CHAPTER 3

STUDIES ON THE FUKUOKA METHOD

3.1 Introduction

Started from 1970s, Fukuoka University had developed a new landfill technology in order to increase the leachate treatment. Many researches were in cooperation with the Local Authority in Fukuoka City. These researches demonstrated that stabilization and decomposition of waste can be improved in the presence of air as it increases the rate of microbial activity. Additionally, the leachate had a better quality with the high rate microbial reaction, and the gases generated from landfill, such as hydrogen sulphide and methane, was markedly decreased. After confirming its positive aspects, this landfill model was officially named as Fukuoka Method.

According to the results generated from the researches of Fukuoka Methods formed, landfills started to be classified into five types. It is based on the growth environment of microorganism in landfill layers with different conditions. These five structures are Anaerobic Landfill, Anaerobic Sanitary Landfill, Improved Anaerobic Sanitary landfill, Semi-aerobic landfill and Aerobic landfill.

a) Anaerobic landfill is normally excavated in the flatland or in usage of existing valley. It keeps flooding the waste materials with water and anaerobic condition (Figure 3.1).

b) Semi-aerobic landfill installs the leachate collection system. The leachate collection pipe is surrounded by pebbles. Internal landfill layer can keep lower water content (Figure 3.2).

c) Aerobic landfill has the leachate collection pipes as well. The air is pumped into the internal layer in order to improve the aerobic activity (Figure 3.3).

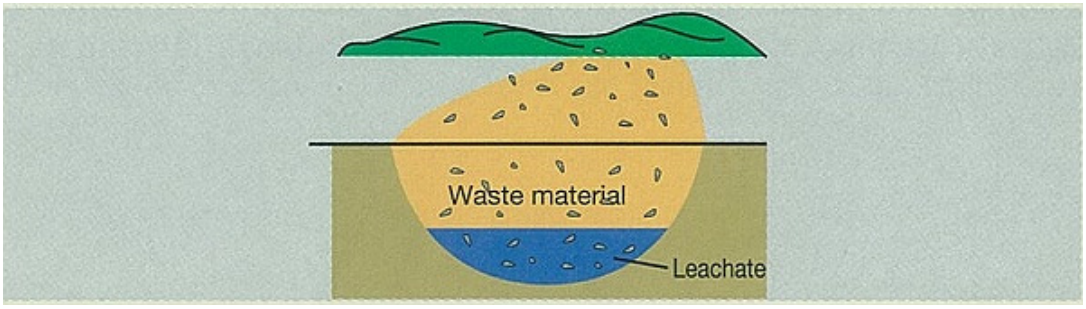

Figure 3.1 A Schematic Structure of Anaerobic Landfill
(Source: Matsufuji, 2007)

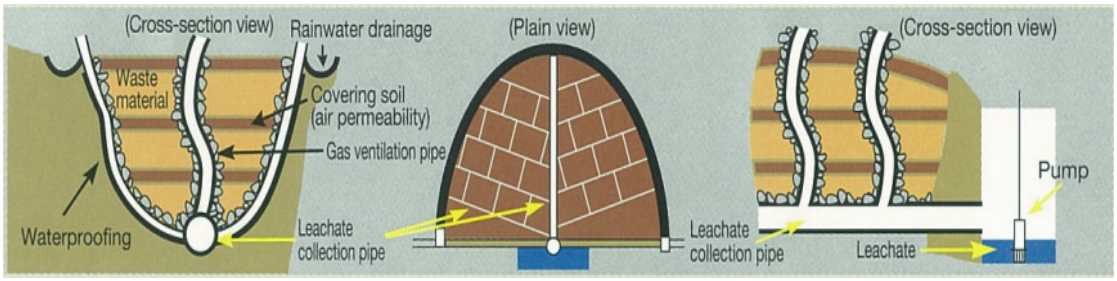

Figure 3.2 A Schematic Structure of Semi-aerobic Landfill
(Source: Matsufuji, 2007)

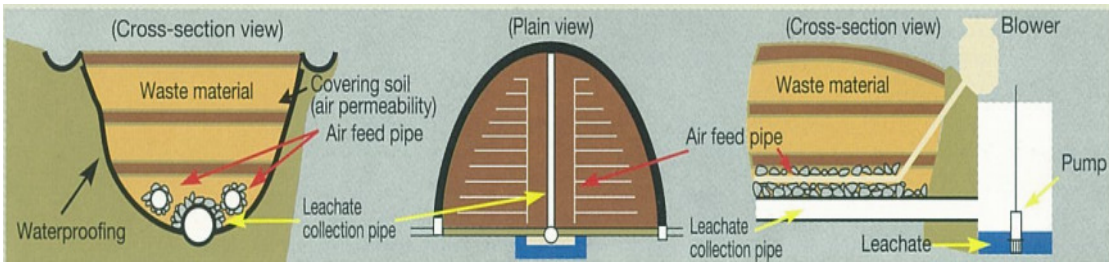

Figure 3.3 A Schematic Structure of Aerobic Landfill
(Source: Matsufuji, 2007)

Another comparison has been done to prove the benefits of semi-aerobic landfill shown in Table 3.1.

Table 3.1 Comparison among Semi-aerobic Method and Other Conventional Method

Item	Anaerobic Landfill	Improve Sanitary Landfill	Semi-Aerobic Landfill	Aerobic Landfill
Construction Cost	Good	Good	Good and low	Negative and high
Operation Cost	Good	Good	Good and low	Negative
Decomposition	Negative	Negative	Good and short	Good and short
Stabilization	Negative	Negative	Good and short	Good and short
Methane Gas Generation	Negative	Negative	Good and small	Good and small

(Source: Matsufuji, 2007)

As the representation of semi-aerobic landfill, Fukuoka Method (FM) can be feasibly implemented in the developing countries. It is highly recommended as a good example to achieve cost–effective landfill system.

3.2 Technology Description

In developing nations, the "low tech, low cost" waste disposal projects are quite attractive as budget limitation. Theng *et al.* (2005) reports that some developing countries like Malaysia, Mexico and Iran have implemented FM landfill system successfully. Additionally, FM is well-known as “zero emissions”. The FM landfill aims to use the wastes generated from one factory as raw materials for another industry. Finally, in this materials-cycle society, the waste generation will be minimized to zero. Therefore, the waste in FM landfill can be maximally decomposed. FM landfill has environmental friendly construction process and maintenance system.

Technology aspect refers to landfill design, construction process, maintenance control, and landfill operation. Based on the above introduction, the FM landfill can be illustrated as an integrated system where the leachate and gas can be removed continually. It installs proper leachate collection and gas venting facilities. Appropriate engineering designs of the leachate collection system help the air flow into the internal layer of landfill naturally. This contributes to increase stabilization of waste and reduce the moisture content. Based on the enhancement of microbial reaction, the leachate quality is highly improved and the gas generation is reduced (Matsufuji and Sinha, 1990). The structure of FM landfill is illustrated in Figure 3.4.

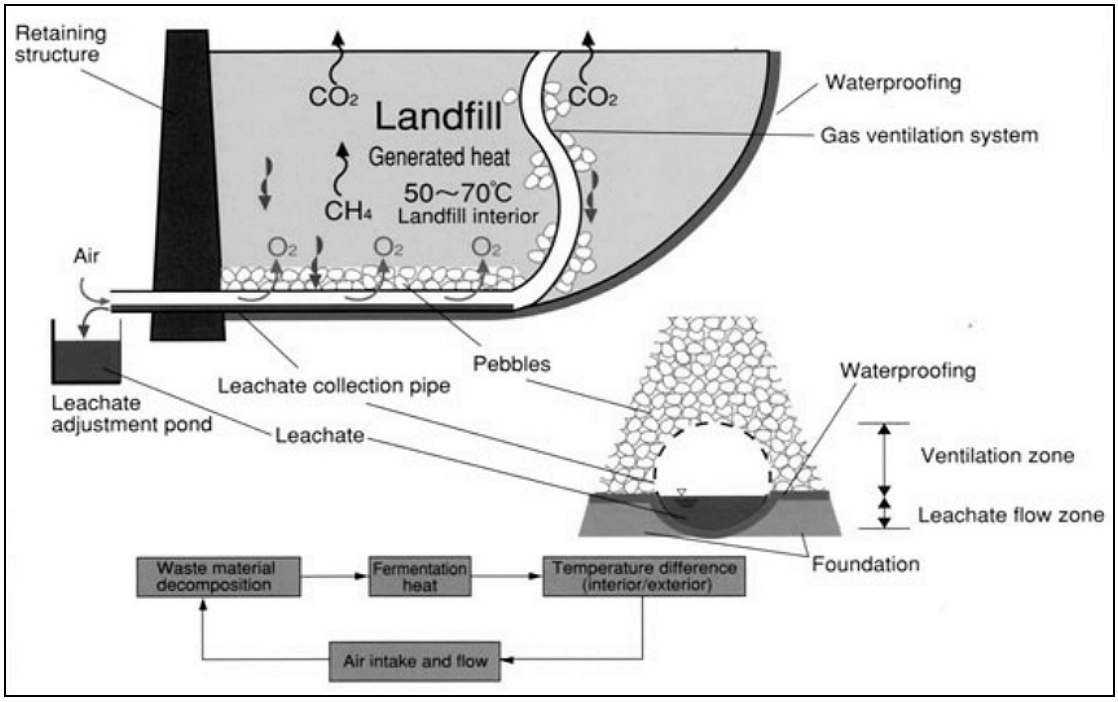

Figure 3.4 The Mechanism of Fukuoka Method Semi-aerobic Landfill

(Source: Matsufuji and Sinha, 1990)

a) Site Location and Planning

In the stage of site location and planning, the following aspects are focused on:

1) Considerations for Amount of Precipitation

The FM technology is mainly used to enhance aerobic micro-organism activity that consumes the organic matters in solid waste. There is a minimum requirement of moisture content to keep microorganisms active. Therefore, in high precipitation regions, the landfill layers can offer enough moisture content for microorganism activity. On the Contrary, in areas with insignificant rainfall, additional layer is required to prevent the waste from drying out and the leachate needs special control without flowing out of the landfill.

2) Considerations for Temperature

The ideal living temperature of microorganism is between 15 ℃ and 40 ℃. The decomposition rate can achieve best value within this temperature zone. It is necessary to consider the operation temperature to make sure the microbial reaction is active. Therefore, in cold areas the FM landfill cannot work effectively unless there is control system to adjust temperature to suitable value. In that case, the cost will increase significantly. Since surrounding temperature may exceed 40 ℃ sometimes, installation of cooling water pipes can be effectively used to adjust the high temperature at an cost is acceptable cost.

b) Site Construction

In site construction stage, there are 4 main considerations which are:

1) Cost of Construction

In developing nations, industrial development requires high investment to maintain the economic growth rate. The budgets of environmental programs always occupy an insufficient percentage. Low cost will be the first choice. FM landfill has simple structure and is easy to maintain. There are various replaceable materials obtained locally. For example, bamboo and old tyres are usable in building drainage and ventilation facilities. The cost can be controlled as low as possible based on assuring the quality of final disposal site.

2) Technical Support of Maintenance And Control

It is crucial to keep the professionals in control of the maintenance process at the final disposal sites. However, there is quite limited number of experts in developing nations. Therefore, a manual about maintenance and control needs to be provided. The structure of facilities and functions of materials are required as well. The regular training is necessary for the operation group.

3) Leachate removal and collection system

In FM design procedure, it is required that excess interstitial water needs to be removed immediately when it is generated. Therefore, it is important to ensure that the leachate collection discharge pipes keep opening to the atmosphere, so that the air can flow into the landfill layers. The estimation amount of leachate generation needs to be considered and calculated carefully in order to provide proper capacity of leachate control pond. The leachate collection discharge pipes are installed at the bottom of landfill. A good design of the construction form and appropriate gradient at the bottom can improve the efficiency of leachate collection system.

There are 4 main stages about the usage of facilities and operations to define the level of sanitary landfill. Table 3.2 demonstrates the general 4 levels.

Table 3.2 General Stages of FM Landfill

Primary operation method, facility	Stage 1	Stage 2	Stage 3	Stage 4
Control facility	√	√	√	√
Weight measuring of waste brought in	√	√	√	√
Enclosing bunds		√	√	√
Buffer zone		√	√	√
Landfill machinery	√	√	√	√
Daily soil covering, gas venting		√	√	√
Approach and on-site roads	√	√	√	√
Leachate circulating system			√	√
Leachate treatment				√
Seepage control works			√	√
Moveable fence for littering preventing				

(Source: Matsufuji, 2007)

4) Gas Venting pipes

In order to maintain the aerobic condition in the layers, the gas venting pipes are required to be installed in suitable area with proper intervals. It is recommended to use materials obtained locally for the configuration. Since the rate of organic waste decomposition is quite fast, the oxygen in the internal layer of landfill can be consumed rapidly. To avoid the aerobic condition switching to anaerobic condition, the pipes need to be installed 10-15 m each. These pipes have three main advantages:

- Suppress generation of CH4 through expanding aerobic area
- Rapid removal of leachate function
- Circulation of leachate using vertical gas venting pipes

c) Landfill Operation

In the operation stage, 3 considerations are required:

1) Maintenance of Leachate Collection and Discharge System

In FM landfill, the pipes for leachate collection and discharge have crucial functions. To maintain the continuous oxygen supply, leachate disposal and aerobic condition maintenance, the pipes are required to be under protection from overload. Therefore, the types of waste disposal into the landfill need to be considered carefully. The level of leachate needs to be controlled and monitored.

2) Maintenance of Gas Ventilation Pipes

Gas venting pipes can enable that there is enough air for microorganism to decompose organic waste in aerobic conditions. It is important to maintain and monitor the gas venting pipes under effective working ability.

3) Recirculation of Leachate

After the leachate is removed from the landfill, leachate will be stored in control pond temporarily. In FM landfill, the recirculation of leachate can help to reduce the hazardous components with the purification of waste layers. It is suggested to run an effective leachate recirculation between control pond and landfill layers. If the capacity of leachate treatment facility is limited, the leachate recirculation can help to reduce the treatment load. Hence, it is important to locate the landfill in a suitable area with considerable leachate piping facilities.

d) Environmental Monitoring

Environmental monitoring can always control the landfill under effective operation. The two main elements are required to be considered:

1) Understanding the Aerobic and Anaerobic Reaction Processes in FM Landfill

It is known that gases generated in FM landfill have less impact to global warning compared with other landfill model. The crucial point is to maintain the aerobic condition. The leachate quality can be improved significantly of under this condition. To achieve effective operation of FM landfill, monitoring to both aerobic and anaerobic reaction processes is required to be controlled under appropriate situation. The indicators are the concentration of CH_4, CO_2 and H_2S in the exhaust gases. For the leachate inspection, BOD, pH, amount of ammonium nitrate and heavy metals need to be tested before discharging. Figure 3.5 illustrates aerobic and anaerobic general decomposition processes in the FM landfill.

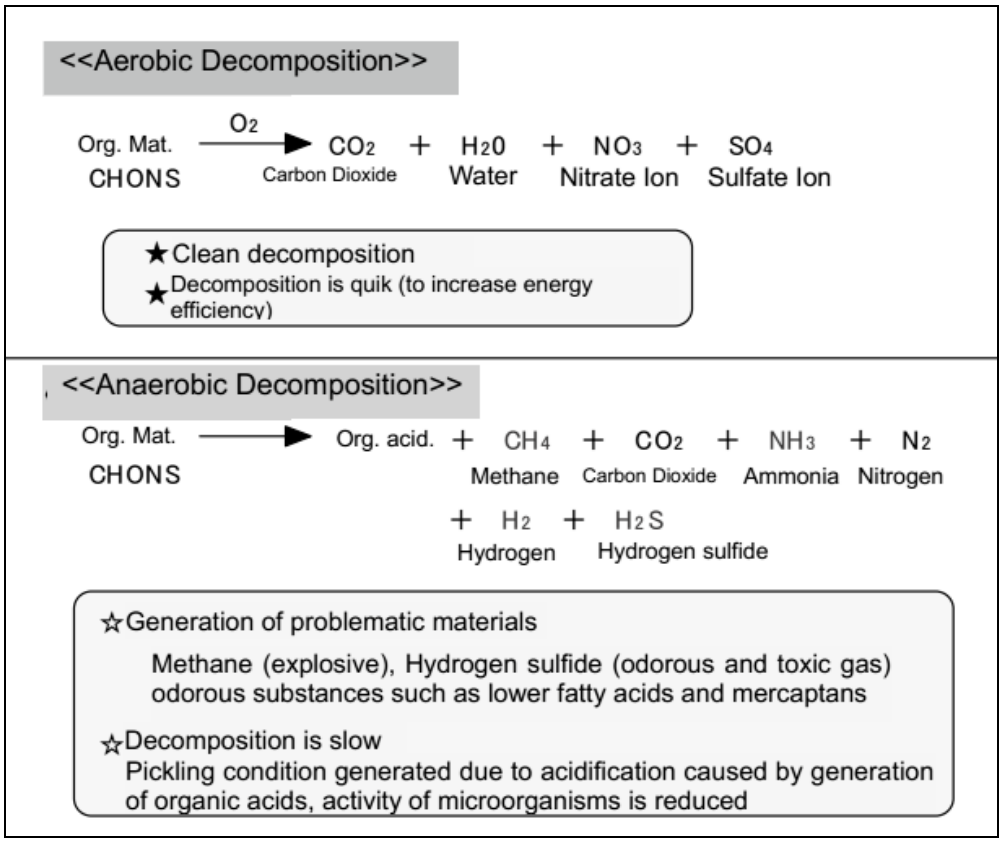

Figure 3.5 Outline of Aerobic and Anaerobic Decomposition

(Source: Matsufuji, 2007)

2) The Important of Stabilization to FM Landfill

Stabilization of landfill can be explained as when the decomposed waste is able to be discharged to environment without causing impacts. The aerobic degradation of FM landfill can accelerate the stabilization. When the waste is under decomposition process, pollutants (leachate and harmful gases) are released. Therefore the stabilization of landfill can be monitored via the degradation process. Heat is realised during degradation which can increase the temperature of landfill layers. Normally, the average of reaction temperature is from 50℃ to 70℃. It is important to monitor the temperature

regularly. Therefore, when the temperature decreases close to the circumambience, it means the easily degradable waste has been consumed during biodegradation.