Summary Version

Semi-aerobic Landfill Concept

Guide to Introducing The Fukuoka Method

< Semi-Aerobic Landfill Method >

for Final Waste Disposal Sites

Fukuoka Prefecture

1 Overview of the Fukuoka method

1.1. History of the Fukuoka method

The Fukuoka method (semi-aerobic landfill method) for final waste disposal sites (hereinafter, the “Fukuoka method”) was invented by Professor Emeritus Masataka Hanashima of Fukuoka University and put into practical application in cooperation with Fukuoka University and Fukuoka City. In Japan, the Fukuoka method was first put into practical application in 1975 at the Shin-Kamata landfill site in Fukuoka City, and in 1979 it was adopted as the standard design for Japan's final landfill site guidelines.

1.2. Structural overview of the Fukuoka method

Fig.1 shows a structural diagram of the Fukuoka method. The Fukuoka method is a final waste disposal site mainly composed of a gas venting system, leachate collection and discharge system, leachate treatment system, rainwater collection and drainage system, and groundwater collection and discharge system. In this method, a leachate collection and discharge system consisting of stone rubble and perforated pipes is installed at the bottom of the landfill, so leachate in the waste layers is promptly drained to the leachate treatment system, and thermal convection occurs due to fermentation heat generated by decomposition of waste inside the layers.

This design reduces the moisture content inside the layers, with air being naturally supplied from the leachate collection/discharge pipes, which promotes decomposition of waste while maintaining the interior in an aerobic state.

In other words, compared to conventional an anaerobic landfill method, this technique improves the water quality of leachate, suppresses greenhouse gas emissions, reduces the amount of hydrogen sulfide and volatile organic compounds generated, and enables early stabilization of landfills.

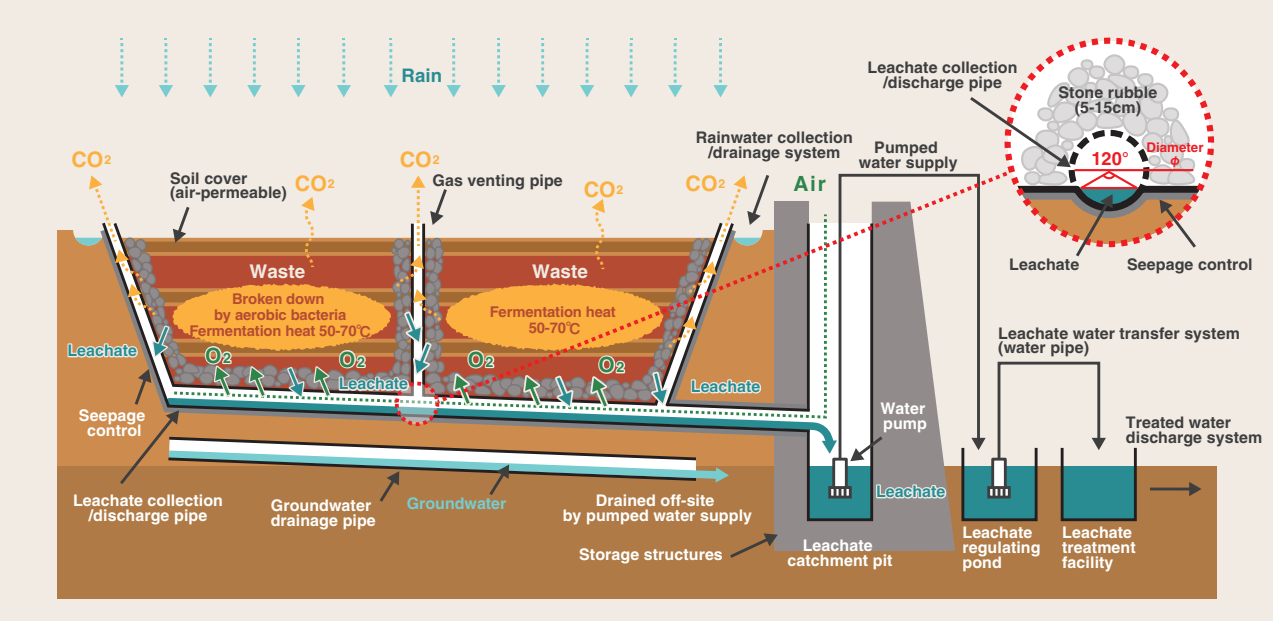


Fig. 1 Structural diagram of Fukuoka method for final waste disposal sites (created by Fukuoka Prefecture)

Items sent to the Fukuoka method disposal sites should not include hazardous waste items, such as medical waste. It is also desirable that garbage such as food waste is mainly treated as raw waste, and also that waste does not contain a significant proportion of plastic, glass, ceramics, or the like. In addition, sharp objects should be removed because they can damage the seepage barrier sheeting.

To this end, depending on the properties of the waste, it is effective to introduce a waste separation process before burial at the final disposal site, and to carry out awareness-raising activities among local residents for waste separation.

1.3. Advantages of the Fukuoka method

As shown in Fig. 2, in the anaerobic landfill method, which is widely used in developing countries, the landfill layer has an anaerobic atmosphere, there are not only problems in terms of sanitation, such as deterioration of leachate water quality and odors caused by generation of hydrogen sulfide—there is also the risk that generation of methane gas will trigger fires or explosions in the landfill.

However, with the Fukuoka method, air naturally flows into the landfill layer through the leachate collection/discharge pipes, so that an aerobic atmosphere is maintained, and generation of methane gas and hydrogen sulfide is suppressed by vigorous microbial activity. As a result, an odor-improving effect can be expected and the landfill can be stabilized at an earlier stage.

In addition, since the design prevents leachate accumulating inside the landfill layer, this method can be expected to improve the water environment both inside and outside the disposal site, compared to the anaerobic landfill method.

Furthermore, by undertaking appropriate maintenance management, the final waste disposal site can be stabilized at an earlier stage and the costs of spraying chemical agents as part of maintenance management can be reduced.

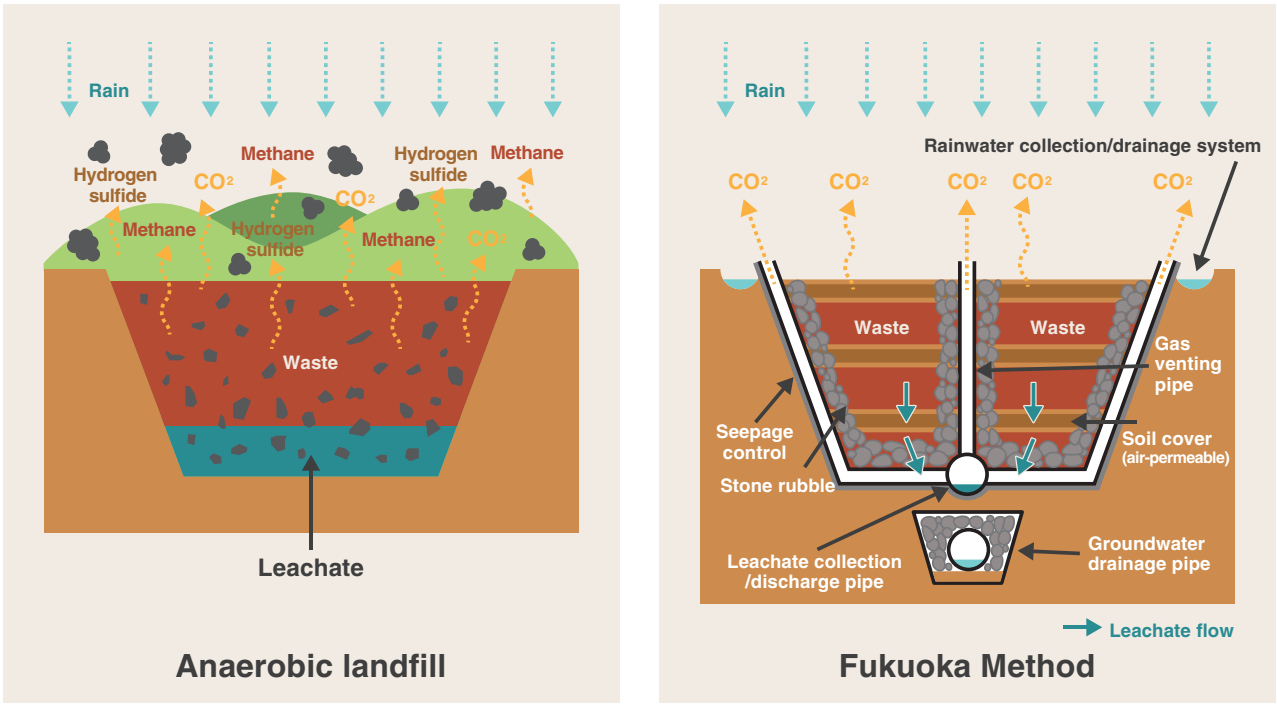


Fig. 2 Structural diagrams of Fukuoka method and anaerobic landfill method (created by Fukuoka Prefecture)

1.4. The Fukuoka method deployed outside Japan

After the Fukuoka method was adopted as the standard design for final disposal sites in Japan, the overseas deployment of this method commenced, starting with Malaysia.

To date, the Fukuoka method has been introduced in more than a dozen countries. In 2011, the method was recognized as one of the Clean Development Mechanisms (CDM) under the United Nations Framework Convention on Climate Change (UNFCCC).

As part of its commitment to international environmental cooperation, in response to requests from overseas, Fukuoka Prefecture has been providing support for the introduction and maintenance of the Fukuoka method, which is the standard method for final disposal sites in Japan. To date, support has been provided in the city of Hanoi in Vietnam and the district of Sikhio in Thailand.

2 Current situation and issues related to final waste disposal sites in Asia

The amount of waste generated in the Asian region is increasing due to rapid population growth and economic development. In countries and regions where generation of waste has increased sharply, cases of environmental pollution and associated health damage at disposal sites have been observed due to lack of proper waste management.

Across the Asian region, the state of development of waste-related legal systems varies for each country and local government, and the state of disposal methods also varies.

The graph in Figure 3 shows the state of waste disposal in East Asia and Oceania. Recycling, incineration, and other means of disposal account for only 35% of the total, with the majority of waste going to landfill. Direct landfill accounts for 46% of the total and open dump for 18%, with less than 1% going to semi-aerobic landfill. It can be seen that anaerobic landfill methods such as open dumping are predominant in many Asian countries, including the state of landfills in Vietnam and Thailand.

The Philippines and Indonesia are taking measures to ban open dumping.

Next, regarding the composition of household waste in Vietnam, according to the case of Hội An City in central Vietnam, the ratio of kitchen waste and plants (organic waste) is extremely high, accounting for 67.2% of the total. Looking at the composition data for household waste in Thailand, the proportion of organics is also extremely high, accounting for 64% of the total.

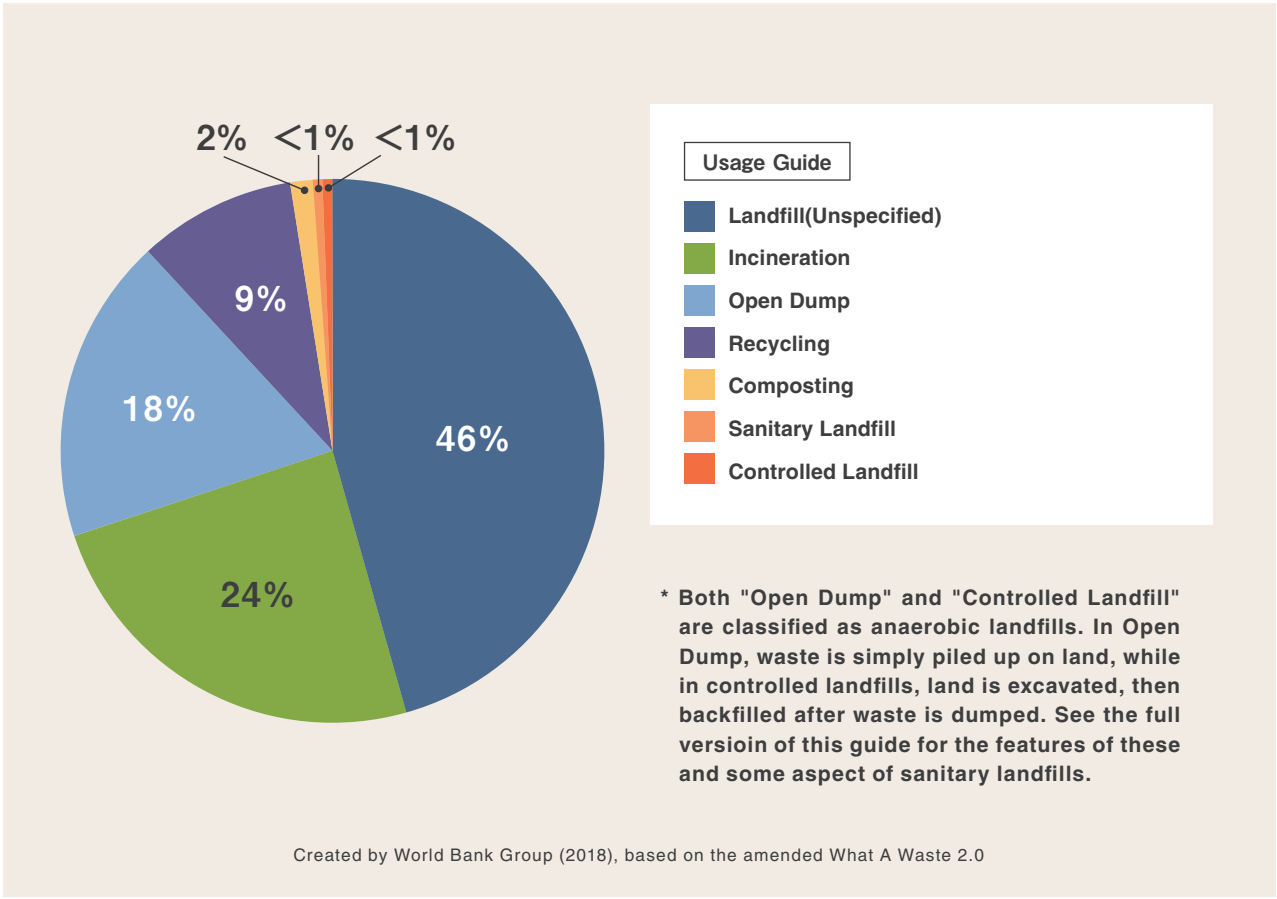


Fig. 3 Status of waste management in East Asia and Oceania

3 Basic conceptual points for introducing the Fukuoka method

3.1. Methods of managing final waste disposal sites

Final waste disposal sites are owned, financed, designed/constructed, operated, and dismantled by governments (including local governments) or private companies.

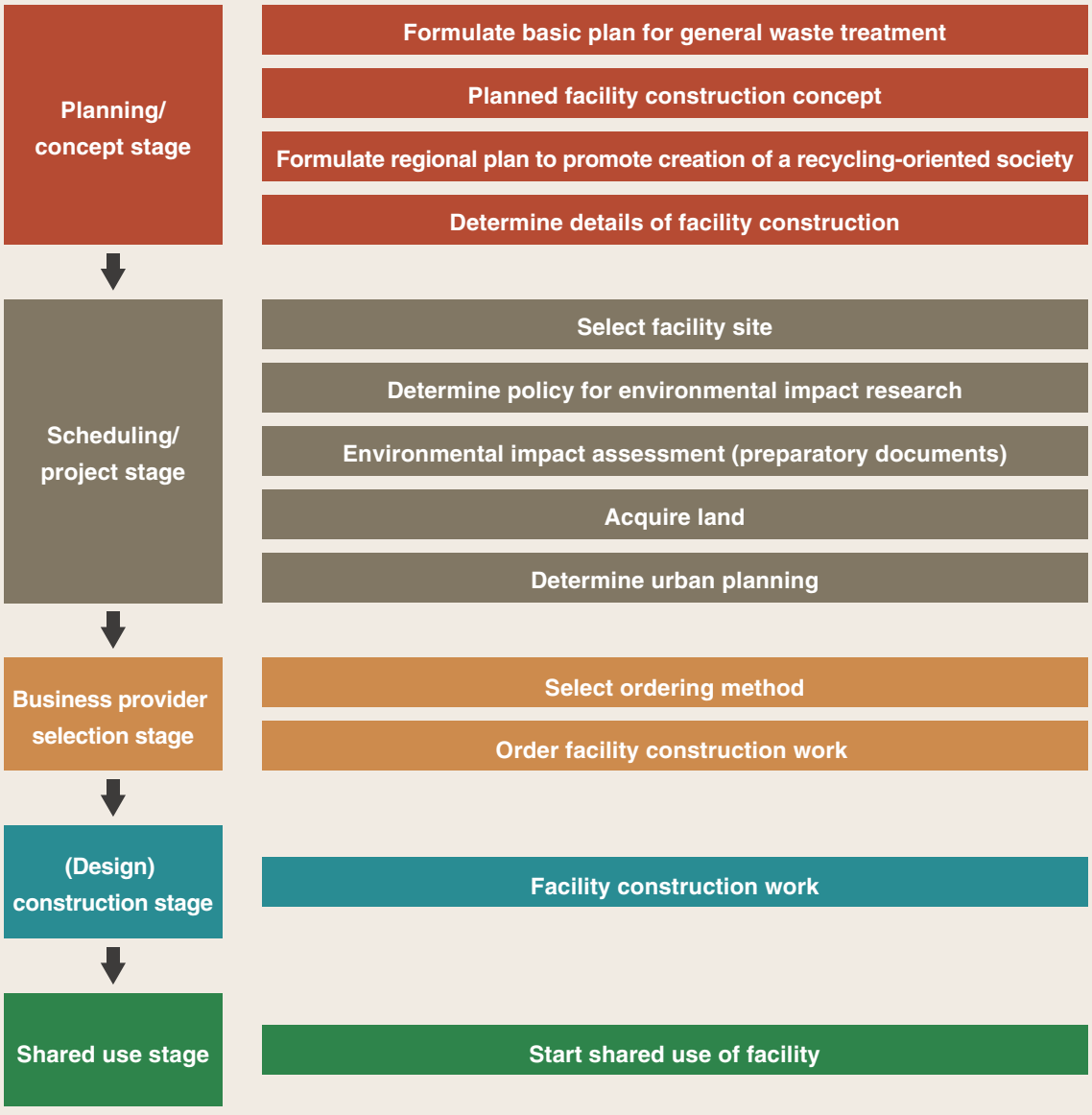
Public-private partnerships that provide public services are also known as PPP. PFI (Private Finance Initiative) is a typical PPP method. Its intention is to provide efficient and effective services by having the private sector take a leadership role in ownership, financing, design/construction, operation, and dismantling of public facilities and other facilities.

3.2. Steps and procedures for establishing final waste disposal sites

Steps and procedures related to final waste disposal sites vary, depending on the country where the waste is disposed.

In Japan, consideration moves forward as shown in Fig. 4. The procedures for setting up a final waste disposal site can be broadly classified into the planning/concept stage, the scheduling/project stage, the business provider selection stage, the (design) construction stage, and the shared use stage.

The main procedures for construction of disposal sites include the formulation of a basic plan for general waste treatment based on the Waste Disposal Act, the implementation of an environmental impact assessment, and the ordering of facility construction work.



Created by the Japan Waste Management Association (2010), based on the amended 2010 planning, design, and management guidelines for the development of final waste disposal sites improvement

Fig. 4.Items and details for implementation of final waste disposal site facilities improvement in Japan

Please refer to the Full Version of this guide for steps and procedures in Vietnam and Thailand.

3.3. Site selection

The laws and regulations relating to the selection of suitable sites vary from country to country. Therefore, when planning a final waste disposal site, it is essential to check local laws and procedures for selecting suitable sites before proceeding.

An example of suitable site selection survey flow is shown in Fig. 5 below. When selecting a suitable site in Japan, the legal and regulatory status of land use should first be checked and the candidate facility sites extracted.

Based on the results of this first stage, candidate sites that satisfy the geographical conditions are extracted into the second stage. In the third stage, any candidate sites that present planning difficulties are excluded, taking into account field surveys, economic evaluations, etc. Finally, each of the extracted candidate sites is evaluated, and a final candidate site is selected.

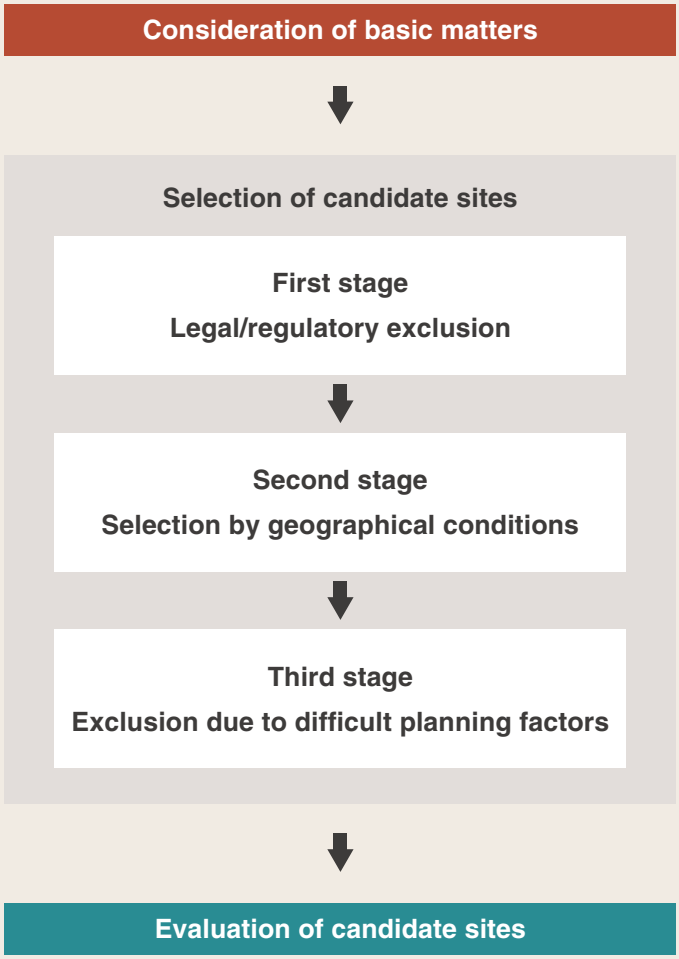


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Fig. 5 Example procedure for selecting candidate sites

Please refer to the Full Version of this guide for the relevant laws and procedures in Vietnam and Thailand.

3.4. Environmental impact assessment

The objective of conducting an environmental impact assessment is to assess the potential impact on surrounding areas that may arise from the construction of a treatment facility. For environmental impact assessments, the basic flow involves conducting surveys during the construction period, the landfill implementation period, and after the landfill is completed; however, the surveyed items will vary depending on the country and local authority, and each country's standards should be met. This section will introduce some examples from Thailand and Vietnam.

In Thailand, impact assessments are conducted in regard to the following four aspects of environmental resources. Analysis is conducted based on these aspects, and the impact on the surrounding environment is evaluated.

- Physical Environmental Resources
  Air quality, surface water quality, groundwater sources, topography, etc.
- Biological Environmental Resources
  Forest resources, wildlife, etc.
- Human Use Values
  Land use status, public transportation, use values of water sources, etc.
- Quality of Life
  Economic status, neighboring communities, workplace safety, public health, landscape and recreation, etc.

Chapter Ⅲ: Environmental Impact Assessment in Vietnam's basic law regarding waste (Law on Environmental Protection: Law No. 55/2014/QH13) stipulates the items for impact assessment and prediction as follows.

- Natural environmental conditions
  Climatic and weather conditions, hydrological and marine conditions, soil, water, and atmospheric environment quality, biological resources, etc.
- Socio-economic conditions
  Economic conditions, social conditions
- Environmental impact prediction
  Predictions of impact during the project's preparation, construction, operation, and any other phases (dismantling, renovation, etc.)
  Prediction of project risks and impact due to incidents

3.5. Building consensus with neighboring residents

It is assumed that obtaining the approval of local residents at the final disposal site will be difficult, due to environmental and technical concerns, among others. Accordingly, it is important to explain to the residents the details of the plan, methods of introduction, environmental impact, countermeasures against environmental impact, etc., and to reach consensus. In actual consensus building, responses should follow the deliberative process of each local authority.

Different countries have different laws. For example, Vietnam has Decree 40/2019/ND-CP (No. 40/2019) under the Environmental Law, which is a law about explaining to residents. In Thailand, details of conducting public hearings with residents are stipulated in the Special Item 55 of 122 of Royal Thai Government Gazette.

4 Sequence of points and items to implement from initial design to use of former landfill site

4.1. Design

When designing and constructing sites following the Fukuoka method, various consideration is required in advance to prevent any impact on public health, hygiene, and the environment surrounding the disposal site. This section describes matters that need to be considered at the design stage: (1) Estimation of required landfill capacity; (2) Basic structural design; (3) Design of gas venting equipment; (4) Design of leachate collection and discharge equipment; (5) Design of leachate regulating ponds; (6) Design of leachate treatment facilities; (7) Design of rainwater collection and drainage facilities; (8) Design of groundwater collection and drainage facilities; (9) Design of seepage barrier works; and (10) Storage structures.

Please refer to the Full Version of this guidebook for details.

4.2. Construction

This section describes matters that need to be considered at the construction stage of the Fukuoka method: (1) Construction on sloping areas; (2) Ground survey; (3) Ground improvement; (4) Groundwork shaping; (5) Groundwater drainage system; (6) Seepage barriers; (7) Leakage collection/discharge pipes; (8) Gas venting equipment; (9) Water catchment pit; and (10) Stormwater drainage ditch, as well as giving examples of construction in Japan.

Please refer to the Full Version of this guide for details.

4.3. Maintenance management

At disposal sites using the Fukuoka method, it is necessary to maintain an aerobic atmosphere in the landfill layers by draining leachate and to carry out appropriate maintenance to lower the BOD value of leachate, thus stabilizing the landfill as soon as possible. The leachate collection/discharge pipes, which facilitates ventilation, water flow, and drainage, and the stone rubble layers, are important elements of maintenance management. This section describes the policies and aspects that should be kept in mind when carrying out various maintenance operations: (1) Intake management; (2) Landfill; (3) Soil cover; (4) Monitoring; and (5) Rainwater drainage treatment, etc.

Please refer to the Full Version of this guide for details.

4.4. Landfill completion, abolition, use of site

It is important to take into account that the properties of final waste disposal landfill sites will change over time due to the wide variety of landfill waste.

The main expected items for monitoring after landfill is complete include leachate, landfill gases, land subsidence, surrounding groundwater, and the management status of decomposition and stabilization of waste. Continuous monitoring of these items can be expected to improve the system efficiency of the disposal site as a whole. Monitoring should be continued until it is confirmed that there is no impact on the surrounding environment.

One advantage of the Fukuoka method is that sites can be used earlier because the period until stabilization is shorter than with other landfill methods (anaerobic landfill methods, etc.). In Japan, this method is used not only for greening, but also for public facilities, including sports facilities and multipurpose plazas, and sites for solar power plant.

Photo: Example utilization of former landfill site (Solar power plant: DINS Mega Solar)

Photo courtesy of Daiei Kankyo Holdings

5 Overseas case studies of introduction of the Fukuoka method

5.1. Status of international cooperation

The Fukuoka method is introduced outside of Japan by dispatching experts, accepting trainees and observers, providing technical guidance, and holding seminars, whether independently or as part of international cooperation efforts. International cooperation efforts are conducted not only by Fukuoka Prefecture but also by various organizations such as Fukuoka City, the Japan Environmental Sanitation Center (JESC), and the Japan International Cooperation Agency (JICA).

Instances where Fukuoka Prefecture has supported the introduction of the Fukuoka Method as part of international cooperation efforts include the Xuân Son landfill site in Hanoi, Vietnam (completed in 2015), and the Fukuoka method waste landfill site in Sikhio District, Nakhon Ratchasima Province, Thailand. Overviews of these disposal sites and some details of introduction can be found below.

5.2. Hanoi, Vietnam

5.2.1. Background to introduction of the Fukuoka method

The background to introduction of the Fukuoka method at the Xuân Son disposal site in Hanoi, Vietnam, is as follows.

In Hanoi, waste disposal has become a serious problem following economic development, and proper waste disposal has become a priority, especially in rural areas. Ways to develop and improve sanitary final landfill sites were sought.

Fukuoka Prefecture and Hanoi City signed an environmental cooperation agreement in 2010, and introduction of the Fukuoka method in Hanoi City was considered as a priority project for exchange of environmental technology. Based on this history, it was decided that a final waste disposal site in Hanoi would be constructed using the Fukuoka method under the guidance of the method's inventor, Emeritus Professor Masataka Hanashima of Fukuoka University. Utilizing a grassroots technical cooperation program from JICA, support was provided, which involved training of staff invited from Hanoi City to Fukuoka Prefecture and dispatching Japanese experts to offer on-site guidance.

Table 1 History of introduction at the Xuân Son disposal site

Year	Event
2008	In February, a friendship agreement was signed with Hanoi City
2009	In December, an environmental study team was dispatched to propose measures to improve environmental problems in Hanoi
2010	In October, an environmental cooperation agreement was signed with Hanoi City
2012	In February, experts conducted a field survey of candidate sites for introducing the Fukuoka method
	In July, Hanoi City made the decision to introduce the Fukuoka method
2013	In August, a memorandum of understanding was signed with Hanoi City regarding development of the Fukuoka method waste disposal site
	In December, a JICA grassroots technical cooperation project commenced: "Project Enhancing Development of Sanitary Landfill in Hanoi" (until December 2016)
2014	In June, work on the Xuân Son disposal site commenced
2015	In June, work on the Xuân Son disposal site was completed
2018	In November, the Xuân Son landfill reached its planned capacity and landfill was complete
To present	Implementing management and monitoring of gas venting pipes, etc. for earlier stabilization of landfill site

5.2.2. Overview of disposal site

An overview of the Xuân Son waste disposal site can be found below.

Table 2 Overview of Xuân Son disposal site

Location of disposal site	Sơn Tây district in Hanoi City Xuân Son disposal site
Scale of disposal site	Area 3 ha (Waste disposal amount 300 t/day) Landfill capacity about 240,000 m3
Implementation status of the project	Completed in June 2015 Technical guidance provided for maintenance management and monitoring Landfill completed in November 2018
Total construction cost	54.2 billion đồng (cost borne by Hanoi City, Vietnam)

The Xuân Son waste disposal site is located about 90 minutes (about 60 km) west of Hanoi by car. The landfill area of the Fukuoka method final disposal site is 24,000 m2 and landfill capacity is 240,000 m3. Most waste disposed here is flammable waste. According to site staff, introduction of the Fukuoka method has been effective in improving unpleasant odors and pests.

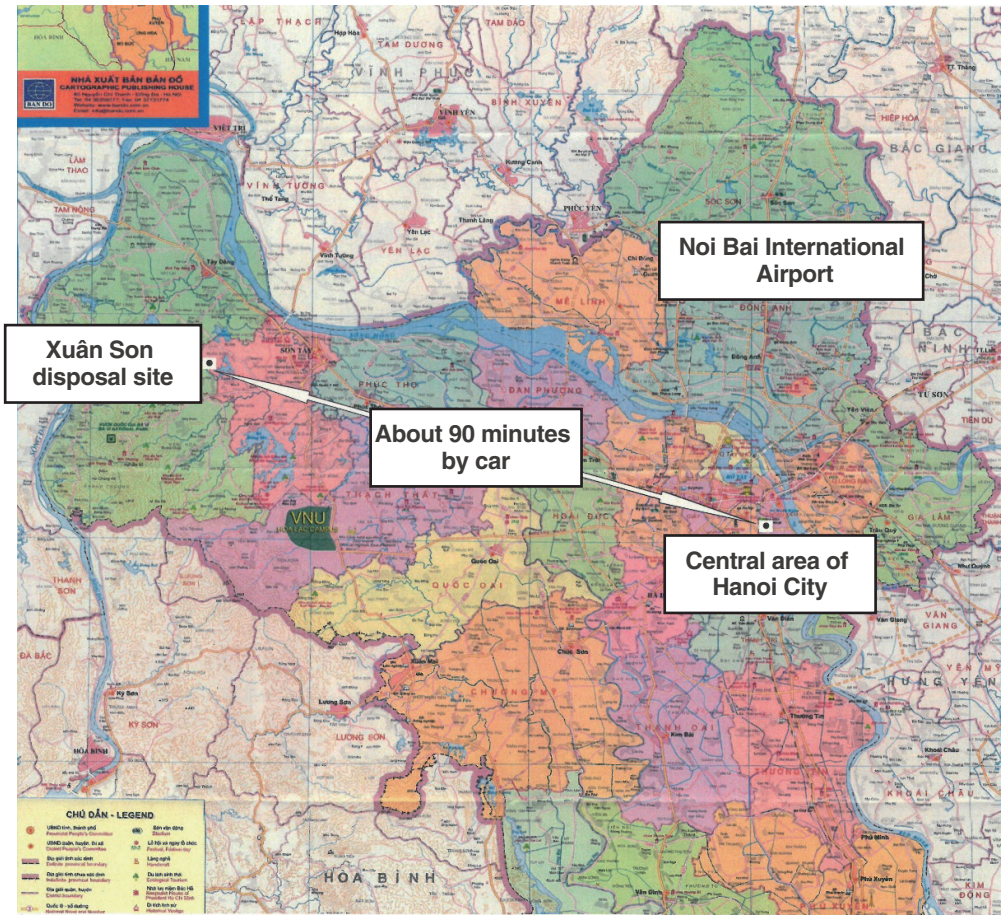

Fig. 6 Map location of disposal site (data from Fukuoka Prefecture)

Construction complete (June 2015)

Landfill complete (as at August 2019)

In June 2015, work on the Xuân Son disposal site was completed. After completion of construction, the site operated smoothly and reached its landfill capacity in November 2018.

After completion of the landfill, management and monitoring of gas venting pipes, etc. is now underway to stabilize the landfill site as early as possible.

5.3. Sikhio District, Thailand

5.3.1. Background to introduction of the Fukuoka method

The history of introducing the Fukuoka method in Sikhio District, Nakhon Ratchasima Province, Thailand, is as follows.

Since 2006, Fukuoka Prefecture has been conducting international environmental human resource development training for government officials in various Asian countries and has invited many Thai government officials as participants. Upon returning to Thailand after taking part in this training in Japan, a government official from the Pollution Control Department in the Ministry of Natural Resources and Environment proposed introduction of the Fukuoka method. Its adoption was decided by the country, and Fukuoka Prefecture was asked to provide support.

In response to this, Fukuoka Prefecture provided support while utilizing the JICA Grassroots Technical Cooperation Project, including inviting Thai government officials to Fukuoka Prefecture for training and dispatching experts to offer on-site guidance.

Table 3 History of introduction at the Sikhio disposal site

Year	Event
2009	A trainee from the Pollution Control Department (PCD) in Thailand's Ministry of Natural Resources and Environment participating in the international environmental human resource development training toured the Fukuoka method disposal site. After this, the Thai government officially requested the prefecture to provide support.
2012	In April, JICA Grassroots Technical Cooperation Project commenced: "Waste Landfill Planning Assistance for Thailand" (Phase I) (until March 2015)
2014	In September, work on the Sikhio District disposal site commenced
2015	In September, work on the Sikhio District disposal site was completed
2016	In March, a plan was formulated for operation and maintenance management of the Sikhio District disposal site
	In August, an environmental cooperation agreement was signed with PCD
	In September, operations commenced at the Sikhio District disposal site
2017	In April, JICA Grassroots Technical Cooperation Project commenced: "Support for the Construction of Proper Waste Treatment Processes in Kingdom of Thailand" (Phase II) (until March 2020)
To present	The landfill site is properly managed and maintained and is operating smoothly

5.3.2. Overview of disposal site

An overview of the Fukuoka method final waste disposal site in Sikhio District can be found below.

Table 4 Overview of the Sikhio District disposal site

Location of disposal site	Sikhio District, Nakhon Ratchasima Province * Adjacent to existing anaerobic landfill site
Scale of disposal site	Site area: 18,712 m2 Landfill area: 2,496 m2 Landfill capacity: 6,966 m2
Implementation status of the project	Construction complete: September 2015 Operation started: September 2016 Landfill period: 10 years (planned)
Total construction cost	Approximately 9.2 million baht (cost borne by Sikhio District)
Landfill method	Cell method
Landfill target waste	Household waste (no incineration, waste separated)
Water treatment	Aeration method

Sikhio District is located about 350 km northeast of Bangkok, about 4.5 hours' travel by car.

The Sikhio District landfill is a small-scale experimental landfill formed of layers about 50 cm deep, with 9 layers of landfill. The city consists of 19 villages and 6 schools (approximately 20,000 people), but only 3 villages and 6 schools (approximately 11,000 people; current intake: about 1 ton/day) are eligible to bring waste to the disposal site.

According to local staff, introduction of the Fukuoka method has been effective in improving unpleasant odors, pests, and birds. Sikhio District also recognizes that it will play a role as a learning center for other municipalities based on its success story with the Fukuoka method.

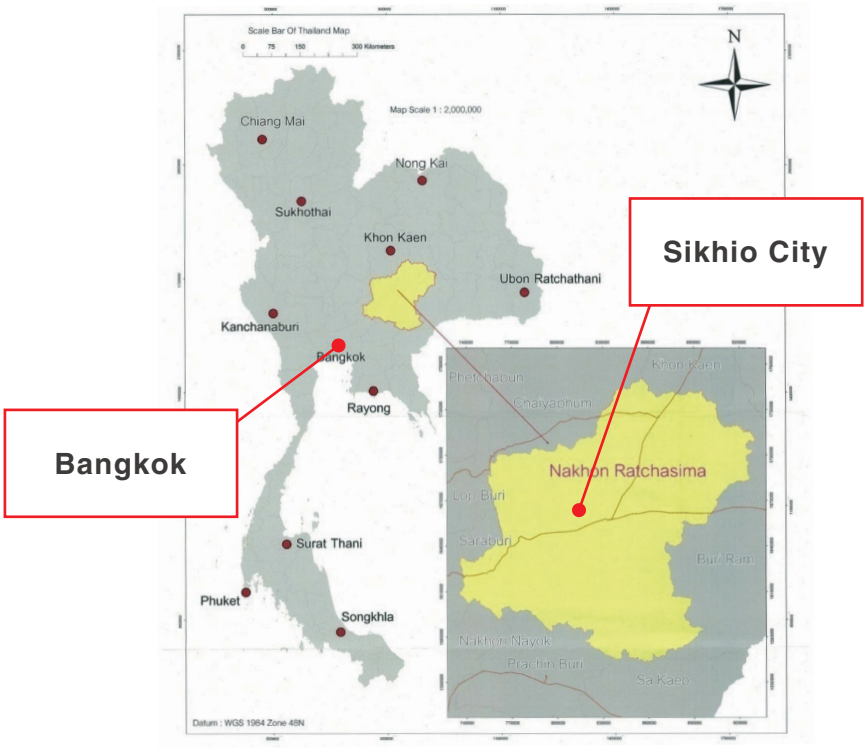

Fig. 7 Location of disposal site (data from Fukuoka Prefecture)

Completion (September 2015)

Status of disposal site (as of October 2019)

After completion in September 2015, the site has been properly maintained and is operating well (as of October 2019). The Thai government, which holds a high opinion of the Fukuoka method as used in Sikhio District, intends to continue spreading the Fukuoka method throughout Thailand.

Fukuoka prefectural mascot,
Ecoton

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