording)</td><td colspan="2">・The types and quantities of landfilled waste monthly.</td></tr>
<tr><td>Water quality inspection (1 time/ 6 months)</td><td colspan="2">・Locations where groundwater and discharged water were sampled.
・Dates when groundwater and discharged water were sampled.
・Dates when water quality inspection results were acquired.
・Water quality inspection results</td></tr>
<tr><td>Investigation of water quality deterioration and countermeasures</td><td colspan="2">・Date when action was taken.
・Contents of the action</td></tr>
<tr><td>Remaining capacity (1 time/ year)</td><td colspan="2">・Date when the landfill remaining capacity was measured and calculated, and the results.</td></tr>
<tr><td rowspan="4">Facility</td><td>Retaining walls, etc.</td><td rowspan="4">・Date when the inspection was conducted and results. (1 time /year)</td><td>・If an inspection shows that a retaining wall or another facility may be damaged, the date when action was taken and the content of the action.</td></tr>
<tr><td>Water liner construction</td><td>・If an inspection shows that waterproofing liner damage is suspected, the date when action was taken and the content of the action.</td></tr>
<tr><td>Leachate adjustment pond equipment</td><td>・If an inspection shows that an adjustment pond may be damaged, the date when action was taken and the content of the action.</td></tr>
<tr><td>Leachate treatment equipment</td><td>・If an inspection shows that the leachate treatment equipment functions are abnormal, the date when action was taken and the content of the action.</td></tr>
</table>

Source: Based on the Japan Waste Management Association “Planning, Design, and Management Procedures for Preparing Waste Landfill Sites, Revised 2010 Edition” (2010)

3.5 Appropriate Closing and Use of the Site

In Japan, landfill sites are appropriately operated and maintained according to standards. This applies to the plans and design when a landfill is being constructed, and also to the operation and maintenance once it is operational. Various standards for suitable closing, monitoring period and abolishing are also in place for after the termination of disposal operation of the landfill. Because the landfill site is strictly managed until it is abolished, it is possible to use the site effectively after the landfill site has been abolished. Additionally, there are guidelines for using the site.

(1) Appropriate Closing

In Japan, when waste is no longer received at a landfill site and landfilling work is terminated, facility services are ended by taking actions, such as the final covering with soil to close it appropriately. When a facility is closed, although there is no new delivery of waste, the disposed waste has not completely decomposed, so the water quality of leachate and gas from the landfill must continue to be controlled according to the facility standards, and operation and maintenance standard. Once a landfill site is closed, entrance to the site is limited and managed so that landfill waste is not agitated.

After a monitoring period during which the decomposition of the landfill waste has stabilized, the water quality of leachate, landfill gas emissions, and landfill waste temperature are confirmed to make sure that they comply with the standards. If the abolition standards are met, a new project may be commenced at the site according to the guidelines related to site usage of landfill sites.

Figure 4-37 shows the flow from the start of a landfill site until the site is reused for another purpose.

Flow Chart from the Start of Landfill to the Abolished Landfill Site and Reuse

- **From "Start of Landfill" to "End of Landfill"**

The landfill period of a landfill site is the period from the commencement of waste delivery to the end of landfill after the last waste delivery to the landfill. During the landfill period, it is necessary to manage the disposal site in compliance with the structure standards, and operation and maintenance standards.

- **"Closuring" of the Landfill Site**

For landfill site where waste has been delivered and landfilling has been completed, the landfill site is closed to maintain the site in a safe condition by applying the final soil cover and other measures.

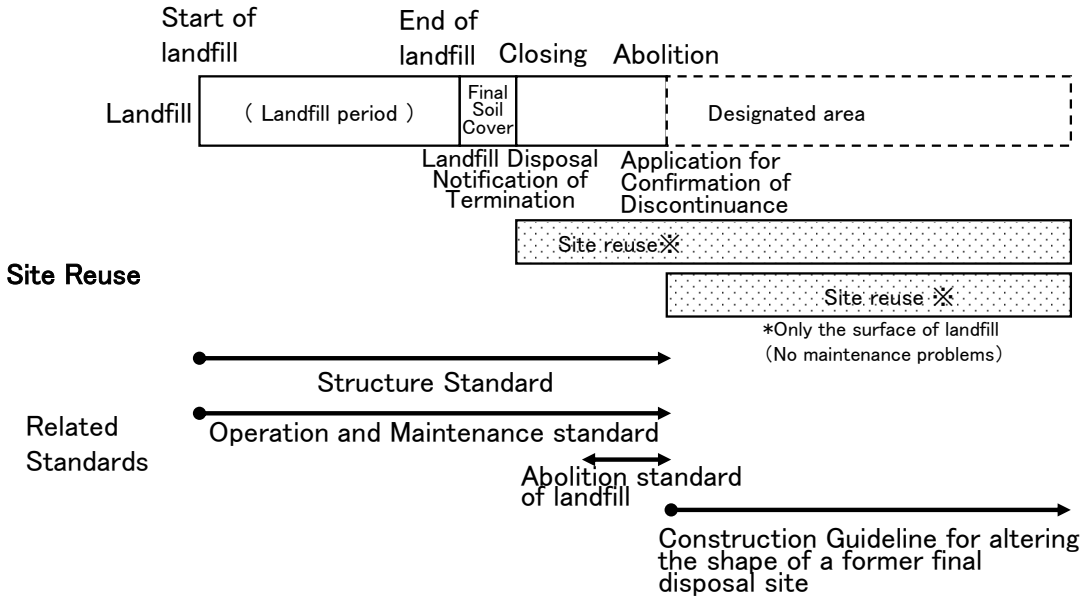
- **"Abolition" of a Landfill Site**

A closed landfill site can be abolished when it is confirmed that the waste disposed inside the landfill is sufficiently stable and that the quality of leachate generated and the gas emissions do not adversely affect the environment in the landfill site and the surrounding area, and when there is no longer a risk to the living environment with the discontinuation of operation and maintenance.

In order to abolish a landfill site, it must meet the criteria for abolition standards, as shown in Figure 4-38.

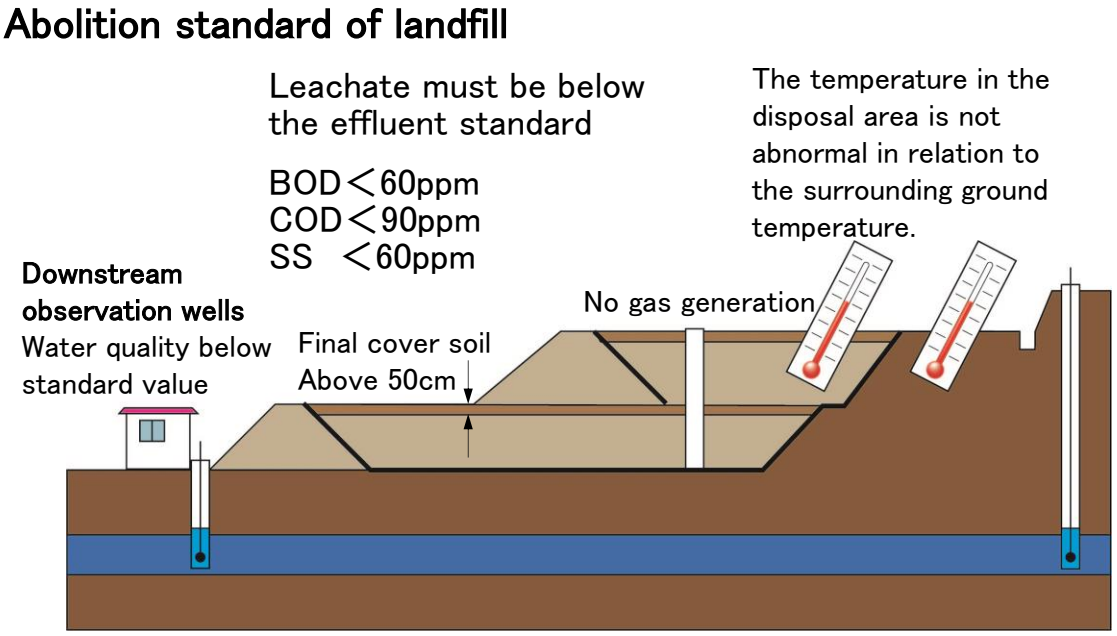
- **"Site Reuse" of Landfill Site**

In accordance with the guideline, an abolished landfill site can be reused as park, etc.



Source: Japan Waste Management Association "Planning, Design, and Management Procedures for Preparing Waste Landfill Sites, Revised 2010 Edition" (2010).

Figure 4-37 Final Disposal Site Utilization and Related Standards



*: BOD : Biochemical Oxygen Demand
COD : Chemical Oxygen Demand
SS : Suspended Solids

Figure 4-38 Abolition Standard of Landfill

(2) Site Reuse

After landfilling at landfill sites has been terminated, the site will be relatively large and flat and similar to a vacant lot very much like the condition just before the development of the landfill. It is therefore possible, after a site has been used as a landfill site, to reuse it effectively to help develop or revitalize the area. The site reuse is expected to deepen residents' awareness and understanding of the construction of landfill sites and promote the locating of new landfill sites. Table 4-38 shows typical land uses for landfill sites reuse.

Table 4-38 Typical Land Uses for Landfill Sites Reuse (Surface Utilization)

Type	Example	Features
Parks	Nagaoka Park, Utsunomiya City, Tochigi 	The site of Nagaoka landfill has been reused to develop Nagaoka Park. It is being heralded as a park that "would be a waste not to use". The theme of Nagaoka Park is "Creating greenery and formation of a community". Landfill capacity: 490,000 m^3 Landfill area: 60,000 m^2 Landfill period: 1983 to 2005
Sports facilities	Senogawa Park, Hiroshima City, Hiroshima 	This park was built on the site of the Senogawa landfill site, which was the final disposal site of Hiroshima City. There is a baseball field, tennis courts, indoor exercise facility, and a park golf course. Landfill capacity: 2.75 million m^3 Landfill area: 210,000 m^2 Landfill period: 1974 to 1990 Reuse period: 1994 -
Solar power generation	Saitama Environmental Center (Osato-gun, Saitama) 	The Saitama Prefectural landfill site is being reused as a solar power generation facility. [Only the solar power generation area] Landfill capacity: 530,000 m^3 Landfill area: 60,000 m^2 Landfill period: 1993 to 2007 Reuse period: 2013 -

Source: Utsunomiya City Website "Nagaoka Park" https://www.city.utsunomiya.tochigi.jp/kurashi/machi/1020735/1015510/1015537.html (accessed February 24, 2022)
Senogawa Park Website "Overview of the Park" https://www.midori-gr.com/senogawa/overview/ (accessed February 24, 2022)
Ministry of the Environment, EX Research Institute Ltd. "Report on the Commissioned Study of Measures to Promote the Introduction of Photovoltaic Power Generation into Landfill Sites, etc., in Fiscal Year 2015" (2016)

Column: Beautiful "Moerenuma Park" where Nature and Art Merge

Moerenuma Park with its green hills is located in the northeast of Sapporo, Hokkaido. Construction of this park started in 1982 and it opened in 2005. The basic design was done by the world-famous sculptor, Isamu Noguchi. The park covers a wide expanse of 1.888 million square meters featuring hills, playgrounds, fountains, etc.

This wonderful facility which is much loved by the citizens, was originally a municipal waste landfill. From 1979 to 1990, about 2.7 million tons of waste was disposed of here. To reconfigure the land, construction waste soil from public works projects was used. As of 2022, the Sapporo municipal government monitors the quality of discharge water, and the water in surrounding rivers.

Source: Based on Moerenuma Park Website https://moerenumapark.jp/ (accessed on March 15, 2022)

Photo 4-74 Landfill (1985)

Photo 4-75 Moerenuma Park (2007)

Photo 4-76 Mt. Moere in the Park

Photo 4-77 Play Hill in the Park

Source: Sapporo City "Waste Disposal Administration/3R Policy in Sapporo City (JICA training materials)" (2019) (Photo 4-74, Photo 4-75)
Yachiyo Engineering Co., Ltd. (Photo 4-76, Photo 4-77)