Solid Waste Management and Recycling Technology of Japan

— Toward a Sustainable Society —

Ministry of the Environment
Minister's Secretariat, Waste Management and Recycling Department
Policy Planning Division, Office of Sound Material-Cycle Society

With the aim of preserving the environment in rapidly developing nations, we will introduce Japanese waste management and recycling technologies, which effectively turn waste into resources or appropriately dispose of it.

Due to economic development, industrialization and increasing population, problems related to the expanded consumption and depletion of resources, and the increased output of wide-ranging types of waste are becoming more serious worldwide than ever.

On the other hand, there is a word in Japan: Mottainai. This word encompasses the practice of treasuring and using all things as long as possible. While economies continue to grow, this spirit of Mottainai has been restraining the generation of waste and motivated the development of technology for reuse, recycling and heat recovery.

As Japan's landmass is limited and finding landfill disposal sites is difficult, we have developed a system to collect and transport waste, process it through intermediary treatment by incineration and other methods, and then dispose it in landfills in a sanitary manner, in order to prevent environmental pollution in the areas surrounding densely populated cities.

This booklet introduces Japanese waste disposal and recycling technologies which are considered to be useful for Asia and other developing countries.

We hope to create a material-recycle society that generates as little waste as possible and recycles and reuses wastes as resources. We also hope that the most advanced technologies and systems based on our experience and achievement may assist to preserve the environment and recycle resources on a global level.

Ministry of the Environment

CONTENTS



1 Collection and Transport

Technology for efficient waste collection and transport

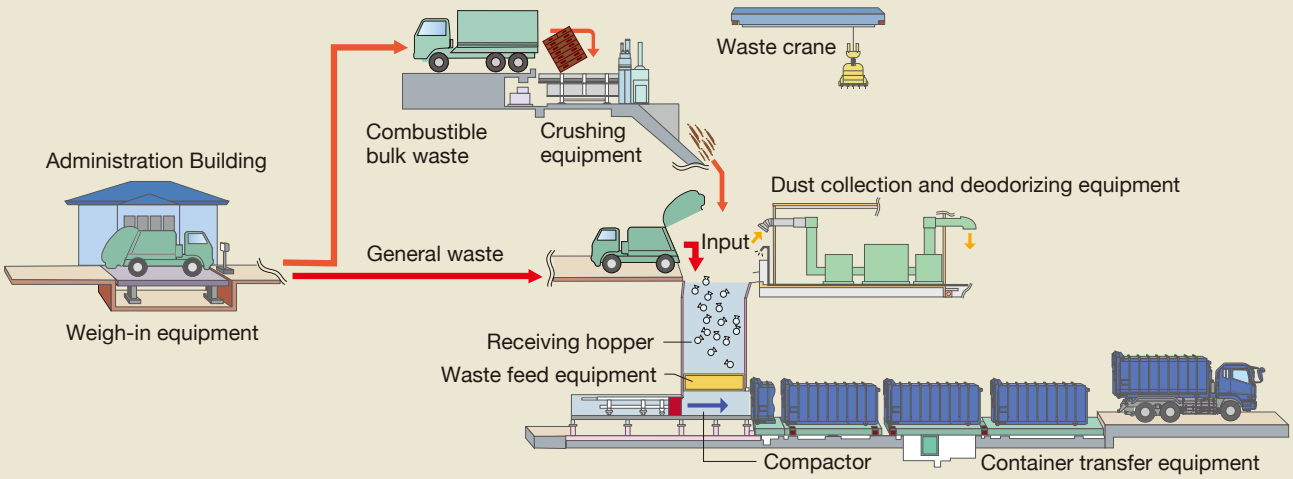
Increased efficiency of wide-area collection and transport through transfer stations

The expansion of urban areas widens the garbage collection zone. It is possible to improve the efficiency of collection and transport operations in cities with widening collection zones by setting up waste transfer stations where wastes can be transferred from small- or medium-sized garbage trucks to larger trucks.

The cost of collecting and transporting garbage accounts for high percentage in total cost of waste disposal operations. Improving the efficiency of collection and transport leads to cost reduction while maintaining or improving services to residents.

Domestic Case

The transfer station method commonly adopted in Japan is the one using compactor container transfer station shown below.



Garbage collected by small garbage trucks is dropped in a hopper, compressed in containers and reloaded onto larger trucks. In this transfer station, garbage collected by three 2-ton trucks can be compressed in one container.
The container is then transported to a disposal site or incineration plant on a large container truck.

Source: ShinMaywa Industries, Ltd.

Overseas Case

Some Japanese enterprises have established joint ventures in China with high achievements in the production and sale of transfer stations. Some also sell them to other Asian countries.

Transport Station (Xian, China)

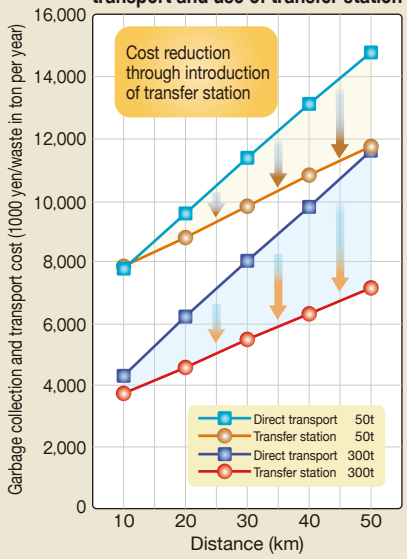
Transport Station (Kuala Lumpur, Malaysia)

Setting up transport station to streamline collection and transport operations

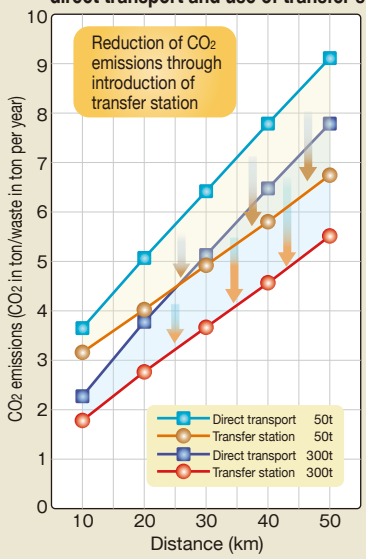
Transfer to larger trucks at transport stations improves transport efficiency and reduces fuel consumption by transport vehicles per garbage volume. This not only leads to cost reduction, but it also reduces CO_2 emissions, contributing to the prevention of global warming.

Economic effect and CO_2 emissions after introduction of transport station

Comparison of cost between direct transport and use of transfer station



Comparison of CO_2 emissions between direct transport and use of transfer station



【Conditions】

- Collection area 500km^2
- Operating days 250days/year
- Operating hours 5hr./day
- CO_2 emission factors for collection and transport vehicles 0.002619tCO_2/L

	Collected volume	Collection vehicle	Transport vehicle
Direct transport	50t/day	2t packer vehicle	
Transfer station	300t/day		
Direct transport	50t/day	2t packer vehicle	10t arm roll vehicle
Transfer station	300t/day		

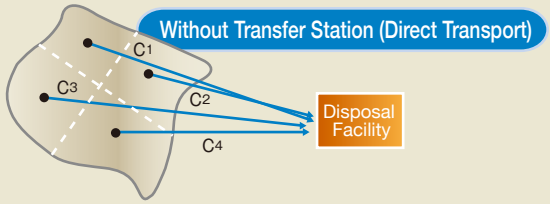
※1 Calculated for compactor-container type

※2 CO_2 calculation is emissions from collection and transport vehicles

Source：ShinMaywa Industries, Ltd.

Determination of whether or not to set up transport stations depends on its cost effectiveness. As shown in the figure below, it is advantageous to introduce a transport station when the total collection and transport fee with the transport station (T_{cB}) is cheaper than the total collection and transport fee without the transport station (T_{cA}) ($T_{cA}>T_{cB}$).

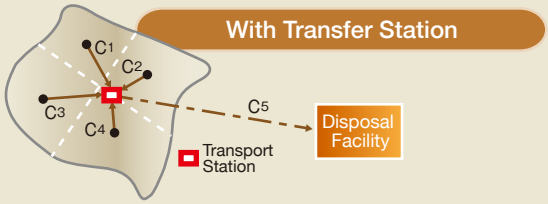
Generally speaking, when the transport distance exceeds 18km, a transport station should be considered.



$T_{cA}=C_1+C_2+C_3+C_4$

T_{cA}：Total cost for collection from collection zones 1~4 and direct transport to disposal facility

C_1,C_2,C_3,C_4：Cost for collection at each collection zone 1~4 and transport to disposal facility



$T_{cB}=(C_1+C_2+C_3+C_4)+R_c+C_5$

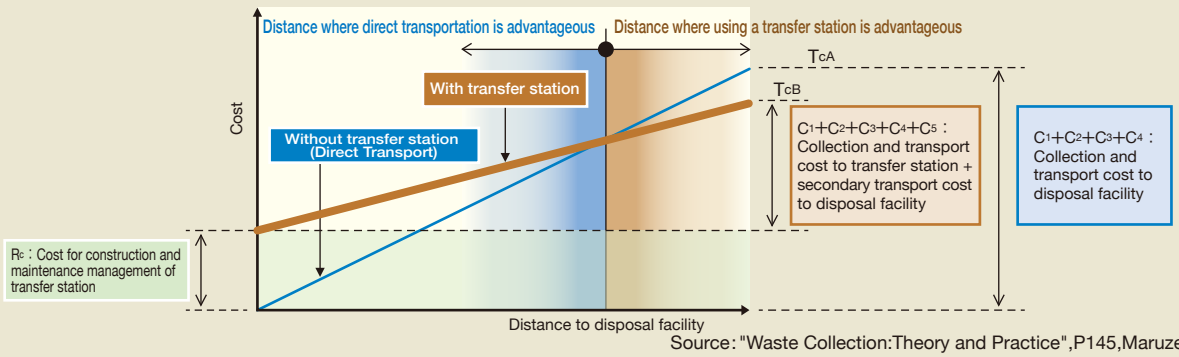
T_{cB}：Total cost for collection from collection zones 1~4 and transport to disposal facility via transport station

C_1,C_2,C_3,C_4：Cost for collection at each collection zone 1~4 and transport to transport station

R_c：Cost involving operation at transport station (Construction cost, operation and maintenance management cost)

C_5：Cost to transport from transport station to disposal facility (Secondary transport)

Cost structure for with and without transfer station



Source："Waste Collection:Theory and Practice",P145,Maruzen(2011)

Fuel-efficient collection and transport vehicles with high load volume

It would be more efficient in many of the Asian countries to use small collection trucks because of narrow roads. Many of the roads in Japan, too, are narrow, and 1t to 2t compact garbage collection trucks were developed with reduced body weight in order to increase load capacity.

There are two types of garbage collection trucks - mechanical trucks (Mobile Packers) and compressor-type trucks, but mobile packers are more commonly used. Packers scoop up the garbage with a spinning disk and thrust it into the storage space with a sliding board. In general, garbage with high moisture content reduces compression efficiency; however, with continuous modification, trucks have achieved high compression rate, with 1.5 times more load than flat pile trucks.

Compressor-type trucks press down the garbage on to the floor with a compressor board (pressing plate), and after breaking it up and reducing volume, the garbage is slid into the storage area. The trucks efficiently collect large garbage requiring breakdown, bulky PET bottles and plastic waste.

Due to the worldwide problem of global warming, low-pollution-type garbage trucks, such as electric motor-drive and hybrid trucks are being developed and put into practical use.

Safety, loading efficiency and operability are required for garbage collection trucks. Smaller trucks have openings set less than 800mm above the ground to realize outstanding workability and operability.

●Low-pollution garbage collection trucks (Example)
Generally, garbage loading and unloading is powered by the engine. This type of truck generates electricity required for loading and unloading while the truck is running. This reduces the consumption of light oil and CO_2 emissions.

Source: ShinMaywa Industries, Ltd.

Column

History of Garbage Collection and Transfer in Japan

Kitchen waste being collected during 1950s

Truck first used for garbage collection during 1950s

Transferring garbage carried by rickshaw during 1950s

Concrete garbage box equipped in each household removed during 1960s

Source: 100-year History of Cleaning Operations in Tokyo

2 Municipal waste incineration technology

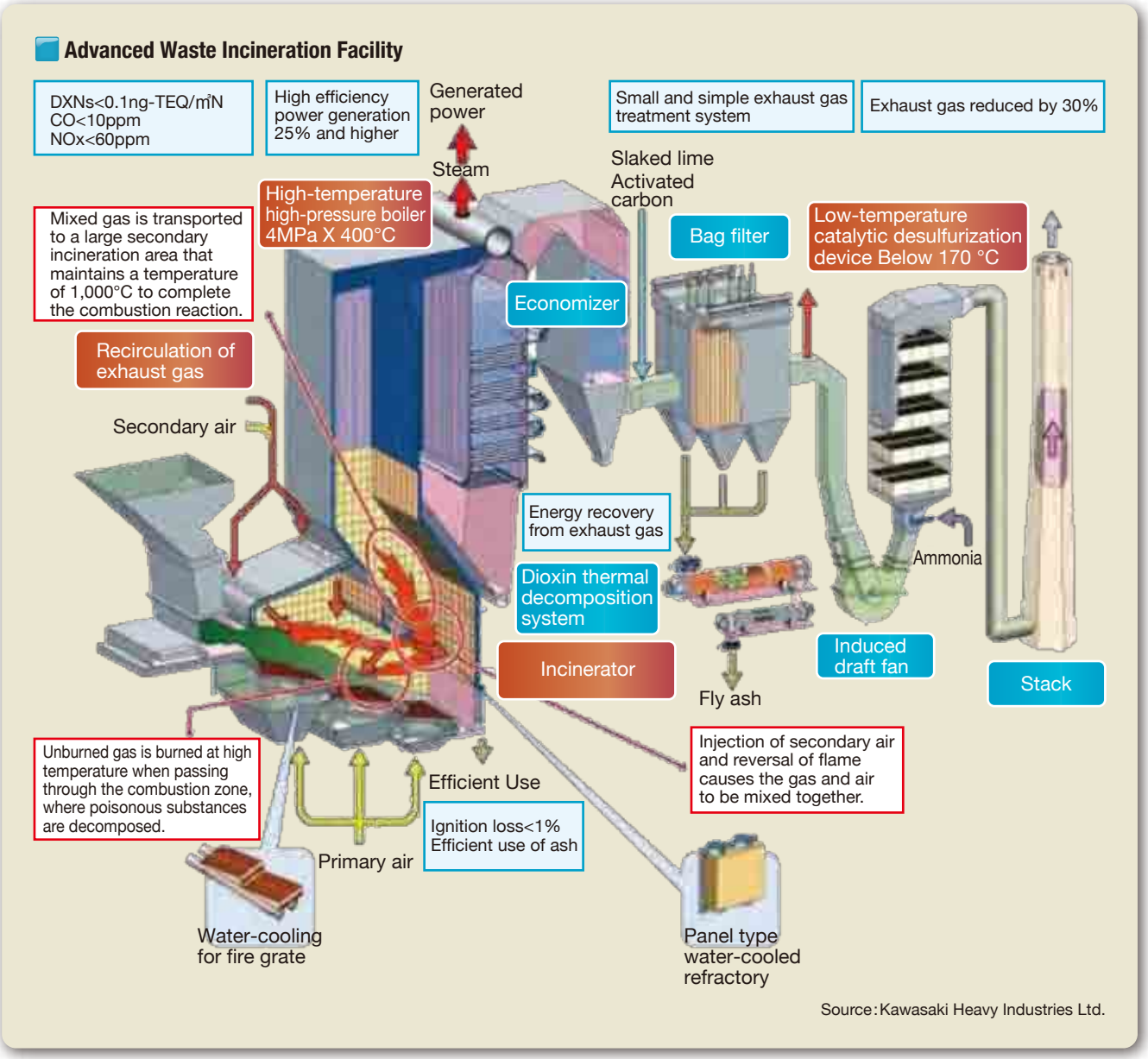
Safe and sound municipal waste incineration and high-efficiency power generation

Advanced ability to prevent pollution and high-efficiency power generation

From about 1960, Japan began disposing urban garbage by incineration, and today, Japan possesses the world's leading garbage incineration facilities. In the fiscal year 2011, there were 1,211 incineration facilities in Japan, incinerating garbage using several methods - stoker furnaces, fluidized bed furnaces, and gasification -melting furnaces with the objective of incinerated ash recycling. Stoker furnaces account for 70% of all furnaces, and improvement of this type of furnace is progressing rapidly.

Today, while high level environmental conservation technologies are being introduced, technologies related to high-efficiency power generation and technologies related to safe operation, such as automatic incineration devices and automatic cranes, are also being developed. We are now accumulating know-how on handling diverse types of garbage of today, ranging from the low-calorie garbage, which was generated when incineration facilities were first being built, to the high-calorie garbage. Such technology can be utilized for the type of garbage generated in the Asian region.

The newest stoker furnace technology is low air incineration that aims for high-efficiency power generation, which is already under construction in Japan. The figure below shows one example of the latest technology: a facility exhibiting high pollution prevention and high-efficiency power generation capacity.



Source: Kawasaki Heavy Industries Ltd.

Waste incineration facilities in residential and commercial areas

With Japan's high-tech incineration facilities, waste incineration has won trust as safe and sound technology, and when planning construction of such facilities, communication with the surrounding residents about risks is smooth, enabling swift progress in plans to construct incineration facilities in urban and residential areas. Some of the incineration plants are shown in the photographs below.

●Shibuya Incineration Plant / Tokyo (Example)
In Tokyo, a metropolis in Japan, there exists a mixed commercial and residential area where a large amount of waste is generated. In August 2001, an incineration plant was constructed near Shibuya Station in the center of a high-density urban district. The facility was constructed with a high technology with a capacity of 200t/day, which cleared strict gas emission regulations for NOx, SOx, smoke, dioxin and other gases. Shibuya Incineration Plant is small compared to other waste treatment facilities in Tokyo, and it uses a swirling flow fluidized-bed incinerator. Fluidized-bed furnaces fluidize sand layer on the floor of a tubular furnace with air to maintain high temperature, which leads to efficient incineration of waste.

Operation of the incineration plant is managed from the central control room under automatic control (Shinagawa Incineration Plant)

The waste reservoir is separated from the crane operating room by a glass plate and there is no odor. One bucket can drop in waste brought in by one mobile packer. (Kita Incineration Plant)

This incineration plant is equipped with a steam turbine generator that generates a maximum of 4,200kW, which is used in the plant. Excess electricity is sold to Tokyo Electric Power Company. The generator uses high-temperature water of 1Gcal/h, 130°C, with the maximum steam flow and pressure of 23.1t/h and 3.82MPa. (Shibuya Incineration Plant)

Source: Clean Association of TOKYO 23

Column

Along with the high economic growth of the 1960s, waste volume in Japan increased to cause a strain on landfill plots and dioxin problems from incineration. As Japan's landmass is limited, a reduction of waste volume and quick disposal in landfill became essential. However, urbanization and resident consciousness made it difficult to construct the plants needed to make this possible. Improvement in gas emission treatment enabled resident trust to be won, and heat recovery is now being sought from the operation.

Strain on landfill plots due to increased waste volume and diversified waste categories

Incineration furnace emitting smoke and gas, causing serious problems with dioxin

Source: 100-year History of Cleaning Operations in Tokyo

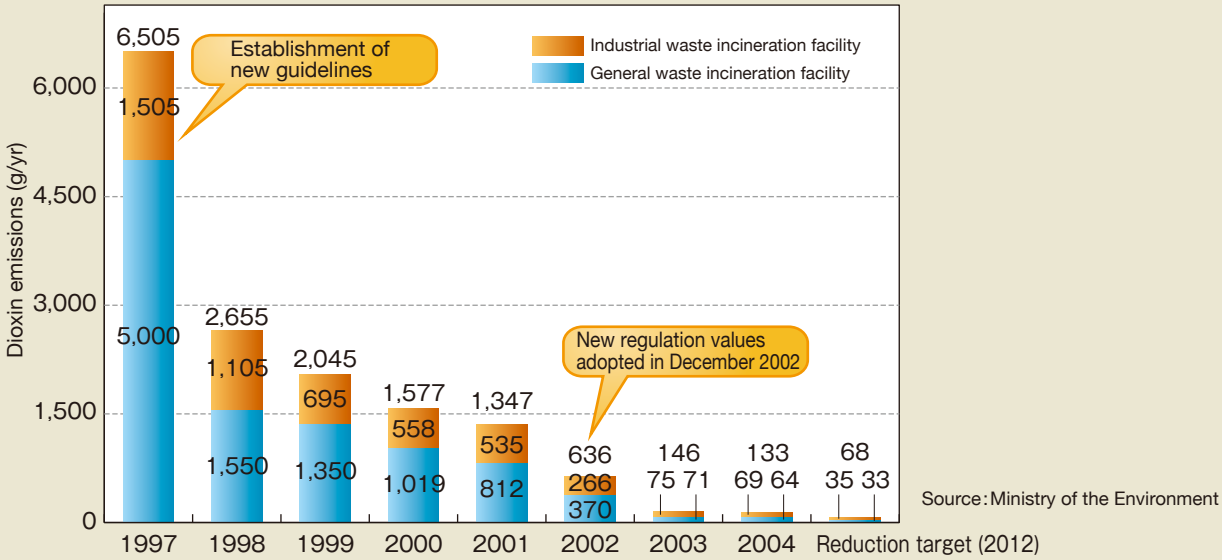
Solution to poisonous gas and dioxin emissions

It is known that incineration plants for municipal waste generate SOx, HCl, NOx, smoke and dioxin. From the perspective of environmental preservation and to obtain approval from people residing near the plant, harmful substances in the exhaust gas must be sufficiently reduced. In response to this need, many studies have been conducted by public and private institutes, where many countermeasure technologies were developed and improvements have been made on operation technology.

Studies have shown that dioxin is produced by incomplete combustion of waste, and measures have been taken to prevent and reduce dioxin generation with complete combustion in the furnace. Other countermeasures taken include exhaust cooling to prevent the resynthesis of dioxin, application of bag filters to thoroughly eliminate dioxin contained in smoke, and the development of activated coal, which adsorbs and eliminates dioxin in exhaust fumes and a catalyst that decomposes dioxin. Based on the above-mentioned studies, structural and maintenance management standards for the incineration plants were established, as illustrated below. The standards apply not only to new facilities but also to existing facilities, where improvements have been achieved. Methods of control for dioxin and other poisonous gas emissions that have been employed by the private and public sectors are as shown in the figure, and problems related to dioxin from incineration have been nearly resolved.

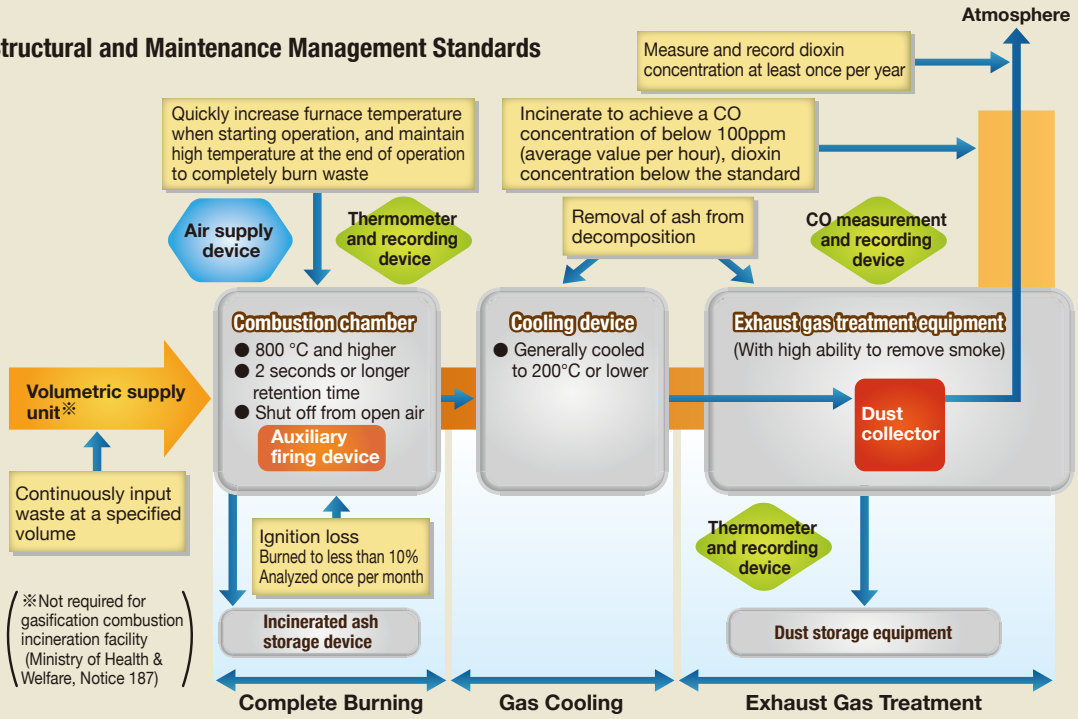
Sufficient environmental measures are also taken for SOx, HCl, NOx and other substances.

Reduced dioxin emissions by 99% compared to 1997 from incineration plants in Japan



Source: Ministry of the Environment

Structural and Maintenance Management Standards



New-Generation Incineration Technology

Changeover to new-generation incinerators

There are many city incineration plants, both large and small, being operated in compliance with the strict antipollution policies implemented in Japan. While many technologies have been developed, including technology to reduce dioxin emission, remove acidic gas and recycle incinerated ash, the conventional stoker furnace has seen significant improvement. The conventional stoker furnace's highly efficient technology enables electric generation from recovered heat waste and makes it an effective measure against greenhouse emissions. Its improvement is summarized in the chart below. Together with the improvement of heat recovery after incinerating, this system makes it possible to efficiently generate clean electricity compared to the conventional method. Japan's incineration plants have now become safe and sound while generating electricity efficiently.

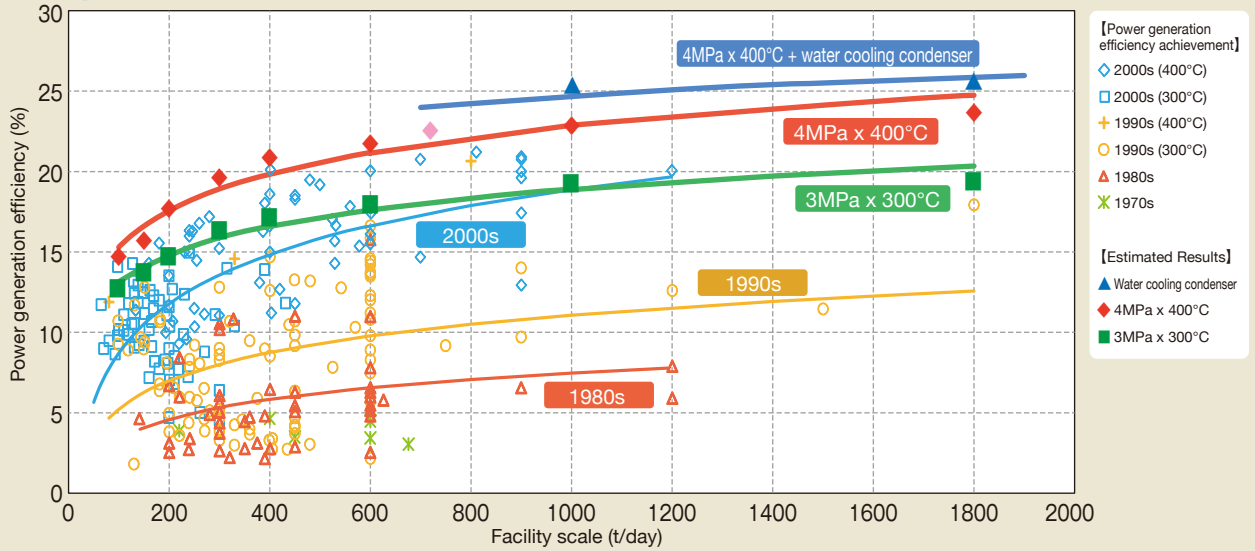
New Generation Incinerator

1	Improved combustion quality	○ Lowered combustion air ratio 2.0 -> 1.4 or 1.3 ○ Resolved uneven burns with infusion of high temperature air ○ Improved mixing of combustion gas and air ○ Improved oxygen-enriched combustion and combustion quality, resulting in clean incinerated ash
2	Improved quantification and control of garbage supply	
3	Cooling of stoker	○ Water cooling and air cooling
4	Improved durability of fire-resistant furnace wall material	○ Tile cover for radiation heat transfer surface on boiler
5	Recycling incinerated ash	
6	Sophisticating operation control system	

Status of transition to high efficiency electricity generation

In the past, the priority factor in setting up waste incineration plants was antipollution control, which resulted in a significant upgrading of facilities from this perspective; however, priority was not placed on the efficiency of energy recovery. Rising the temperature and steam pressure for electricity generation results in high efficiency; however, acid gas contained in the exhaust gas causes high temperature corrosion of the super heater. In recent years, research has moved forward to achieve long-service heat-transfer tubes that show resistance to high temperature corrosion. Many plants now construct highly efficient electricity generation facilities with longer operating lives as demanded by greenhouse gas emission measures.

Power generation efficacy achievement of waste incineration facilities and estimated results



※The above shows the theoretical power generation efficiency calculation according to the age and facility scale of the waste incineration and power generation in Japan. Estimation is based on feasible scenario on the premise that the incinerator is operating stably for a long period, and including factors to raise power generation efficiency.

Suitable Incineration Technology in the Asian Region

In Asia, where urbanization is progressing at a rapid speed, the volume of waste is quickly increasing along with population increase. In many Asian cities, collected garbage is transported directly to repository sites. Due to the lack of land available for repository sites and concern for environmental pollution in areas near repositories, there is a heightened interest for incineration plants.

As a solution to the increasing garbage problem, China made the decision to introduce incineration and has begun to build plants. In Singapore, Thailand and Taiwan, too, Japan's incineration technology is helping in the improvement of public sanitation and environmental conservation.

Japan is a leader in the construction and management of incinerators worldwide, realizing incineration treatment of waste with its world-class standard of technology to dispose of from low-calorie to high-calorie garbage.

Examples of some of the incineration plants delivered by Japanese enterprises

The world-largest scale plant with the capacity to handle 4,320t/day was built in Singapore in only 38months
Source: Mitsubishi Heavy Industries, Environmental & Chemical Engineering Co., Ltd.

There are several incinerators operating in Taipei, and most of the garbage generated in the country is being disposed of and reduced in a sanitary manner.
Source: Hitachi Zosen Corporation

In Thailand, an industrial waste incinerator has been operating from 2006. Its treatment capacity is 100t/day.
Source: JFE Engineering Corporation

An electric generating facility with the capacity of 30,000 KW and steam condition of 4MPa and 400°C has been delivered to the incineration plant in Beijing, with capacity to handle 1,600t/day.
Source: Takuma Co., Ltd.

3 Medical waste disposal technology

Sanitary disposal technology with high environment preservation capability

Safe and appropriate disposal of medical waste

Some waste generated from medical institutes may be contagious. In the past, Japan experienced medical accidents in which medical staff were infected by used needles which eventually caused death. Such accidents attracted public attention and made people aware of the need for the sterilization of medical waste. Today, there are laws regulating methods of medical waste disposal. The risk of contaminated waste being mixed with general waste and increasing the possibility of the spread of contamination highlights the need for appropriate treatment and disposal.

The number of hospitals in Asia and Africa has increased, yet there are only few treatment facilities for medical waste, causing the risk of infection through contact with contagious waste. Appropriate treatment and disposal of medical waste is strongly advised.

Medical waste discarded at open garbage dumps

Syringe needles coming out of garbage bags

Column

Containers for the disposal of medical waste (Example)

In order to avoid contamination, plastic containers, cardboard boxes and metal containers are used for disposal of medical waste to prevent contact and assure safety for workers.

Pail

Cardboard box

Bag

Source: the website of Japan Industrial Waste Information Center

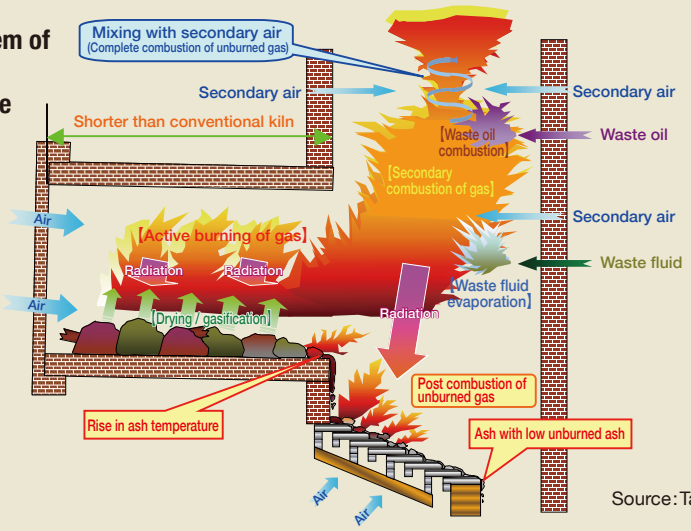
Some of the containers used by medical institutes

Diverse incinerators that control the generation of dioxins

Other than harmful bacteria and viruses, medical waste contains vinyl chloride and organochlorine chemicals, and simple incineration may generate hydrogen chloride and dioxin. Japan has strict regulations regarding the generation of dioxin and measures are taken to reduce dioxin through incinerator structure, operation methods, and dioxin elimination systems, and incinerators specifically for medical waste are used to reduce dioxin content in the gas emissions.

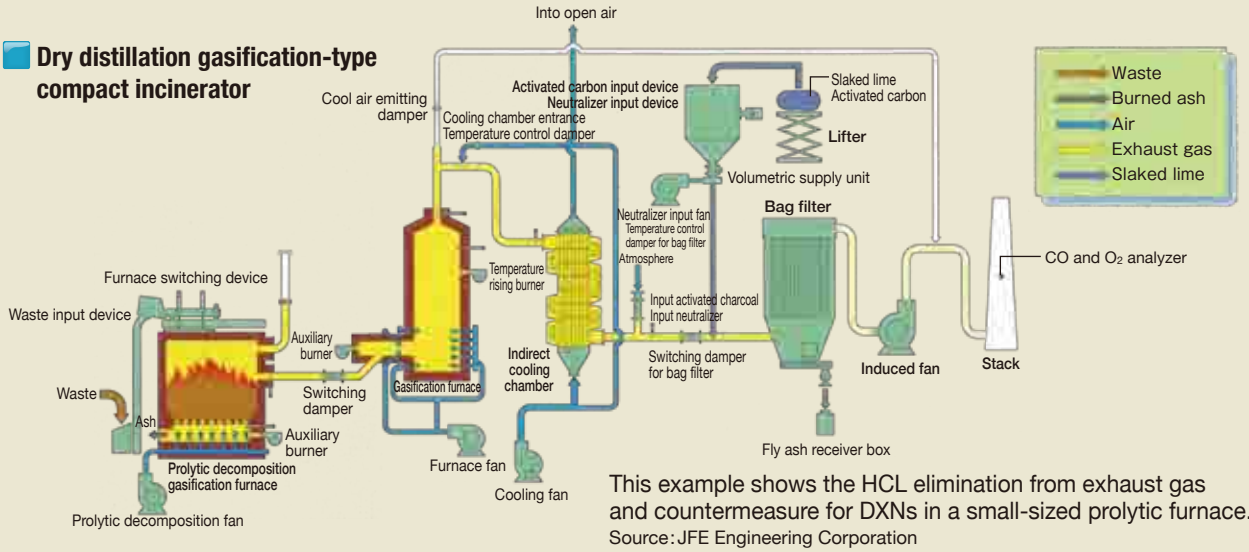
Some of the furnaces used as medical waste incinerators to control the emission of dioxin are gasification furnaces, kiln furnaces and vertical furnaces that safely and completely burn waste.

Figure of combustion system of the Rotary kiln + Post burning stoker furnace



Source: Takuma Co., Ltd.

Dry distillation gasification-type compact incinerator



This example shows the HCL elimination from exhaust gas and countermeasure for DXNs in a small-sized prolytic furnace.

Source: JFE Engineering Corporation

Column

Treatment of contagious waste in Japan

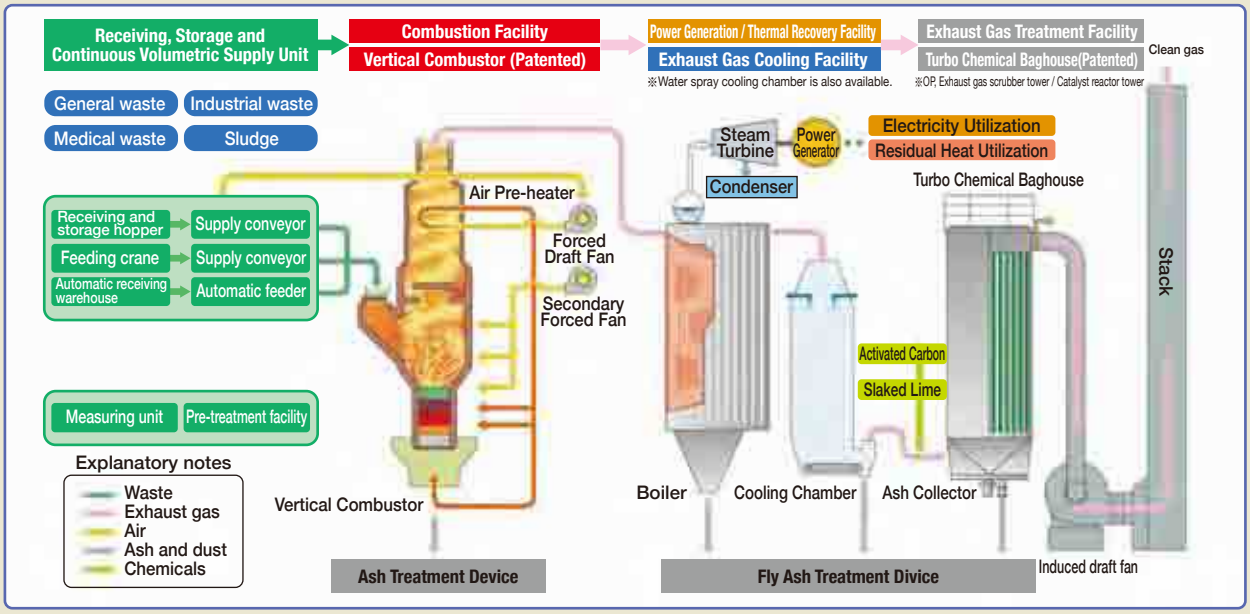
Contagious waste is designated as a specially-controlled waste under the Wastes Disposal and Public Cleansing Act, and its disposal must be executed as shown on the right.

The act stipulates the treatment of contagious waste as follows: In measures 3 to 5, waste must be broken down and fully disinfected so that contagious pathogens cannot spread through the air. In measures 1 or 2, gas temperature in the incinerator must be maintained at 800°C or higher, and when the treatment capacity of the incinerator is less than 2t/hour, dioxin should be 5ng-TEQ/m³ or lower.

1. Burning in incinerator
2. Melting in melting facility
3. Sterilizing with high pressure steam
4. Sterilizing with dry heat sterilizer
5. Disinfecting

Examples of incineration construction overseas

A Japanese medical waste incineration facility was constructed in Quezon, Philippines and Dobai, United Arab Emirates (UAE). The facility in Dobai was the first large scale incineration facility for medical waste in Gulf Countries that conforms to EU standards.



The medical waste incineration facility completed in Dobai is equipped with a vertical combustor that has the capacity to handle 19.2t/day and an air-purifying smoke and dust collection device for exhaust gas.
Fuel, such as heavy oil, is not used to supplement incineration, which meets the strict exhaust gas regulations of Europe. The facility was introduced as an efficient and environmentally-outstanding new incinerator.

Source: Plantec Inc.

Contagious waste is commonly treated through incineration or autoclaving. Japan was able to solve its dioxin issue by improving small incinerators and contagious waste is mainly treated through incineration; however, dry heat sterilizers and autoclaves that sterilize at the source, namely at hospitals, are being developed and put into practical use.

Dry heat sterilizer

Autoclave (High-pressure steam sterilizer)

Autoclaving is one of the most universal and versatile methods of sterilization.
It is used to sterilize medical instruments.

4 PET bottle recycling technology

Technology to produce high-grade recycled PET resin and recycle products

Collection and recycling to make diverse products

Under the 3R policy (Reduce, Reuse, Recycle), Japan has been collecting PET bottles, food trays, and cans separately for reuse as recycle resources in the manufacturing of new products. PET bottles are collected in accordance with the Act on the Promotion of Sorted Collection and Recycling Containers and Packaging, and they are used to make a variety of textile products, etc. Relatively high-grade PET bottles are collected and remade into PET bottles or carpets with the high technology possessed by Japan.

Collection of PET bottles and handing them over to reproduction contractors

The collected bottles are cleaned, and caps and labels taken off to improve their quality. The bottles are then compressed, bound and passed on to reproduction contractors.

PET bottles at collection

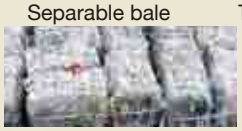
Sorting

PET bottles when delivered to recycling operators

Source: The Council for PET Bottle Recycling

Removal of foreign matters from PET bottles

Separable bale



Transparent bottles

Effluent treatment equipment

Receiving yard → Bale opener → Separation of color and other material bottles → Coarse crusher → Fine crusher → Label/cap separation → Washer → Dehydrator → PET flake

Valued transparent PET resin is sorted and extracted for raw resin. Residual plastic is used for chemical recycling. Water discharged during processing is purified to prevent water pollution.

Color bottles and bottles made with other materials

Label/cap debris

Chemical recycling, etc.

Recycled products

(1) Textiles : Suits, shirts, carpets, etc.
(2) Bottles : Bottles for detergents, cosmetic containers, etc.
(3) Sheets : Paper packs and cases, partitions in boxes, etc.
(4) Other : Stationery, containers, etc.

Examples of products made from recycled PET resin

Collected PET bottles

Crush

Flake

Pelletize

Pellet

Recycled uniform

Spun yarn

Fiber

Examples of material recycling (PET bottle)

Many products are made from flakes and pellets. They are used to make PET sheets, resin products or remade into PET bottles.

Cotton work gloves and bags

Source: The Council for PET Bottle Recycling

Resource recycling technology to produce high quality products

Recycled resin from PET bottle waste is used to make material for civil engineering and inner cotton for bedding. It was thought that making long fiber or resin product that will not decolorize would be difficult to achieve.

One Japanese company began recycling and reproducing PET bottles in China, Thailand and Taiwan. There are cases of recycled material being colored at the resin stage and made into high quality carpets using high level sewing skill.

Examples of high added value recycled products

Carpets, car mats, hot covers, area rugs
Examples of making floor covering for living space

Source: Negoro Sangyo Co., Ltd.

Packing tape

Column

One major food corporation is moving forward with the remaking of used PET bottles into new PET bottles by combining material recycle method and chemical recycle method. With the material recycle method, collected bottles are washed, dissolved under high temperature and filtered to reproduce high quality plastic resin. New PET bottles are made using 50% recycled resin produced through the material recycle method and 50% recycled resin produced through the chemical recycle method, for 100% recycled PET bottles for beverages.

This reproduction led to an approximately 90% reduction in the use of petroleum-derived resources and a 60% reduction in CO_2 emission.

Source: Suntory Holdings Ltd.

System to efficiently collect PET bottles

Japan passed the Law for the Promotion of Sorted Collection and Recycling Containers and Packaging in 1995, driving municipalities to collect recyclable resources. With it Japan has structured a sophisticated recycling system. Used PET bottles contain foreign material and substances which only allowed reproduction into low quality products; however, today's recycling technology developed sophisticated methods for foreign matter removal and recycling, bringing out high added value products.

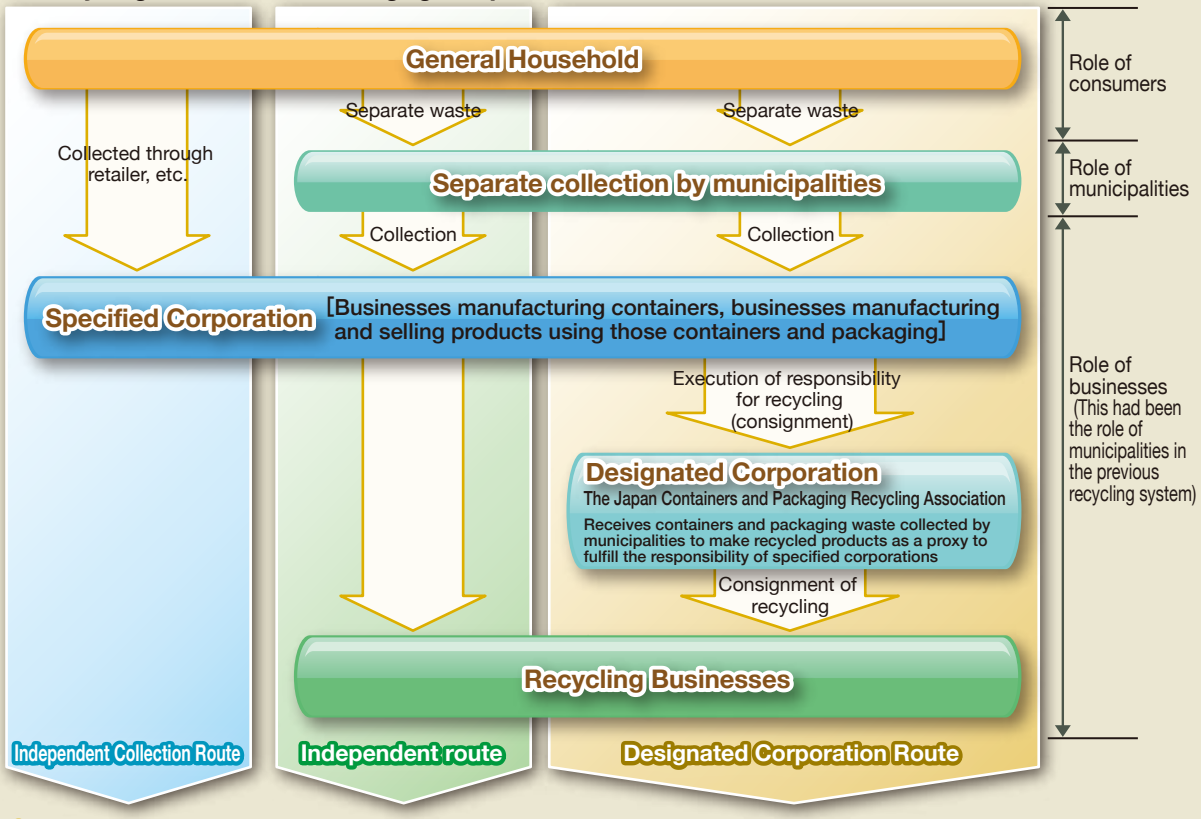
Some municipalities set up a subsidy system for neighborhoods that voluntarily collect recyclable waste, thereby promoting the PET bottle collection and recycling of waste.

Voluntary recycling activities to collect resources, such as PET bottles, and hand them over to contracted recycle businesses is called Shudan Kaishu (Group Collection).

With the objective of reducing and recycling waste, separate collection boxes are set up to collect PET bottles, food trays, milk car tons and newspaper. Source: Hino City's website

Structure of the Law for the Promotion of Sorted Collection and Recycling Containers and Packaging in Japan

(Issued on June 1995, Enforced on April 1997)



Law for the Promotion of Sorted Collection and Recycling Containers and Packaging

This law establishes a system in which waste plastic containers and packaging, glass and paper containers discarded from homes are collected through sorted collection by municipalities and retailers, which are then handed over to the Japan Containers and Packaging Recycling Association. The association then consigns reproduction companies to recycle them into new products.

5 Home appliance recycling technology

Technology for high quality recycling that is ecologically safe

Home appliances can be a source of pollution if handled inappropriately, but become useful resources if handled in the right way

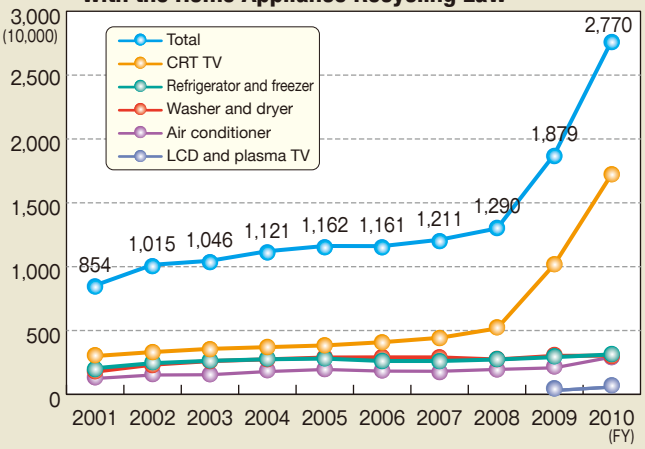
In developing countries, small companies recover precious metal from appliance waste manually, which is a health hazard for workers and contributes to environmental pollution. Home appliances contain both hazardous substances and useful resources, such as rare metals. Treatment through sophisticated resource recovery technology produces merit in term of environmental preservation and the reuse of precious resources.

During the 1990s, the introduction of wide-ranging larger home appliances increased the burden of municipality-managed bulk waste treatment facilities in Japan. The compacting of these appliances became difficult, and the ability of such facilities to recover useful resources reached its limit, making it necessary to search for higher level of recycling, which led to the enactment of the Home Appliance Recycling Law in 2001. This law included the concept of Extended Producer Responsibility (EPR), in which the responsibility of the producers extended to disposal at the end of product life. Now, appliance producers, etc. are the ones recycling items specified in the law and recycling is made more efficient through a high recycling rate.

In Asian regions, electronic parts that contain hazardous lead are abandoned, causing anxiety about environmental pollution.

In developing countries, copper is recovered by open burning, creating labor hygiene problems, and air and water pollution.

Number of home appliances collected in accordance with the Home Appliance Recycling Law



Status of parts and material recycling based on the Home Appliance Recycling Law (FY2010)

(in tons)	Air conditioner	TV		Refrigerator, freezer	Washer, dryer
		CRT	LCD/plasma		
Iron	35,628	43,737	2,709	88,121	48,015
Copper	8,367	15,153	90	2,895	1,785
Aluminum	14,395	218	290	1,479	1,257
Composite of nonferrous and ferrous material	40,238	2,636	102	25,887	13,216
Glass from picture tube	–	217,846	–	–	–
Other valuable resources	14,220	94,309	2,358	41,454	29,543
Total weight	112,848	373,899	5,549	159,836	93,816

Total weight of products and material when released at cost or free of charge for parts and material recycling

Column

Home appliance recycling in Japan

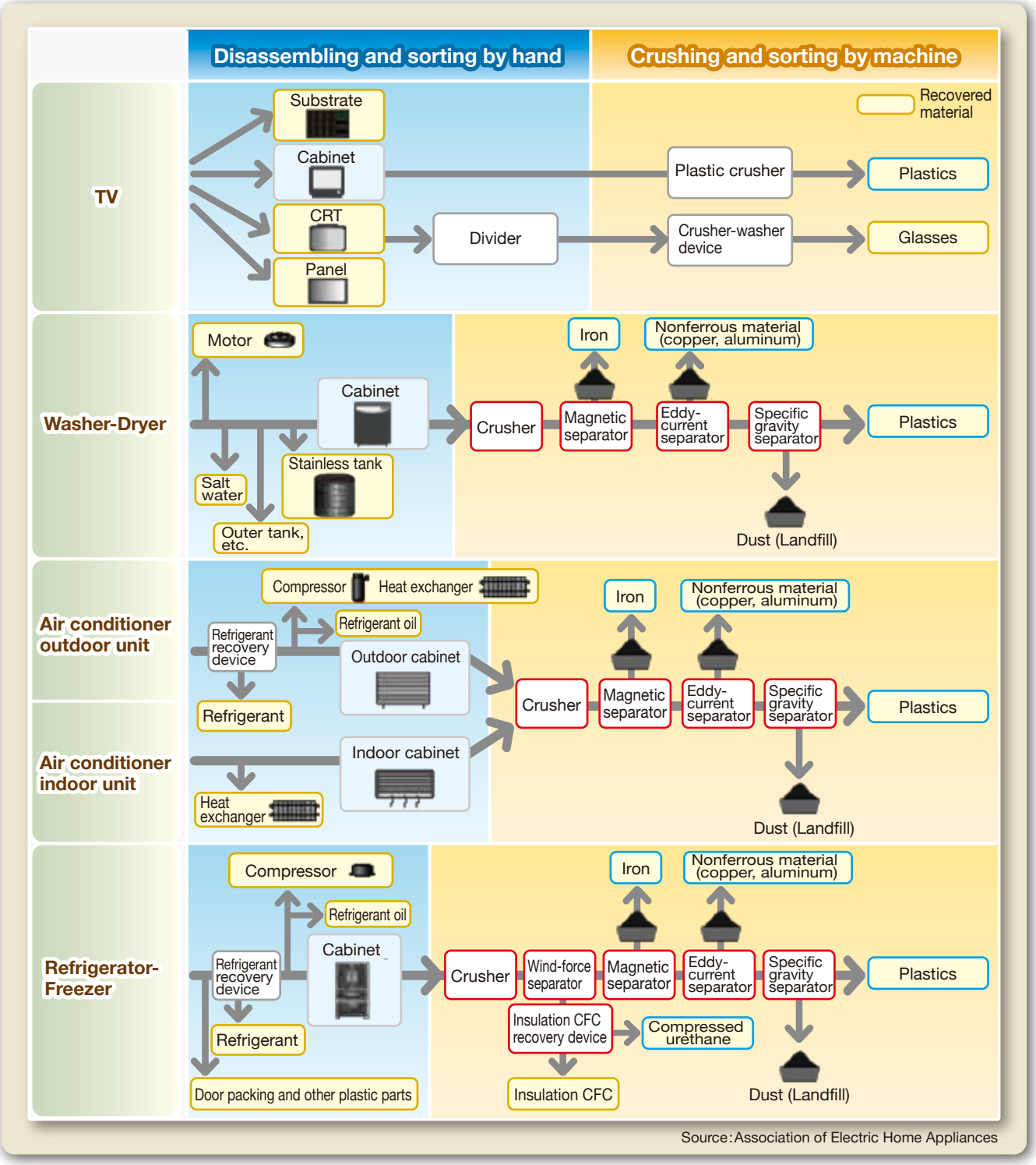
The Home Appliance Recycling Law stipulates that four home appliances - air conditioners, TVs, refrigerators, and washer-dryers - are to be disposed of with responsibility shared by several parties. Waste generators deliver the used appliances to retailers, who charge for disposal. The retailers take the appliances to the manufacturers/ importers of the said appliances, etc., who are responsible for recycling.

Home appliance recycling technology in Japan

Home appliance recycling technologies in Japan focus on the effective utilization of resources and the safe treatment of hazardous material, and methods and operations becoming more and more sophisticated. Japan has many outstanding recycling achievements and many recycling facilities are operating stably.

The prevailing method of handling used home appliances in the past was to first break them apart with a simple machine and then sort out the recyclable parts using magnets. Today, recycling has become more sophisticated. To improve the purity of recovered resources, appliances are first taken apart and sorted manually, then compacted with a machine. The operation is efficient in that not only metallic material but also plastic parts are recovered for recycling.

Refrigerators and air conditioners contain chlorofluorocarbons that damage the earth's ozone layer. These hazardous liquid chlorofluorocarbon and chlorofluorocarbon in insulating material are recovered for proper disposal. Furthermore, consideration is given for the safety of workers and protection of the environment of surrounding areas.



Source: Association of Electric Home Appliances

Japanese Corporations Advancing Overseas

Japanese Corporations are already advancing into China and other countries with home appliance recycling businesses.

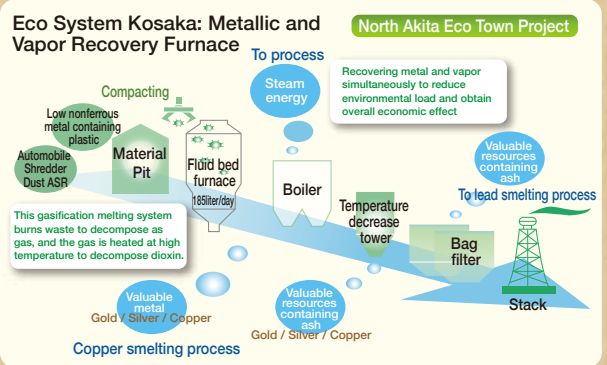
A home appliance recycling plant constructed as a joint venture between Japanese and local company (Suzhou, China)

Japanese home appliance recycling plants are operating in China and other countries.

Source: DOWA Eco-System Co., Ltd.

Column

Collaboration with the nonferrous refining industry



Valuable metals are recovered through heat and chemical treatment.

Diverse recycling materials

In collaboration with the nonferrous refining industry, heat and chemical treatments recover useful metals of high purity. Research is also conducted to develop technology to recover and use rare metal in the future.

6 Biomass utilization technology

Technology to efficiently recover electricity and fuel from biomass waste

Active use of biomass

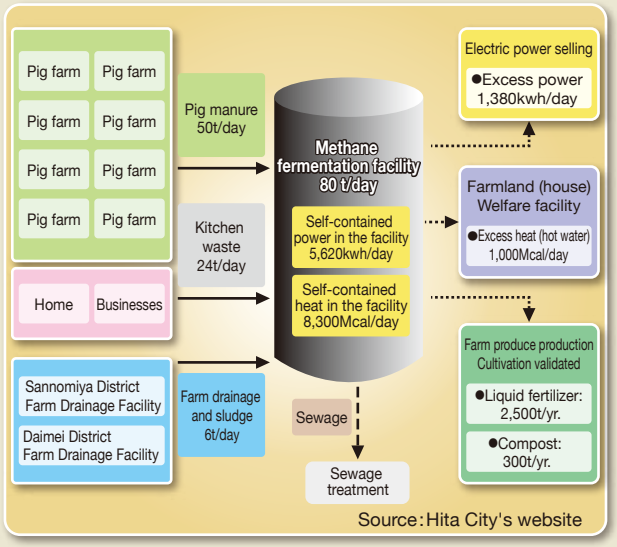
Waste generated in cities and villages includes combustible waste with low moisture content, such as paper, plastic, and wood debris; and waste with high moisture content, such as food production waste, kitchen waste, manure, sewage sludge, biomass and other organic sludge. Waste with high moisture content will generate methane gas and hydrogen sulfide when buried without treatment, causing environmental pollution. Incineration of high moisture waste requires sub-material to assist with the incineration. Cooking oil waste with low moisture content may be effectively recycled as BDF, and energy can be recovered from wood debris incineration. Waste treatment, such as composting, methane fermentation, and use as animal feed, that best suits the features of the locale is selected.

Aiming for the structuring of a recycling society, food production waste and kitchen waste from homes, barn animal manure, sludge and other biomass are treated independently or in combination with incineration. Below are examples of leading biomass technology.

Hita City, Oita (High moisture content biomass use)

An operator commissioned by pig farms collects hog manure, kitchen waste from homes and businesses, and sludge from an effluent treatment facility and treats them in an integrated manner at a methane fermentation facility.

(1) Treatment capacity: 80t/day (kitchen waste - 24t/day; swine excrement - 50t/day; farming settlement discharge sludge - 6t/day)
(2) Methane fermentation facility: wet-type mesophilic fermentation
(3) Power generator: gas engine 170kWx2units (generates 7,070kWh/day)
(4) Liquid fertilizer facility: Annual production of 2,500tons
(5) Composting facility: Annual production of approx. 290tons
(6) Water treatment facility: Active sludge + sludge solubilization

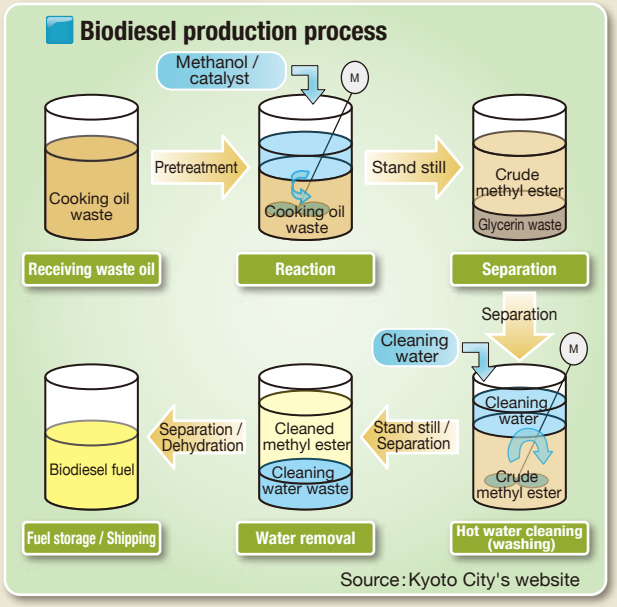


Source: Hita City's website

Kyoto City (production of fuel oil (BDF) from oil waste)

Cooking oil waste recovery system is structured to manufacture BDF, which is used as fuel for city-operated buses and garbage collection trucks.

(1) Treatment capacity: Vegetable oil waste - approx. 5t/day
(2) Treatment method: Fatty acid methyl ester
(3) Biodiesel fuel production: 5,000liter/day



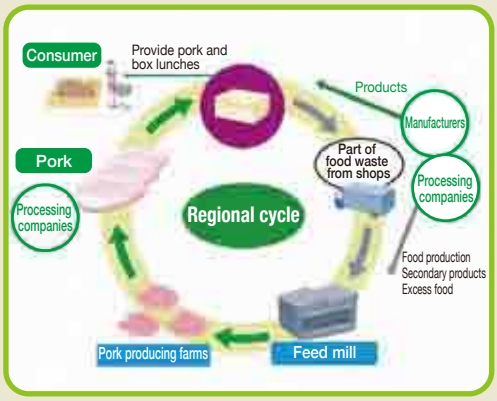
Source: Kyoto City's website

Japan's concrete measures for food waste, etc.

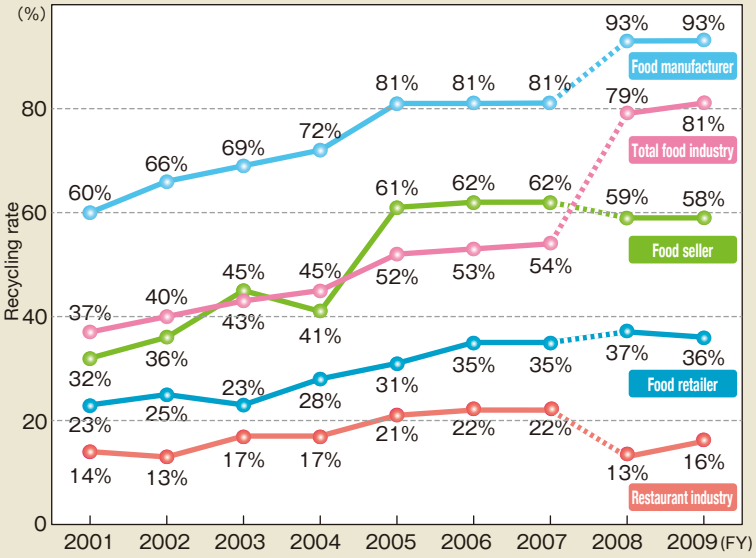
Fertilizer and feed producers, users, collection and transport companies cooperate to collect and treat 20 million tons of food waste, etc. annually. The waste is then recycled into feed and fertilizer, or gas fuel by methane fermentation for power generation.

There are cases in Japan of restructured pork production infrastructure that reuses and recycles food waste, etc. as feed in order to reduce CO_2 emission from incinerators.

Structure a society where recycling is completed within the region (Example)



Status of recycling food waste, etc.



※Method of estimation for 2008 and onward better reflects the actual status; therefore comparison of the values before and after 2008 will not be accurate.

Law for promotion of Recycling and Related Activities for treatment of Cyclial Food Resources (Food Recycling Law)

The Food Recycling Law that came into effect in 2000 calls for the reduction of food waste, etc. and their collection surpassing municipals to create a recycle loop for feed and fertilizers, with which a recycling society is achieved.

Column

Recovery of energy and other resources from food waste biomass

Foreign matter is removed from food waste to produce safe feed. Composting and methane fermentation facilities are actively recycling waste while employing technology to reduce foul odor and dirty water. Reduction in disposed food waste, etc. leads to a decrease in waste disposal cost and holds down greenhouse gas emissions.

Feed production facility

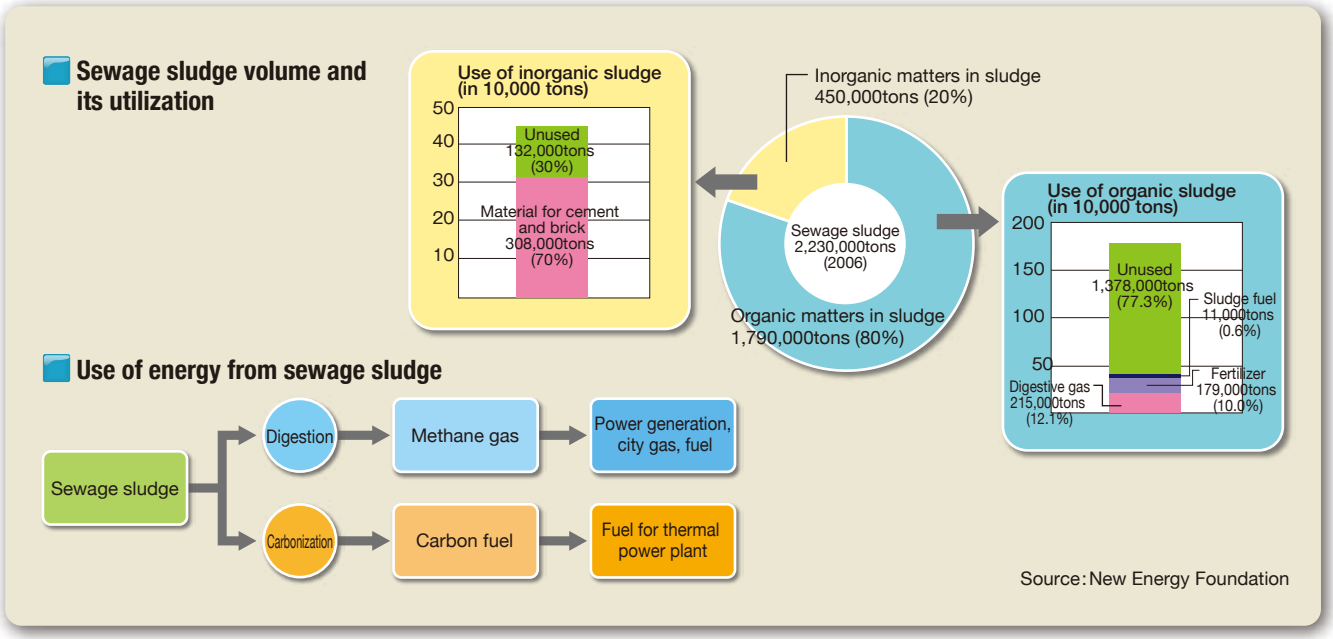
Composting facility

Methane fermentation and power generation facility

Using energy generated from sewage sludge

Sewage sludge collected at sewage treatment plants in Japan totaled 2,230,000 tons in the fiscal year 2006. Composition of the sewage sludge is approximately 80% organic matter (1,790,000 tons) and the remaining 20% is inorganic matter (450,000 tons). Seventy percent of inorganic matter is recycled as material for cement and bricks. Organic matter is recycled as fertilizer (10%), sewage gas (12%) and sludge fuel (0.6%), and the remaining 77% is incinerated or buried.

If 2,230,000 tons of sewage sludge is recovered as energy, heat equivalent to that produced by approximately 975,000 kiloliters of crude oil is generated. Fossil fuel is now being replaced by fuel obtained from sewage sludge in order to reduce CO_2 emissions. There are two methods of recycling sewage sludge as fuel: sewage gas (methane gas) generation and carbonization (carbon fuel). The figure below shows the recent use of energy from sewage sludge in Japan. Sewage sludge will always be generated by human activity. Seeing this as energy, energy from the sludge can be supplied stably in large cities, increasing the value of sludge as a resource. Recycling sewage sludge as energy is expected to increase to full-scale in the years to come.



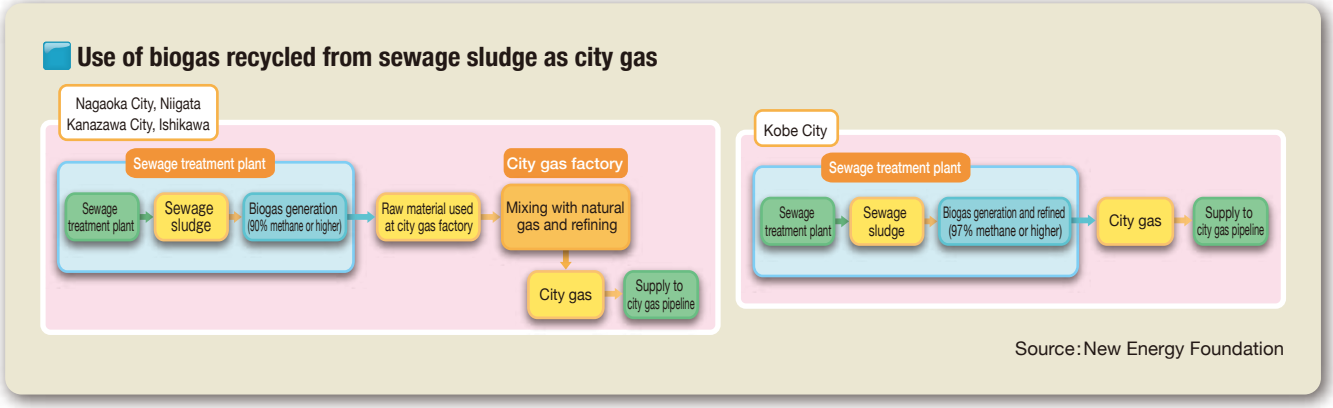
Source: New Energy Foundation

Use of Biogas from sewage sludge

Kobe City began a project in October 2010 through which biogas (97% methane or higher) from sewage sludge is injected directly into city gas pipes. Biogas generated from this project totals 800,000m³ per year, which is equivalent to the gas used by 2000 households. The effect on CO_2 emission reduction from this operation is estimated to be 1,200tons per year.

In other cases, biogas produced from sewage sludge - 600,000m³ in Nagaoka and 280,000m³ in Kanazawa per year - is supplied to city gas production plant, and used as fuel for plant operation.

The biogas business in Kobe employs the method of supplying the gas as city gas without passing through the city gas production plant. Gas is delivered directly into pipelines without detouring to the city gas production plant, which enables full use of the biogas generated at the sewage treatment plant.



Source: New Energy Foundation

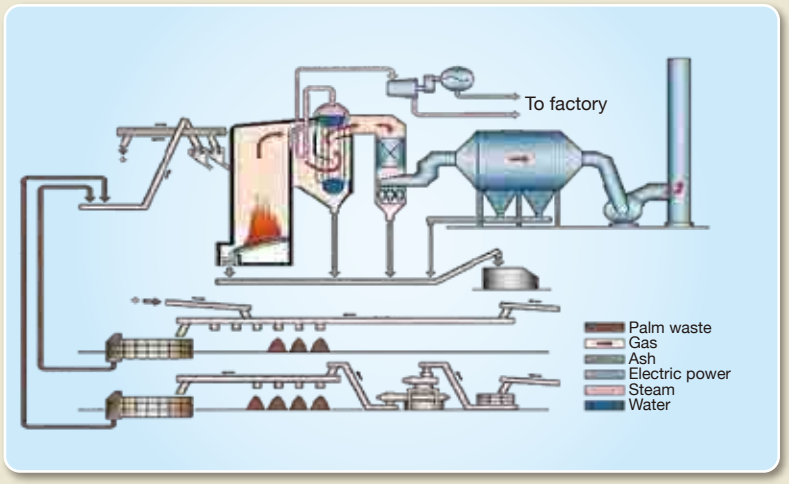
Utilizing farming, forestry and paper industry biomass as energy

Biomass boilers in Asian countries

There is a high ratio of organic waste in waste products, and it is desirable to make effective use of organic waste generated from paper factories and from the palm oil production process.

■ Bark, wood debris incinerator boiler, power generation facility

Bark generated by paper factories, wood refuse generated by lumber and plywood factories, and wood debris generated from the dismantling of old homes and buildings are some of the wide-ranging material used for boilers. Moisture content and shape differ depending on where the waste is generated, and it is burned in several types of incinerators. In order to obtain steady supply of power, moisture content in fuel is unified, and the operational functions of high performance power plants are introduced.



■ Palm incineration boiler, power generation facility

Cooking oil is extracted from palm. Palm oil is produced in Malaysia and Indonesia and plays a role in tropical farming as an export item. Palm waste is a valuable boiler fuel, and steam generated from boilers is used for oil extraction process or electrical power generation which responds to the electricity demand within the plant. This is a small-scale operation, but supports the driving force of the tropical industry.

Source: Takuma Co., Ltd.

Column

Transition from simple treatment to an energy source

Dairy cow excretion 1ton	Methane fermentation	Power generator	Electricity 58MJ(16kWh)		
			Heat 54MJ	Equivalent to 1.5liters of kerosene	
Pig excretion 1ton	Methane fermentation	Power generator	Electricity 133MJ(37kWh)		
			Heat 180MJ	Equivalent to 4.9liters of kerosene	
Kitchen waste 1ton	Methane fermentation	Power generator	Electricity 583MJ(162kWh)		
			Heat 896MJ	Equivalent to 24.4liters of kerosene	
Wood debris 1ton	Direct combustion	Steam turbine power generator	Electricity 1,417MJ		
Cooking oil waste 1ton	Recycling into biodiesel		Biodiesel fuel 1,004kg	Heating value 37,128MJ	Equivalent to 972liters of light oil

※Calculated by assuming the heating value of kerosene at 36.7MJ/liter

※Substance or energy produced by transition of 1ton biomass feedstock

※Calculated by assuming the heating value of biodiesel fuel at 36.98MJ/kg

※Calculated by assuming the heating value of kerosene at 38.2MJ/liter

Excerpt from: Design and Evaluation of the Biomass Utilization System (Edited by the systemization sub-team of the biorecycling of wastes from agriculture, forestry and fisheries researching sector)

7 Waste landfill technology

Landfill disposal technology that enables the stabilization of waste in a short time

Enabling early use of land with a semi-aerobic landfill structure

In many Asian cities' waste landfill sites, waste is dumped and burned openly. Japan used to be the same; however, a joint research by Fukuoka University and Fukuoka City in 1970s produced and applied a semi-aerobic landfill structure for landfills that is sanitary and presents no environmental problem.

Compared to anaerobic landfill, the semi-aerobic landfill technology quickly stabilizes landfill sites after the land has completed its role as landfill, enabling it to be used for parks and open space for sports. This technology was accredited as CDM methodology by the UN CDM Executive Board.

The Moerenuma Final Disposal Site in Sapporo City, Hokkaido was used from 1979 to 1990, and now the site is a recreational park open to residents and tourists.
The park was designed by world famous designer, Mr. Isamu Noguchi.

Fukuoka City had been using Imazu Landfill to dispose waste from 1975 to 1999. A section of the landfill is now used as a sports park and allotment garden.

Source: Hydraulic Sanitary Engineering Laboratory, Faculty of Engineering, Fukuoka University

Column

Improvement of the current landfill to a semi-aerobic landfill structure was accredited as a CDM method

In the past, CDM accreditation for waste disposal had been limited to aerobic landfill and methods for the recovery and use of methane gas generated at landfill as energy. At the 62nd UN CDM Executive Board held in Morocco on July 15, 2011, it was officially recognized that improvement of the current landfill to a semi-aerobic landfill structure is an effective method and added as a new methodology for Clean Development Mechanism (CDM) stipulated in the UN Framework Convention on Climate Change (UNFCCC).

- Accreditation: AM0093 "Avoidance of landfill gas emissions by passive aeration of landfills"
- Announced: URL: http://cdm.unfccc.int/EB/index.html

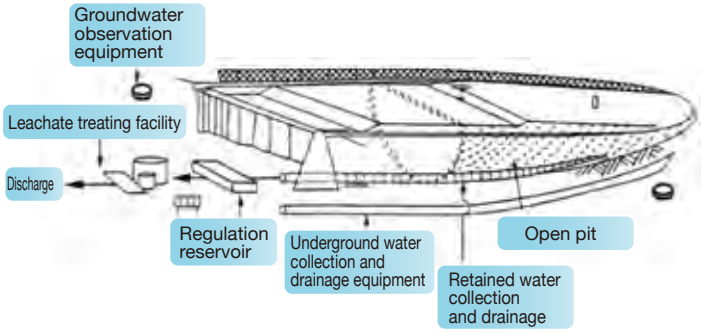
Waste landfill technology and system

In 1977, structural and maintenance management standards were established for final disposal sites. The standards grouped the final disposal sites for industrial waste into three categories - controlled landfill, inert landfill, and isolated landfill - and stipulated that waste must be safely disposed at landfill according to their properties. The semi-aerobic landfill structure is employed as the structure for controlled landfill. And the same standards for controlled landfill are applied to municipal waste.

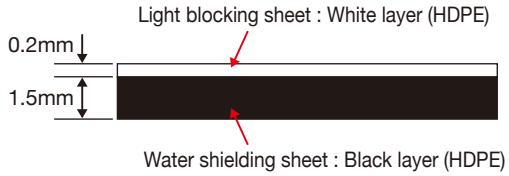
Harmful waste such as waste containing heavy metal and PCBs has the potential to adversely affect health and the environment, and must be disposed of at isolated landfill sites. Non-harmful waste that has the potential to pollute public water areas and underground water, or may affect the environment because of gas, odor and/or pests must be disposed of at controlled landfill sites. Plastic waste, rubber debris, metal debris, glass, ceramics and bricks that has little potential to cause environmental pollution can be disposed of at inert landfill sites.

Controlled Landfill Sites

Water catchment and treatment facilities for seepage control and leachate are established because landfill waste may decompose and pollute the environment.



■Cross section of the sheet (example)

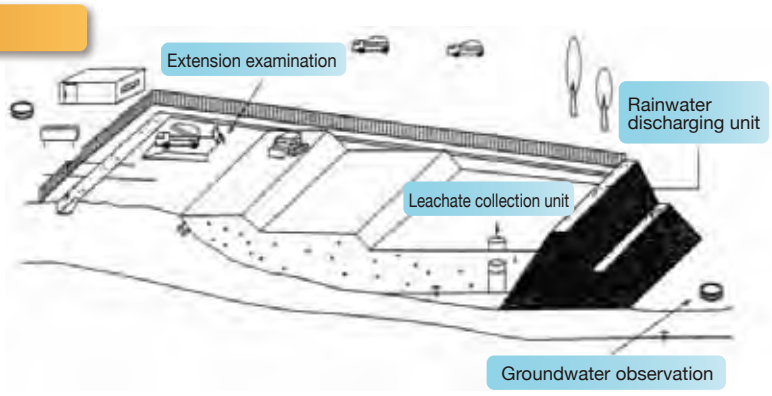


A water shielding sheet covers the floor and sloped surfaces of the controlled landfill site to prevent the pollution of underground water. Sheets with outstanding durability are being developed and used.

When the site is constructed over an impervious layer, a liner sheet need not be required if the layer has a thickness of 5m or more and the coefficient of permeability is 1×10^{-5}cm/second or less.

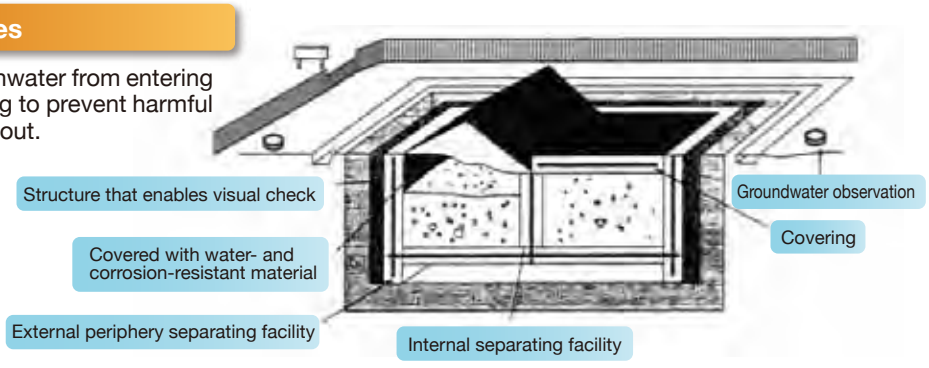
Inert Landfill Sites

Landfill waste is bio-chemically stable and will not pollute water. Water catchment and treatment facilities for seepage control and leachate are not established because of the low risk of environmental pollution.



Isolated Landfill Sites

The structure prevents rainwater from entering or leachate from outputting to prevent harmful substances from seeping out.



Source: "Comprehensive Construction Byproduct Recycling Measure" 2002 Edition, Advanced Construction Technology Center

Semi-aerobic Landfills

The semi-aerobic landfill structure was developed in a joint study by Fukuoka University and Fukuoka City. A leachate collecting pipe is set up at the floor of the landfill to remove leachate from the landfill, so that leachate will not remain where waste is deposited. Natural air is brought in from the open pit of the leachate collecting pipe to the landfill layer, which promotes aerobic decomposition of waste. Since this enables early stabilization of waste and prevents the generation of methane and greenhouse gases, the technology is effective in terms of the prevention of global warming.

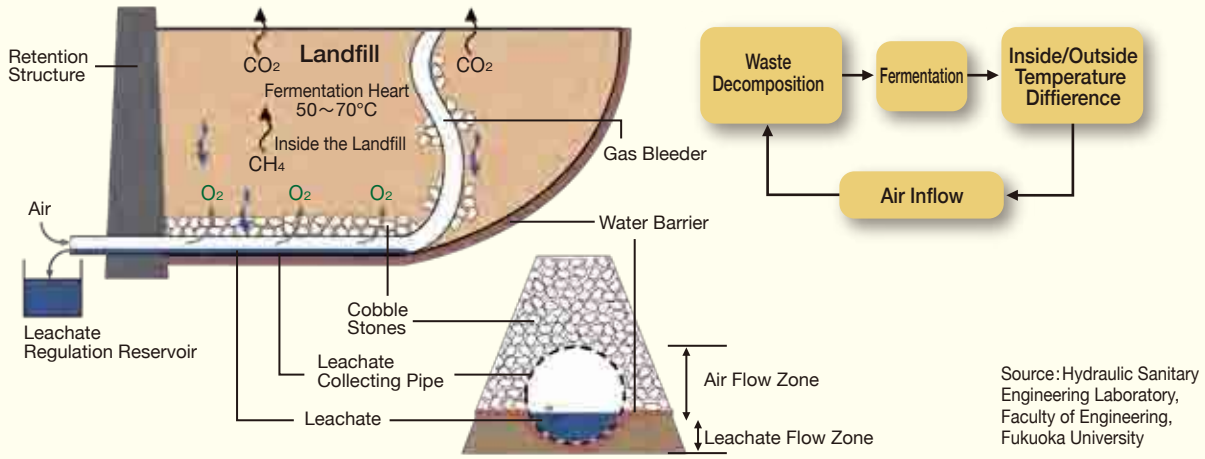
Generally, the air present in an aerobic environment transforms carbon in organic matter to carbon dioxide, nitrogen to nitrification denitrification, and sulfur to sulfur ion, which reduces the generation of foul odor and flammable gas. Moreover, an aerobic environment increases the activity of microorganisms that decompose waste, accelerating the stabilization process.

On the other hand, in an anaerobic environment, where oxygen is not present, organic matter is transformed into volatile organic acids, such as acetic acid, and then becomes methane gas or carbon dioxide, and nitrogen and sulfur are transformed to ammonia, amine, hydrogen sulfide, and mercaptan, which emit foul odor and negatively affect the living environment of the surrounding area.

Features of Semi-Aerobic Landfill

1. Better leachate quality than anaerobic landfill
2. Low emission of greenhouse gases
3. Landfill stabilizes faster than anaerobic type
4. Less underground water pollution from leachate
5. Cheaper to operate and manage

Mechanism of semi-aerobic landfill structure



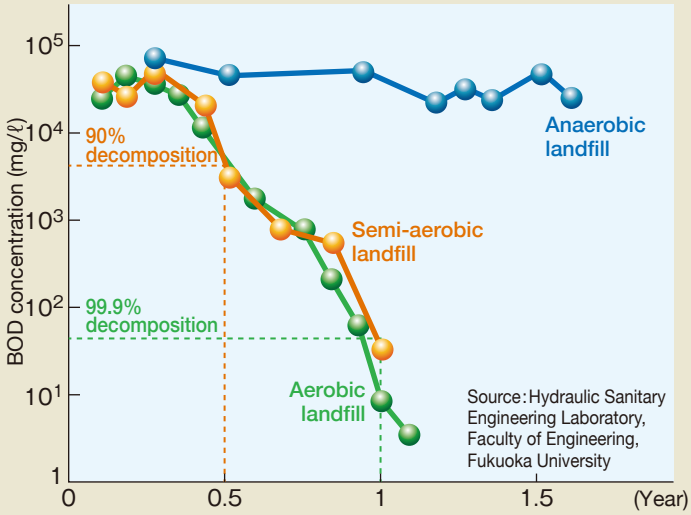
Composition of gas generated from landfill

	Semi-aerobic landfill	Anaerobic landfill
Methane	30%	60%
CO_2	70%	40%

The global warming coefficient of methane, one of the greenhouse gases, is 21 times that of CO_2

The quality of the leachate improved significantly with a significant drop in BOD one year after the semi-aerobic landfill structure was introduced. NH_3-N also showed a significant drop within one year. Anaerobic landfill, on the other hand, shows very little drop.

Landfill structure and changes of BOD in leachate over time (combustible waste)



Semi-aerobic landfill sites are increasing in Asia

The semi-aerobic landfill structure developed and commercialized in Japan was first introduced overseas at an open dump site in Penang, Malaysia. Before that, all waste generated in the city was brought into this 20 hectare site and fire erupted daily affecting the health of residents living near the site and the waste pickers who collect recyclable resources from the waste.

Measures for improvement began with controlling fire incidents. Degassing was performed by setting up degassing tubes and the ground was covered with earth. In one year, the foliage that had stopped growing due to gas returned to the site; and in two years, the site was reborn as a non-pollution generating ground.

A new disposal site was then constructed with a semi-aerobic landfill structure standing 5 meters high and 10~20 meters wide, which made it possible to treat polluted water and turn the disposal site into a sanitary location.

The semi-aerobic landfill structure is technology that quickly transforms open burning sites into sanitary ground that emit no smoke. This is a low cost, low-tech method, which is being introduced and spreading to Asian countries, such as Malaysia, Pakistan, China, Thailand and Vietnam, as well as Samoa, the Dominican Republic, Mexico, Italy and many others.

Before and after the improvement (Malaysia) Source:Hydraulic Sanitary Engineering Laboratory, Faculty of Engineering, Fukuoka University

Leachate Treatment Facility

Before and after the improvement (The Dominican Republic) Source:Santiago City CASA

Semi-aerobic landfill facility under construction

Column

Final Disposal Site in Tokyo

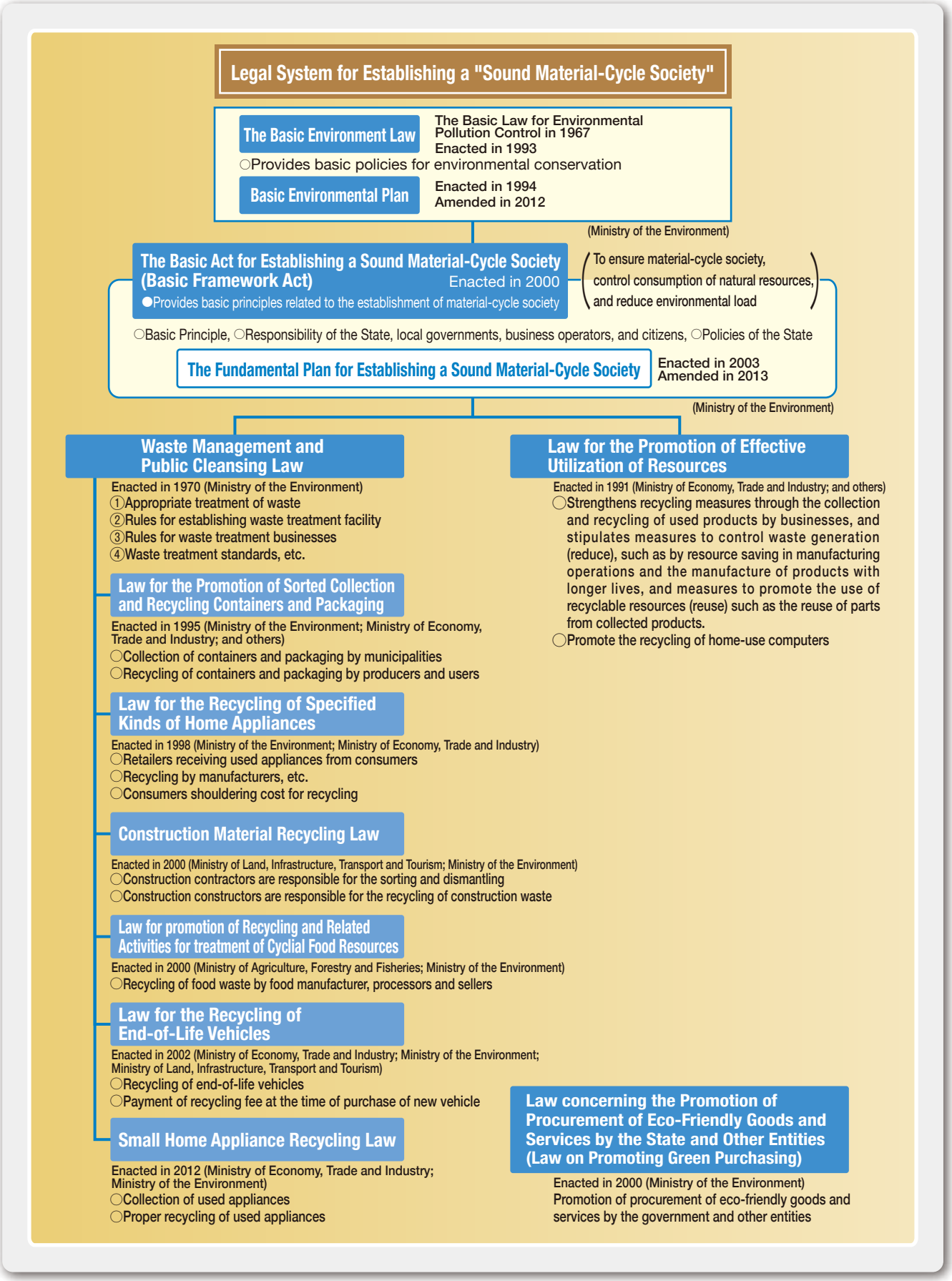
Site is managed appropriately today

Former disposal site where wild birds swarm

Source:Clean Association of Tokyo 23「Waste Report for Tokyo's 23 wards」

Legal System for Establishing a "Sound Material-Cycle Society"

Japan has a legal system for establishing a "Sound Material-Cycle Society", in which consumption of natural resources will be conserved and the environmental load will be reduced to the greatest extent possible.



Ministry of the Environment
Minister's Secretariat, Waste Management and Recycling Department
Policy Planning Division, Office of Sound Material-Cycle Society

Contact

Minister's Secretariat, Waste Management and Recycling Department
1-2-2 Kasumigaseki, Chiyoda-ku, Tokyo 100-8975
TEL: 03-3581-3351 (Ext 6819)
FAX: 03-3593-8262
Japanese Waste Management and Recycling website
http://www.env.go.jp/recycle/circul/venous_industry/index.html

Revised in December 2013
Created by : Japan Environmental Sanitation Center
URL http://www.jesc.or.jp/