Environmental Symbol Character
[Ecoppa]

Ecoppa holds up a hand with “F”, capital letter of Fukuoka City, looks over the world to protect the environment.

Our Aggressive Commitment to Achieve Co-Benefit (mutually beneficial) CDM stands for our project-based great efforts to achieve the reduction of green house gas, and simultaneously solve water pollution, air pollution and environmental problems caused by wastes.

Idea behind the front-page design

“The Fukuoka Method” is based on the landfill method that concerns for the environment, so we demonstrate concrete image of “sky, ground and green” to express “earth-friendly”. We also emphasize the aspect of clean and safe image of the Fukuoka Method by the picture of the appearance of the floral stem that explain the landfill is used for green field and playground afterward.

■ Editorial Supervisor/
Fukuoka University

Published in March, 2013.
Fukuoka City Environmental Bureau Facilities Section
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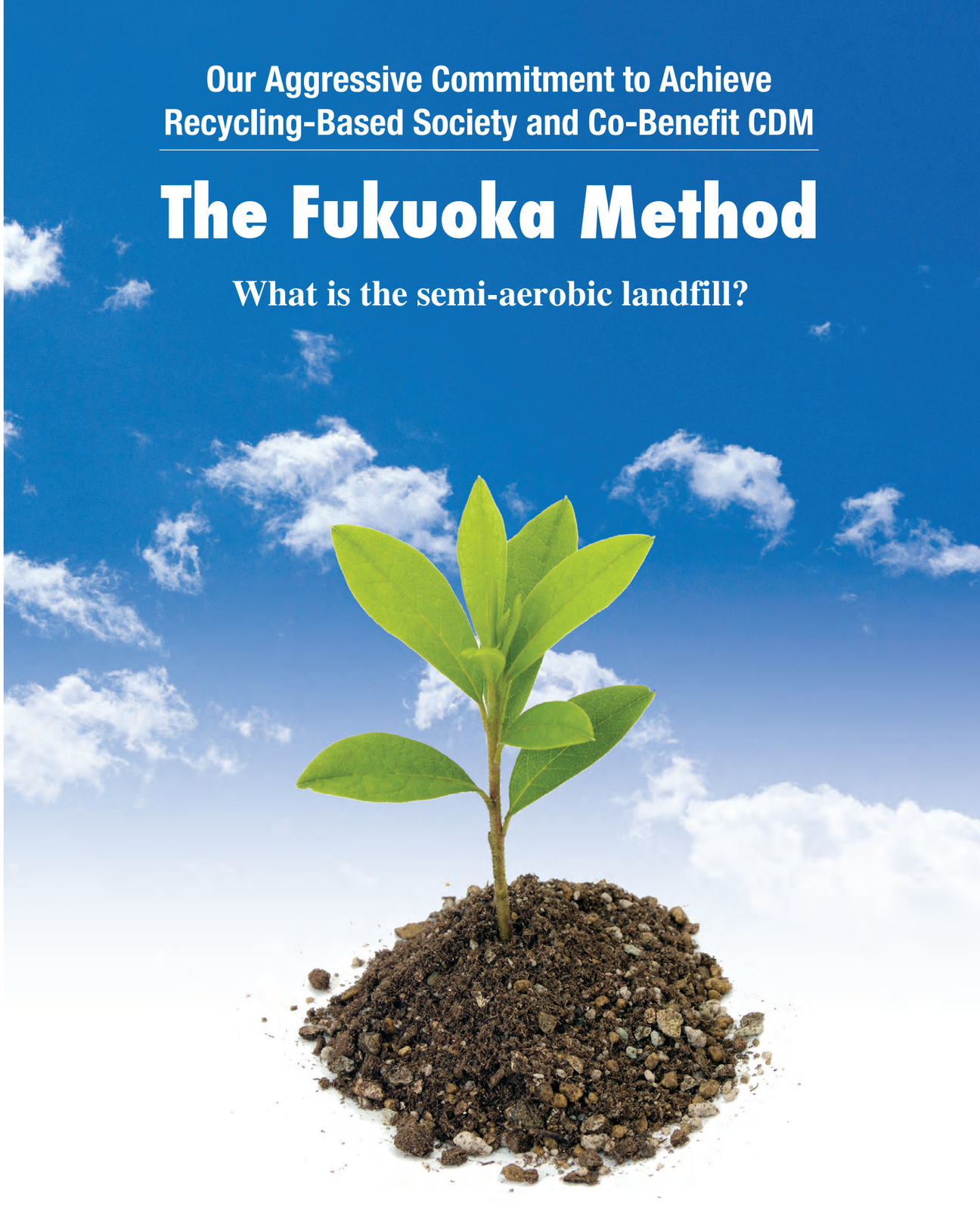
Recycle paper is used.

Our Aggressive Commitment to Achieve Recycling-Based Society and Co-Benefit CDM

The Fukuoka Method

What is the semi-aerobic landfill?



Fukuoka City Environmental Bureau JAPAN

Nakata Landfill in Fukuoka City, by semi-aerobic landfill method (2013)

Landfill area
(Photo provided by Fukuoka Fire Prevention Bureau)

The Fukuoka Method (semi-aerobic landfill) attracts the attention of the world.

I. What is the Fukuoka Method?

①Development outline: Cooperation between Fukuoka City and Fukuoka University

The semi-aerobic landfill structure is an innovative landfill technology originally developed by Dr. Masataka Hanashima, a current professor emeritus of Fukuoka University, who successfully completed this new technology after studying the results of the joint experiments with Fukuoka City.

Back in 1970s, Fukuoka City was seriously suffering from polluted dirty leachate or drain, nasty smell and other environmental problems from its kitchen-garbage-composed-landfill sites. In order to purify such leachate, Fukuoka City, in collaboration with Fukuoka University, started experimental studies on improving the quality of the landfill sites. They carried out a large-scale joint experiment in Hisayama Landfill Site for three years from 1973, and Dr. Hanashima suggested the basic idea of semi-aerobic landfill structure on the basis of its results. His concept was successfully put into practical use in Shin-Kamata Landfill Site that was newly built in 1975. Then, this system of semi-aerobic landfill structure was adopted in local landfill sites all over Japan. In 1979, the Administrative Guideline on Final Disposal Sites was established by former Health Welfare Ministry (currently Ministry of the Environment), and semi-aerobic landfill structure was newly adopted in the guideline as the standard landfill structure to be used in landfill sites. Since then, semi-aerobic landfill structure has been called "the Fukuoka Method." Fukuoka City, in collaboration with Fukuoka University, has been receiving overseas trainees from and sending Japanese experts on this system to Asia Pacific and other regions in the world. Thus, Fukuoka City has been making international cooperation in improving landfills and promoting other environmental preservations.

Back in July 2011, the quality improvement of existing landfill sites by use of the Fukuoka Method (semi-aerobic landfill structure) was newly certified as an innovative method of Clean Development Mechanism (CDM) that is specified in United Nations Framework Convention on Climate Change.

Experiment with the landfill model at Fukuoka University (1974)

The first semi-aerobic landfill in Japan (Shin-kamata) (1975)

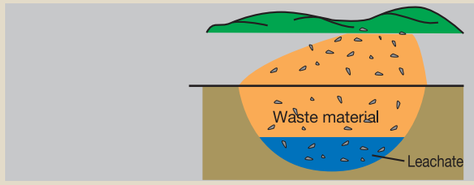
Field experiment at Hisayama Landfill (1974)
Left: Aerobic landfill, Right: Semi-aerobic landfill

②Types of Landfill Structure

Landfill sites have been classified into five types(*), based on the microbial environments existing in the landfill layers. Under an aerobic condition of landfill layers, the level of leachate pollution is decreased and the amount of gases like methane or hydrogen, is also decreased at the same time, and it's obvious that the stabilization of waste landfill at the early stage.

Fig-1 Classification of landfill structure (shows three main structures out of five)

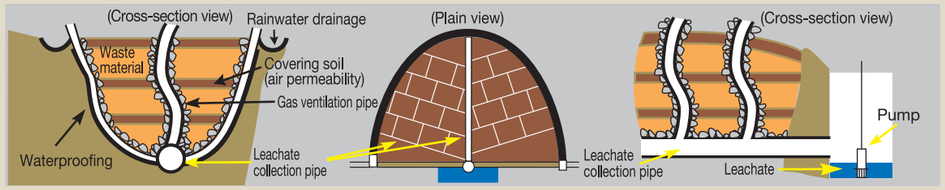
Anaerobic landfill



This is formed by excavating flatland, or wasting disposal into valley. It keeps flood the waste materials with water and anaerobic.

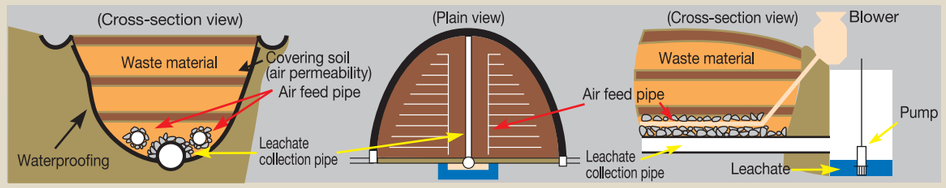
***Five types of landfill structure**
1. Anaerobic landfill
2. Anaerobic sanitary landfill
3. Advanced anaerobic sanitary landfill (Advanced sanitary landfill)
4. Semi-aerobic landfill
5. Aerobic landfill

Semi-aerobic landfill



It is the structure with leachate collection pipe that is rapped around by pebbles, which has wide cross-section and its aperture area opens to the air. Inside the landfill, moisture content is low and condition is kept aerobic by supplying air from leachate collection pipe.

Aerobic landfill



In addition to the leachate collection pipes as in the semi-aerobic design, air-pipes are constructed to pump in air into the waste layers to maximize internal aerobic activity.

※Effects of leachate collection pipes in the semi-aerobic landfill:

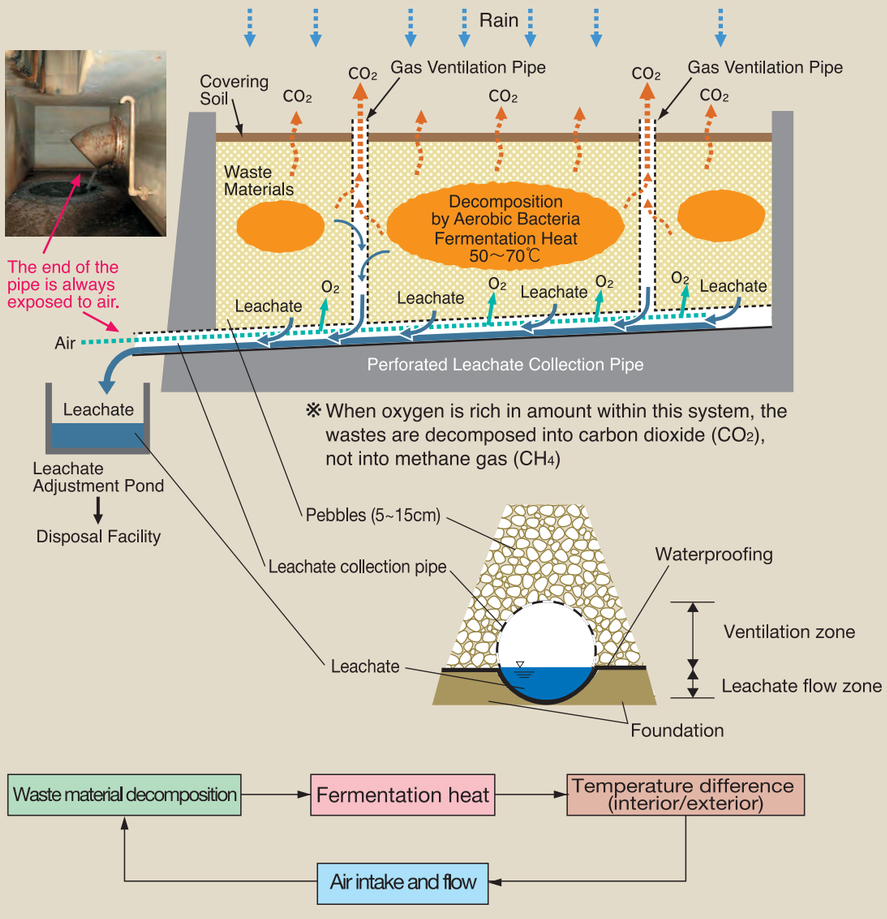
The leachate collection pipes offer a number of advantages:

(A) By draining out the leachate as quickly as possible, it prevents leachate from stagnating in the waste material and makes it easier for fresh air to penetrate, thereby promoting aerobic condition in the waste layers.
(B) By promoting aerobic conditions, microbial activity is enhanced and the decomposition of waste accelerated.
(C) By parallel usage of the collection pipes and the pebbles, the strength of the collection pipes are complemented, and water quality of leachate is improved to make air diffusion effectively at the same time.
(D) The collection pipes are laid at 50cm above from the bottom of the landfill, and protected from clogging by parallel usage with the pebbles of 5-15cm in diameter.
(E) By draining out the leachate rapidly, water pressure on the liner is prevented from building up, reducing the danger of seepage.

③Semi-aerobic Landfill Mechanism

The semi-aerobic landfill is a construction with the pebbles and the leachate collection pipe that are laid at the bottom of the landfill to drain away leachate as quickly as possible, preventing leachate inside of the layer from remaining.
Also, by the generated heat from microbial activity, the heat convection arises for the difference of internal and external temperature as the result of temperature rise in the landfill, and the air (oxygen) flows into the landfill in the reverse direction of water flow in the leachate collection pipe. Therefore, the special air blasting facility is not necessary, and it makes easier in construction, operation and maintenance.
The semi-aerobic landfill utilizes these characteristics to prevent leachate from infiltration into foundation of the landfill. It also accelerates the decomposition of waste materials, and purifies the leachate as much as possible at the collection level by making air flow into the landfill through the collection pipes naturally with the fermentation heat of the landfill layers.

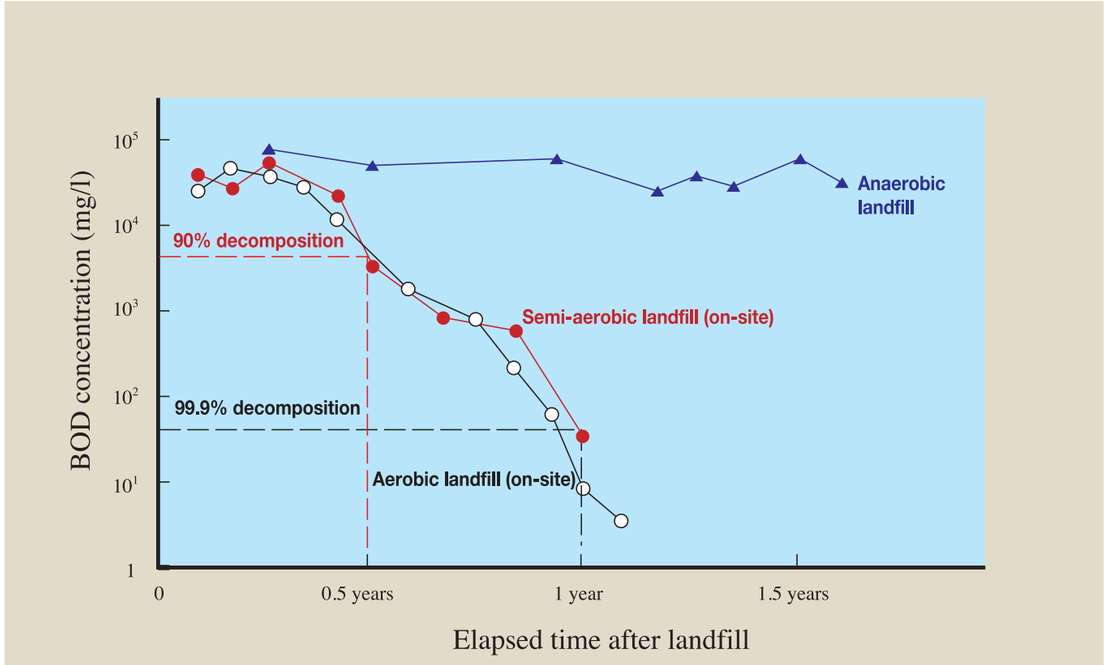
Fig-2 Semi-aerobic Landfill Mechanism



④Advantages of the Fukuoka Method

(A) The Fukuoka Method utilizes the self-purifying capacity inherent in nature to stabilize waste materials. This landfill method requires only commonly used machinery and equipment.
(B) The quality of leachate is improved significantly by accelerating decomposition of the waste materials. (See fig.3)
(C) It reduces methane gas, and contributes to the prevention of global warming. (See page.7)
(D) Early use of the completed landfill will be expected by enhancing stabilization. Appropriate review of the usage and monitoring will be needed during that period.
(E) The Fukuoka Method is cost-effective and simple in the technology, and allows a high degree of freedom of choice in materials.
(F) It is easy to construct, operate and maintain. However, for the effective use of the Fukuoka Method, it is very important to understand its mechanism, management and maintenance of the landfill, and continuous monitoring for the quality of leachate.

Fig-3 Landfill type and change in leachate BOD over time (burnable waste materials)

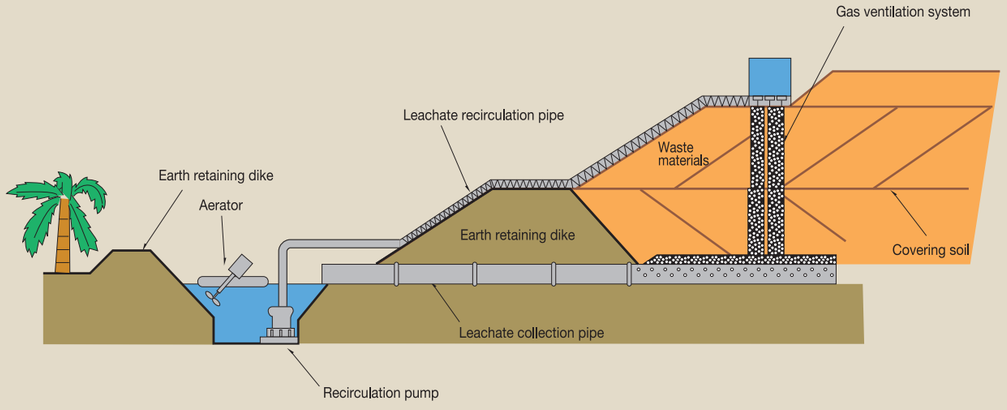


As the ending of leachate collection pipe is opened to the air, external air enters the landfill through the collection pipe by fermentation heat of microorganism inside the landfill. This heat convection helps to maintain inside the landfill layers aerobic, which results in accelerating waste materials decomposition speed and improving the leachate quality.

Ⅱ. Recirculatory Semi-aerobic Landfill

Recirculatory semi-aerobic landfill makes full use of original purification ability of the landfill layers to purify leachate, and stabilizes waste materials in early period by making leachate returns to the landfill.
The features of this method by recirculating leachate, go as follows, ①it contributes to early stabilization of the landfill due to accumulation of microorganism and acceleration of microorganism activity, ②both organic and nitrogen components are removed by accelerating nitrification and denitrification reaction, ③it enables the reduction of the leachate volume and/or the control of the fluctuation in the volume.
This method was developed to expand semi-aerobic landfill functions and to provide the control function to landfill. This method is especially expected to spread throughout developing countries where the leachate is highly contaminated.

Fig-4 Recirculatory Semi-aerobic Landfill



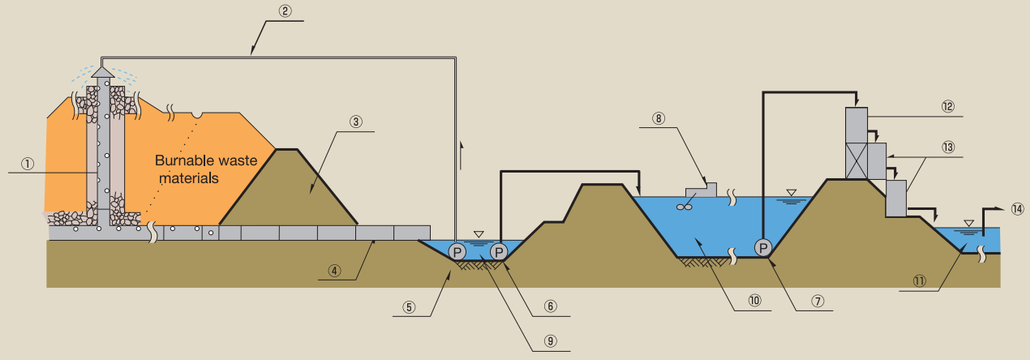
Ⅲ. Leachate Treatment

Organic waste, including household garbage, can result in extremely contaminated, highly concentrated leachate when it is processed by landfill. In anaerobic landfills, leachate BOD and COD concentrations can reach several thousands parts per million (ppm). It takes significant cost and time to process highly concentrated leachate to an established standard at leachate treatment facilities. For this reason, it is necessary to make landfill semi-aerobic first, then try to purify the leachate by using purification function of the landfill.
By using the method of recirculatory semi-aerobic landfill, accelerating the purification of leachate is also required to consider.
A combination of biological treatment and coagulating sedimentation is effective in processing leachate. The biological activity can also be used for denitrification. By adding flocculant to the leachate and processing it in a mildly acidic (pH6.5) environment, COD components can be reduced efficiently.
As temporary measures until a full-scale leachate treatment facility is constructed, it is very effective to utilize the combined uses of leachate recirculation, aeration in a retention ditch, simplified coagulation sedimentation, filtration and adsorption processing.
Here is a simplified flow diagram of leachate treatment as adopted in the Ampang Jajar Landfill in Seberang Perai, Malaysia. In this process, leachate is first recirculated into the landfill and then transferred to the retention ditch (multipurpose oxidation pond) for aeration. The aerated leachate is filtered through charcoal and activated carbon plant. The activated carbon for the Ampang Jajar Landfill was obtained from an old landfill containing waste activated carbon with no commercial value.

Fig-5 Leachate treatment flow chart: Ampang Jajar Landfill

Recirculatory semi-aerobic landfill with leachate processing system

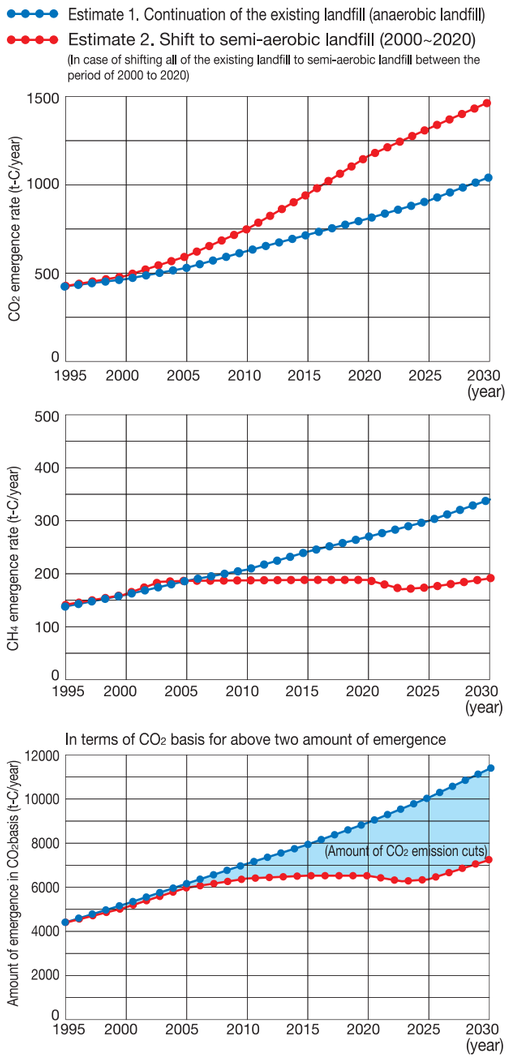
① Gas ventilation equipment
② Recirculation pipe
③ Earth dike
④ Leachate collection pipe
⑤ Leachate recirculation pump
⑥ Pump
⑦ Pump
⑧ Aerator
⑨ Retention ditch
⑩ Oxidation pond
⑪ Discharge adjustment pond
⑫ Charcoal filtration system
⑬ Activated carbon adsorption system
⑭ Discharge



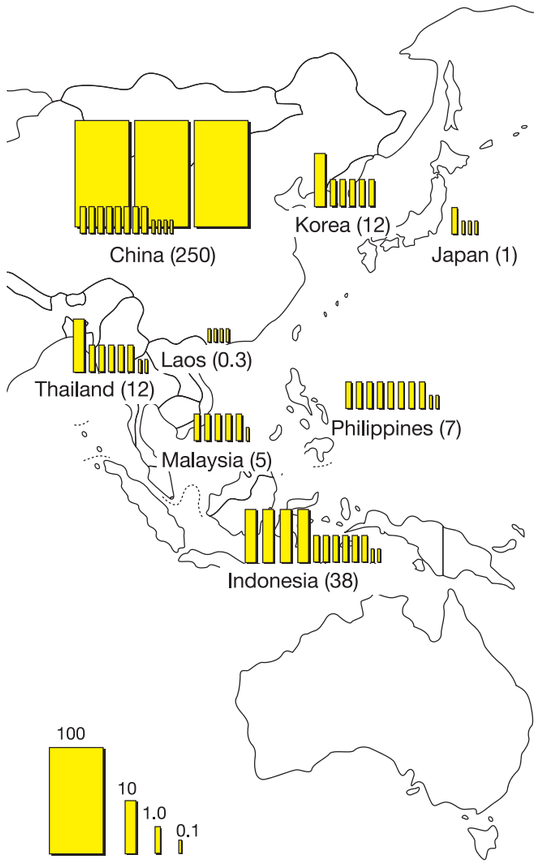
Ⅳ. Restrictive Effect of Greenhouse Effect Gas

According to the result of the experiment by using burnable waste materials, landfill in the Fukuoka Method can reduce more than 50% of the greenhouse effect gas compared to anaerobic landfill.
In comparison with an anaerobic landfill, the Fukuoka Method (semi-aerobic landfill) can accelerate the aerobic decomposition of organic because of oxygen supply. The supplied oxygen binds to carbon (C) in the solid waste material to produce carbon dioxide gas (CO_2) and emitted from the landfill. In anaerobic landfill, oxygen is not supplied. Once oxygen, incorporated with waste material at the beginning of the landfill has consumed, it transfers to anaerobic methane fermentation period to produce methane gas (CH_4) and carbon dioxide gas.
In comparison with an anaerobic landfill, the Fukuoka Method can reduce the generation of the greenhouse effect gas by the suppression of the methane gas that seriously effects on global warming, and acceleration for the decomposition to shorten the gas generation period.

◎Reduction effect of green house effect gas yield from a landfill (In case of Malaysia)



◎Amount of CO_2 and CH_4 emergence from a landfill in Asian countries <2004> (In CO_2 basis)



Amount of emergence in CO_2 basis ($\times 10^6$t/year)

( ) describe the ratio of each country when Japan's amount of emergence in CO_2 basis is replaced as 1.

Chapter and verse: Both of the above "Master's thesis by Hideki Kobayashi of Fukuoka University"

Ⅴ. Joint Activities with Japan International Cooperation Agency (JICA)

As for the technology transfer of waste material landfill technology to Asia-Pacific cities, Fukuoka City has been actively promoting this technology transfer in cooperation with Japan International Cooperation Agency (JICA), and has been earnestly cooperating in reducing environmental pollutions and methane gas, which result from local final disposal sites in the world.
For example, Waste Disposal Skills Improving Training for Pakistan Engineers was carried out from FY 2005 to FY 2008 at the request of JICA. In this training, experts and engineers of Fukuoka University and Fukuoka City gave one-month technical instructions to Pakistan people who were engaged in waste disposal as supervisors or practitioners. Their instructions included on-site inspections, practical trainings on how to select proper landfill sites, how to build landfill site on the Fukuoka Method, how to manage landfill sites and their healthy environments, how to close landfill sites safely, how to improve existing landfill sites, etc. Special trainings are also conducted to instruct trainees on how to collect and transport wastes, how to create a recycling society, etc.
Fukuoka City has been sending its technical officials to developing countries to give local people a variety of technical instructions on land-reclaiming skill. So far, Fukuoka City has sent 75 technical officials to 11 countries. Also, as the landfill technology-training foothold, Fukuoka City has received about 4,000 people from over 70 countries for their inspecting and studying landfill sites.


Lecture on the Fukuoka Method by officials at a landfill site


Practical training on how to install wasted tire-using gas collection and ventilation system (2008)


Practical installation of leachate collection pipe from bamboo


Practical training on installation of leachate collection pipes by use of waste tires.


Practical training on how to measure gas from gas ventilation pipe (2012)


Inspection training on landfilling machines

Ⅵ. Improvement of Landfills in Malaysia (Technology Transfer of a low-cost model “The Fukuoka Method”)

Back in 1988, Dr. Yasushi Matsufuji (Fukuoka University) was sent to Malaysia as a sanitary landfill expert by Japan International Cooperation Agency (JICA). As a part of the project to improve the final waste disposal facilities in Seberang Perai, Malaysia, Dr. Matsufuji proposed and implemented a modified semi-aerobic design, by use of bamboos, used steel drums and other locally available materials. This initiative in Malaysia marked the first attempt to introduce the Fukuoka Method in Southeast Asia, and it has been highly-evaluated as a successful case example of technical transfer in the waste material fields.

The Ampang Jajar Landfill before improvement (1988)

Ongoing improvement

The Ampang Jajar Landfill after improvement (1996)

Ongoing improvement

Aeration in the retention pond (1996)

Introduction Example of Semi-Aerobic Landfill Structure Seberang Perai City, Malaysia

Recirculatory semi-aerobic landfill, using concrete pipe, bamboo and used steel drums

Gas ventilation system utilizing used steel drums

Vegetation recovery after the installation of the gas ventilation system

Leachate treatment facility (pilot plant)

Adsorption processing using activated waste carbon

Leachate
(1: Untreated, 2: After aeration, 3: After filtration and adsorption processing)

Introduction of International Cooperation Examples
Weifang City, The People's Republic of China

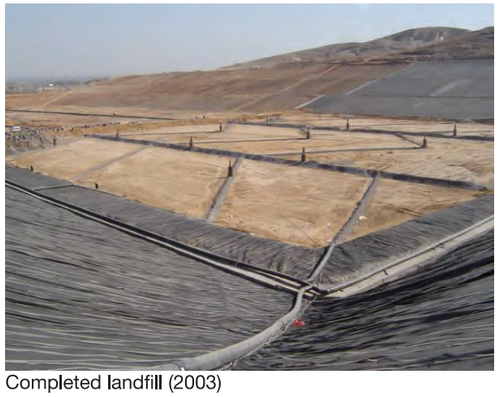
Ⅶ. Technical Cooperation with United Nations Human Settlements Programme (UN-HABITAT) in China

United Nations Human Settlements Programme (UN-HABITAT) Fukuoka Office that addresses the improvement of habitat in Asia-Pacific region formed a project to introduce the Fukuoka Method in Weifang City, Shandong Province and concluded to memorandum with China Ministry of Construction. Fukuoka City assumes that aggressive approach for international cooperation solves the urban problems by using method of waste material landfill which belongs to the city, as a contribution to Asia, and dispatches staffs to the scene by the request of technical assistance over many fields to this city from the United Nations Human Settlements Programme (UN-HABITAT) Fukuoka Office.

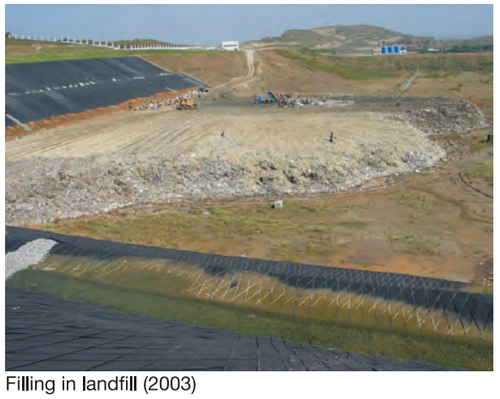

Forming slope before impermeable liner installation (2002)


Research for planned landfill construction site (2002)


Conference on design (2002)


Completed landfill (2003)


Monitoring for generated gas (2004)


Filling in landfill (2003)

Introduction of International Cooperation Examples
Mengzi Prefecture, The People's Republic of China

Ⅷ. Conclusion of Technological Cooperation Agreement with Tsinghua University (China) and Fukuoka University

Among the problem of developing waste material disposal with the economic growth in China, environmental group of Tsinghua University of the People's Republic of China (Beijing City) visited Nakata Landfill Site in Fukuoka as the exchange program between Fukuoka University and Tsinghua University. They requested for cooperation toward the diffusion of the Fukuoka Method (Semi-Aerobic Landfill) in China as they assumed that the Fukuoka Method is extremely appropriate for the smaller cities of China.

The agreement of "Technological Cooperation of the environment, including the diffusion of waste materials disposal technology, the Fukuoka Method, etc. by Tsinghua University, Fukuoka City and Fukuoka University" has concluded on November 7, 2003 and technological cooperation of the landfill in the Fukuoka Method in Mengzi, Yunnann Province had started by Tsinghua University as the first step in the landfill technology diffusion in China.

Skull practice for waste disposal technology
(At Tsinghua University) (2003)


Landfill condition before improvement
(Waste material in spontaneous fire) (2003)

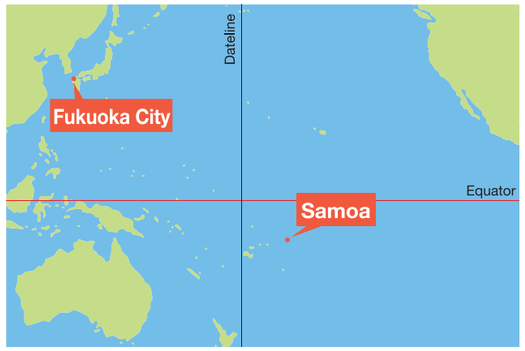

Completed landfill site (2007)


Courtesy call on Fukuoka City Mayor by environmental group of Tsinghua University (2004)

Introduction of International Cooperation Examples
Independent State of Samoa

Ⅸ. Improvement of Landfill in Independent State of Samoa

Independent State of Samoa made an official request through JICA to Fukuoka City and Fukuoka University for technical cooperation in landfill improvement based on the Fukuoka Method. So, Fukuoka City sent its delegates, who worked as JICA's long-term technical experts, to an international organization named Secretariat of the Pacific Regional Environmental Program (SPREP). The technical experts made technical instructions on how to improve local landfill sites and trained local human resources in Samoa and its neighboring countries. This case example of successful improvement has been highly evaluated as a good model site in an atoll region.



Conditions of landfill before improvement (2001)

Conditions of landfill before improvement (2001)

Ongoing improvement of landfill through the Fukuoka Method (2003)

Leachate before improvement and improved Leachate (2005)

Introduction of International Cooperation Examples
Neighboring countries

Ⅹ. Extend Environmental Administrative Exchange and Technical Cooperation of Fukuoka City

Responding to requests made by JICA for overseas cooperation and also committed to technical cooperation in tie-up with UN-HABITAT, Fukuoka City also made environmental administrative exchanges with its sister cities such as Ipoh City (Malaysia) and Guangzhou City (the People's Republic of China). In this exchange, Fukuoka City held seminars, experiments and practical trainings on how to improve local landfill sites. Fukuoka City also sent its technical delegation to Hanoi (Vietnam) from which an official request had been made for cooperation in improving Nam Son Landfill Site by use of the Fukuoka Method. This cooperation was carried out under the 2004 Program for the International Cooperation for Local Authorities (Model Program) by Council of Local Authorities for International Relations (CLAIR). The delegation held seminars and practical trainings on the Fukuoka Method.

Conference on Environmental Administrative Exchange (Gunagzhou City, The People's Republic of China)(2003)

Exchanging opinions on Environmental Administrative Exchange (Ipoh City, Malaysia) (2002)

Installing gas collection pipe and ventilation system built from waste steel drums (Nam Son Landfill, Hanoi City, Vietnam) (2005)

After the workshop (Nam Son Landfill, Hanoi City, Vietnam) (2005)

Introduction of International Cooperation Examples
Hai Phong City

XI. Improvement of Landfills in Vietnam

(Support for Technical Improvement of Waste-Materials-Landfill Management Technology)

Under the "Urban Environment Improvement Project in Hai Phong City, the Socialist Republic of Vietnam" (one of the Yen Loan programs), which we assisted from fiscal 2005 to fiscal 2008, we were successful in our support on the efficient execution of waste collection and transportation and in suggesting improvements on the existing waste-disposal-commissions collection system. On the other hand, a new problem emerged when the collected wastes were not properly disposed in the landfills, thus generating leachate, polluting the surrounding environment.
To resolve the leachate problem, we carried out a JICA technical cooperation project at the grass-roots level, named "Support for Technical Improvement of Waste Materials-Landfill Management Technology in Hai Phong City, the Socialist Republic of Vietnam," for three years from fiscal 2010. For further assistance, special technical trainings on "How to Design, Maintain and Manage Semi-aerobic Landfill (the Fukuoka Method Landfill)" is being carried out for three years since fiscal 2012.

Condition of landfill before improvement in Dinhvu, Hai Phong City (2010)

Tornado installed in leachate adjustment pond (2012)
※The Tornado is a device that properly stirs the pond by creating whirlpools in the leachate and mixing air into the leachate.

Ongoing improvement of landfill through the Fukuoka Method in Dinhvu, Hai Phong City (2011)

Installation of ECO-FAN completed in leachate adjustment pond (2012)
※The ECO-FAN, made of waste materials, uses wind power to properly stir the pond.

Improved condition of landfill in Dinhvu, Hai Phong City (2012)
(Its vegetation has been restored.)

A memorandum of understanding on how to develop the partnership among the five concerned parties of Hai Phong City, Hai Phong Urban Environmental Company, Fukuoka University, Fukuoka Environment Foundation and Fukuoka City was signed (2012).

XII. Certified as Clean Development Mechanism (CDM)

The improvement of existing reclaimed lands by the use of waste-landfill technology, semi-aerobic landfill (known as the Fukuoka Method) was certified as an innovative method of Clean Development Mechanism (CDM), which is stipulated in the United Nations Framework Convention on Climate Change (UNFCC).
In the 62nd Session of the United Nations CDM Council, held in Morocco on July 15, 2011, this innovative method that controls the occurrence of methane gas in existing reclaimed lands through the Fukuoka Method was certified as a new method to be used as Carbon Credit (Certification of Emission Reductions in the amount of Green House Gas which can be traded among developed countries).

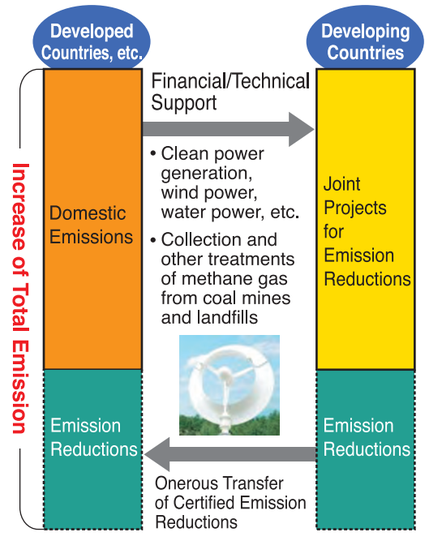
■ Please enter the following retrieval code on the top page of the website of the United Nations Framework Convention on Climate Change (UNFCC), and the detailed references will be indicated.

AM 0093:Avoidance of landfill gas emissions by passive aeration of landfills.

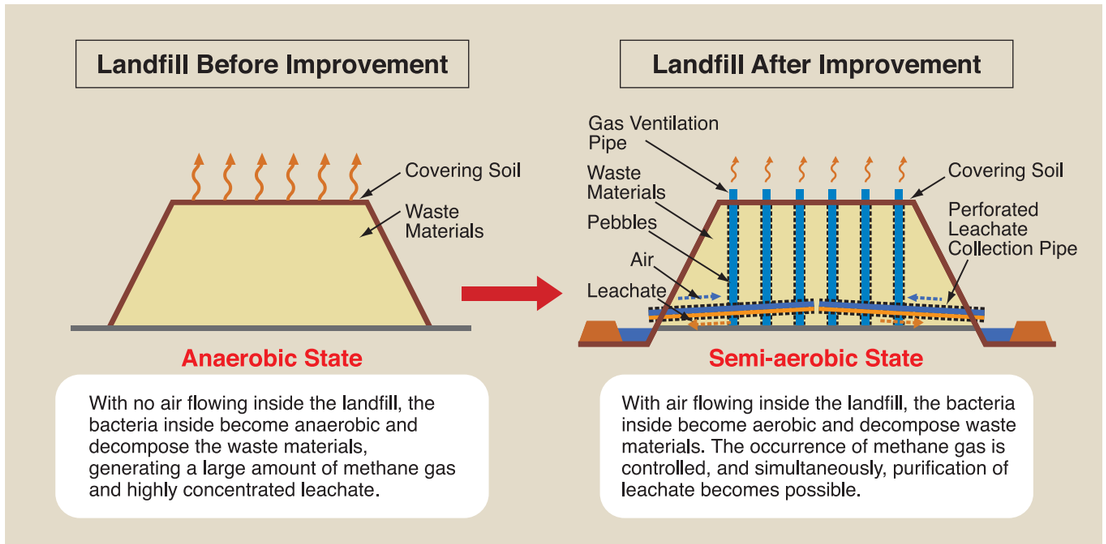
■What is Clean Development Mechanism (CDM)?

The Clean Development Mechanism (CDM) is one of the Kyoto Mechanism policy approaches that are designed to reduce Greenhouse Gas (GHG). (The Kyoto Mechanism is defined in the 1997-adopted Kyoto Protocol.) Under the CDM, both developed and developing countries actively cooperate with each other to achieve GHG emission reductions and other green activities in developing countries and thus contributing to the environmentally friendly growth of developing countries. At the same time, under the CDM, developing countries can make an onerous transfer of Certified Emission Reductions, acquired through the above activities, to developed countries, which take such Emission Reductions into their own GHG emission reductions.
CDM has been widely applied to clean power generation certified by the United Nations (wind power/water power generation), methane gas collection in coal mines and reclaimed lands, and other green projects.

The Outline of CDM



●Example of Landfill Improvement (Based on the Fukuoka Method)



XIII. The Utilization of Completed Landfills

○ Compared to other landfills reclaimed by other methods, the landfills created by the Fukuoka Method become stable in the early stage after completion. Because of that, after long-term environmental monitoring and adequate safety measures, these landfills have been utilized as farmlands, arranged lands for school use, tennis courts, and other sport parks.
○ In April, 2010, the Children's Village FUKUOKA was opened on one of the landfills. The Children's Village FUKUOKA is a facility organized by a worldwide NGO named SOS-Kinderdorf and for children who cannot live with their family for various reasons.
○ As an effective use of the slopes and green areas on the landfill created by the Fukuoka Method, large-scale solar power generation is also performed there.

Landfill Site Outline
Name: Imazu Landfill Site
Landfill Volume: 1,687,000t
Start of Landfill: February, 1975
Completion of Landfill: September,1999

How has the Completed Imazu Landfill Site been utilized?

Imazu Sports Park
Opened in April, 1992

Children's Village FUKUOKA,
Japan's first SOS-Kinderdorf Facility
Opened in April, 2010

(Photo provided by
Fukuoka Fire Prevention Bureau)

Imazu Refresh Farm
Opened in August, 1995

Fukuoka City
Imazu Special Education School
Opened in April, 1989

The Utilization of Eastern (Fushitani) Landfill Site

Ground Golf Field
(On the 1st section of the completed landfill)
Opened in August, 2007

The Utilization of Seibu (Nakata) Landfill Site

Obaru Mega Solar Power Plant
(Idle land on landfill)
Operation started in February, 2013