# Technical reference

# “Basic Concepts of Landfill Site”

## 1 INTRODUCTION

### 1.1 Background

From the experience of the 2011 East Japan earthquake and tsunami, Japan could learn various lessons and practices regarding the disaster waste management. Although Japan did not have any knowledge and experience of disaster waste management, all the disaster waste could be treated within three years and most of the waste could be utilized using various experiences of ordinary waste landfill operations. After this experience, in Japan, two laws about waste management and disaster countermeasures were amended in 2015 at the same time, which means that the ordinary waste landfill operation can be a key issue for the success of disaster waste management technically and legally.

In these decades, the number of natural disasters is increasing not only in Japan but also all over the world, according to climate change. Although the existing techniques and equipment should vary depending on the countries and regions, the basic concepts and ideas can help establish disaster waste management frameworks, especially in Asian and Pacific countries where natural disasters often occur.

### 1.2 Objective of this guideline

To cultivate the preparation for disaster waste management, this technical guideline aims at introducing the basic concepts of waste landfilling in Japan.

### 1.3 Landfilling techniques in Japan

Table 1 shows the typical classification of landfilling techniques in Japan.

**Table 1 Classification of landfilling techniques in Japan**

| Landfill method | Function | | | | |
|---|---|---|---|---|---|
| | Anaerobic | Aerobic | Cover soil | Liner system | Leachate treatment |
| Anaerobic landfill | ✓ | | | | |
| Anaerobic sanitary landfill | ✓ | | ✓ | | |
| Improved anaerobic sanitary landfill | ✓ | | ✓ | ✓ | ✓ |
| Semi-aerobic landfill | ✓ | ✓ | ✓ | ✓ | ✓ |
| Aerobic landfill | | ✓ | ✓ | ✓ | ✓ |

1) Anaerobic landfill

The waste is merely dumped into the pits that were excavated at the level ground or valley. In this case, the waste is inundated and kept anaerobic.

2) Anaerobic sanitary landfills

This is also the anaerobic type landfill that has the additional option in the structure of several layers of cover soil (sandwiched) therein. Waste is kept in anaerobic condition.

3) Improved anaerobic sanitary landfill

An improved type structure that has the water collection pipe system at the bottom for the drainage. The moisture content is higher, while the waste is kept anaerobic.

4) Semi-aerobic sanitary landfill

A structure that has the sufficient size of water collection pipes, with their opening in contact with the air and the circumference covered with cobblestones. Moisture content is smaller, and the oxygen supplied through water collecting pipes keeps the landfill aerobic.

5) Aerobic sanitary landfill

A structure that has the air blowing pipe system, in addition to the water collection pipes, through which the air is mechanically blown in. The inside waste is kept much aerobic.

## 1.4 History of waste landfilling and challenges tackled

In this section, the history of waste landfilling in Japan is briefly introduced to clarify the technical and environmental issues raised in each era. Table 2 shows the history of waste landfilling with some relevant laws and regulations.

**Table 2 History of waste landfilling in Japan**

| Era | | –1950s | –1960s | –1970s | –1980s | –1990s | 2000s– |
|---|---|---|---|---|---|---|---|
| Critical target (phase) of landfill operation | | Improvement of public health | Pollution control and preservation of the living environment | Promotion of a recycling-oriented society | | | |
| | | | | | | | |
| | | | | | | | |
| Major waste landfilled | Combustible | ✓ | ✓ | ✓ | | | |
| | Incombustible | | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Incinerated residue | | | | | ✓ | ✓ |
| Type of landfilling | Anaerobic | ✓ | | | | | |
| | Anaerobic sanitary | | ✓ | | | | |
| | Improved anaerobic sanitary | | ✓ | | | | |
| | Semi-aerobic sanitary | | | ✓ | ✓ | ✓ | ✓ |
| Relevant laws and regulations | | 1900 Filth Cleansing Law<br>1954 Public Cleansing Law | | 1970 Waste Disposal Law (WDL)<br>1976 Amendment to WDL<br>1977 Technical Standards for Landfills<br>1979 Guidelines for Landfills | 1988 Amendment to Guidelines for Landfills | 1991, 1997 Amendment to WDL<br>1998 Amendment to Technical Standards for Landfills | 2000, 2017 Amendment to WDL<br>2000 basic act on establishing a sound material-cycle society<br>2001 Directions for Landfill Planning and Construction<br>2015 Amendment |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | to WDL and Disaster Countermeasures Basic Act |

**Phase: 1 Improvement of public health (–1960's)**

1) Historical background
   - Up until the 1950s, waste was merely dumped into depressions and shallow alongside the seashore without any cover soil or water treatment facility.
   - Due to Japan's remarkable economic recovery after the War and the diffusion of chemical fertilizers and rootage of the hygienic concept, the recycle of organic wastes to farmland gradually decreased.
2) Environmental problems
   - Foul odor
   - Infestation of flys which bring the epidemic
   - (Ground)water pollution by leachate
   - Smoke and odor by open burning
3) Major waste landfilled
   - In the 1950s, combustible wastes accounted for 70 to 80% of waste dumped, and the water content was over 50%.
   - Its lower calorific value was at lower levels than that of the natural limit of 500 to 800 kcal/kg.
4) Type of landfilling
   - Open dumping was the major operation of landfilling.
   - Although incineration of waste was recommended, the equipment and specifications were not regulated, and, therefore, open burning of waste was often done.

**Phase: 2 Pollution control and preservation of the living environment (1960's–)**

1) Historical background
   - In the 1960s, the amount of municipal and industrial waste generated dramatically increased due to the rapid economic growth as shown in Fig. 1.
   - While incineration was promoted since the 1950s, the construction of incineration facilities was not enough against the increase in waste generation.

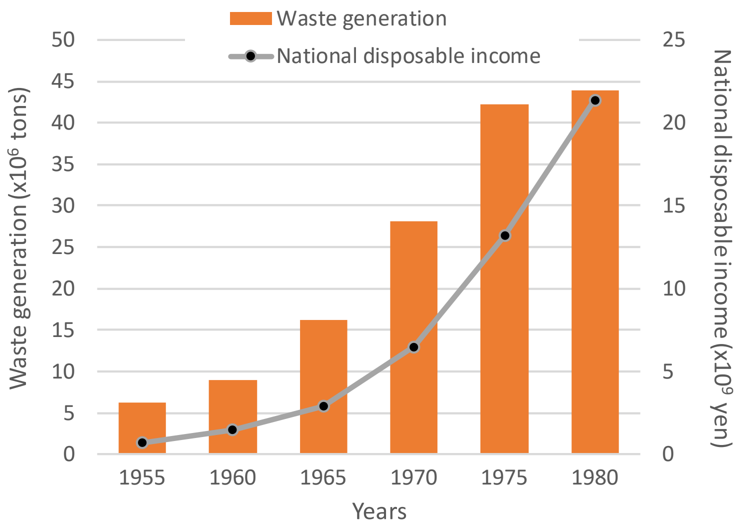



**Figure 1 Waste generation and national disposable income in Japan from 1955 to 1980**

2) Environmental problems
   - Due to industrialization, the air and water pollution caused by toxic chemicals such as methyl mercury and cadmium emerged.
   - Because the public awareness of pollution was formed, the pollution caused by waste landfills also started attracting general attention.
   - In 1964, the spillage of polluted water from a landfill in the Tokyo Metropolitan area was revealed.
   - The fly infestation became a serious problem.
3) Major waste landfilled
   - Combustible waste was still the major waste which accounted for more than 50%; however, the proportion of incombustible waste increased because of the increase in construction and demolition (C&D) waste which was caused by the population concentrations in megacities.
   - After the 1970s, the proportion of combustible waste decreased due to the spread of incineration facilities. The combustible waste accounted for approximately 50%, and the incombustible waste and the incineration residue accounted for 20–30%.
4) Type of landfilling
   - To solve the environmental problems, the application of cover soil got started and the leachate treatment system gradually prevailed in the 1960s.
   - The mainstream of landfill methods started to change from the anaerobic landfill to the anaerobic sanitary landfill, in which cover soil was applied periodically.

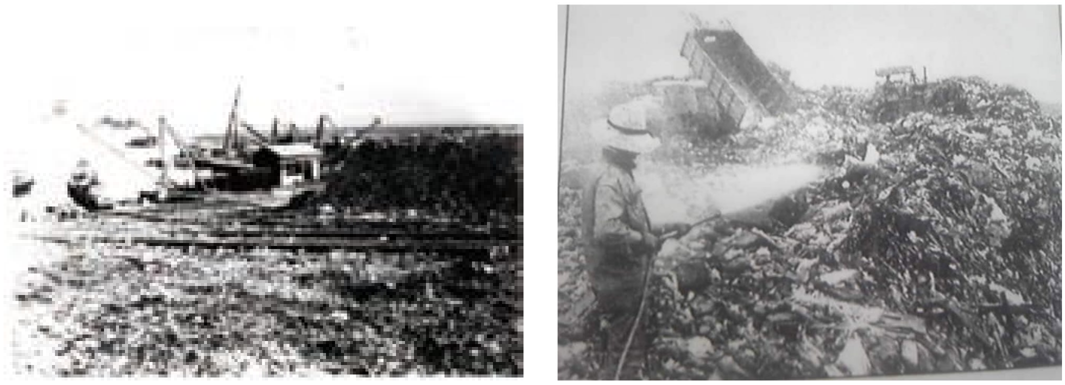


**Figure 2 Yumenoshima coastal landfill where fire and fly infestation often occurred due to organic waste**

- After a series of research started in the late 1960s, in the 1970s, the number of the semi-aerobic (Fukuoka-method) landfills rapidly increased.

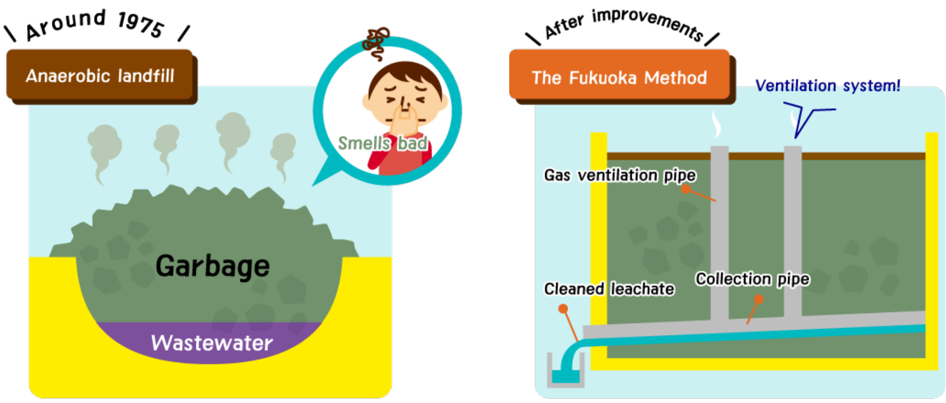



**Figure 3 Basic concept of: (Left) anaerobic landfill and (right) semi-aerobic landfill. (HP of Fukuoka Facts)**

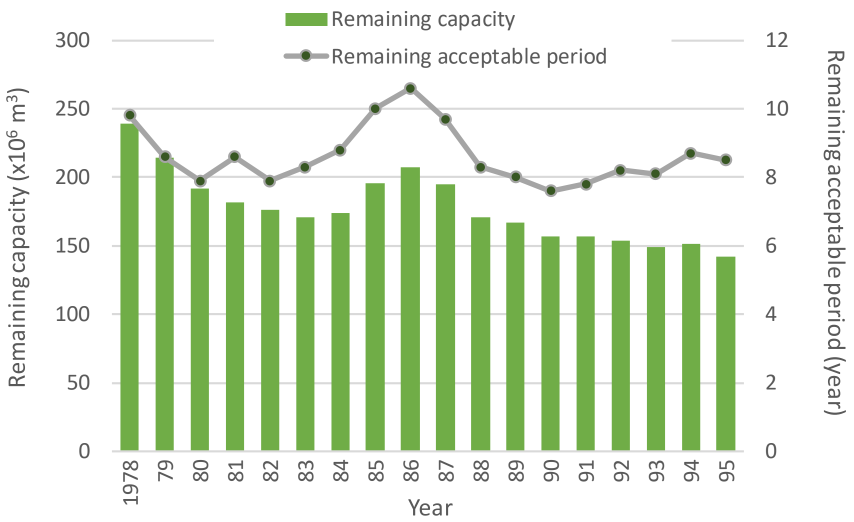
- The volume reduction treatment such as incineration and/or shredding/sorting process also became popular with the increased difficulty to secure the new landfill space.
- In 1977, three landfills—inert waste, controlled (non-hazardous) waste, and hazardous waste—were defined to appropriately manage hazardous wastes.

**Phase: 3 Promotion of a recycling-oriented society (late 1980's–)**

1) Historical background

- Due to the economic growth, the amount of waste generation increased. Because of the insufficient capacity of the volume reduction facilities, the amount of combustible waste dumped into landfills again increased.
- Because of the public awareness of pollution which may be caused by waste landfills, it got much more difficult to construct new landfills.

- Accordingly, the remaining capacity and the remaining acceptable period of domestic landfills dramatically decreased for both municipal and industrial wastes as shown in Figure 4.



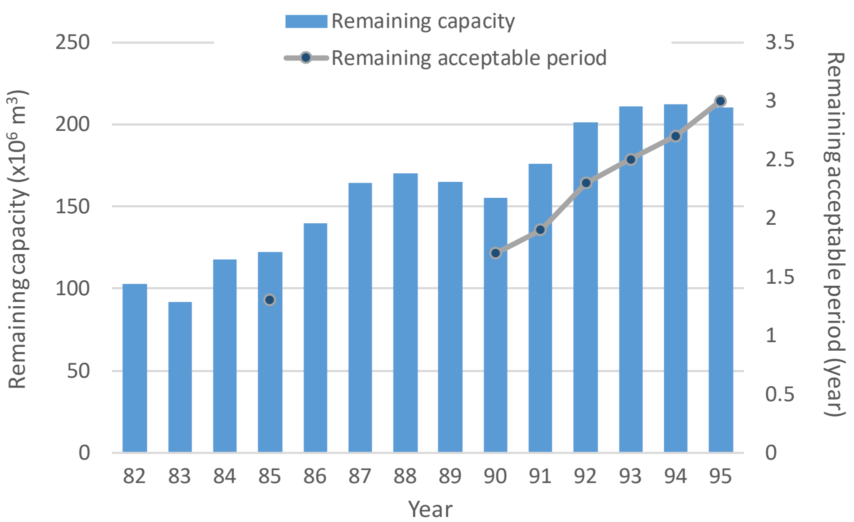




**Figure 4 Remaining capacity and remaining acceptable period in Japan from 1978 to 1995: (Top) for municipal solid waste and (bottom) for industrial waste landfill**

- By the amendment to the waste disposal law, the main target of this law was changed to the limitation of waste generation, adequate separation (sorting), and utilization.
- In 2000, the basic act on establishing a sound material-cycle society was established.

2) Environmental problems

- In the 1980s, the pollution by dioxin generated by incineration started attracting general attention.

- The target of waste management started to shift from “proper waste management” to “reduction in the waste volume”.
- Popularization of dry flue gas treatment device that sprays slaked lime inside the furnace to remove hydrogen chloride gas in incineration treatment facilities resulted in a mixture of a large amount of calcium and chloride ion in landfills. Also, salt pollution occurred near water treatment facilities and in the downstream areas of the effluent treatment facilities.
- Thorough waste separation (sorting) resulted in the waste ground containing a lot of plastics where the quality of leachate deteriorates, and the strength is not enough to be utilized for construction.

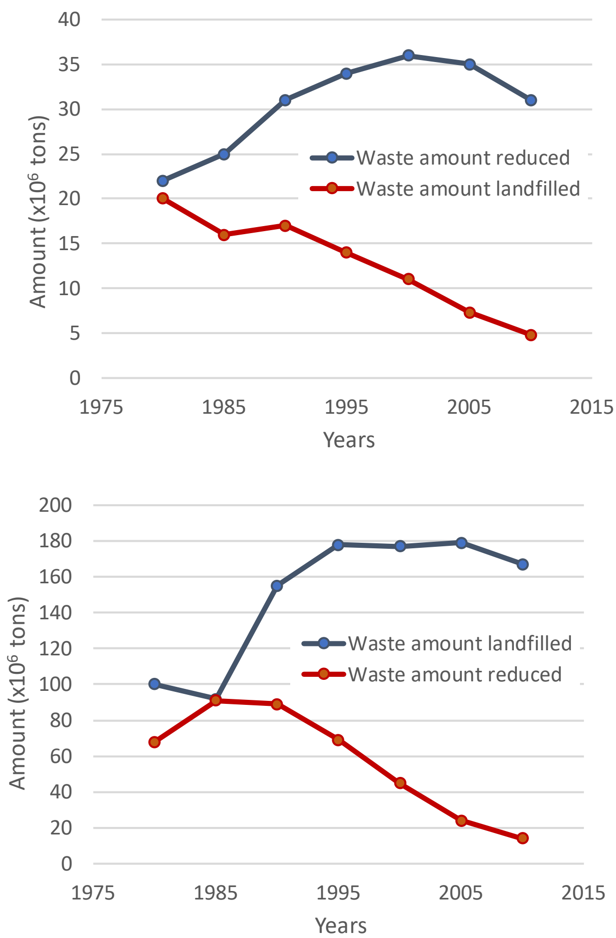



**Figure 5 Waste amount reduced and landfilled from 1980 to 2010: (Left) municipal solid waste and (right) industrial waste**

3) Major waste landfilled

- In 1994, the ratio of combustible waste decreased to about 20%, while that of incombustible waste and incineration residue accounted for about 40%, respectively.

## 2 Ordinary operation and preparation of waste treatment facilities

In this chapter, ordinary operation of waste landfills and necessary preparation which can help prompt and adequate management when disasters occur is introduced. Because every social and industrial system would be severely damaged during and immediately after disasters, the preparedness of frameworks for disaster waste treatment and utilization needs to be carefully discussed based on anticipated damage.

### 2.1 Estimating the possible amount of disaster waste generation

Estimating the possible amount of disaster waste generation is the most fundamental and core information to establish technical frameworks of disaster waste treatment. For the estimation, information of past disasters, types of disasters, affected areas, land use, and buildings, the weight of each material used in the buildings, etc. is necessary. For more details, documents of the estimation method should be referred to.

### 2.2 Calculating treatable/acceptable amount of existing facilities

It is a crucial issue to figure out the capacity of existing facilities in areas of anticipated disasters. In the countries/regions where volume reduction facilities, such as incineration, shredding, and sorting, exist, their maximum capacities need to be clarified in consideration of daily (ordinary) waste generation and treatment. As for landfills, the acceptable volume of existing landfills must be figured out. Since waste generation by disasters is plused to ordinary waste generation, enough treatable/acceptable capacities need to be always secured.

### 2.3 Securing where to use recycled materials

To minimize the volume and amount of waste dumped into landfills, recovery of disaster waste as resources, such as metals, bricks, crushed concrete, woods, soil, etc., must be an important consideration (Figure 6). However, the other important consideration for recycling is to secure the application of recycled materials. To solve this problem, the national/local governments are required to discuss with industries for the utilization and to establish legal frameworks to promote the utilization of recycled materials. For example, it is effective to utilize crushed concrete, bricks, and recovered soil and rocks in reconstruction works of infrastructure including road, embankment, and leveling. Regarding the rules and criteria of each institution or company to accept the waste, the governments and industries should communicate sufficiently.

**Figure 6 Crushing of concrete debris (Otsuchi district, Iwate prefecture) (Ide 2016)**

## 2.4 Improving resilience of facilities

Landfills and treatment facilities need to be resilient against disasters in order to accept disaster waste immediately after disasters. In earthquake-prone countries and areas, the aseismic performance of existing landfills and facilities needs to be considered well and inspected regularly (Figure 7). Recovery scenarios and necessary materials and procedures in case of damage also need to be considered.

**Figure 7 Mixing cement in a landfill for improvement of aseismic performance in Japan (HP of K.E.C. Corporation)**

## 2.5 Treating hazardous substances

A mixture of hazardous substances in disaster waste and in dumped waste causes serious environmental problems. Therefore, it is required to clarify how to treat hazardous substances beforehand.

## 2.6 Securing land space

- Flat and broad space for pre- and post-storage and treatment of disaster waste

**Figure 8 Examples of temporary storage site after the Great East Japan Earthquake**

- Height limitation of waste piles for prevention of spontaneous firing and exotherm (see Table 3 and Figure 9)

**Table 3 Recommended configuration of pile in temporary storage site (MoE 2017a)**

| | Combustible waste | Degradable waste |
|---|---|---|
| Typical waste | Wood, tire, plastics, furniture, and their mixtures | Trimmed branch, litter, (paddy) straw, organic fabric |
| Allowable height of pile | < 5 m | < 2 m |
| Allowable area of pile | < 200 $m^2$ | < 100 $m^2$ |
| Interval between piles | > 2 m | > 2 m |

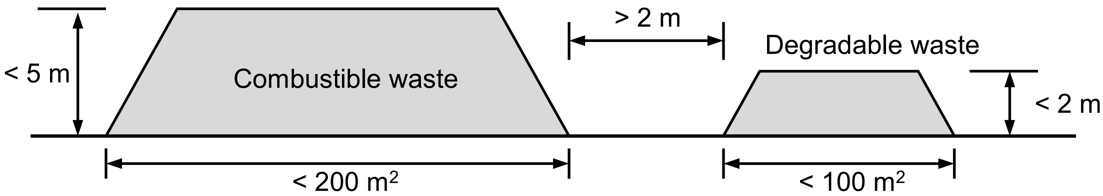



**Figure 9 Sketch of recommended configuration of waste pile (MoE 2017a)**

- Some equations to calculate necessary space for temporary storage site are proposed as follows:

(1) $$S(\mathrm{m}^2) = M(\times 10^3\,\mathrm{t}) \times 87.4(\mathrm{m}^2/\mathrm{t})$$

where: $S$ is necessary area of temporary storage site and $M$ is amount of disaster waste treated.

(2) $$S(\mathrm{m}^2) = M(\mathrm{t}) \big/ \rho(\mathrm{t/m}^3) \big/ H(\mathrm{m}) \times (1+\alpha)$$

where: $S$ is necessary are of temporary storage site, $M$ is amount of disaster waste which needs to be treated, $\rho$ is apparent specific gravity of disaster waste, $H$ is height of waste piles and $\alpha$ is a coefficient for necessary additional space for treatment. $\rho$ of combustible waste and incombustible waste is proposed to be 0.4 t/$m^3$ and 1.1 t/$m^3$, respectively. $H$ should be smaller than 5 or 2, as recommended above. $\alpha$ of 0.8–1.0 is recommended based on the experiences of Japan.

Note: Since disaster waste should be generated continuously (not at the same time) and the waste can be treated gradually, it is also reasonable to secure necessary space for 50% of a total amount of disaster waste.

## 2.7 Considering possible installation of separation (sorting), treatment and utilization techniques

- Various materials mixed each other in disaster waste
- Possible separation (sorting) methods of the mixed disaster waste using daily waste treatment techniques
- To promote the 3R (reduce, reuse and recycle) concept in disaster waste management, separation of materials, such as metals, bricks, crushed concrete, woods, soil, etc. is strongly recommended.
- For such an "advanced" treatment, treatment schemes combining manual separation, machinery separation, and mechanical sieving need to be discussed and prepared.
- When economically and technically possible, additional installation of (temporary) incineration facilities can also help reduction in the volume of disaster waste.

## 2.8 Selecting possible space used as temporary storage sites

Temporary storage sites play a very important role in disaster waste management and prompt recovery of affected areas. It is also reasonable to discuss the necessity of temporary storage site to minimize the total transportation cost, as shown in Figure 10. However, temporary storage sites are basically necessary to remove disaster waste for recovery of affected areas.

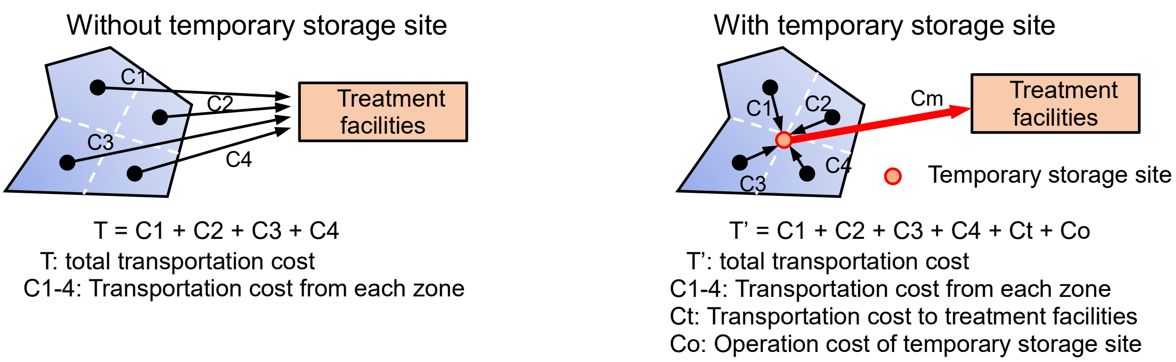



**Figure 10 Models of disaster waste treatment with and without temporary storage site (MoE 2013)**

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## 3 Actions in case of disasters

In this chapter, necessary actions in waste landfills when a disaster occurs are explained. The key point in case of disasters is the prompt implementation of disaster waste management actions which should be planned before disasters. In waste landfills, the daily and total acceptable amount of the disaster waste should be clarified immediately after the disasters, based on a rough estimation of disaster waste generated.

### 3.1 Rough estimation of disaster waste generation

A rough estimation of disaster waste generation needs to be done as the first step after disasters. The estimation should be done based on information of types of disasters, areas, land uses, and buildings, the weight of each material used in the buildings, etc. To estimate the area of affected land, satellite images should be used when available, as shown in Figure 11. Field surveys also give information when satellite images are not available or when the affected zones cannot be judged only by satellite images.


**Figure 11 A satellite image of the damaged house (left) and actual condition (right) (MoE 2017b)**

### 3.2 Health diagnostics of waste landfills and treatment facilities

The soundness of waste landfills and treatment facilities including access roads need to be ensured before accepting wastes. When damages are observed, they need to be promptly repaired.

### 3.3 Securing lands for temporary storage site

Based on the positional relationship of affected areas and possible temporary storage sites which are listed at pre-disasters, temporary storage sites need to be selected appropriately. Before accepting disaster waste, necessary measures to prevent ground contamination and dust generation should be considered.

### 3.4 Designing treatment facilities combining separation (sorting) and crushing

Since it is impossible to newly develop equipment and facilities immediately after disasters, the design of treatment systems combining existing separation and crushing techniques can be a realistic measure for disaster waste treatment. It is also important to flexibly re-design and change the systems in accordance with the characteristics and proportion of disaster waste generated.

### 3.5 Estimating volume of waste dumped into landfills

Non-recyclable items such as incombustible waste and incineration residue need to be landfilled. Hazardous waste including contaminated soils and rocks also needs to be adequately managed and landfilled according to regulations of each country.

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## 4 situation of waste management systems in asian and Pacific Island countries

In Asian countries, waste management systems are getting better and organized in association with their economic growth. However, in most Pacific islands, there are some common features that are quite different from those of industrialized countries. Such features include, but are not limited to, the following:

- Geographical isolation (surrounded by vast ocean and poor access)
- Smallness (small and limited land space)
- Remoteness (far from the international markets)
- Dependency (heavy reliance on imported goods and foreign aid)

## 4.1 Indonesia (as of 2016)

1) Legal framework

- While being obligated by the waste management law of Indonesia, closure of existing open-dumping landfills has not been completed as of 2016.

2) Pick-up and treatment

- Waste is directly delivered to waste landfills.
- Since the public pick-up system of municipal solid waste has not been fully provided, illegal dumping of waste often occurs across the country.
- Securing land space for new landfills is difficult.

3) Environmental problems

- Infestation of mice in landfills
- (Ground)water pollution by toxic leachate
- Cardiorespiratory diseases of residents
- Death of more than 100 people by the collapse of piled waste

**Figure 12 Waste landfill in Kota Palembang, Indonesia (NIES 2016)**

## 4.2 Nepal (as of 2014)

1) Waste management

- The construction of new waste treatment facilities is not enough against the increase in waste generation attributed to the rapid urbanization of many cities.
- Illegal dumping into empty lots and riversides is still being done not only in cities not having landfills but also in cities.
- Because of such inadequate management and operation of waste landfills, environmental pollution is often observed around the landfills.

2) Operation of landfills in Kathmandu (capital)

- The semi-aerobic system (Fukuoka method) is adopted, but leachate is not treated.
- Waste is landfilled without volume reduction such as incineration.
- Gas vent pipes are not installed throughout landfills
- Cover soil is insufficiently installed.
- Fences are not installed at the boundaries of landfills.
- Foul odor often occurs.

**Figure 13 Waste landfill in Kathmandu, Nepal (JICA 2016)**

## 4.3 Thailand (as of 2018)

1) Municipal solid waste management (see Fig. 14)

- The amount of waste generation is increasing due to urbanization.
- The number of improper waste disposal is gradually decreasing every year. In 2018, municipal solid waste of 10.88 million tons out of 27.82 million tons of waste generated was properly treated and disposed.
- While the waste pick-up service is getting well established in Bangkok, such a system has not been fully provided.
- The incineration treatment is also used at the solid waste collecting center in Nhong Khaem, Bangkok.
- In 2018, there were 3205 solid waste disposal and transfer sites, with 2786 sites still in operation and another 419 closed sites.
- There are 35 electric power plants that use waste as their fuel, with a capacity of 313.354 MW altogether, where they produce electricity generated from waste and sell it commercially.
- 2 million tons out of 27.8 million tons of solid waste generated in 2018 was municipal plastic waste.

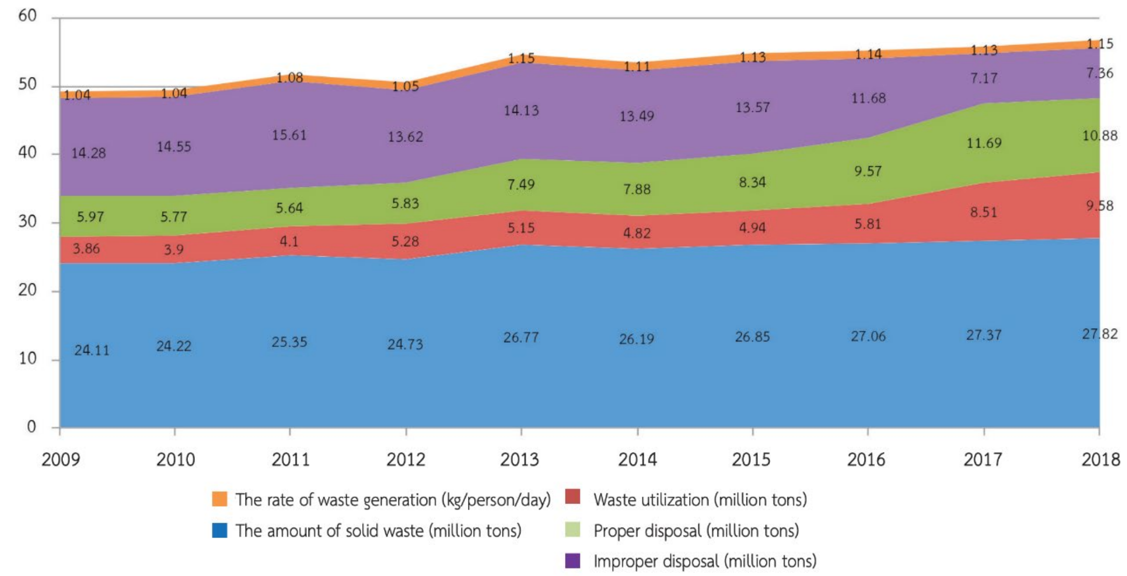


**Figure 14 The proportion of the solid waste generated, re-utilized, disposed appropriately, and disposed inappropriately in 2019-2018, in Thailand (MNRE 2019)**

2) Hazardous waste management

- The amount of municipal hazardous waste generated in 2018 was 638,000 tons, a 3.2% increase from 2017.
- There is still no regulation to separate hazardous waste from general solid waste, as well as regulations that would enforce the private sector to be responsible for waste electrical and electronic equipment.

3) Industrial waste management

- The amount of industrial waste tends to be lower and is being improved by a proper managing system which has the potential to serve all industrial waste countrywide.
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## 4.4 Solomon Islands (as of 2017)

1) Waste management

- Uncontrolled disposal of waste puts pressure on the vulnerable ecosystems and biodiversity of the Island.
- Combustible waste such as kitchen waste and papers are the major waste.
- JICA through the J-PRISM project had been working on the improvement of the Ranadi Landfill with rehabilitation and application of the Fukuoka method (semi-aerobic landfill system) in 2012. The Randi landfill had been an uncontrolled ‘open dump” site without any proper care of leachate, large populations of flies, bad odor, poor road access, and no site management.
- The Radani landfill is the only landfill in Honiara and accepts all types of waste with a

daily disposal amount of about 50 tons in the acceptable area of 400 ha.

- It is difficult to obtain appropriate soil as cover soil.

**Figure 15 Development of the Fukuoka system at Ranadi (MECDM 2019)**

2) Challenges and issues

- Stakeholders in the Solomon Islands answered the major challenges and issues related to waste management in 2015, as shown in Figure 16.
- All provincial centers faced challenges with the allocation of land and/or designation of the proper landfill. Another challenge is the fact that provincial land may not be large enough to include a landfill within its boundary, and thus, the province may find difficulties in convincing customary landowners to use their land as a landfill. Financial resources and human resources are also limited in any provinces.
- To cultivate awareness of waste management in public, educational activities are often held with the leadership of the government.

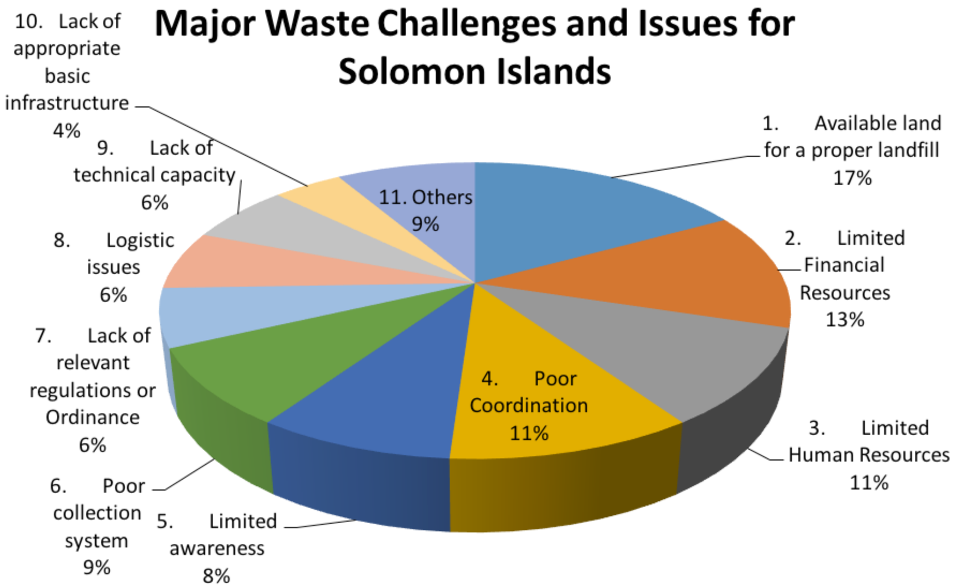


**Figure 16 Major waste challenges and issues for Solomon Islands (MECDM 2019)**

## 4.5 Samoa (as of 2018)

1) Waste landfills

- The Tafaigata landfill in Upolu has been transformed from a messy, smelly dump to a clean and fresh semi-aerobic landfill structure using the Fukuoka method with the aid of JICA and SPREP, as shown in Photo 17.
- Samoa's Ministry of Natural Resources and Environment constructed another semi-aerobic sanitary landfill on Savai'i island with its own budget, technically supported by the training participants. (ADB 2014)

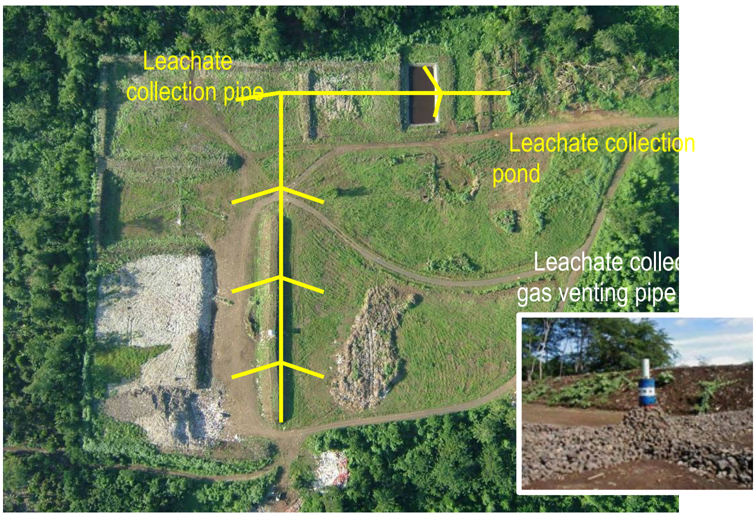


**Figure 17 Application of the Fukuoka method to Tafaigata landfill (edited from SPREP 2018)**

2) General issues about the waste management

- Organic and degradable wastes account for more than 60% of the total municipal solid waste which frequently causes spontaneous firing in landfills. Each of papers, plastics, glass, and metals account for 6-12%.
- While being picked up every day in rural areas, wastes are picked up every two weeks in rural areas.
- According to the MNRE, Samoans generate per capita about 175 kg of waste per annum in the Apia urban area, and 130 kg, per capita, per annum in rural areas. Household waste is composed mostly of organic refuse, but plastics and other inert materials also constitute a significant and growing share of waste output.
- The government has adopted include fining companies and individuals for dumping waste illegally, improving waste collection systems

## 4.6 Fiji (as of 2018)

1) Waste landfills

- In most landfills in Fiji, anaerobic open dumping is still the major landfilling system.
- After opening the Naboro landfill in 2005 with the financial aid of the European Union (EU), the waste management system and legal frameworks in Fiji have been steadily improved.
- At the Naboro landfill where the anaerobic sanitary system is adopted, leachate from the waste body is collected and treated on-site, to achieve the standards listed in Table 4. A truck scale is installed to measure the weight of trucks before and after dumping.
- The Naboro landfill is owned by the government of Fiji and has a life of more than 70 years (ADB 2014).

**Figure 18 Waste in the Naboro landfill**

**Table 4 National wastewater discharge standards in Fiji (EMA Regulations 2008)**

| | Unit | Standard |
|---|---|---|
| pH | | 7-9 |
| Oil&Grease | | No visible |
| BOD | mg/L | 40 |
| SS | mg/L | 60 |
| TDS | mg/L | 1000 |
| Fecal Coliform | c/100mL | 400 |
| Sulphate | mg/L | 500 |
| Total N | mg/L | 25 |
| Ammonia | mg/L | 10 |
| Total P | mg/L | 5 |
| Iron | mg/L | 5 |
| Arsenic | mg/L | 0.05 |
| Cadmium | mg/L | 0.05 |
| Lead | mg/L | 0.05 |
| Mercury | mg/L | 0.02 |
| Zinc | mg/L | 1 |

2) General issues about the waste management

- Food and kitchen wastes account for about 50% of the total municipal solid waste in the Great Suva region.
- Municipal solid waste is stored by residents and commercial establishments in small bins (generally of 60-liter capacity).
- Illegal dumping and burning of waste are still common due to inadequate enforcement.
- There is no large-scale treatment facility at either Naboro or Suva for the high proportion of organic waste.

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