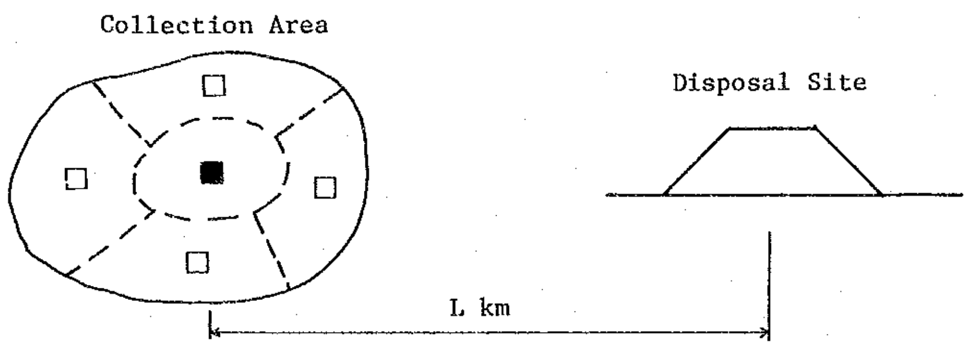
The farthest break-even distance is obtained in Case 4. The distance is about 18 km when the amount of transfering waste is 100 ton/day. When the waste amount is more than 200 ton/day, the distance (L) becomes about 17 km. The shortest distance (L=9.5) appears in Case 1.

This calculation shows that provision of T/S helps to decrease the collection and transportation cost when the distance is more than 10-17 km.

4-2-4 Cost comparison

(1) Comparison Model



: C/A -- Area for a vehicle or hand cart

□ : T/S.H -- Transfer station for hand cart

■ : T/S.V -- Transfer station for vehicle

1) Waste Stream of Each Model

1. Hand cart collection

C/A $\xrightarrow{\text{L1}}$ T/S.H $\xrightarrow{\text{L2}}$ Disposal site

L1 = 550 m (ave.) by hand cart

L2 = L km by 7-8 ton dump truck

2. Vehicle collection

C/A $\xrightarrow{\text{L3}}$ T/S.V $\xrightarrow{\text{L4}}$ Disposal site

L3 = 5 km (ave.) by 2 ton dump truck

L4 = L km by 10 ton container

Remarks:

- o T/S.V assumed to be located at the centre of the collection area
- o Average transportation distance of each T/S.H to disposal site on Hand Cart collection system is considered to be L km.

2) Basic Date for Estimation

1. Bulk Density of the Wastes: 0.4 t/m^3

2. Capacity of the hand cart and each vehicle
   - 2-1 Hand cart: 0.56 t/cart (=1.4 m^3/cart x 0.4 t/m^3)
   - 2-2 7-8 ton Dump truck: 6 t/truck (=15 m^3/truck x 0.4 t/m^3)
   - 2-3 2 ton Dump truck: 1.6 t/truck (=4 m^3/truck x 0.4 t/m^3)
   - 2-4 10 ton Container: 8 t/container (=20 m^3/container x 0.4 t/m^3)

3. Hauling speed
   - 3-1 Collection site to transfer station: 20 km/hr
   - 3-2 Transfer station to disposal site : 30 km/hr

3) Equation for O/M Cost Estimation

1. Collection and Transportation

$$\text{Cunit} = \frac{m}{q} + \frac{f\ o}{q} + \frac{sw + d}{k.l.q} + \frac{v}{k.l.q.t.u}$$

Cunit	:	O/M unit cost	[₩/t/km]
m	:	Vehicle O/M cost	[₩/km]
f	:	Fuel comsumption volume	[l/km]
o	:	Fuel unit price	[₩/l]
S	:	Worker unit cost	[₩/day]
W	:	Number of workers	[head]
d	:	Driver's unit cost	[₩/d]
V	:	Purchase cost	[₩/vehicle]
q	:	Hauling amount	[t/vehicle]
k	:	Number of trips a day	[trips/day/vehicle]
t	:	Durable time	[year]
u	:	Working days a year	[day/year]
l	:	Haul distance a trip	[km/trip]

Remarks: Meaning and value of each symbol are described in section 5-5-3.

$Ct = Cunit \times 1$

Ct : O/M unit cost per ton [₩/ton]

$$= \frac{m \times 1}{q} + \frac{f \times o \times 1}{q} + \frac{sw + d}{k \times q} + \frac{V}{k \times q \times t \times u}$$

2. T/S.V

$$Ct = \frac{660 \times Q + 17,840}{Q} = 660 + \frac{17,840}{Q}$$

Ct: O/M unit cost ton [₩/ton]

Q : Treated waste amount [ton/day]

Remarks:

o 17,840 is the fixed charge per station

o O/M cost for T/S.H is ignored in this estimation

3. Trip around distance: 1

$1 = L' + 2L$

L' : Hauling distance on collection

L : Transportation distance - one way

(2) Calculation of O/M Cost

1) Hand Cart

1. Collection site to transfer station (hand cart)

$$Ct_1 = \frac{M}{q \times k \times u} + \frac{f \times o \times 1}{q} + \frac{sw + d}{k \times q} + \frac{V}{k \times q \times t \times u}$$

M: O/M cost for hand cart [10,000 ₩/year]

$$k = \frac{Te}{Tk} = \frac{420}{140} = 3.0 \quad [trip/day]$$

Te: Effective working time [min/day]

Tk: Working time per trip [min/trip]

$$Ct_1 = \frac{10,000}{0.56 \times 3 \times 300} + \frac{0 \times 270 \times 1}{0.56} + \frac{9,500}{3.0 \times 0.56} + \frac{50,000}{3.0 \times 0.56 \times 3 \times 300}$$

$= 5,708$ [₩/ton]

2. Transfer station to disposal site (7-8 ton truck)

$$Ct2 = \frac{m \times l}{q} + \frac{f \times o \times l}{q} + \frac{sw + d}{k \times q} + \frac{V}{k \times q \times t \times u}$$

$$k = \frac{Te}{Tt + Tn + Td} = \frac{420}{40 + 120 \times L/30 + 20} = \frac{105}{15 + L}$$

Tt:	Loading time at T/S.H	[min/trip]
Tn:	Hauling time	["]
Td:	Unloading time at disposal site	["]

$$Ct2 = \frac{96x2xL}{6} + \frac{0.4x270x2xL}{6} + \frac{12,500x(15+L)}{105x6} + \frac{21,700,000x(15+L)}{105x6x6x300}$$

$$= 585 + 107 \times L \qquad [₩/ton]$$

3. O/M cost of hand cart model

$$Ct = Ct1 + Ct2 = 107xL + 6,293 \qquad [₩/ton]$$

2) Vehicle Collection with T/S

1. Collection Site to T/S.V (2 ton dump truck)

$$Ct_1 = \frac{m \times l}{q} + \frac{f \times o \times l}{q} + \frac{sw + d}{k \times q} + \frac{V}{k \times q \times t \times u}$$

$$k = \frac{Te}{q(16.7xEe+Et)+Th+Td} = \frac{420}{1.6x(16.7x1+4)+120x5/20+10}$$

Ee:	Loading efficiency	[sec/kg]
Et:	Moving efficiency	[min/ton]
Th:	Hauling time	[min/trip]
Td:	Unloading time at T/S.V	["]

$$l = 2 \times L + L' = 2 \times 5 + \frac{1}{60} \times Et \times Vc \times q = 11.07 \quad [km]$$

Vc: Hauling speed on collecting [km/hr]

$$Ct_1 = \frac{68 \times 11.07}{1.6} + \frac{0.17 \times 270 \times 11.07}{1.6} + \frac{2 \times 9,500 + 12,500}{5.74 \times 1.6} + \frac{12,300,000}{5.74 \times 1.6 \times 6 \times 300} = 4,962 \ [₩/ton]$$

2. T/S.V to disposal site (10 ton container)

$$Ct_2 = \frac{m \times l}{q} + \frac{f \times o \times l}{q} + \frac{sw + d}{k \times q} + \frac{V}{k \times q \times t \times u}$$

$$k = \frac{Te}{Tt + Th + Td} = \frac{420}{20 + 120 \ L/30 + 20} = \frac{105}{10 + L}$$

$$Ct2 = \frac{171 \times 2L}{8} + \frac{0.4 \times 270 \times 2L}{8} + \frac{12,500 \times (10 + L)}{105 \times 8} + \frac{42,150,000 \times (10 + L)}{105 \times 8 \times 6 \times 300} = 427 + 113 \times L$$

3. O/M cost for T/S.V

$$Ct_3 = 660 + \frac{17,840}{Q}$$

4. O/M cost of vehicle collection model

$$Ct = Ct_1 + Ct_2 + Ct_3 = 113 \times L + 6,049 + \frac{17,840}{Q} \text{ [₩/ton]}$$

(3) Comparison of Hand Cart Collection and Vehicle Collection

The formulas for calculation of collection cost by hand cart and vehicle are obtained as shown in Table 4-2-17.

Talbe 4-2-17 O/M Cost of Different Collection Methods

Method	O/M Cost [₩/ton]
Collection by hand cart with T/S	$107 \times L + 6,293$
Collection by vehicle with T/S	$113 \times L + 6,049 + \frac{17,840}{Q}$

Note L : Haul distance from a transfer station to a disposal site [km]

Q : Amount of waste [ton]

Cost comparison of hand cart collection and vehicle collection is shown in Table 4-2-18 .

There is not much difference between both systems under the same condition such as working hours, working days per year, etc, however, personnel expenses, as part of the total cost is very big with hand cart system as shown in Table 4-2-19. Vehicle collection system will be more advantageous in the future as personnel expenses escalate.

Table 4-2-18 Cost Comparison

unit:(won/ton)

Item	Hand Cart System	Improved System	Remarks
(1) Collection	* 5,708	4,962	* Including cost for unloading from hand cart onto dump truck
(2) Transfer Station	* -	700	* Small scale transfer station
(3) Transportation (to Nanjido)	2,190	2,122	Hauling distance is assumed to be 15 km
(4) Transportation (to Incheon)	4,865	4,947	Hauling distance is assumed to be 40 km
Total (1)+(2)	5,708	5,662	
Total (1)+(2)+(3)	7,898	7,784	
Total (1)+(2)+(4)	10,573	10,609	

Note: Including depreciation costs

Table 4-2-19 Portion of the Personnel Expenses against Total Cost

Distance	Item	Hand cart		Vehicle (Q=100t)	
		Cost	%	Cost	%
L = 10 km	P/E T/C	6,151 7,363	84	4,387 7,197	61
L = 20 km	P/E T/C	6,349 8,433	75	4,536 8,327	54
L = 30 km	P/E T/C	6,548 9,504	69	4,681 9,457	50

Note: P/E personnel expenses

T/C total cost

4-2-5 Proposed Alternative Systems

A proposed plan of the collection and transport system mainly using vehicles is as follows:

(1) Source Separation

- 3 component separation
- 2 component separation (central heated apartment houses)

(2) Storage Method

- Standardized container boxes (0.4-0.6 m^3)
- Paper or plastic bags (50 cm x 70 cm)

(3) Collection Method

- Station collection
- Curbside collection

(4) Frequency of Collection

- 3 times per week (combustible waste)
- 1 time per week (non-combustible waste)
- 1-4 times per week (briquet ash)

(5) Collection Vehicle*

- 2 ton or 4 ton compactor truck (combustible waste)
- 2 ton or 4 ton dump truck (non-combustible waste and briquet ash)

  * 4 ton truck is used for a road width of over 6m.

(6) Transfer Station

Common method with hopper

(7) Transportation vehicles

10^t container truck ($20m^3$)

(8) Parking Lots

By increasing the number of collection cars in the future, it will be difficult to park all of the collection cars at the existing parking lots in the city center. Therefore, it is necessary to establish new parking lots for collection cars at the new sites or at the transfer stations.

(9) Collection and Transport Diagram

Collection and transportation system diagram is shown in Table 4-2-20.

Table 4-2-20 Collection and Transportation System Diagram

Dwelling Type		Waste	Storage Method			Collection* Vehicle [2 or 4 ton]	Inter-midiate Facility	Transportation Vehicle [10 ton]	Description
			Storage Place	Storage Receptacle	Discharged Place				
Independent House		Combustibles	Home	Polyethlene Bag	Station or Curbside	Compactor Truck	I/C	Container Truck	Need to discharge with bag or sack
		Non-Combustibles	Home or Existing Concrete Box	Carriable Bag	Station or Curbside	Dump Truck with Crane	T/S	"	Need to discharge with bag or sack. Container Box is more desirable for collection efficienty
		Briqnet Ash	Container Box	Container Box	Container Box	Dump Truck with Crane	T/S	"	Station is applied if appropriate place for Container Box is not acquired
Apart-ment House with Dust Chute	Ordinary	Combustibles	Home	Polyethlene Bag	Station or Curbside	Compactor Truck	I/C	Container Truck	Ditto as Independent House
		Non-Combustibles	Home	Carriable Bag	Station or Curbside	Dump Truck with Crane	T/S	"	Ditto as Independent House
		Briqnet Ash	Container Box (Dust Chute Pit)	Container Box (Dust Chute Pit)	Container Box (Dust Chute Pit)	Dump Truck with Crane	T/S	"	Container Box is desirable however, Dust Chute Pit is acceptable to reduce citizens' burden
	Central Heated	Combustibles	Home	Polyethlene Bag	Station or Curbside	Compactor Truck	I/C	Container Truck	Ditto as Independent House
		Non-Combustibles	Home (Dust Chute Pit)	Carriable Bag (Dust Chute Pit)	Station or Curbside (Dust Chute Pit)	Dump Truck with Crane	T/S	"	Dust Chute Pit is acceptable to reduce citizens' burden
Apartment House without Dust Chute		Combustibles	Home	Polyethlene Bag	Station or Curbside	Compactor Truck	I/C	Container Truck	Ditto as Independent House
		Non-Combustibles	Home or Existing Concrete Box	Carriable Bag	Station or Curbside	Dump Truck with Crane	T/S	"	Ditto as Independent House Existing storage shed can be used as the station
		Briqnet Ash	Container Box	Container Box	Container Box	Dump Truck with Crane	T/S	"	Existing storage shed can be used as the station, if appropriate place for container Box is not acquired

Note, I/C: Incineration
T/S: Improved Transfer Station

4-3 Intermediate Processing

4-3-1 Processing Alternatives

(1) Processing system

The basic concept of solid waste management consists of resource recovery, volume reduction and return to nature while producing innocuous and stable refuse. Though intermediate processing such as size reduction, resource recovery, incineration, composting and others are the principal parts of the management system in this concept, at the same time, adoption of an economical system has to be considered as part of public works. Generally, the landfill method without processes is the cheapest one from a short term viewpoint but the solid waste management system should be developed from a long term viewpoint. Therefore, incorporation of the processing into the total system is controlled by management policy on the basis of local conditions.

Intermediate processing can be divided into two types by purposes: One aims at volume reduction for economical use of subsequent landfills and the other one focuses on resource recovery. Incineration which is most effective in volume reduction belongs to the former type, but in the case of large capacity units, it can be considered as the latter type, because waste heat can be recovered economically.

A processing system is a combination of unit processes according to intentions. Resource recovery in processing can be categorized into the following operations.

1. Materials processing and recovery for use as raw materials
2. Recovery of chemical conversion products
3. Recovery of biological conversion products
4. Recovery of energy from conversion products
5. Materials and energy recovery

The typical unit processes are described as follows.

(2) Unit Processes

a. Size Reduction

Size reduction of waste into a relatively constant size is necessary for the efficiency of the succeeding separation operations. Size reduction may be achieved by a variety of equipments. The roles of this process are listed as follows:

1. Preprocessing for separation: The refuse is reduced and uniformed in size for better separatability.

2. Volume reduction: In the case of crushing wastes, transportation costs become reduced and the life of the landfill site is extended.

3. Preprocessing for incineration and composting: Size reduction and uniformity increase combustion and fermentation efficiency due to the increase in surface area.

b. Separation Process

Separation processes are centered around the basic differences in size and weight. In addition, the differences in magnetic, electrical, optical, chemical, and other characteristics can be adapted.

Other than mechanical types of separation, manual separation is also possible. Hand picking of selected materials is used widely as a simple means of separation. However, some problems are inherent, such as the factor of human error as always being present, and hand separation being limited to a certain size of materials.

c. Incineration Process

Incineration is the controlled combustion process of combustible waste to gases and residual ash. The most attractive feature of the incineration process is that it can be used to reduce the original volume of solid waste by 80 to 90 percent. The residue as ash is stabler for disposal than the other alternatives. This process is suitable for the city that cannot find sufficient areas for landfills.

However, the incineration process needs not only high initial investment and operating cost but also high level technique for maintenance. Furthermore, air pollution will occur if no provisions for air pollution control measures are made. Investment on air pollution equipment raises costs. The typical incinerators for refuse are shown in Table 4-3-1.

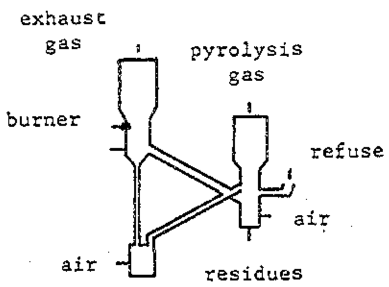
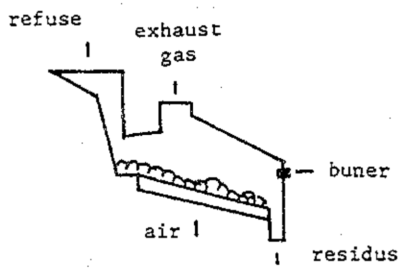
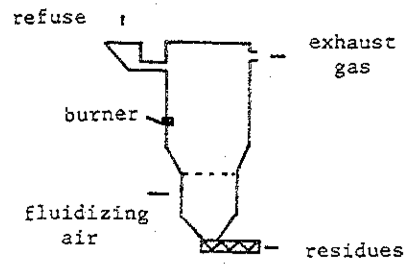
d. Pyrolysis Process

Pyrolysis is the process of decomposing organic materials at elevated temperatures in an oxygen-free or low-oxygen atmosphere. From an overall viewpoint, this process is endothermic, i.e., heat absorbing, unlike incineration, where it is exothermic. The important objectives of pyrolysis are the reduction in the volume of wastes, the recovery of fuels, and the reduction of gas emissions.

e. Composting Process

Composting is the biological conversion of organic wastes into a stable, humus-like end product used as fertilizers and soil conditioner. Modern composting is mostly aerobic. The important controlling factors for composting are nutrient balance and moisture content. If requirements in carbon-nitrogen ratio and moisture content cannot be met, adjustments are needed, such as the addition of sewage and nightsoil sludge. However, one of the biggest problems associated with composting is its marketability.

Table 4-3-1 Typical Incinerator and Pyrolysis Units

	Dual Tower Pyrolysis	Stoker Incinerator	Fluidized Bed Incinerator
Cross Section			
Description	The reactor consists of two fluidized beds. One pyrolyzes feedstock and another burns char produced by the pyrolysis. Two beds are sealed by heat media (sand). Partial product gas is used for fluidization of the pyrolysis reactor and air for lift and fluidization of the heat medium in the other bed.	Feedstock on the stoker goes through drying, burning and after-burning by the movements of stokers.	Refuse is fed onto the fluidized bed which is heated to 700 - 900°C, where incineration occurs. Heat medium is fluidized by an air flow and the air is used in the burning.
Advantages	High calorific gas makes storage or delivery easy. Char and tar which are difficult for further use are utilized in the reactor, but gas can be recovered.	Power consumtion is small.	Operation is relatively simple.
Disadvantages	1. System is unproven as yet. 2. Initial cost is high.	1. Feedstock containing more than 20% plastics is difficult to process. 2. NO_x is generated more than fluidized bed type.	Waste material containing more than 20% - 30% plastics is difficult to process.

Composting processes can be broady divided into mechanical and manual types. Typical types of composting processes are illustrated in Table 4-3-2 along with their descriptions.

f. RDF Process

Since municipal waste contains a large portion of paper and plastics, their fuel value can be utilized. The resultant solid fuel, called RDF or refuse-derived-fuel, can be pelletized or briquetted, or even used as is. RDF is employed by direct burning in a similar manner as coal. However, this process requires preprocessing to remove impurities such as metals and glass. Moreover, economics of this process is still unproven.

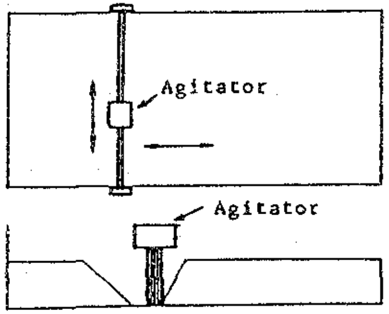
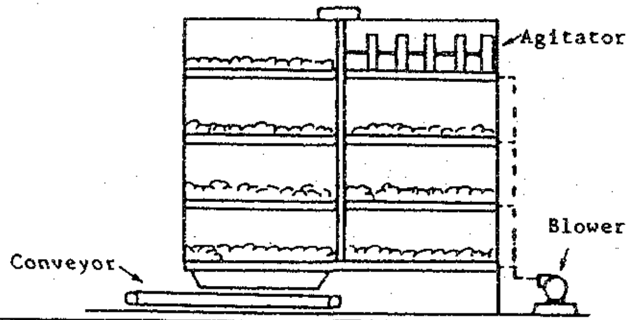
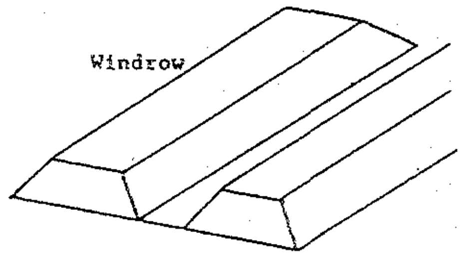
g. Methane Recovery Process

Methanation as an energy recovery process can be carried out by either anaerobic digestion of landfill gasifiers. In anaerobic digestion, the organic portion of waste is first broken down into organic acids and alcohols, and these are then converted to methane, carbon dioxide and water by anaerobic fermentation. Methane can also be recovered from landfills through collecting pipes. The recovered methane from these methods can be utilized as fuel.

h. Feed Production Process

Cellulosic wastes can be processed into animal feed and feed supplement by microbial fermentation or simple boiling. Unfortunately, application of this process to municipal waste is currently considered economically unfeasible.

Table 4-3-2 Typical Composting Units

	Mechanical Horizontal Type	Mechanical Vertical Type	Manual Type (Windrow)
Cross Section			
Description	Refuse is spread, moved and mixed by a mechanical device which moves back and forth on a horizontal plane. The mixing achieves aeration. The required fermentation period is from 10 to 30 days.	Waste is injected from the top and is slowly transferred to a successively lower floor by a mechanical means. This gradual dropping accomplishes aeration. The needed fermentation period is from 10 to 30 days.	Refuse is spread out into windrows where the fermenting materials are mixed periodically by a payloader. The necessary fermentation period is from 30 to 90 days.
Advantages	1. Construction is simple. 2. Operation and maintenance are easy. 3. Construction cost is lower than vertical type.	1. Can be installed in a smaller area than others. 2. Odor is prevented due to closed type.	1. Construction is very simple 2. Construction cost is lower than others.
Disadvantages	1. Larger construction area is needed than vertical type. 2. Odor control is difficult.	Construction cost and maintenance cost are high.	1. Larger area is needed than others. 2. Longer fermentation period is required than others. 3. Odor control is difficult. 4. Mixing is troublesome.

4-3-2 Possibility of Incineration and Power Recovery

(1) Calculation of Three Major Components and Lower Heating Value

The projected characteristics for intermediate processing is different from the actual generated one and should be established according to the collection method, such as separate or composite collection. In this section, the suitabilities of waste for processing methods are discussed on basis of the characteristics projected in Section 3-3 and collection of waste separated into two and three components.

The best criterion for incineration is the lower heating value. In this subsection, three major components of waste collected by 2 and 3 component separation methods are calculated, and their lower heating values are discussed. Here separation is assumed to be carried out as follows.

2 Components
- Briquet Ash
- Others

3 Components
- Briquet Ash
- Non Combustibles
- Combustibles

Three major components are calculated by the following equations.

$$\text{Volatile matter, } V\ (\%) = \frac{100v}{v+a+m}$$

$$\text{Ash, } A\ (\%) = \frac{100a}{v+a+m}$$

$$\text{Moisture, } M\ (\%) = \frac{100m}{v+a+m}$$

v, a and m are calculated as follows.

- In case of two component separations

$$v = 0.8 \sum_{i=1}^{7} c_i \left(1 - \frac{m_i}{100}\right)$$

$$a = 0.2 \sum_{i=1}^{7} c_i \left(1 - \frac{m_i}{100}\right) + \sum_{i=8}^{10} c_i \left(1 - \frac{m_i}{100}\right) + 0.1\, c_{11} \left(1 - \frac{m_{11}}{100}\right)$$

$$m = \sum_{i=1}^{10} c_i \frac{m_i}{100} + 0.1\, c_{11} \frac{m_{11}}{100} + 0.9\, c \frac{m_{11} - 8}{100}$$

$$= \sum_{i=1}^{11} c_i \frac{m_i}{100} - 0.072 c_{11}$$

- In case of three component separations

$$v = 0.8 \sum_{i=1}^{7} c \left(1 - \frac{m_i}{100}\right)$$

$$a = 0.2 \sum_{i=1}^{7} c_i \left(1 - \frac{m_i}{100}\right) + 0.1 \sum_{i=8}^{11} c_i \left(1 - \frac{m_i}{100}\right)$$

$$m = \sum_{i=1}^{7} c_i \frac{m_i}{100} + 0.1 \sum_{8}^{10} c_i \frac{m_i}{100} + 0.1\, c_{11} \frac{m_{11}}{100} + 0.9 \sum_{i=8}^{11} c_i \frac{m_i - 8}{100}$$

$$= \sum_{i=1}^{11} c \frac{m_i}{100} - 0.072 \sum_{i=8}^{11} c_i$$

Here, c_i and m_i are the per capita generation rate and the moisture content of component i, respectively. Component number, c and m are shown in Table 4-3-3.

In above equations, volatile matter is supposed to be 80% of dry portion of combustibles, whereas the residual 20% is ash. All of the dry portion of noncombustibles is supposed to be ash. Moreover, moisture content of briquet ash is supposed to be 8% when it is collected separately. In composite collection, the moisture content becomes higher because briquet ash seems to absorb moisture of other components.

Table 4-3-3 Moisture Content and Generation Rate Fluctuation

Component	Moisture Content (%)		Generation Rate in 1988 (kg/cap/d)			Generation Rate in 2005 (kg/cap/d)			Component No.
	Average	Summer	Summer	Average	Winter	Summer	Average	Winter	
(Combustibles)									
Paper	37.5	40.9	0.241	0.228	0.217	0.387	0.431	0.470	1
Wood	25.1	27.4	0.038	0.036	0.034	0.032	0.036	0.039	2
Textiles	24.9	27.1	0.044	0.042	0.040	0.069	0.076	0.083	3
Garbage	80.6	88.0	0.384	0.364	0.346	0.343	0.382	0.417	4
Plastics	22.3	24.3	0.108	0.102	0.097	0.188	0.209	0.228	5
Rubber	6.1	6.6	0.008	0.008	0.008	0.007	0.008	0.009	6
Others	16.5	18.0	0.122	0.116	0.110	0.104	0.116	0.126	7
(Sub-total)			0.945	0.896	0.852	1.130	1.258	1.372	
(Non combustibles)									
Metal	0	0	0.031	0.029	0.028	0.048	0.054	0.059	8
Glass	8.9	9.7	0.069	0.065	0.062	0.110	0.122	0.133	9
Others	8.9	9.7	0.081	0.077	0.073	0.069	0.077	0.084	10
(Sub-total)			0.181	0.171	0.163	0.227	0.253	0.276	
(Briquet Ash)	18.9	20.6	0.457	0.975	1.428	0.280	0.596	0.873	11
T O T A L			1.583	2.042	2.443	1.637	2.107	2.521	

For the calculation of medium quality waste and low quality waste, the moisture content of annual average and the adjusted summer value are used, respectively. The adjusted summer value is obtained by multiplying 1.15 to the summer value (Table 4-3-3) based on the analysis of the basic field survey.

An assumption was made that 10% of generated briquet ash is mixed in the input-waste to the plant in case of 2 component separation. In case of 3 component separation, 10% of generated non-combustibles and briquet ash is assumed to be mixed to the combustibles (Table 4-3-4).

Table 4-3-4 Conditions on Calculations of Three Components by Separation Methods

	Medium Quality Waste	Low Quality Waste
(2 Component Separations)		
Moisture Content	annual average	summer x 1.15
Combustibles	m = 100%	m = 100%
Non Combustibles	m = 100%	m = 100%
Briquet Ash	m = 10%	m = 10%
(3 Component Separations)		
Moisture content	annual average	summer x 1.15
Combustibles	m = 100%	m = 100%
Non Combustibles	m = 10%	m = 10%
Briquet Ash	m = 10%	m = 10%

Note m: Mixture rate of the component to the input-waste to the plant.

The result of the calculation is shown in Table 4-3-5. In 1988, the lower heating values are 720 kcal/kg and 840 kcal/kg on the conditions of two component separation and three component separation, respectively. The critical point of self burning is estimated to be about 700 - 750 kcal/kg from experience. From this point of view, the waste separated into two components is not always reliable to burn without supplemental fuel. On the other hand, the waste separated into three components has enough heating value to burn. The details on separated collection and incineration facility are discussed in the correspondent sections of this report.

Table 4-3-5 Estimated Characteristics on Separation

Separation Type	Component	1988		2005	
		Medium Quality Waste	Low Quality Waste	Medium Quality Waste	Low Quality Waste
2 Components	Volatile (%)	28.9	23.4	34.1	27.8
	Ash (%)	26.1	21.9	25.9	23.0
	Moisture Content (%)	45.0	54.7	40.0	49.2
	Lower Heating Value (kcal/kg)	1,030	720	1,290	950
3 Components	Volatile (%)	32.9	26.9	39.7	32.4
	Ash (%)	16.8	11.5	15.1	11.5
	Moisture Content (%)	50.2	61.6	45.2	56.1
	Lower Heating Value (kcal/kg)	1,180	840	1,520	1,120

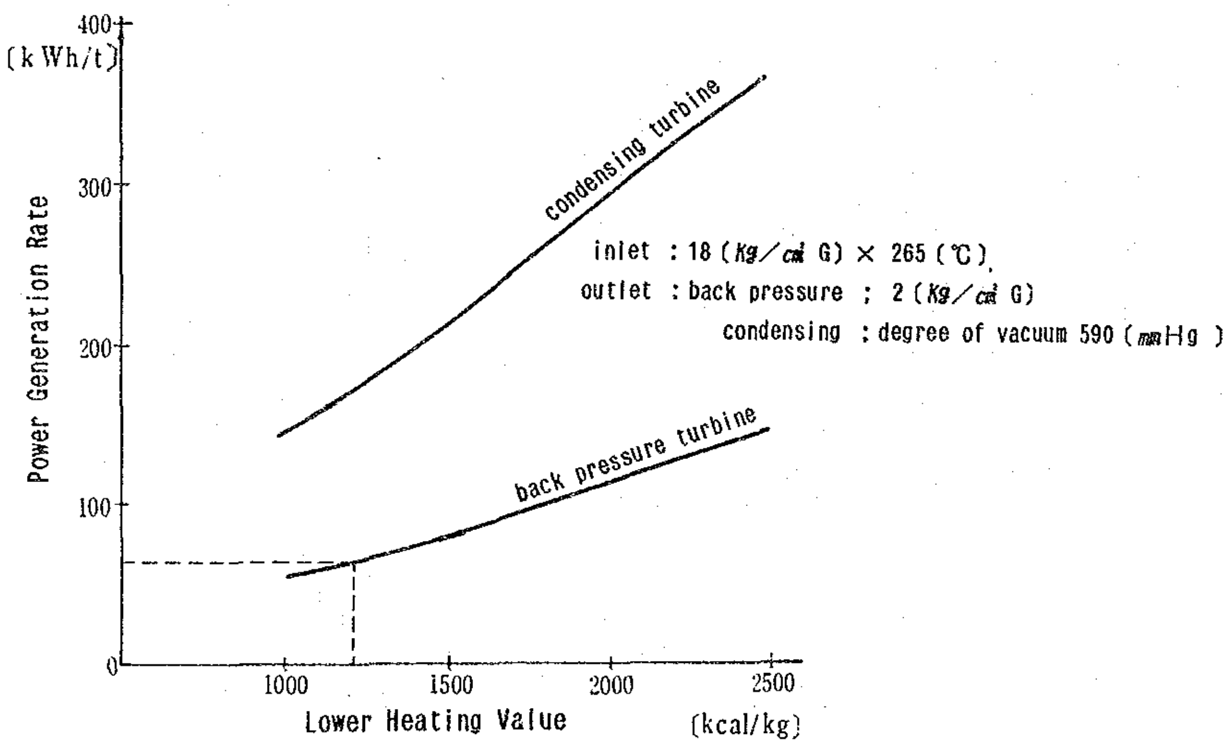
Note: Lower heating value (H_1) was calculated by

$H_1 = 45V - 6M$

where, V: Volatile matter (%), M : Moisture content (%)

(2) Lower Heating Value and Power Recovery

Power generation rate is determined by lower heating value of waste, type of turbines and scale of the power generation unit. Relationship between lower heating values and generation rates are examined from experiences and depicted in Fig. 4-3-1. As the power consumption for an incineration facility is assumed to be 40-70 kWh/t, lower heating value should be about 1,200 kcal/kg to be self-sufficient if back pressure turbine is used.



Source : Japan Environmental Sanitation Center

Fig. 4-3-1 Relationship between Lower Heating Value and Power Generation Rate

4-3-3 Marketability of Recoverables

(1) Briquet Ash

Since briquet ash occupies a large percentage of Seoul's waste, effective use of this ash is very important to reduce the load on disposal. Usages such as filling material for land reclamation, soil conditioner and material for brick manufacture have been tried without enormous successes. Other possibilities include use as road filler when conglomerated with glass cullet to improve the foundation of roads, and as cover material for landfill operations.

As of now, however, use of ash as filling material and cover material seem to be most promising. The other uses need further research to determine their actual feasiblilties. However, revenues from recycling briquet ash cannot be expected.

(2) Compost

a. General Aspects

As compost is processed from the organic portion of waste, it can be used as a stabilized material for land reclamation and landfill covering, or it can be used as a soil conditioner or a fertilizer if nutrients are added. The former use is obviously a year-round pursuit, but the latter is highly seasonal and requires a sufficient storage area.

However, the existence of a viable market is the key to the successful operation of a composting system. For landfilling and landfill covering, benefits are plenty, but not much profit can be expected. If selling as a soil conditioner is planned, and if a certain amount of income is anticipated, many factors must be considered. These factors include, among others, institutional arrangements, distribution, promotion, visual attractiveness as a product, and production of a high-grade, low-cost product.

b. Desirability factors

Compost made from refuse alone can be used as a soil conditioner, and cannot be considered as a fertilizer, unless some nutrients are added. However, in the long run, compost increases the water holding capacity of the soil, among others, which means that the quality of the soil will become better for a higher yield in crops. On the other hand, using chemical fertilizers can worsen the quality of the soil after long usage. Furthermore, it is true that chemical fertilizers yield faster and better crops, but chemical fertilizers can destroy the soil and cost enormously higher, and also do not help in solving the solid waste disposal problem.

Interviews and questionnaire surveys were carried out on shops selling fertilizers and farmers in and around Seoul City. The results revealed that shops are willing to sell products made from solid waste, but the consumers seem reluctant to buy compost. However, if the farmers were to buy these products, the most preferred packaging type seems to be 20 kg bags. Furthermore, preferable prices were also inquired and the results indicated that the consumers would like to buy the products at prices on the average of 70% less than the sellers' demand prices.

c. Potential Demand Rate

For this study, the scope of demand for compost will be extended to include Seoul City, Incheon City and Kyeonggi Do. The land areas of these two Cities and one Do in 1982 are given below.

Seoul City	:	605.33 km^2
Incheon City	:	201.90 km^2
Kyeonngi Do	:	10,854.61 km^2
Total		11,661.84 km^2

The total planted area of crops, excluding rice, within this area in 1982 was about 133 thousand hectares. Rice was not included because compost can rot the roots of crops planted in paddy fields.

As a rule of thumb, (one ton compost)/(10a farmland)/year is a reasonable estimate. Consequently, the potential demand comes to about 1,330,000 t/yr. The breakdown into regions is as follows.

Seoul City	:	40,000 ton/year
Incheon City	:	20,000 ton/year
Kyeonggi Do	:	1,270,000 ton/year
Total		1,330,000 ton/year

d. Storage Space

Since the use of compost is seasonal, availability of storage space becomes a significant factor. If a storage requirement of 120 m^2 for one ha of farmland is assumed, this availability at the surveyed farms indicated that only 15% of them have enough space to store compost.

e. Compost Marketability

The most important factor to determine the feasibility of composting is its marketability. The largest market of compost is considered to be the farmland in Seoul and adjacent municipalities. If compost is to be delivered to distant places in Kyeonggi Do, the cost for transportation may aggravate the feasibility. As shown above, potential demand is 40,000 ton/year and 20,000 ton/year in Seoul and Incheon, respectively. Although there is relatively large demand in Kyeonggi Do, the demand is not considered to be large around Seoul.

On the other hand, compost supply is expected from resource recovery plant in Nanjido. The recovery rate is 648 ton/day, that is, 194,400 ton/year. The supply is regarded to be sufficient for Seoul and adjacent area.

However, if composting is to be considered, uses other than as soil conditioner or fertilizer need to be planned. Possibilities include using the product as fill material for land reclamation or as cover material for landfill operations. The benefits from these uses do not necessarily include financial aspects.

(3) Materials

The potential separatability and possible revenues for materials in mixed solid waste of Seoul for the year 2005 are indicated in Table 4-3-6. This recovery will require elaborate technology and resultant high expenses, especially for the combustible portion.

Table 4-3-6
Material Recycle Potential on Mixed Refuse
(for Year 2005)

Material	Separatable Percent (%/t)	Separatable Rate (Dry Basis) (1,000 t/yr)	Possible Current Unit Price (W/kg)	Potential Revenue (million W/yr)
Paper	2	39	20	780
Plastics	3	29	25	720
Textile	1	3	20	60
Glass	10	34	15	510
Ferrous Metals	15	34	25	850
Nonferrous Metals	20	4	100	400
Total	4	143		3,325

Next, the potential on source separated non-combustible waste is shown in Table 4-3-7. This recovery is less complicated than that on mixed refuse.

Table 4-3-7

Material Recycle Potential on Separated Non-combustibles (for Year 2005)

Material	Separatable Percent (%/t)	Separatable Rate (Dry Basis) (1,000 t/yr)	Possible Current Unit Price (W/kg)	Potential Revenue (million W/yr)
Glass	25	84	15	1,260
Ferrous Metals	25	57	25	1,425
Nonferrous Metals	35	8	100	800
Total	26	149		3,485

Materials recovery on mixed refuse will give about a 1.5% reduction in volume, and if recovery on separated non-combustibles is carried out, a similar 1.6% reduction can be accomplished. The revenue of recycling from source separated waste is slightly higher than that from mixed waste. As a consequence, materials recovery on waste collected separately for non-combustibles is more effective technically and will have better marketability.

On the other hand, the easily recoverables in the waste, such as card-board, newspaper, bottles, cans and rags, should be separated at the source of generation before they are put out as waste. If this is carried out, some recommended programs for handling the source separated recyclables are described below.

1. Collection of source-separated recyclables by self-support work corps under the control of district police offices. (This way, the corps members will be able to collect recoverables more easily and sorting by the corps becomes unnecessary.)

2. Community involvement programs in which the citizens with the help of the administration manage the separated materials and salable materials are sold to secondary materials dealers.

3. Community recovery centers in which centers are set up where recovery activities, including workshops for repair and reconditioning, marketing research and swapping events, are carried out with the involvement of residents.

If the generators themselves separate recyclables, less burden will be borne on waste collection and disposal. Furthermore, this can result in reduction of waste management costs, prevention of resources depletion and, in some cases, increase of employment.

4-3-4 Evaluation of Processing Systems

(1) Establishment of Alternatives

The various processes described above cannot be easily incorporated into a solid waste management system without scrutiny of waste characteristics, output marketability and other significant factors. However, the processes listed below will be initially compared and evaluated on appropriateness for consideration as alternatives, especially from the viewpoint of technical provenness on a world-wide basis. (See Table 4-3-8.)

- Incineration
- Pyrolysis
- Composting
- Materials Recovery
- RDF
- Methane Recovery
- Feed Production
- Non-processing (Direct Landfill)

With respect to the RDF process, an actual scale plant is now under construction at a corner of the Nanjido landfill site. Furthermore, since the process itself is not yet proven world-wide, this process will not be recommended in this study. However, the new plant can be used as a demonstration to accumulate pertinent data and monitor results for future planning. The success of this plant can set an example for other municipalities around the world.

Therefore, the alternative processing systems for intermediate processing in Seoul City are proposed as listed below and these should be adopted singly or in combination according to generated waste characteristics, marketability of processing products and other local conditions.

1. Non-intermediate processing system : Collected waste is directly hauled to the final disposal site.

Table 4-3-8 Preliminary Evaluation of Intermediate Processing

Process	Initial Cost	O/M* Cost	Provenness	Volume Reduction	Score	Comment
Incineration	X	X	O	O	6	Proven on a wide-scale, World-wide. Most effective process for waste volume reduction.
RDF	Δ	Δ	X	Δ	3	Has been researched extensively in the U.S.A., but actual demonstrations were unsuccessful.
Material Recovery	Δ	Δ	Δ	Δ	5	Recovery of non-combustibles is successfully proven. Other materials have yet to be proven.
Composting	Δ	Δ	O	Δ	7	Marketability of end-product is insufficient for feasibility. Proven in some European cities.
Methane Recovery	X	Δ	X	Δ	2	Digestion is proven as a technology, but is yet unproven on municipal solid waste. Landfill methane recovery is presently on-going demonstration in U.S.A. and Europe.
Feed Production	Δ	Δ	X	Δ	3	Uncomplicated process, but yet to be proven on mixed municipal solid waste.
Pyrolysis	X	X	X	O	2	High volume reduction, but actual demonstration yet to be proven.
Landfill	O	O	O	X	8	Traditionnally favored if acquisition of suitable sites is possible.

Note : X: 0 point, Δ: 1 point , O: 2 points points for provenness receive double.
*O/M: Operation and maintenance

2. Incineration system : Collected waste is brought to the processing plant where the waste is incinerated and residues are hauled to the final disposal site. In this case, the waste to be processed should have enough calorific value for incineration. Therefore, source separation of combustibles may be necessary.

3. Incineration with heat and/or power recovery system : Same as 2. above except waste heat from incineration is recovered as energy. In this case, stabilization of output heat must be considered.

4. Materials recovery system : Collected waste is transported to the processing plant where recoverable materials are sorted manually and/or mechanically, and the residues are brought to the final disposal site. In this case, marketability of materials must be carefully studied, and source separation of non-combustibles may be desirable.

5. Composting system : Organic portion of collected waste brought to the processing plant is fermented and matured to yield a product useful as a soil conditioner or a stabilized and volume-reduced fill material. If the compost is to be used as a soil conditioner, a thorough marketing survey is essential, and upgrading facilities may be required.

(2) Evaluation of Alternatives

The above alternatives are compared for advantages and disadvantages in Table 4-3-9. The possible outputs from these alternatives are listed in Table 4-3-10. The processing costs of each alternative are estimated in Table 4-3-11 on the basis of the material balance shown in Fig. 4-3- 2. If compost is marketable, composting is the most economical from viewpoints of volume reduction. When the compost is distributed free of charge, the reduction cost is a little less expensive than the incineration cost. However, since compost marketability is not sufficient in Seoul City and its neighborhood, it is difficult to distribute all of the product. If it is assumed that compost is conveyed to landfill sites, the reduction cost of composting becomes more than that for incineration. Therefore, incineration is an economical processing method for Seoul City taking into account the compost marketability and transportation cost.

Evaluation from technical viewpoints, waste characteristics, marketability of by-products and other significant local conditions is compiled in Table 4-3-12. From results of the evaluation, a combination of processes is recommended for waste excluding briquet ash. As for briquet ash, processing is not feasible, but use as cover material for operation of sanitary landfills is recommended. The combination of processes will be further studied when considerations are made on the total solid waste management system for the master plan in the following chapter.

Table 4-3-9 Comparison between Alternative Systems

System	Advantages	Disadvantages
Non-intermediate Processing	-Low costs -Easy management -High technology not required	-Siting of Landfills difficult -Can require high transportation cost -Environmental disruption feared -Unaesthetic
Incineration	-Waste volume reduction -Yields stable and harmless output	-High initial cost -High operation and maintenance cost -Requires high technology -Consideration of combustibility needed -Requires air pollution control measures
Incineration With heat and/or power recovery	-Waste volume reduction -Yields stable and harmless output -Waste heat can be recovered as energy	-High initial cost -Required high technology -Consideration of combustibility needed -Requires air pollution control measures -Stabilization of waste heat required
Materials Recovery	-Waste volume reduction -Yields valuable resources -Can increase employment	-Marketability of recovered materials uncertain -Requires high technology and high costs
Composting	-Yields stable and harmless output -Can be operated in combination with sewage and nightsoil treatment	-Marketability of compost is uncertain -High operation and maintenance cost -Requires seasonal storage area

Table 4-3-10 Potential Outputs from Intermediate Processing

System	Recoverable Materials	Recoverable Energy	Residue
Non-Intermediate Processing	Land	(Methane gas)	Leachate Gases
Incineration	None	None	Ash Clinkers Wastewater Flue gas
Incineration with energy recovery	None	Heat Power	Ash Clinkers Wastewater Flue gas
Materials recovery	Plastics Metals Glass Paper Textile etc.	(Solid fuel such as RDF)	Nonrecoverable materials
Composting	Compost	None	Noncompostable Materials

Note : outputs in parentheses require another process.

Table 4-3-11 Cost Comparison of Intermediate Processing

Identification	Relationship	Processing Method / Item	Unit	Composting: Marketable	Composting: Free of Charge	Composting: Non-Marketable	Incineration	Material Recovery
		Type		Mechanical	Mechanical	Mechanical	Stoker	Mechanical
		Processing Waste		Combustibles	Combustibles	Combustibles	Combustibles	Non-combustibles
a		Capacity	(t/d)	600	600	600	600	100
b		Volume Reduction Ratio*	(m^3/t)	0.59	0.59	0.27	0.80	0.12
b'			(m^3/m^3)	0.66	0.66	0.30	0.88	0.15
c		Investment	(₩)	$17,500 \times 10^6$	$17,500 \times 10^6$	$17,000 \times 10^6$	$23,000 \times 10^6$	$2,200 \times 10^6$
d	c/20	Depreciation**	(₩/y)	875×10^6	875×10^6	850×10^6	$1,200 \times 10^6$	100×10^6
e		O/M (without Dep.)	(₩/y)	680×10^6	680×10^6	650×10^6	$1,000 \times 10^6$	150×10^6
f	d + e	O/M (Including Dep.)	(₩/y)	$1,555 \times 10^6$	$1,555 \times 10^6$	$1,500 \times 10^6$	$2,200 \times 10^6$	260×10^6
g		Revenue***	(₩/y)	690×10^6	-	-	-	99×10^6
h	(f-g)/330a	Processing Cost	(₩/t)	4,370	7,850	7,580	11,110	4,880
i	h/b	Reduction Cost	(₩/m^3)	7,400	13,300	28,100	13,900	40,700

Note: * Volume reduction ratio (m^3/t) = (input-output)/input

** Durable length of time is 20 years

*** Compost price is assumed to be W10,000/t. Since energy recovery from incineration is assumed for in-plant supply only, revenue is not considered.

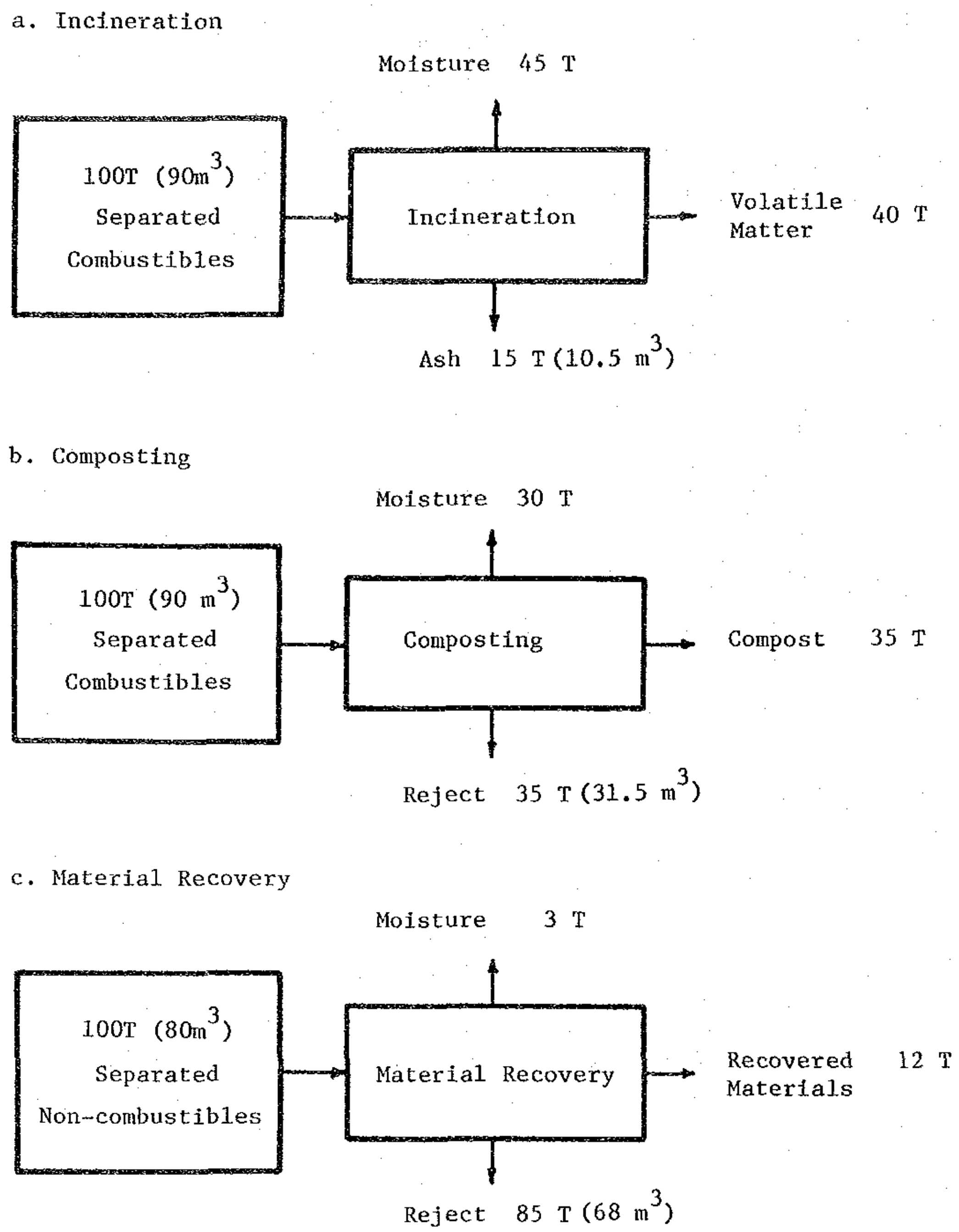


Fig. 4-3- 2

Mass Balance for Processing of Separated Waste

Table 4-3-12 System Evaluation

System	Source Separation Recommendation	Volume Reduction* (m^3/t)	Evaluation
Non-intermediate processing	None	0 %	Since Nanjido is almost saturated and acquisition of other sites is difficult, and moreover, does not help in resources preservation, this system is not suitable for Seoul City.
Incineration with or without energy recovery	Combustibles	80 % (Comb. only) 74 % (With noncomb.)	This is a well proven system on a world-wide scale and greatly reduces waste volume. If energy is recovered, further benefits are obtained.
Materials Recovery	Non-combustibles	12 % (Noncomb. only) 3 % (With comb.)	Though recovered materials are marketable, instead of sophisticated recovery at the intermediate processing stage of solid waste management, recovery at the source of generation is more beneficial for refuse of Seoul City.
Composting	Compostable (Garbage,paper)	59 % (Comp. only) 57 % (With others)	Marketability of compost product as soil conditioner or fertilizer is rather low in and around Seoul to make this system economically feasible.

* Reduced landfill volume (m^3)/input amount (t)

4-4 Final Disposal

4-4-1 Landfill Technology

(1) Landfill Method

Selection of an appropriate landfill method is required to promote the stability of filled refuse and to control environmental impacts. Landfill methods are categorized into the following five types (Fig. 4-4-1).

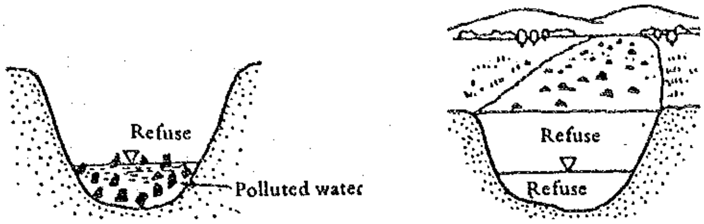
1. Anaerobic landfill	:	Dumping refuse and leaving alone without cover material
2. Anaerobic sanitary landfill	:	Alternately filling refuse and cover material
3. Modified sanitary landfill	:	Anaerobic sanitary landfill with drainage pipe for leachate (fill interior is in an anaerobic state)
4. Semi-aerobic landfill	:	Collecting leachate and keeping fill interior in a semi-aerobic condition
5. Aerobic landfill	:	Sending air to refuse layer and keeping fill interior aerobic

For the stability of the refuse layer, aerobic landfills is more effective in keeping the interior aerobic and also in keeping the quality of leachate lower in organic content than anaerobic landfills. However, the initial cost of aerobic landfills is higher because drainage pipes, aeration pipes and blowers are required.

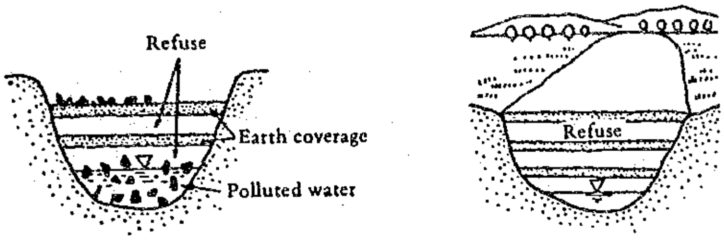
Cover material is useful for prevention of refuse scattering, odor emission and vector generation. The Refuse Cleansing Law (Articles 18 and 19 in the regulation) prescribes the following.

- The refuse layer is to be less than 2 m in thickness after compaction and to be covered with soil of over 60 cm in thickness.
- The moisture content of the filling refuse is to be under 80%.
- The daily cover layer is to have a thickness of over 5 cm after a day's operation is completed.

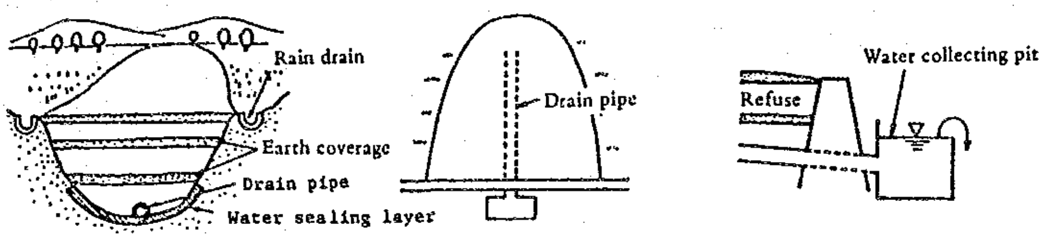
1. Anaerobic landfill



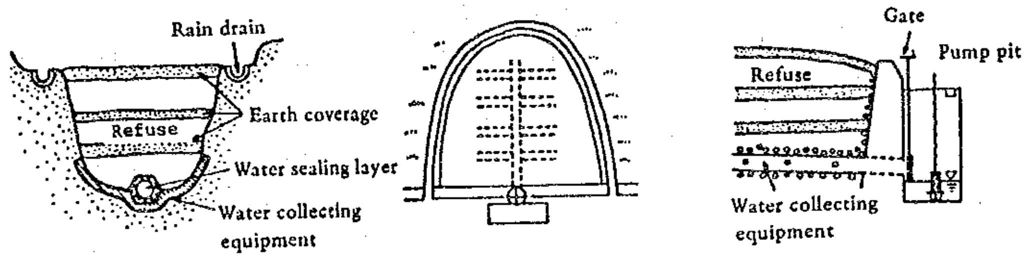
2. Anaerobic sanitary landfill



3. Modified sanitary landfill



4. Semi-aerobic landfill



5. Aerobic landfill

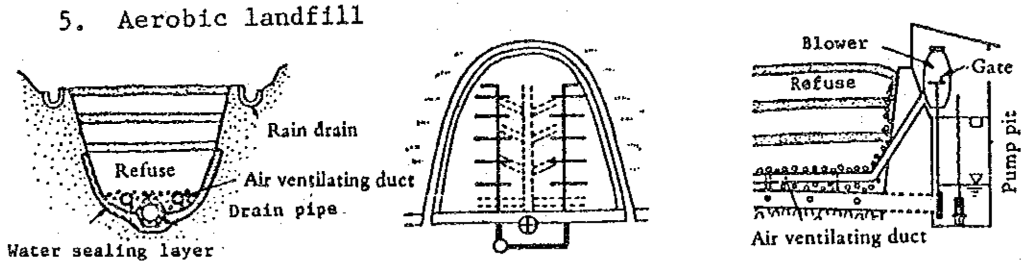


Fig. 4-4-1 Typical Landfill Methods

(2) Cover Material

The cover material needs to be acquired easily and economically in sufficient volume and should be suitable for the covering objective. The covering layer can be divided into the following three types: 1. Daily covering layer, 2. Interim covering layer and 3. Final sealants. Since the daily covering layer intends to seal the refuse layer for prevention of waste dispersion, the characteristics of the cover material are insignificant.

Concerning the interim covering layer, two options can be considered: 1. Tight layer to prevent the venting of gases from the refuse layer and the penetration of precipitation into the refuse layer, and 2. Permeable layer for promotion of gas removal. For the former option, since the cover material has to be laid tight, impermeable soils such as clay and clay-sand are suitable. Permeable soils such as gravel and coarse sand are suitable for the second option. Because final sealants, especially on slopes, are necessary to be waterytight and nonerosive, viscous soil is appropriate. The thickness of the final sealants is generally required to be 50 to 60 cm, but if plants are to be grown, the thickness needs to be 1.5 to 2.0 m to protect plant roots from evolving gases. Typical sealant materials are shown in Table 4-4-1.

Table 4-4-1 Landfill Sealants for Gas and Leachate Control

Sealant		Remarks
Classification	Representative types	
Compacted soil		Should contain some clay or fine silt
Compacted clay	Bentonites, illites, kaolinites	Most commonly used sealant for landfills; layer thickness varies from 6 to 48 in; layer must be continuous and not allowed to dry out and crack
Inorganic chemicals	Sodium carbonate, silicate, or pyrophosphate	Use depends on local soil characteristics
Synthetic chemicals	Polymers, rubber latex	Experimental, use not well established
Synthetic membrane liners	Polyvinyl chloride, butyl rubber, hypalon, polyethylene, nylon-reinforced liners	Expensive, maybe justified where gas is to be recovered
Asphalt	Modified asphalt, rubber-impregnated asphalt, asphalt-covered polypropylene fabric, asphalt concrete	Layer must be thick enough to maintain continuity under differential setting conditions
Others	Gunite concrete, soil cement, plastic soil cement	

Source: Tchobanoglous, G., "Solid Wastes".

4-4-2 Landfill Planning

(1) Disposal Rate

The waste disposal rate is calculated from the waste generation rate and reduction rate due to intermediate processing. Considering the intermediate processing rate, the annual disposal rate can be calculated. In the calculation of the disposal volume, volume coefficients of compacted wastes were assumed as follows.

Combustibles	:	0.9 m^3/ton
Non-Combustibles	:	0.8 m^3/ton
Incineration Residue	:	0.7 m^3/ton
Briquet ash	:	0.6 m^3/ton

The annual forecasted disposal rates are shown in Table 4-4-2. Though the collectin rate of waste increases 1.27 times from 1985 to 2005 (from 19,610 ton/day to 24,980 ton/day), the annual disposal rate are in the same level (from 5,290,000 ton/year to 5,230,000 ton/year). The tendency is due to the volume reduction caused by the periodical construction of incineration plants.

(2) Candidate Landfill Sites

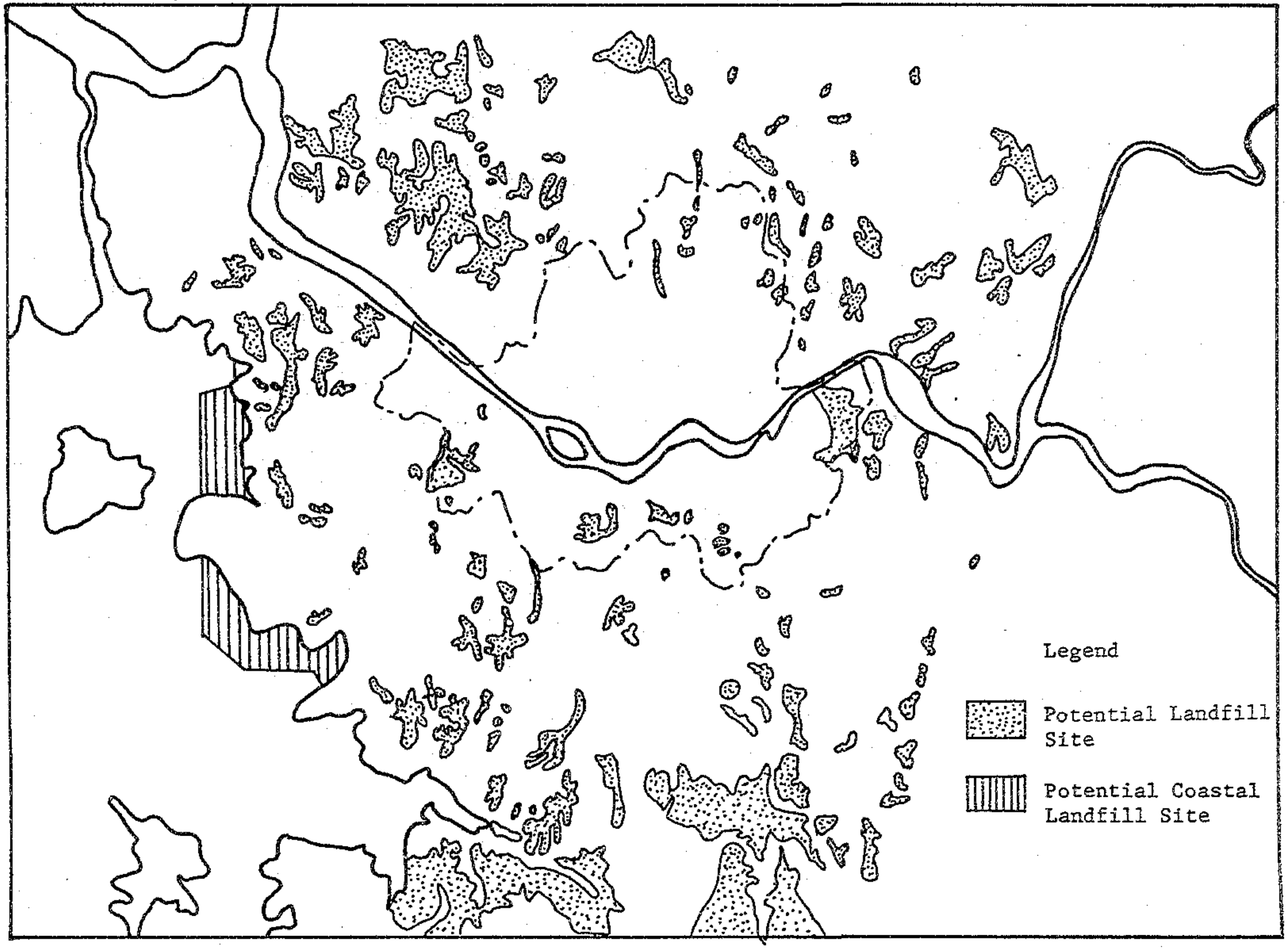
The potential landfill sites were indicated in the Han River Basin Environmental Master Plan Report as shown in Fig. 4-4-2. These were screened by taking into account soil conditions, existing land use, land use plan and preservation areas on environmental and cultural aspects. The adequate potential sites with consideration of capacities and transportation distances can be selected as the following.

1. Incheon coastal area
2. Southeast of Seoul : Kwangju-Gun
3. Northwest of Seoul : Goyang-Gun

Table 4-4-2 Disposal Rate

(1,000 m^3/year)

Year	Combustibles	Non-combustibles	Briquet Ash	Incineration Ash	Total
1985	2,650	440	2,200	0	5,290
1986	2,590	450	2,190	0	5,230
1987	2,530	460	2,170	0	5,160
1988	2,620	490	2,170	10	5,290
1989	2,620	510	2,150	20	5,300
1990	2,760	540	2,140	20	5,460
1991	2,880	570	2,120	20	5,600
1992	3,020	590	2,110	20	5,740
1993	2,770	620	2,080	60	5,530
1994	2,890	640	2,050	60	5,640
1995	3,030	660	2,020	60	5,770
1996	2,810	690	2,000	100	5,600
1997	2,930	710	1,950	100	5,690
1998	3,050	740	1,910	100	5,800
1999	2,820	750	1,880	150	5,600
2000	2,950	780	1,840	150	5,720
2001	3,080	810	1,800	150	5,840
2002	2,660	830	1,750	210	5,450
2003	2,770	850	1,700	210	5,530
2004	2,910	880	1,660	210	5,660
2005	2,470	890	1,600	270	5,230
Total	58,810	13,900	41,500	1,920	116,130



source : Han River Basin Environmental Master Plan

Fig. 4-4-2 Potential Landfill Sites

(3) Landfill Period

a. Nanjido

Nanjido has been utilized as a final disposal site since 1977. However, most of the area has been completed. Consequently, plain landfilling cannot be continued. Since large scale landfill sites around Seoul are presently not available, increasing the capacity of Nanjido by mounding is the only alternative.

Recognizing the present situation mentioned above, Seoul City entrusted mounding plan to Seoul City University. The specifications of the Seoul City University Plan is listed in Table 4-4-3.

b. Incheon

The expected landfill site after Nanjido is Incheon coastal area which has been studied by O.O.E. However, the O.O.E. study is not authorized by the Economic Planning Board at the present time. According to this study, the landfill capacity of the Bekseuk district is 112,854,000 m^3. If it is assumed that 65% of the volume is assigned to Seoul City, the available capacity is 73,355,000 m^3, which is equal to the disposal amount in Seoul during 1995 to 2007. After landfill in Bekseuk districk is over, another coastal landfill site should be secured in Incheon.

c. Subsidiary Landfill Sites

As it is difficult to secure large scale landfill sites in Seoul, efforts should be made to search for subsidiary landfill sites. In small landfill sites, briquet ash and incineration residue should be filled because of the easiness in management such as that for leachate treatment.

Table 4-4-3 Mounding Plan of Seoul City University

Items	Specification
(Basic Concepts)	
1. Land Area	271 ha
2. Altitude (above sea level)	50-70m (30-50m of mounding)
3. Capacity	90 million m^3
4. Landfill Period	10 years (1985-1994)
(Landfill Scheme)	
1. Landfill Method	Sanitary landfill by cells
2. Cover Material	
Daily Cover	Briquet Ash
Intermediate Cover	Construction debris, briquet ash
Final Cover	Clay, surplus soil
3. Layer Thickness	Waste 2m, cover soil 30 cm
4. Structure	
Gradient	3 : 1
(Leachate Treatment)	
1. Prevention of Bottom Water Penetration	Briquet ash (50cm) + clay (30cm) + briquet ash (50cm)
2. Prevention of Side Water Penetration	Separating wall with water tite materials
3. Leachate Collection Pipe Length	63,800m (8,197 ₩/m)
4. Treatment Amount	4,800 m^3/day
5. Treatment Method	Lagoon + coagulating sedimentation
(Rain Water Elimination)	
	Improvement of Nanji River and construction of retarding basin, pumping facilities, rain water canal along Han River
(Gas Control Facilities)	
1. Interval of Gas Wells	50m
2. Total Well Length (horizontal)	57,600m (15,625 ₩/m)
3. Total Well Length (vertical)	59,400m (13,468 ₩/m)
4. Gas Burning Facilities	120 points (@ 833,333 ₩)

4-4-3 Consideration on Nanjido Mounding Plan

As explained in Subsection 4-4-2, the Nanjido site is used for mounding. It's basic methods studied by Seoul City University are summarized in Table 4-4-3. In this subsection, the results of the study made by Seoul City University were reviewed on the following items.

(1) Slope Structure of Landfill

Since the structural strength of the outside slope of landfill is important, stabilization of the slope relevant to rotational slip is analysed by computor.

a. Charactristics of Waste Material for Filling

To analize the slope stabilization, it is necessary to assume charactristics of the refuse to be filled. Based on the Seoul City University Study and the existing field test data obtained in Japan, characteristics of briquet ash, incineration ash, rubbish and domestic refuse are assumed as shown in Table 4-4-4.

Table 4-4-4 Charactristics of Waste Material for Filling

Waste	C (t/m^2)	ϕ (°)	r (t/m^3)	Source
Briquet ash	1.3-5.2	1.4-3.2	1.3	Seoul City University
Incineration ash(W1)	5.0	29	1.25-1.6	*Field test in Japan
Rubbish (W2)	4.0	33	1.0-1.7	Ditto
Domestic refuse (W3)	1.5	13	1.3-1.6	Ditto

Legend:
C : Cohesion
ϕ : Angle of internal friction
r : Unit weight

* Environmental Bureau of Nagoya City

To decide average characteristics of waste material, volumetric component is calculated by assuming that Nanjido is saturated by 1994 based on the disposal rate shown in Table 4-4-2.

The results of calculation on volumetric component are summarized as follows.

Table 4-4-5 Volumetric Component for Calculation

	$x1000^{t}$	Volume Coefficient	x1000m3 Disposal rate	
		m3/t		%
Combustible	30,367	0.9	27,330	(50.4)
Noncombustible	6,638	0.8	5,310	(9.8)
Buriquet ash	35,650	0.6	21,390	(39.4)
Ash from I/C plant	300	0.7	210	(0.4)
Total	72,955		54,240	

Disposal rate and waste characteristics are shown in Table 4-4-6.

Table 4-4-6 Disposal Rate and Waste Charactristics

Component	Disposal Rate (V/V)	C (t/m^2)	ϕ (°)	r (t/m^3)
1. Combustible (Domestic refuse)	50 %	1.5	13	1.3-1.6
2. Non-combustible (Rubbish)	10 %	4.0	33	1.0-1.7
3. Briquet ash & Incineration ash *	40 %	1.3-5.2	14-32	1.3

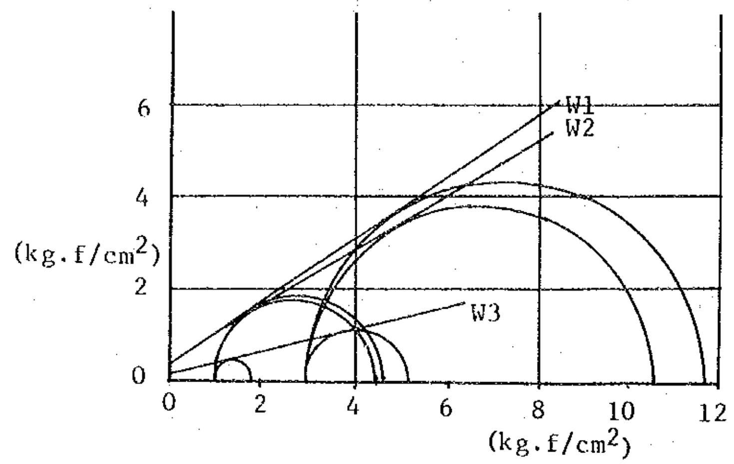
* Incineration ash is included in briquet ash category due to its negligible volume.

For reference, the results of field test implemented in Japan are shown in Fig. 4-4-3 and 4-4-4.

Fig. 4-4-3 Unit Weight Test

Component		Range of Unit Weight (t/m^3): 0.8	1.2	1.6	2.0
Incineration Ash	(W1)				
Rubbish	(W2)				
Domestic Refuse	(W3)				

Fig. 4-4-4 Triaxial Compression Test



W1 C=0.5 (kg.f/cm²) ϕ=29 40"

W2 C=0.4 ϕ=33 00"

W3 C=0.15 ϕ=13 10"

b. Cases to be analyzed

Although characteristics and their disposal rate are established in Table 4-4-6, their values of characteristics still have ranging values due to differences in Sampled Specimens. It is not only difficult to decide one point value from ranging values caused by many unknown factors in solid waste but also dangerous to fix one point value in this analysis.

Accordingly, the following combination of three cases are examined to compute the stability of mounding slope by means of weighted average method.

Case-1 Weak condition

$rw = 1.3 \times 0.5 + 1.0 \times 0.1 + 1.3 \times 0.4 = 1.27\ t/m^3$

$Cw = 1.5 \times 0.5 + 4.0 \times 0.1 + 1.3 \times 0.4 = 1.67\ t/m^2$

$\phi w = 13 \times 0.5 + 33 \times 0.1 + 14 \times 0.4 = 15.4°$

Case-2 Strong condition

$rs = 1.6 \times 0.5 + 1.7 \times 0.1 + 1.3 \times 0.4 = 1.49\ t/m^2$

$cs = 1.5 \times 0.5 + 4.0 \times 0.1 + 5.2 \times 0.4 = 2.08\ t/m^2$

$\phi s = 13 \times 0.5 + 33 \times 0.1 + 32 \times 0.4 = 22.6°$

Case-3 Average condition

$ra = 1.38\ t/m^3$

$Ca = 1.88\ t/m^2$

$\phi a = 19.0\ °$

c. Results of Calculation

Calculation is made regarding the rotationsl slips of Case-1, Case-2 and Case-3. The results of calculation are summarized in Fig. 4-4-5. It shows the minimum resistant safety ratio (Fmin $= \frac{F_R}{F_r}$) obtained from resistant force (F_R) and rotational force (F_r).

Fmin of Case-1 (weak condition) is only 1.21, whereas that of Case-2 (strong condition) and Case-3 (average condition) shows sufficient value.

From viewpoint of soil stabilization, it can be said that Fmin. value should be at least 1.50 for the permanent facilities.

Therefore, a countermeasure is needed to prevent the landfill from rotational slip.

d. Comments on Existing Landfill Plan

The structural strength of the landfill slope depends on characteristics of waste material. Trial calculations are made to find the stabilized type of slope by changing the landfill material.

For the trial calculation of slope stability, following landfill methods are assumed;

- To ensure the expected capacity of mounding volume, the slope of the levee is kept at 1:3 in compliance with Seoul City University plan.
- Briquet ash is used for the slope and the other waste is used inside of landfill (Fig. 4-4-6).
- A part of filled waste under the briquet ash is replaced by briquet ash.

Fig. 4-4-5 Rotational Slip Model of Nanjido Mounding

Assumed Waste Characteristics

Layer	Case	Conditions		
		ϕ (°)	c (t/m^2)	r (t/m^3)
(1)	1	14	1.57	1.22
	2	22	1.98	1.44
	3	18	1.70	1.33
(2)	1	15	1.67	1.27
	2	23	2.08	1.49
	3	19	1.88	1.38
(3)	1	16	1.77	1.32
	2	24	2.18	1.54
	3	20	1.98	1.43
(4)	1	16	1.77	1.32
	2	24	2.18	1.54
	3	20	1.98	1.40

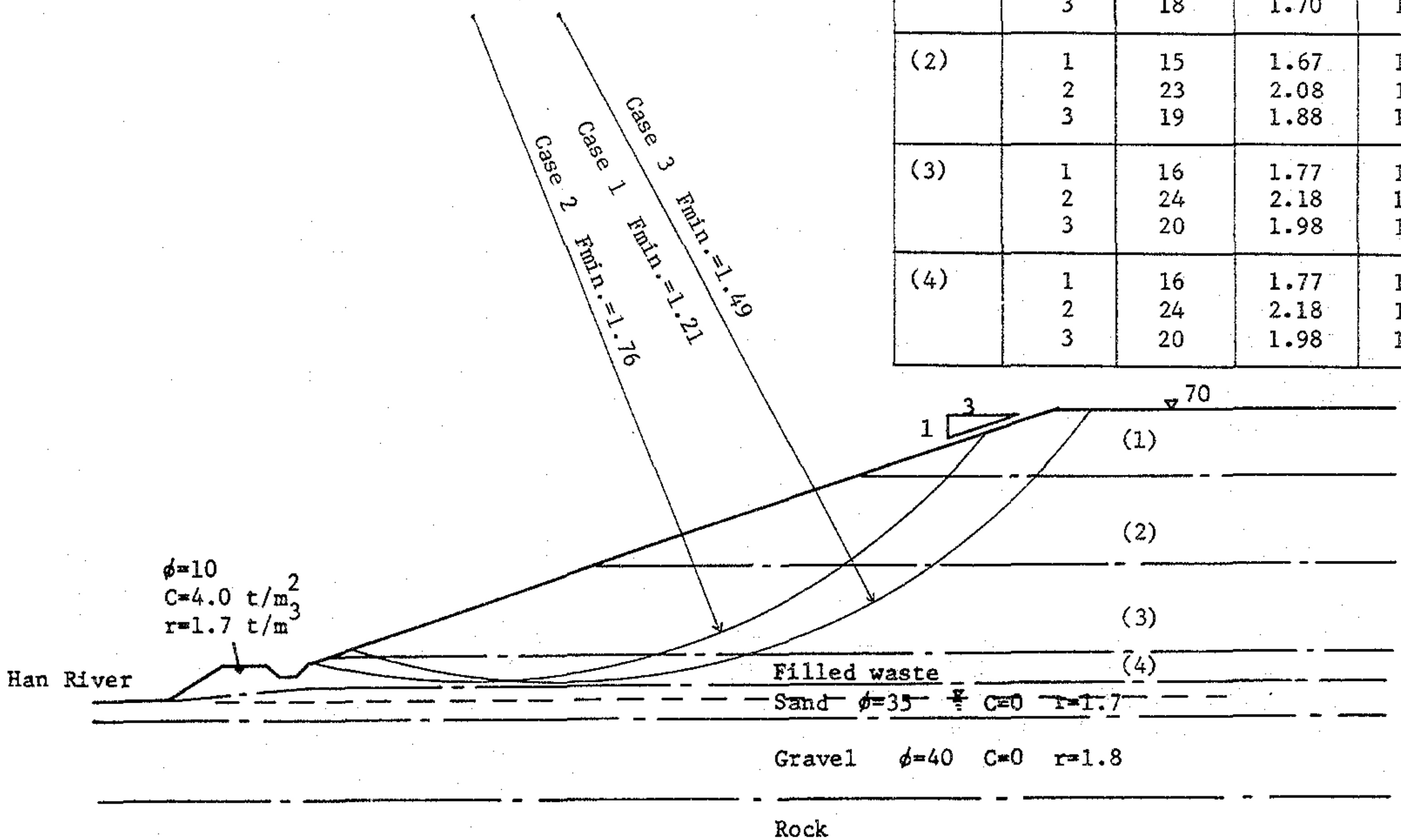
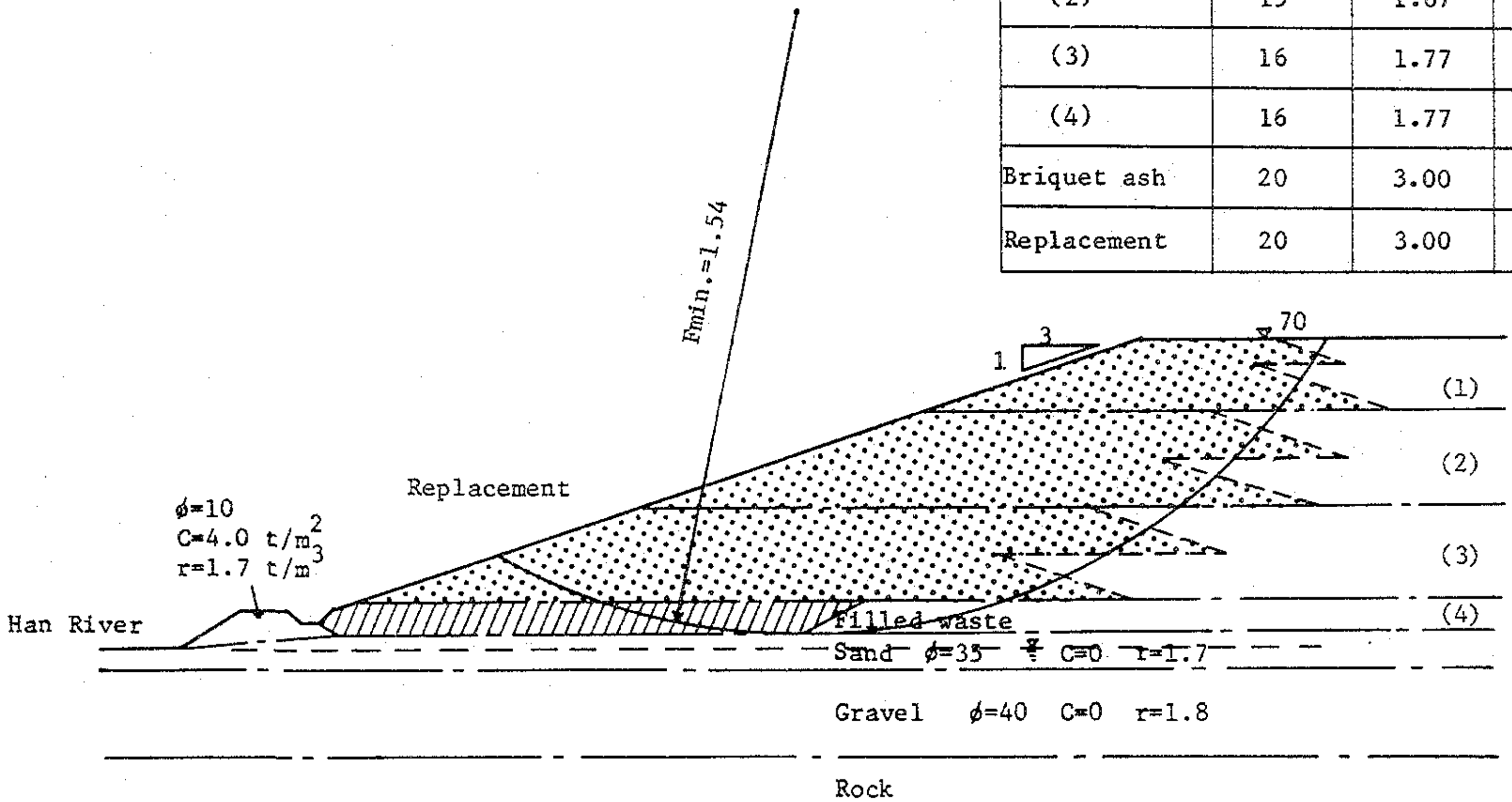


Fig. 4-4-6 Recommended Slope Structure for Nanjido Mounding

Assumed Waste Characteristics

Layer	Conditions		
	ϕ (°)	c (t/m^2)	r (t/m^3)
(1)	14	1.57	1.22
(2)	15	1.67	1.27
(3)	16	1.77	1.32
(4)	16	1.77	1.32
Briquet ash	20	3.00	1.30
Replacement	20	3.00	1.30



Based on the assumed landfill methods mentioned above, several rotational slip analyses are made by changing the depth of briquet ash.

The results of calculation is shown in Fig. 4-4-6. Fmin. Value of weak condition refuse (Case-1) becomes 1.54, exceeds the safety value of 1.50, while previous calculated value was 1.21 (Fig. 4-4-5).

Although refuse characteristics of waste to be filled at Nanjido is unknown at present, the proposed landfill method (Fig. 4-4-6) is one of the appropriate measures for the stabilization of mounding structure when the following factors are considered.

- Nanjido is the only disposal site for Seoul City untill 1994.
- Nanjido is expected to be used as a public park after landfill.
- Briquet ash can be used as a useful landfill material.

(2) Suitability of Briquet Ash as a Cover Material

a. Objective of Covering

Covering is classified into daily covering, intermediate covering and final covering. The objectives of covering are as follows:

- Daily cover
  - Prevention of waste dispersion
  - Prevention of rank odor
  - Prevention of vectors and rats
  - Reduction of rain permeation

- Intermediate cover
  - Prevention of gas leak
  - Prevention of fire
  - Access road for dump trucks
  - Reduction of rain permeation

- Final cover
  - Reduction of rain permeation
  - Land reuse

b. Aptitude as Covering Material

Judging from the above objectives, especially for sealing of leachate the best cover material is regarded as impermeable clay (coefficient of permeability is about 10^{-7}cm/s).

However, impermeability of clay is easily lowered by cracking when dried. Workability of vehicles is affected by muddy clay when it rains. Thus, clayey loam, sandy loam and clay with sand or loam is proposed as the appropriate cover materials.

Usually about 20 to 25% of landfill volume is occupied by cover material. Landfill cost would be high because of high transportation cost of cover material unless there exists suitable cover material around the landfill site. Therefore, sandy soil (coefficient of permeability is about 10^{-4}cm/s) is frequently used if it is obtained easily.

In Nanjido landfill site, about 40% of the whole landfill volume is briquet ash, whose utilization as cover material is advantageous. The aptitude of briquet ash as cover material is studied here based on the results of the tests carried out by Seoul City University.

i) Test Results of Briquet Ash (by Seoul City University)

From the tests on briquet ash, grain size distribution and coefficient of permeability are given as follows.

- Grain Size Test

Table 4-4-7 Grain Size Distribution

Unit : %

Seive Mesh (mm)	4.76	2.38	0.59	0.297	0.149	0.074	0.005
Before Compaction							
(Range)	85-92	73-90	53-72	45-60	34-48	24-33	3-4
(Average)	(88.5)	(81.5)	(62.5)	(52.5)	(41)	(28.5)	(3.5)
After Compaction							
(Range)	89-95	76-87	58.70	50-62	42-52	34-43	8-11
(Average)	(92)	(81.5)	(64)	(56)	(47)	(38.5)	(9.5)

Note: Representative briquet ash was sampled at final disposal site.
Following samples were analyzed in the test.
Sample 1: Sample finer than ϕ19 mm
Sample 2: Sample crushed into ϕ100 mm

- Coefficient of Permeability

As a result of permeability test, compacted briquet ash showed permeability coefficient ranging from 1.9046 x 10^{-5} to 6.109 x 10^{-6} (cm/s).

ii) Consideration

- Grain Size Distribution of Briquet Ash

Grading curve of briquet ash is shown in Fig. 4-4-7 together with representative grading curves of clay and sand.

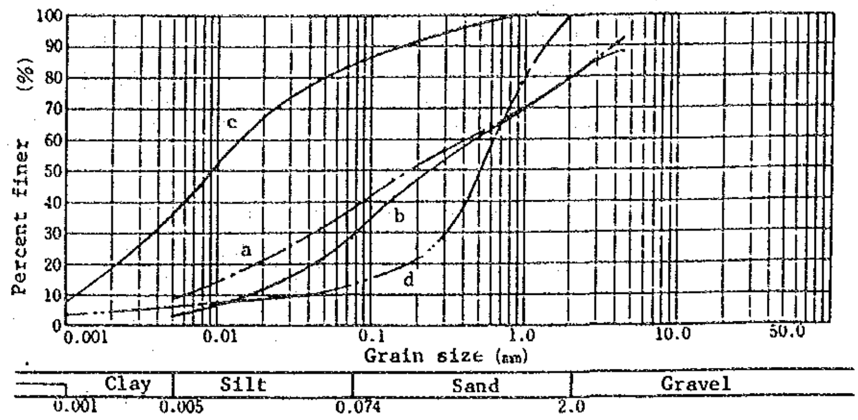


Fig. 4-4-7 Grading Curve

Notes: a. Briquet ash (after compaction)
b. Briquet ash (before compaction)
c. Clay (fine soil)
d. Sand (sand with fine particles)

Briquet ash is classified into sandy soil as shown in triangular soil classification (Fig. 4-4-8).

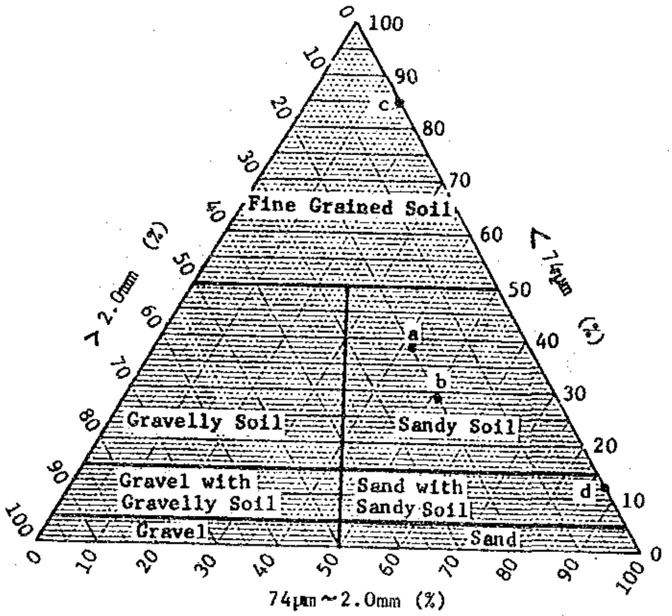


Fig. 4-4-8 Triangular Soil Classification

Because sieved sample and crushed sample were used in the test, the particle size is regarded to be smaller than the real size. The conclusions of the grain size test are;

- Briquet ash contains relatively large amount of small particles. It is classified into the category of sandy soil.

- Uniformity coefficient Uc=67, which means that briquet ash has relatively large density. Here, uniformity coefficient is calculated by following equation.

$$Uc = \frac{D_{60}}{D_{10}} = \frac{\text{60\% diameter of soil particle}}{\text{10\% diameter of soil particle}}$$

- Permeability Coefficient of Briquet Ash

Representative permeability coefficient of soil is shown in Fig. 4-4-9. The order of permeability coefficient is 10^{-5} because of large amount of fine particle content and high density in particle size distribution.

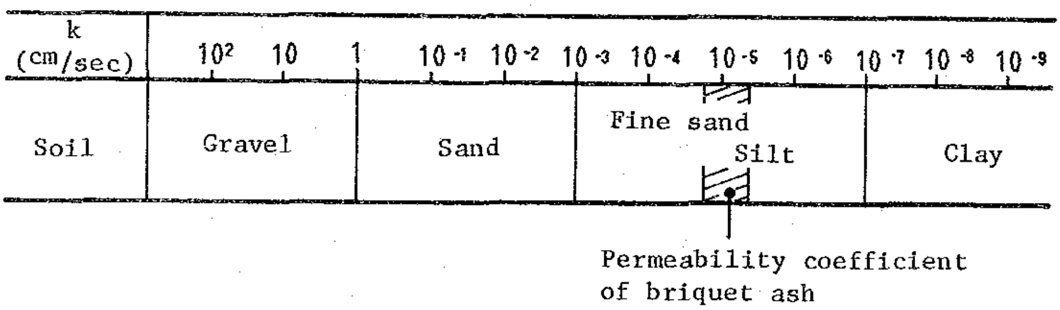


Fig. 4-4-9 Representative Permeability Coefficient of Soil

iii) Suitability as Covering Material

Suitability of briquet ash as covering material is considered as follows.

- Daily Covering

  The object of daily covering is prevention of waste disperse. It is economical to use easily obtainable material for covering because any kind of soil can satisfy the purpose. However, coefficient of permeability is desirable to be small as it works to prevent rain water permeation and rank odor. In this meaning, briquet ash is desirable because it has a small permeability coefficient of 10^{-5}cm/s.

- Intermediate Covering

  From the same stand-point as above, the cover material should have small permeability coefficient. Because briquet ash has enough density as shown above, briquet ash can be used for intermediate covering.

- Final Covering

  Permeability coefficient of final covering material should be small to decrease the generation of leachate. Furthermore, the covering material should be suitable for planting trees and land reuse. Briquet ash is not always suitable for these purposes. Sandy loam and clayey loam are desirable for the final covering materials.

To use the briquet ash for daily covering and intermediate covering, followings are required;

. Separate collection of briquet ash

. Storage of briquet ash in winter and use it in summer when generated amount of briquet ash is less

(3) The Leachate Treatment

Seoul City University has planned leachate treatment plant as shown in Fig.4-4-10. The proposed system mainly consists of aerated lagoon and chemical sedimentation basin, and COD of effluent quality is expected to be 120 ppm.

However, this process seems to be insufficient for removal of COD since water quality at an inlet of this project is extremely high (1500 ppm). Therefore, a leachate treatment process is examined.

Generally, leachate from landfill has high concentration of COD in comparison with sewage, thus, leachate treatment plants are equipped with rapid sand filter and activated carbon adsorption column in addition to ordinary sewage treatment process.

- Effluent quality

Complying with the regulations relevant to effluent quality from leachate treatment plant, the permissible discharge standard specified for Area "B" is recommended to be adopted for this project (Table 4-4-8).

Table 4-4-8 Permissible Discharge Standard of Effluent

pH	5.8 ~ 8.6
BOD	150 or less
COD	150 or less
SS	150 or less

- Alternatives of Water Treatment Process

Taking effluent quality set up above into consideration, three alternative processes are examined. The flow of alternative processes are shown in Fig. 4-4-10 through Fig. 4-4-12. Their effluent quality are estimated as shown in Table 4-4-9.

Table 4-4-9 Estimated Effluent Quality

(mg/l)

Alt	Influent			Effluent		
	BOD_5	COD	SS	BOD_5	COD	SS
Alt-1	1,500	1,500	500	75 (85%)	300 (80%)	50 (98%)
Alt-2	ditto	ditto	ditto	ditto	ditto	ditto
Alt-3	ditto	ditto	ditto	30 (98%)	150 (90%)	20 (96%)

Note: Figures in parentheses show the removal ratios

In comparison of treated effluent quality on each process and target quality of effluent, judgment can be made that effluent COD of alternative-3 seems to satisfy the target quality when the influent COD is 1,500 ppm.

As a next step, the function of construction cost in three alternatives are made based on Japanese prevalent price in Yen as indicated Fig. 4-4-13. From viewpoint of the costs,

: Alternative-3 is most expensive due to rapid sand filter & activated carbon adsorption column.

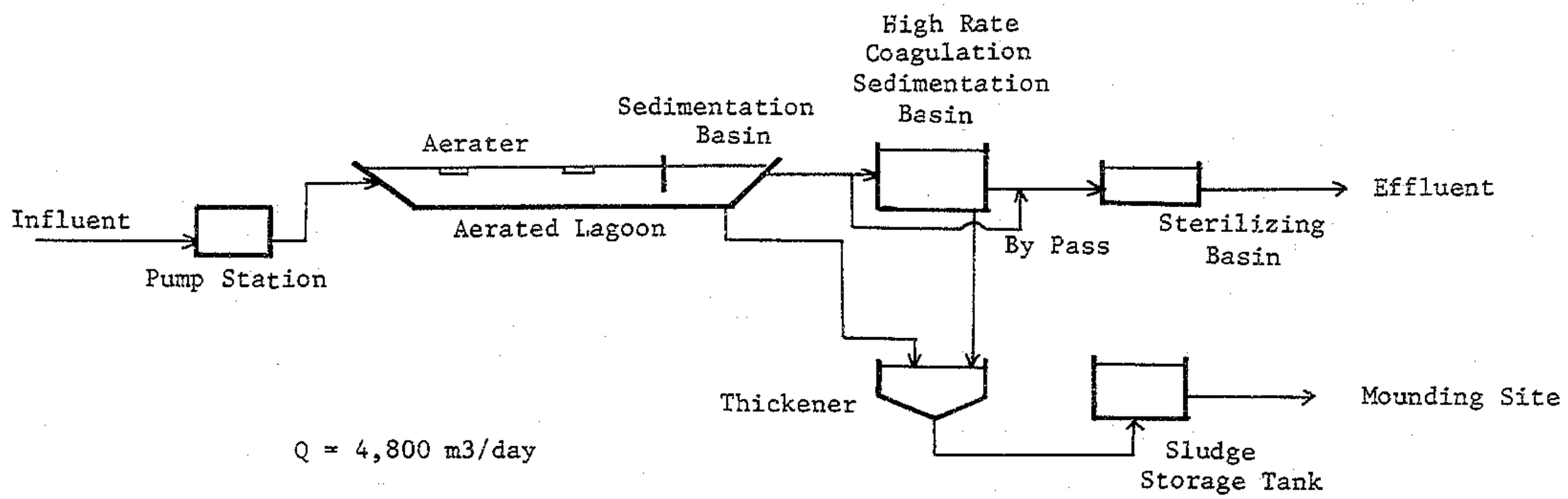
: Alternative-2 is more expensive than Alternative-1 while removal efficiency is equivalent due to mechanical equipment cost of biological treatment unit.

: Alternative-3 is, costly, 1.4 times of Alternative-1.

According to Study of Seoul City University, the construction cost of Alternative-1 is 700 million Won in Prevalent Seoul Price.

The construction cost in Seoul price of alternative-3 can be convertible based on Japanese prevalent price as 1,000 million Won (700 million Won x 1.4 times). Namely, the cost difference between Alternative-1 and Alternative-3 comes to 300 million Won and the increasing ratio of this cost to the total investment cost of Nanjido mounding (10,000 million Won) is only 3 percent.

Fig.4-4-10 Treatment Process of The Seoul City University Plan (Alt-1)



Q = 4,800 m3/day

Planned Water Quality

Item	Influent	Effluent	Removal Ratio
pH	6.0 - 8.4	6.0 - 8.4	
BOD_5	1,500	= 30	98%
COD	1,500	= 120	92%
SS	500	= 50	90%

Fig. 4-4-11 Mechanical Semi-Advanced Process (Alt-2)

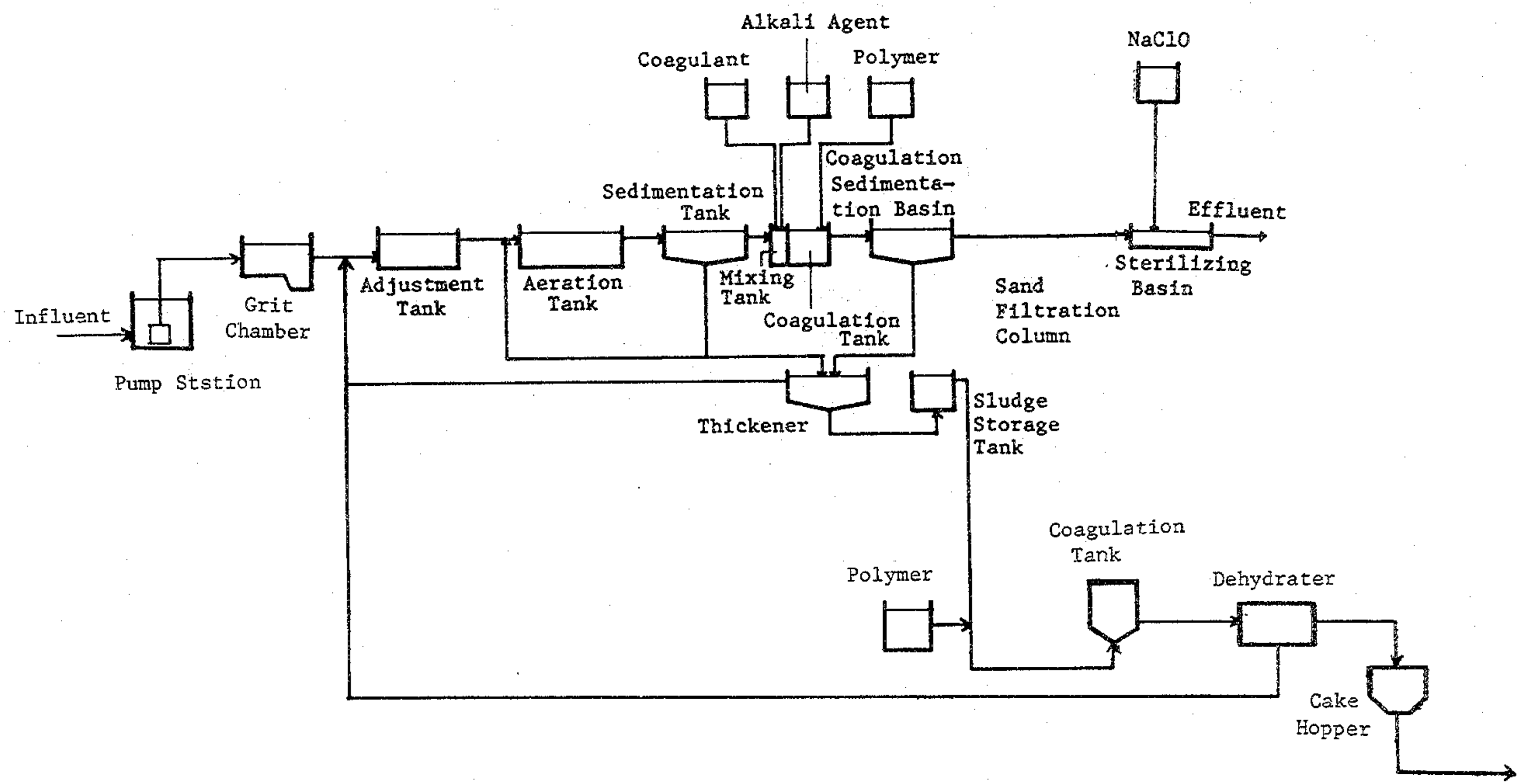


Fig.4-4-12 Advanced Process (Alt -3)

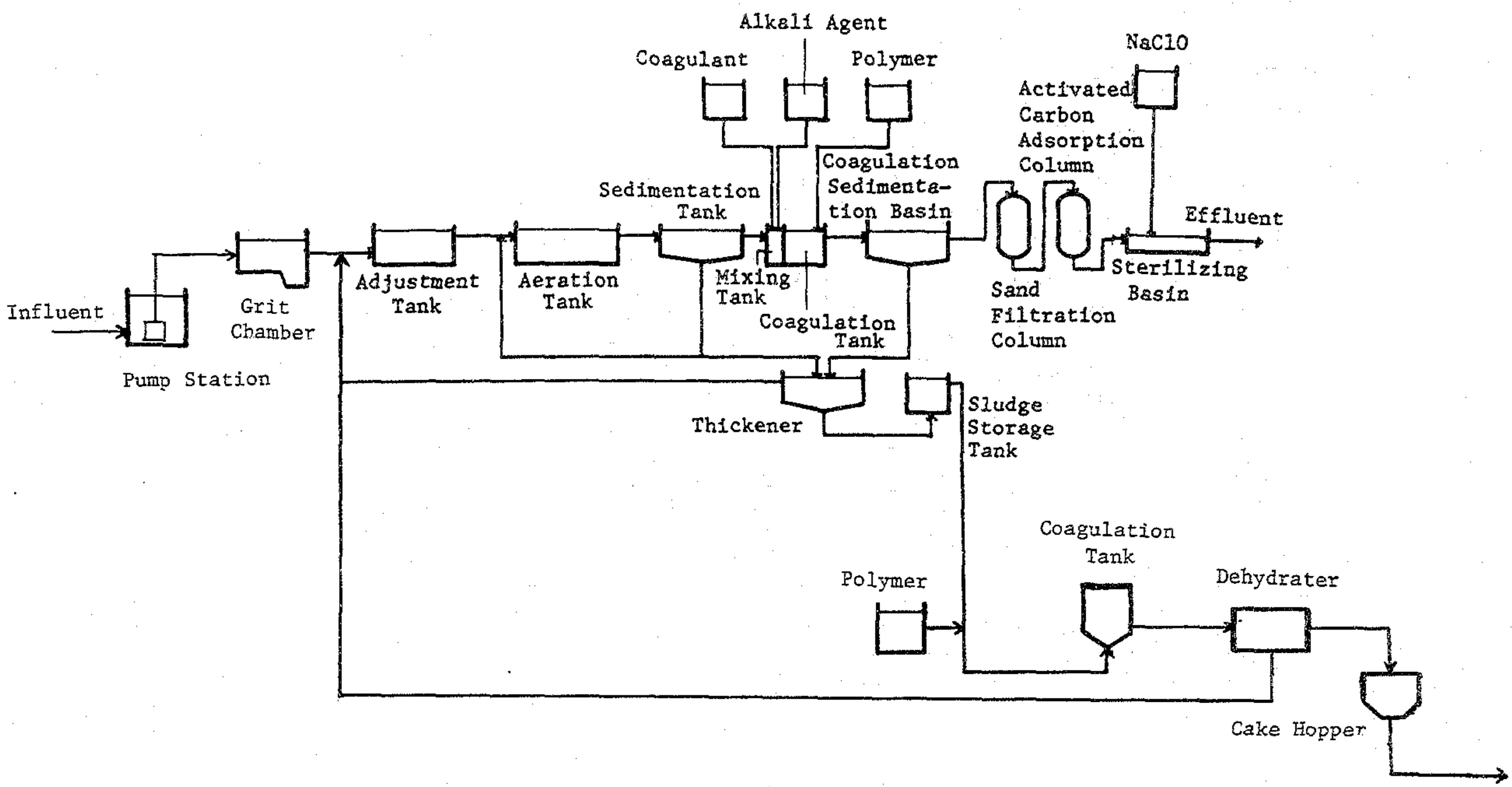
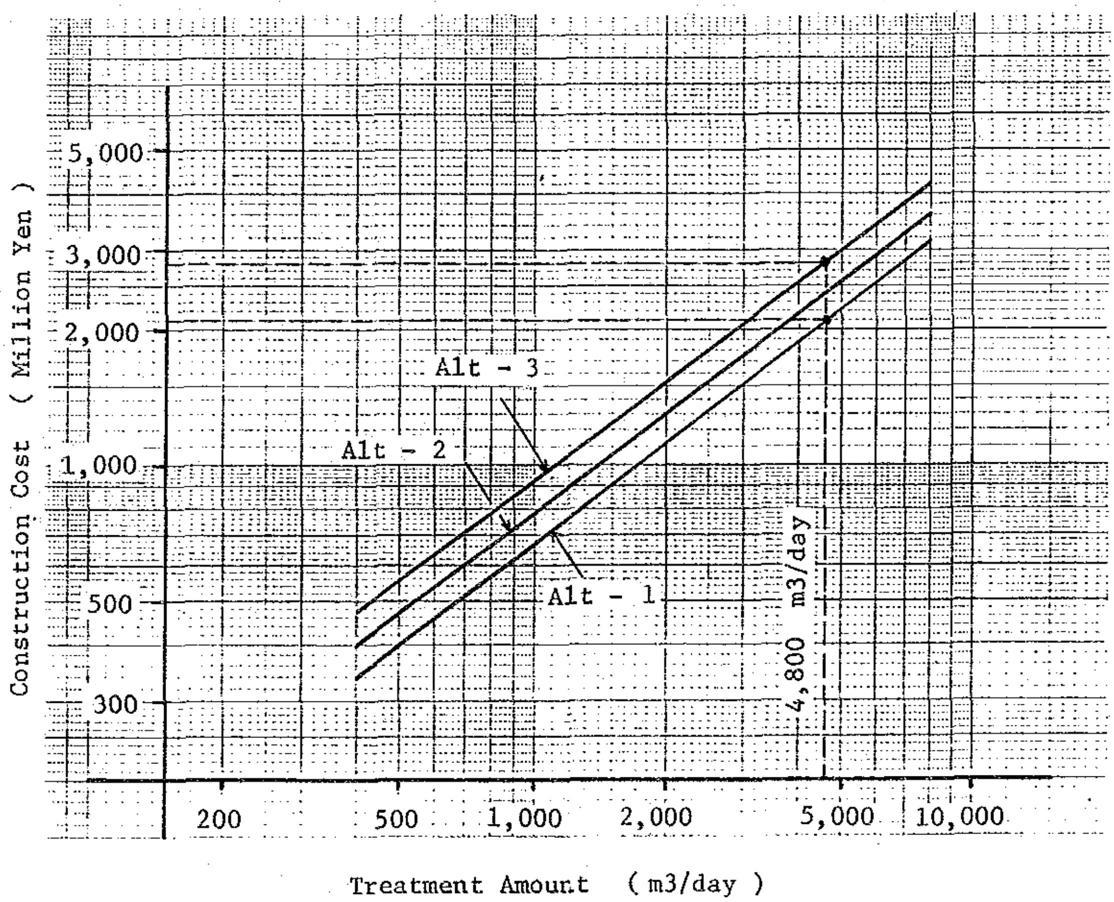


Fig. 4-4-13 Construction Cost Function of each Alternative



Note ; Plant capacity is fixed 4,800 m3/day with Seoul City University Plan

The O/M cost of each alternative is calculated based on Japanese situation (Table 4-4-10).

Here, Alt.-1: Seoul City Univ. Plan (aerated lagoon + high rate coagulating sedimentation system)

Alt.-3: Well mechanized system with sand filtration and activated carbon adsorption

Alt.-1': Alt.-1 followed by sand filtration and activated carbon adsorption system

In Alt.-3 and Alt.-1', about double of O/M cost of Alt.-1 is required because reclamation of activated carbon is necessary in these alternatives.

Table 4-4-10 O/M Cost for Leachate Treatment Plant

Treatment Process	(Million Yen) Construction Cost	O/M Cost (Million Yen/Year)	O/M Cost (Million Yen/20 Years)
Alt.-1	2,100	88	1,760
Alt.-3	2,800	175	3,500
Alt.-1'	2,500	166	3,320

Treatment Amount: 4,800 m^3/day
O/M Cost: Electric power, chemicals, personal expenses and activated carbon reclamation.

Total cost (including both construction cost and O/M cost) of 20 years is shown in Fig. 4-4-14. The total costs are 6,300 million yen and 5,820 million yen in Alt.-3 and Alt.-1', respectively. They are 1.6 times and 1.5 times of Alt.-1 (3,860 million yen), respectively.

O/M cost becomes higher when activated carbon adsorption system is adopted. However, the systems with sand filtration and activated carbon adsorption (Alt.-1' or Alt.-3) are required to satisfy the waste water discharge standard.

In Alt.-1', discharge water quality is expected to be the same level as in Alt.-3, whereas construction cost and O/M cost are cheaper. Consequently, Alt.-1', which is the plan of Seoul City Univ. (Alt.-1) followed by sand filtration and activated carbon adsorption, is recommendable.

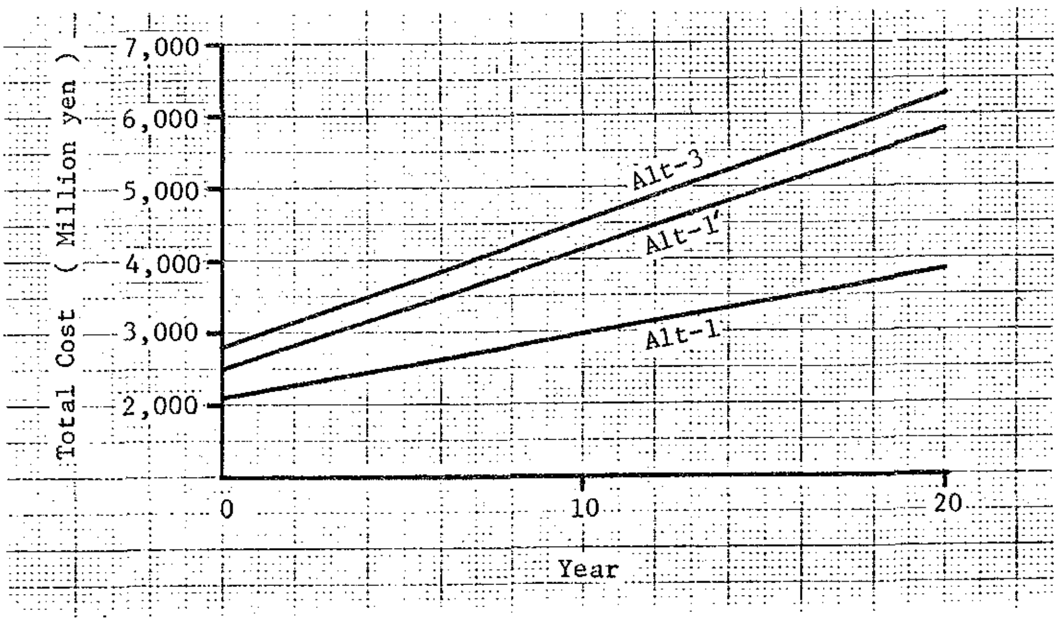


Fig. 4-4-14 Investment Cost and O/M Cost

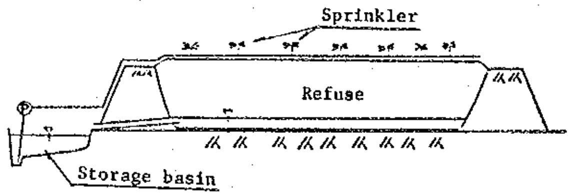
(4) Introduction of Soil Microbiological Filter Process

Examinations have been made on a leachate treatment plant to find a simple process since the prevalent process is too complicated and expensive. The examinations aim to reduce both the leachate volume and organic load by means of evaporation and microbiological purification. Fig. 4-4-15 shows the latest results of examinations experimented in Japan.

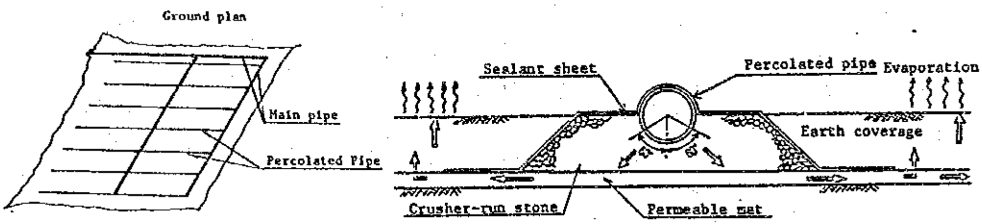
As shown in Fig. 4-4-15, the proposed process of soil microbiological treatment are categorized as follows:

Cace 1 Circulatory Scattering Method (After Completion of Landfilling)

a. Sprinkling Method   (Tokyo Metropolis)

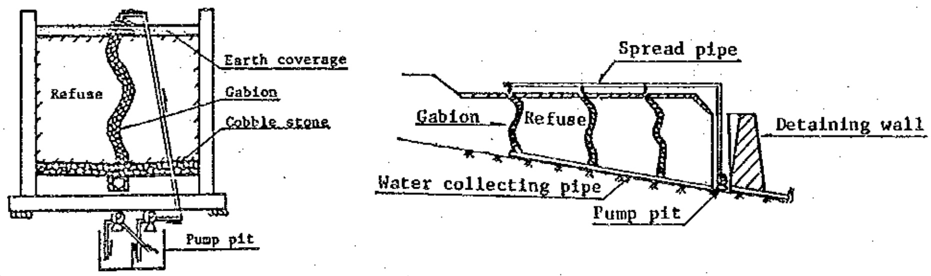


b. Percolated Piping Method   (Tokyo Metropolis)



Case 2. Circulatory Semiaerobic Landfill Method
(From Commencement of Landfilling)

a. Spreading Method   (Fukuoka University)



b. Circulatory Trenching Method   (Fukuoka University)

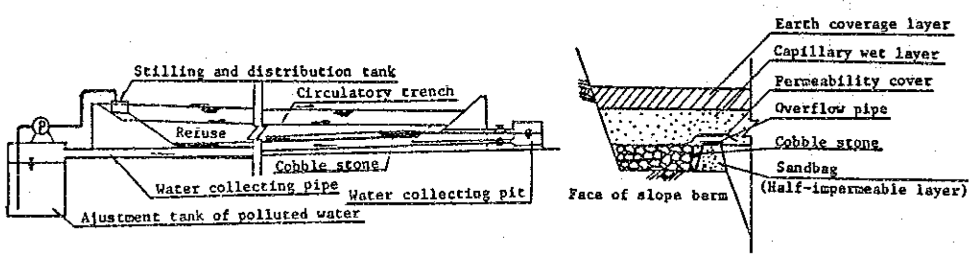


Fig. 4-4-15 Types of Experimented Pilot Plant

Case-1: Circulatory Scattering Method
- Sprinkling method
- Percolated piping method

Case-2: Circulatory Semiaerobic Landfill Method
- Spreading method
- Circulatory trenching method

Case-1 method is applied after completion of landfilling, while Case-2 method is applicable during the process of landfill. Case-2 is more advantageous for treatment of leachate, because it can be treated during the landfill process. But both methods are not expected to purify the leachate to the same level as the prevalent method.

At present, these methods are;

- Still limited to the stage of pilot use.
  Two model plants of circulatory trenching method are under construction in Kagoshima and Sendai.

- Regarded as the pre-treatment facilities preceding the prevalent treatment process.

It is still too early to adopt the soil microbiological filter process as a leachate treatment plant. Studies regarding efficiency and reduction of operating cost through the model plants are required before construction of a full scale plant.

(5) Environmental Protection

a. Pollution Control Facilities

Pollution control facilities generally required for the final disposal sites are:

- To prevent wastes from scattering: Soil cover, net, watering and plantation.

- To stop generation of harmful insects: Soil cover and use of insecticide.

- To prevent dispersion of high level of odor: Soil cover and use of deodorizer.

- To control and treat generated gas: Soil cover and installation of gas pipe.

Preliminary study is made on these items by Seoul City University. Further study should be made in the stage of detail design.

The insecticide should be used only for the emergency cases considering potential impact to the workers and surroundings. Daily soil cover is quite effective for these problems.

b. Monitoring Devices

Monitoring should be made to investigate if landfilling is done safely, and environmental measures are working effectively. Typical devices and their aims are as follows:

- Gas monitoring device:	Safe control of gas, ground subsidence and use after landfill
- Subsidence monitoring device:	Investigate ground subsidence, use after landfill and landfill capacity
- Water quality monitoring device:	Leachate treatment plan and survey pollution level of surrounding water bodies
- Monitoring the living environment:	Investigate change of ecosystem and for environmental conversation

The monitoring systems are briefly commented in the University Plan. In addition to the water quality monitoring of the leachate treatment facility, gas and ground subsidence monitoring is important for assuring workers' safety, environmental conservation and planning the use of landfilled areas.

These monitorings should be continued longer than one year after landfill.

c. Measures for Already Landfilled Areas

The University Plan commented water sealing by using clay soil around the already filled areas to stop leachate. But this is not studies in detail. For prevention of leachate to flow into the Han River, provision of proper sealing such as use of sheet piles is recommended. This also works to prevent outflow of leachate when unequivalent land subsidence occurred.

4-5 Environmental Conservation

4-5-1 Intermediate Processing

(1) Environmental Factors

For planning of the intermediate processing system, consideration must be made on conservation of the environment. The major environmental factors to be considered, in general, are air pollution due to combustion of the waste, and water pollution due to wastewater from the plant.

(2) Air Pollution

a. Present Condition of Air Pollution in Seoul

Rapid industrialization, urbanization and motorization have caused a deterioration of the air quality in Seoul. The level of pollution and the kind of pollutants vary according to its source. Among the nationwide data obtained in 1981, sulfur dioxide (SO_2) recorded the highest amount among the typical pollutants followed by carbon oxide (CO) (Table 4-5-1). The power plants emitted the highest proportion of SO_2 and total suspended particulates (TSP).

The annual mean concentration level of SO_2 in Seoul was 0.084 ppm in 1981 (Table 4-5-2). It decreased to 0.059 ppm during November, 1981 and October, 1982 due to the regulation to use the 1.6% sulfur containing oil. However, it is still larger than the long-term ambient air quality standard (0.05 ppm).

Table 4-5-1 Nationwide Emission Rate of Air Pollutants (1981)

(Unit: 1,000 ton, percentage)

Sector / Pollutants	Total	Transportation	Domestic Heating	Industry	Power Plants
Total	3,526 (100)	854 (24.2)	1,448 (41.1)	472 (13.4)	752 (21.3)
SO_2	1,452 (100)	60 (4.2)	486 (33.4)	332 (22.8)	574 (39.6)
CO	1,145 (100)	249 (21.7)	847 (73.9)	43 (3.8)	6 (0.6)
HC	102 (100)	60 (59.0)	24 (23.6)	17 (16.4)	1 (1.0)
NO_2	679 (100)	470 (69.2)	56 (8.3)	39 (5.7)	114 (16.8)
TSP	148 (100)	15 (10.0)	35 (23.9)	41 (27.6)	57 (38.5)

Source: Environmental Conservation in Korea, Dec. 1982 (Ref. 2)

Table 4-5-2 SO_2 Concentration in Major Cities

	1978	1979	1980	1981
Seoul	0.084	0.093	0.094	0.086
Busan	0.048	0.049	0.058	0.061
Daegu	0.033	0.040	0.038	0.046
Incheon	0.020	0.023	0.026	0.043
Ulsan	0.028	0.035	0.053	0.057
Masan	0.044	0.038	0.044	0.025

Source: Ref. (2)

The concentration of total suspended particulates (TSP) were observed in the main districts of Seoul (Table 4-5-3). The annual average level of TSP of Yeongdeungpo recorded the highest, and exceeded the environmental quality standard (150 $\mu g/m^3$).

Table 4-5-3 Concentrations of Suspended Particulates in Main Districts of Seoul (1979)

	Kwang-hwa-moon	Bul-kwang-dong	Nam-san	Yeoung-deungpo	Dong-dae-moon	Seoul National Univ.	Health Center of Seoul City	Gil eum-dong
Annual Arith-metric ($\mu g/m^3$)	99	82	80	214	91	42	100	109

b. General Characteristics of Emission Gas from Incineration Plant

The characteristics of emission gas is varied depending on the kind of waste and the gas treatment facility. The typical pollutants contained in the gas and their concentrations are shown in Table 4-5-4.

Table 4-5-4 Characteristics of Emission Gas

Type of Incinerator	Treatment Facility	Pollutants (kg/t.waste)			
		Dust	SOx	HCl	NOx
For Municipal Waste (U.S.A.)	-	7.7	0.9	-	0.9
300 (t/d) (Japan)	EP+MC	0.59	0.48	-	0.99
" (Japan)	None	5.7	0.63	-	0.99
8 (t/h) (Japan)	EP+MC	-	0.21-0.62	0.64-2.5	0.5-1.0
2.5 (t/h) (Japan)	MC	-	0.92-2.9	0.21-1.4	0.85-2.1

Note: EP = Electrostatic Precipitator, MC = Multi-cyclone
Source: Wastewater and Solid Waste Treatment, P.204 (Ref. 1)

As a treatment facility, a multi-cyclone or an electrostatic precipitator, or combination of both is used. The multi-cyclone can collect the dust effectively when the dust concentration is more than 0.4 g/Nm^3. As the electrostatic precipitator can collect dust in amounts as small as 0.03 g/Nm^3 due to its improvement, use in combination is not practical at the present. The dust concentration of gas corresponds to sense of eyesight as follows:

Concentration (g/Nm^3)	Eyesight
0.4	The smoke is seen clearly
0.2	Seen vaguely
0.1	Almost not identified
0.05	Cannot be identified

Source: Ref. (1), P.197

- Dust

The dust in emission gas contains mainly fly-ash and soot which is the main cause of black smoke. The fly-ash contains various components as shown in Table 4-5-5.

Table 4-5-5 Components of Fly-Ash Captured by EP

(%)

Plant	SiO	Al O +Fe O	CaO	Na O	K O	SO	Total
1 (Japan)	21.00	9.52	12.23	7.80	8.20	12.38	71.13
2 (Japan)	13.40	8.06	9.29	11.50	13.64	9.68	65.57
3 (Japan)	13.20	8.44	10.67	11.00	13.20	35.21	91.72

Source: Ref. (1), P.215

When the treatment facility is not equipped, concentration of dust ranges between 2-5 g/Nm^3, and the size of particle is between 10-30 μm.

- Sulfur Oxides (SOx)

The concentration of SOx ranges between 50 - 70 ppm. It is smaller than that of a plant which uses oil for burning things as the waste contains a low amount of sulfur.

- Hydrogen Chloride (HCl)

As the hydrogen chloride is produced by burning the plastics, its concentration depends on the amount of plastics which tends to increase as time passes. The concentration of HCl in an industrialized country ranges between 500 - 600 ppm.

- Nitrogen Oxides (NOx)

The concentration of NOx generated from an incineration plant is between 80 - 150 ppm, and 80 - 90% of that is NO. The thermal NOx is produced when the nitrogen in the air is oxidized under the temperature of more than 1,000°C. The fuel NOx is produced when the nitrogen contained in the fuel is oxidized. As the burning temperature of an incinerator is between 800 - 900°C, the emission gas from combustion of waste contains mainly the fuel NOx.

c. Local Conditions

The principal conditions of air pollution on the local level are horizontal convective transport (average wind speed and direction), vertical convective transport (atmospheric surface stability), and topography. Horizontal convective transport pertains to the pollutant dispersion resulting from local wind patterns. Decrease in the mean wind speed will lower the downwind concentration of the pollutants by diluting the pollutant emissions.

The average wind speed observed in Seoul ranged between 2.3 and 2.6 m/sec since 1977 through 1982. The predominant wind direction is west in summer and northeast in winter.

The major determinant of vertical convective transport is the temperature gradient in the atmosphere which is called the lapse rate and given the symbol dt, defined by

$$dt = -\frac{dT}{dz}$$

where, T : Temperature

z : Height

The prevailing temperature decreases with altitude. A temperature increasing with elevation is referred to as an "inversion" because the temperature profile is inverted from the prevailing lapse rate. The ordinary lapse rate is given as

$$dt = -\frac{1°C}{100m}$$

(Source: Environmental Impact Analysis Handbook, Rau and Wooten, P.3-14)

The effectiveness of the atmosphere in mixing dispersing pollutants in the vertical direction is dependent on the "atmospheric stability".

When the lapse rate is positive, it is called a stable atmosphere which suppresses vertical mixing. When the lapse rate is smaller than the ordinary rate, it is called an unstable atmosphere which promotes vertical mixing.

The topographical features also affect the dispersion of pollutant. The roughness of the ground surface may promote vertical and lateral mixing. Offsetting this improved vertical mixing is a decrease in wind dilution caused by the decreased wind speed due to the ground surface roughness.

d. Pollution Index

To describe air pollution, reference is usually made to sulfur dioxide. Its level is monitored in many areas as part of the pollution index. The effect of sulfur dioxide upon human-beings is widely debated in the medical research field. As its concentration increases, the initial annoyance gradually leads to breathing difficulties and eventually to severe irritation. A sulfur dioxide level of 6 ppm paralyzes and corrodes the respiratory organs. (Source: A Guide to the Study of Environmental Pollution, Andrews, editor, P.109)

Judging from the permissible discharge standards established in accordance with the Environmental Preservation Law, and the characteristics of the waste, SOx will be chosen as a representative of pollutants for forecast. The forecast will be made based on the preliminary design regarding the discharge level as well as its concentration after dispersion, aiming to use the result for comparison with the ambient air quality standard. The concentration of other pollutants can be forecasted by a simple calculation using its relationship to the level of SOx.

(3) Water Pollution

The leachate from waste should be treated properly within the plant site so that it does not cause water pollution of the surrounding water body. When the water is used for cooling the emission gas and to reduce the concentration of HCl, it should also be treated before discharging it outside of the site. The quantity of gas washing wastewater is said to be 500 to 1,000 liters per ton of refuse processed.

The quality of gas cooling water contains the pollutants is shown in Table 4-5-6.

Table 4-5-6 Quality of Gas Cooling Water

Expected Quality		Permissible Discharge Standard (Area C)	
pH	2.0 - 5.0		5.8 - 8.6
BOD	200 - 800 ppm		200 ppm
COD	100 - 400 ppm		200 ppm
SS	300 - 1000 ppm		200 ppm
Cd	0.5 - 1.0 mg/l		0.1 mg/l
CN compounds	trace		1.0 mg/l
Org-P	trace		1.0 mg/l
Pb	10 - 30 mg/l		1.0 mg/l
Cr^{6+}	0.5 - 1.0 mg/l		0.5 mg/l
As	trace		0.5 mg/l
Hg	trace	Hg	0.05 mg/l
n-hexane	10 - 40 mg/l	n-hexane	5.0 mg/l
Phenol	trace	Phenol	5.0 mg/l
Cu	0.5 - 1.0 mg/l	Cu	3.0 mg/l
Zn	20 - 60 mg/l	Zn	5.0 mg/l
sol. Mn	10 - 20 mg/l	Sol. Mn	10.0 mg/l
Cr	1.0 - 2.0 mg/l	Cr	2.0 mg/l

The other water used for ash removal, car washing and household sewage should also be treated.

4-5-2 Final Disposal

(1) Environmental Factors

The environmental factors to be considered for planning of the final disposal site are surface and ground water pollution, hazardous gases and odor, rodents and flies, dust littering, and other nuisances caused by dumping and transporting works. Aesthetic problems should also be considered for planning when the site is near the urban area. As the water pollution due to discharge of leachate and the pollution from hazardous gases are the most important factors, their characteristics and behavior are mainly discussed here.

(2) Water Pollution

a. Present Condition of Water Pollution in Seoul

The major sources of water pollution in Korea are domestic sewage and industrial wastewater. The amount of wastewater discharged into the major rivers, and their BOD_5 loads are shown in Table 4-5-7. The quantity of wastewater flowing into Han River shared 43% of the total quantity.

Table 4-5-7 Sewage and Industrial Wastewater Discharge Quantity and BOD_5 Load as of 1981

River Basin	Quantity of Waste Water (1,000 ton/day)			BOD Load (ton/day)		
	Domestic Sewage	Industrial Waste Water	Total	Domestic Sewage	Industrial Waste Water	Total
Total	6,444	2,209	8,653	966	386.5	1,352.5
Han River	3,254	428	3,682	488	74.9	562.9
Nak-dong River	682	182	864	102	31.9	133.9
Geum River	288	84	372	43	14.7	57.7
Young-san River	169	10	179	25	1.7	26.7
Others	2,051	1,505	3,556	308	263.3	571.3

As shown in Table 4-5-8 the BOD_5 level of the Han River starts to increase markedly from Bogwang water supply intake where domestic sewage of central and northern parts of Seoul City is discharged into the river. The water quality downstream of this station becomes unsuitable for drinking water supply, although still acceptable for industrial use and swimming. From Noryangjin downstream, the river is unsuitable for drinking water supply or recreation, and fish population notably decreases.

Table 4-5-8 BOD_5 Levels along the Han River

(Unit : mg/l)

Chuncheon (Dam)	0.6	Youju	2.3	Noryangjin	5.2
Soyang (Dam)	0.4	Yangpyung	1.8	Seonyu	6.1
Euiam (Dam)	0.7	Paldang (Dam)	1.4	Yeongdeungpo	7.0
Cheongpyung	1.4	Gueui	1.5	Gayang	10.4
Danyang	2.2	Tukdo	2.2		
Joongweon	2.6	Bogwang	4.8		

b. General Characteristics of Leachate from Landfill Site

The leachate from landfills contains organics, nitrogenous compounds, concentrated color and suspended solids. The quality is affected by the characteristics of the filled refuse, landfill methods and filled periods. When inorganic refuse such as glass, ash, bones and stones are filled, the leachate has low organic content. When raw refuse is filled, such as the situation at Nanjido, the leachate contains highly organic and nitrogeneous matters. Furthermore, the leachate in anaerobic landfill sites remains concentrated longer than aerobic type sites.

The quality of leachate at Nanjido as obtained from the basic field surveys in indicated in Chapter 2. The data obtained by the survey of leachate from a landfill site at Pusan shows a high level of biochemical oxygen demand (BOD) (Table 4-5-9).

Table 4-5-9 Characteristics of Leachate

Pollutant	November	December	January	February
pH	7.6	7.4	6.8	6.2
BOD (ppm)	2,340	2,360	22,000	21,000
COD (ppm)	4,700	4,520	41,200	44,000
SS (ppm)	36	58	59	670

Source : Solid Waste Treatment of Seoul, P.133

Table 4-5-10indicates leachate quality during various landfill periods. The table shows that the value of BOD decreases quickly in the case of aerobic landfill, while the decreasing rate is very small in the case of anaerobic landfill. The BOD value decreases faster than the COD value. In the case of anaerobic landfill, the value of NH_3-N decreases very slowly.

Table 4-5-10 Some Examples of Quality of Leachate

Items Measured		Landfilling Duration	6 months after Landfilled	1 year after Landfilled	2 years after Landfilled
		Leachate Quality	Leachate Quality	Leachate Quality	Leachate Quality
Anaerobic Landfill	B O D	40,000 - 50,000 ppm	40,000 - 50,000 ppm	30,000 - 40,000 ppm	10,000 - 20,000 ppm
	C O D	40,000 - 50,000 ppm	40,000 - 50,000 ppm	30,000 - 40,000 ppm	20,000 - 30,000 ppm
	NH_4 - N	800 - 1,000 ppm	1,000 ppm	800 ppm	600 ppm
	pH	6.0	6.0	6.0	6.0
	Transparency	0.9 - 1.0	1 - 2	2 - 3	2 - 3
Anaerobic Sanitary Landfill	B O D	40,000 - 50,000 ppm	7,000 - 8,000 ppm	300 ppm	200 - 300 ppm
	C O D	40,000 - 50,000 ppm	10,000 - 20,000 ppm	1,000 - 2,000 ppm	1,000 - 2,000 ppm
	NH_4 - N	800 - 1,000 ppm	800 ppm	500 - 600 ppm	500 - 600 ppm
	pH	6.0	7.0	7.0 - 7.5	7.0 - 7.5
	Transparency	0.9 - 1.0	1 - 2	1.5 - 2	1 - 2
Semi-aerobic Landfill	B O D	40,000 - 50,000 ppm	5,000 - 6,000 ppm	200 ppm	
	C O D	40,000 - 50,000 ppm	10,000 ppm	1,000 - 2,000 ppm	
	NH_4 - N	800 - 1,000 ppm	500 ppm	100 - 200 ppm	
	pH	6.0	8.0	7.5	
	Transparency	0.9 - 1.0	1 - 2	3 - 4	
Aerobic Landfill	B O D	40,000 - 50,000 ppm	200 - 300 ppm	50 ppm	10 ppm
	C O D	40,000 - 50,000 ppm	2,000 ppm	1,000 ppm	500 ppm
	NH_4 - N	800 - 1,000 ppm	50 ppm	10 ppm	1 - 2 ppm
	pH	6.0	8.5	7 - 8	8.5 ppm
	Transparency	0.9 - 1.0	6 - 7	2 - 3	2 - 5

When the ash from the incineration plant is landfilled in the site, attention should be paid to the contents of heavy metal in the ash. Their concentration varies widely depending on the characteristics of waste (Table 4-5-11).

Table 4-5-11 Concentration of Heavy Metal in Ash

(ppm, dry base)

Source	Cu	Fe	Pb	Cr	Zn	Na
U.S.A.	2,300	84,000	5,000	350	2,500	26,000
Japan	1,300	15,900	470	160	2,800	12,000

Source: Ref. (1), P.213

c. Leachate Control

Leachate control is commonly employed in a sanitary landfill as it is a potential contamination hazard to ground or surface water. The amount of leachate is greatly influenced by rainfall and subsurface condition.

Diversion of runoff to the landfill site from outside, and from the site to surface water is an effective way to reduce the leachate. The soil cover over the landfill helps to reduce the rainwater which infiltrates the fill and leaches out soluble pollutants from the wastes.

The leachate should be collected within the site and treated properly before being discharged to surface water. The pollutant level should conform to the permissible discharge standard.

(3) Gas

a. Present Condition of Gas Generation from Landfill Site in Seoul

The gas volume generated at the Nanjido landfill site was 2,338 x $10^6 m^3$ from the 8.26 x 10^6 tons of waste (Fig. 4-5-1). The volume of gas generated in summer was 2.6 times that of winter. About 280 m^3 was generated from 1 ton of waste.

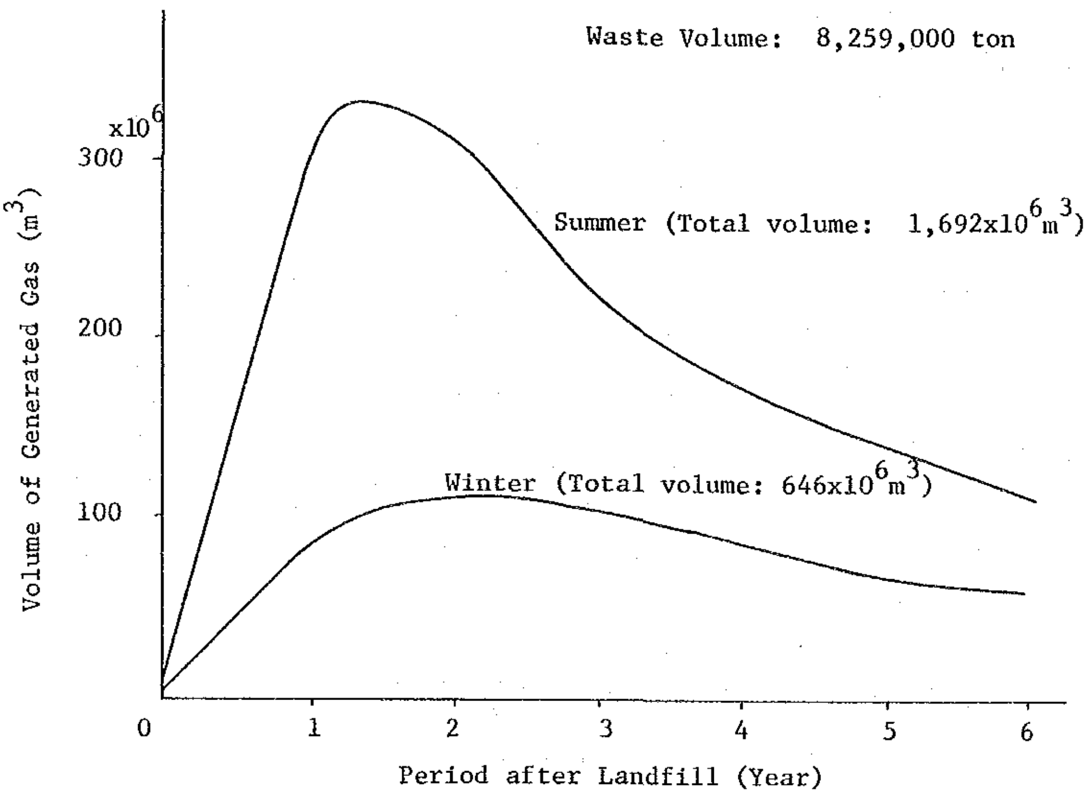


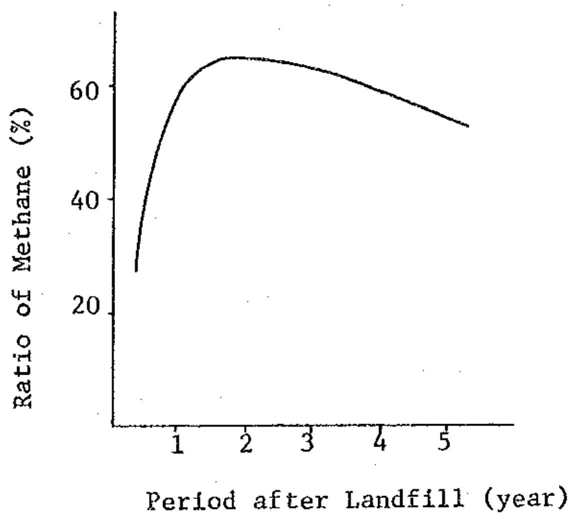
Fig. 4-5-1 Gas Volume Generated after Landfill

Source: Research on safety of municipal waste landfill at Nanjido, October 1981

b. General Characteristics of Gas Generated from Landfill Site

Hydrogen, methane, nitrogen, carbon monoxide, hydrogen sulfide, carbon dioxide, etc., are the gases often encountered at the landfill site. Among these, methane constitutes 40-60% of the total gas volume. The production rate changes as time passes, and it reaches the maximum rate 1-2 years after landfill of the waste (Fig. 4-5-2).

Fig. 4-5-2 Periodical Change of Methane Generation



Source: Characteristics of gas generation of landfill site, Koichi Yamada, et. al.

c. Calculation of Gas Volume

The gas volume generated as the result of anaerobic decomposition of solid waste can be estimated roughly applying the following chemical equation.

$$CH_aO_bN_c + \frac{1}{4}(4-a-2b+3c)H_2O \rightarrow \frac{1}{8}(4-a+2b+3c)CO_2$$

$$+ \frac{1}{8}(4+a-2b-3c)CH_4 + cNH_3$$

where,

C, H, O, N : Carbon, Hydrogen, Oxygen and Nitrogen

a, b, c : Chemical composition ratio by weight of hydrogen, oxygen and nitrogen

When the chemical composition of the waste drawn from Table 10-3-1 (C: 17.21%, H: 2.29%, O: 12.92%, N: 1.00%) is applied, the above formula can be written as follows:

$$C_{1.434}H_{2.290}O_{0.808}N_{0.071} + 0.512\ H_2O$$

$$\rightarrow 0.659CO_2 + 0.775\ CH_4 + 0.072NH_3$$

Thus, 33.7 liters of gas is produced from 100 g of waste. It can be rewritten that 337 (m^3/t.waste) is produced.

Decomposition is active for a few years after landfilling. So, when it is assumed that a half of the total volume of gas is generated in a year, the daily volume of gas in that year is

$$337 \times \frac{1}{2} \times \frac{1}{365} = 0.46\ (m^3/t.d).$$

The gas is generated in the site and dispersed to the outside. The gas may cause natural fire and nuisance of odor when the concentration of pollutant is high.

d. Gas Control

When methane is present in the air in concentrations between 5 and 15 percent, it is inflammable. To prevent gas seepage through the sealant, the gas should be collected through gravel packed cells and wells. A typical gas control system is illustrated in Fig. 4-5-3.

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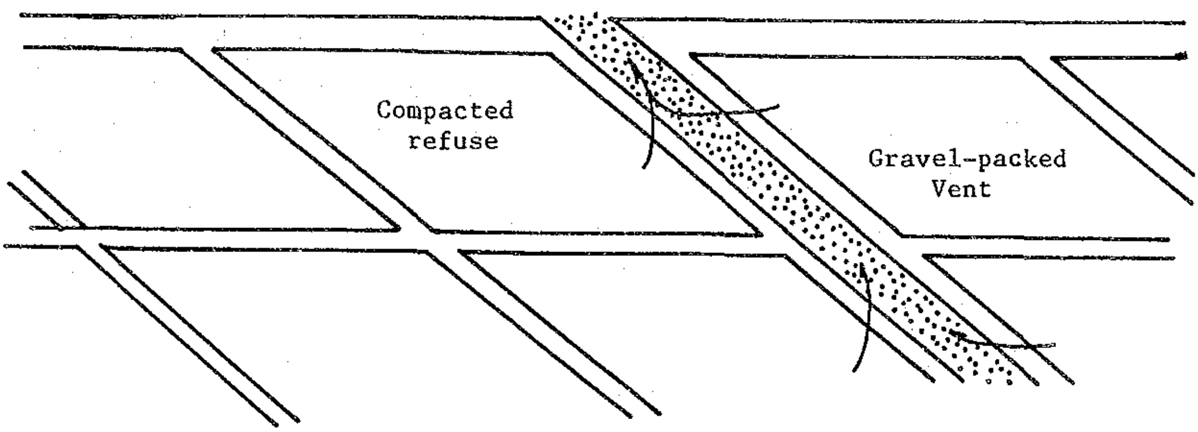
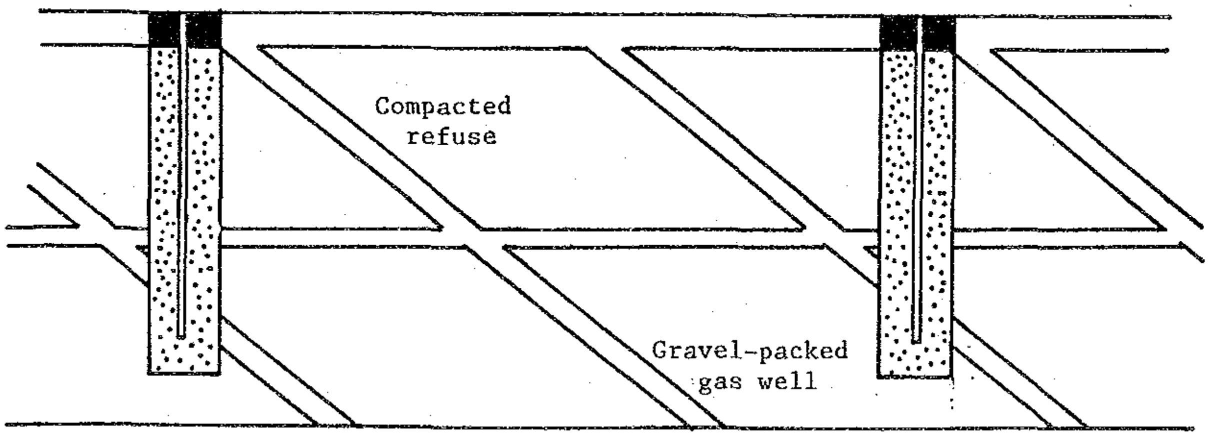


a. Cell

Cover material



b. Well

Fig. 4-5-3 Typical Gas Control Methods

(4) Odor

a. General Characteristics of Odor

The main elements of odor generated from the landfill site are hydrogen sulfide, methyl sulfide and methyl mercaptan. They are produced as a result of decomposition of sulfide compounds in the waste.

Two major methods from measuring the odor are a human sense measuring method, and a device measuring method. The odor is captured and smelled by man. The air is diluted until it comes to the point that he cannot smell the odor. Then the dilution rate is called a dilution/threshold ratio, or odor concentration, and expressed by D/T.

The other way is a method fro measuring the odor concentration by use of a device. An example of pollutants and the standard limit are given in Table 4-5-12.

Table 4-5-12 Standard Limit of Odor Elements
(on the ground surface of the site boundary)

Element	Standard Limit (ppm)
Hydrogen Sulfide, H_2S	0.02 - 0.2
Methyl Sulfide, $(CH_3)_2S$	0.01 - 0.2
Methyl Mercaptan, CH_3SH	0.002 - 0.01
Methyl Disulfide, $(CH_3)_2S_2$	0.009 - 0.1
Trimethylamine, $(CH_3)_3N$	0.005 - 0.07
Acetoaldehyde, CH_3CHO	0.05 - 0.5
Styrene, C_6H_6-$CHCH_2$	0.4 - 2
Ammonia, NH_3	1 - 5

Source: Rank odor protection law of Japan, 1971

b. Odor of Landfill Site

The odor generated at a landfill site is dependent on the characteristics of waste and method of landfill. The elements of odor and their concentration vary a great deal, thus its complete analysis is very hard.

A research shows that a high concentration of odor elements are found when the concentration of methane was about 50-60% (Fig. 4-5-4).

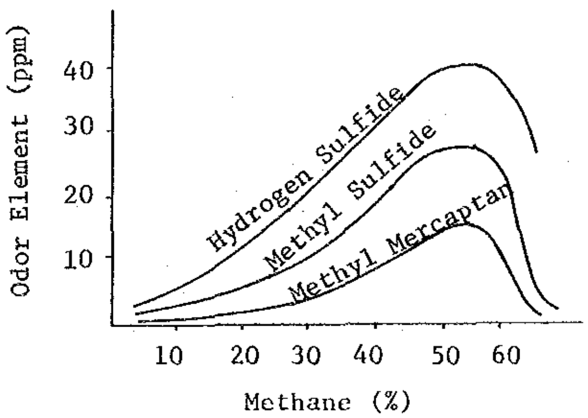


Fig. 4-5-4 Concentration of Odor Elements and Methane

Source: Water use and drainage, Vol.20, No. 11, 1978

c. Control of Odor

The odor generated at a landfill site is diluted by wind and could be harmless outside of the boundary. As it is generated by anaerobic decomposition of proteins and vegetables, it is often accompanied by methane generation. Thus it should be collected together with methane and treated properly when the site is close to a residential area and has potential to affect people.

CHAPTER 5

PROPOSAL AND EVALUATION OF MASTER PLAN

CHAPTER 5 PROPOSAL AND EVALUATION OF MASTER PLAN

5-1 Approach to Master Plan

The master plan should have a continuity, which is an efficient waste stream from generation to final disposal as a total system in solid waste management. The solid waste management system must consist of the concurrence of subsystems having interrelationships with each other. Therefore, the establishment of the reasonable interrelationships will cause the master plan to have system continuity.

The fundamental functions for each subsystem can be identified as listed below.

1. Onsite Storage : Residents' convenience and public health.

2. Collection/Transportation : Efficient and reliable removal of wastes from the served area.

3. Intermediate Processing : Efficient and reliable operation such as volume reduction, chemical stabilization and resource recovery with adequate environmental control.

4. Final Disposal : Reduction of wastes to nature with adequate environmental control.

The general interrelationships between subsystems are illustrated in Fig. 5-1-1 as a basic framework for solid waste management. The arrows in the figure signify the requirements of each subsystem with respect to the others. These requirements have to be evaluated from viewpoints of the local conditions and management policies.

In Seoul City, like other foreign municipalities, the major solid waste management problems can be specified as the scarcity of new landfill sites in the administration area. Taking into account the existing situation in Seoul, opening of the Incheon coastal landfill site, which O.O.E. has studied, can be specified as an important matter

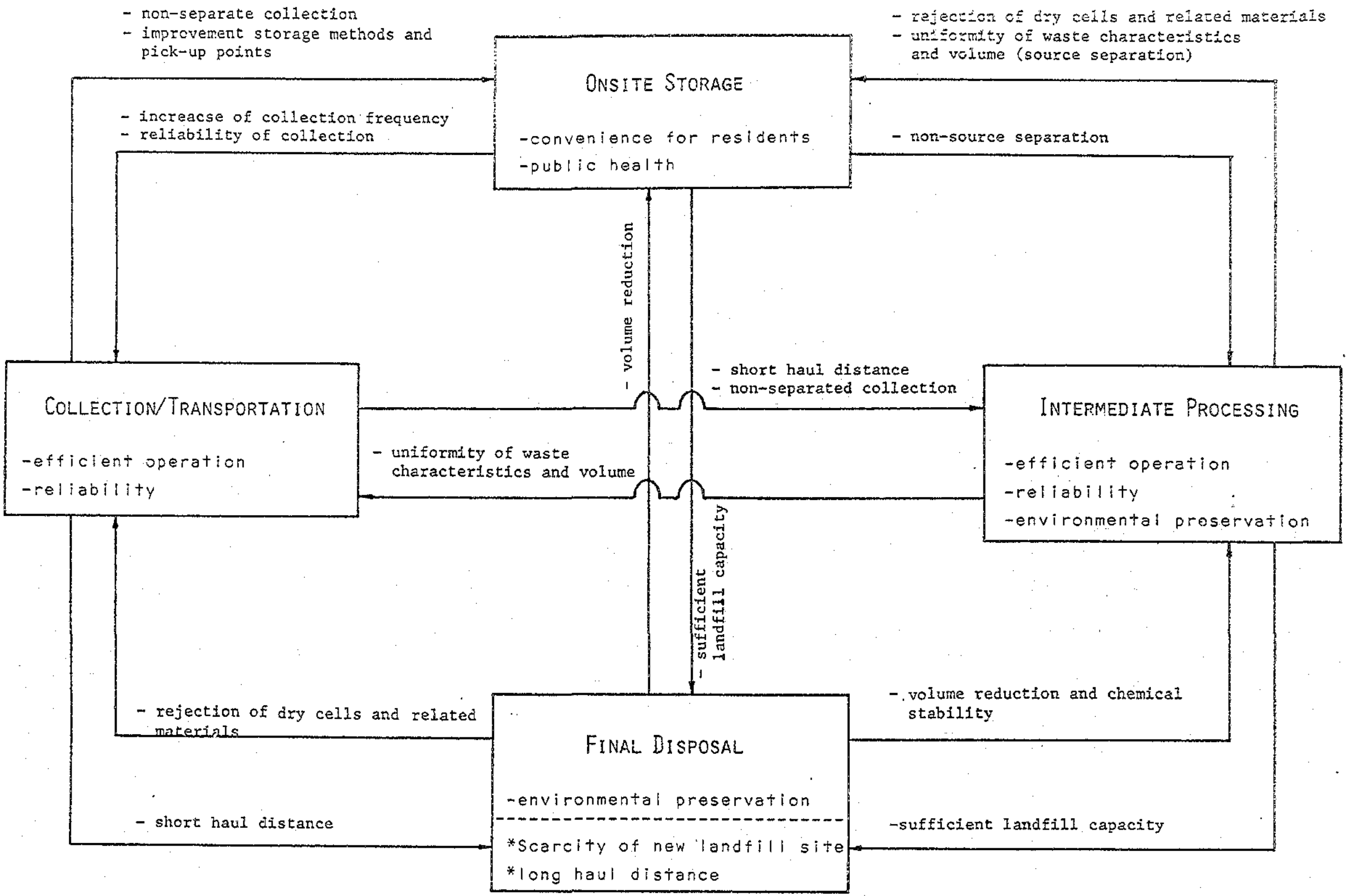


Fig. 5-1-1 Simplified Diagram for Interrelationships between Subsystems

for Seoul City. However, since Incheon landfill planning is within a comprehensive project spanning across several administrative districts, the actual construction must be delayed due to institutional hindrances. Therefore, Nanjido mounding is indispensable for Seoul.

However, although the waste stream may be established by the above landfill projects, the basic problem is not yet solved. It is always difficult to acquire sufficient landfill sites for the future and this problem is also faced by Seoul City. Therefore, the master plan should have effective solutions for the situation and the volume reduction of waste for economical use of landfill sites should be focused in the master plan. Intermediate processing is the most effective method for waste reduction. Though source separation of recoverables is also one of the methods.

In the case where intermediate processing is adopted, waste characteristics, generation rate, marketability of products, initial investment and maintenance and operation cost are necessary to be considered. These technical, and economic aspects were discussed in the previous Subsection 4-3-4. The master plan is evaluated mainly from economic and financial viewpoints in this chapter.

On the other hand, another continuity, which is a smooth transition from the existing system to the future system proposed in the Master Plan is necessary to be considered. This topic is discussed in Section 5-5.

5-2 Framework for Master Plan

The master plan targeted for year 2005 covers the whole Seoul administrative area. The projected population is 12.5 million persons in 2005 as shown in Chapter 3.
The collection served area is also specified as the same area according to the definition of the Seoul refuse cleansing ordinances.

The collection rate is projected to be the same as the generation rate, though recovered materials and illegally dumped waste are necessary to be considered. However, project framework of this study should be limited to the waste which is not treated by other projects. For instance, waste treated by Nanjido waste recovery plant and by Mokdong Incineration plant should be excluded from the framework. Waste generation rate is shown in Table 5-2-1. The waste amount which is taken into account in this study is shown in Fig. 5-2-1 and Table 5-2-1 together with projected population.

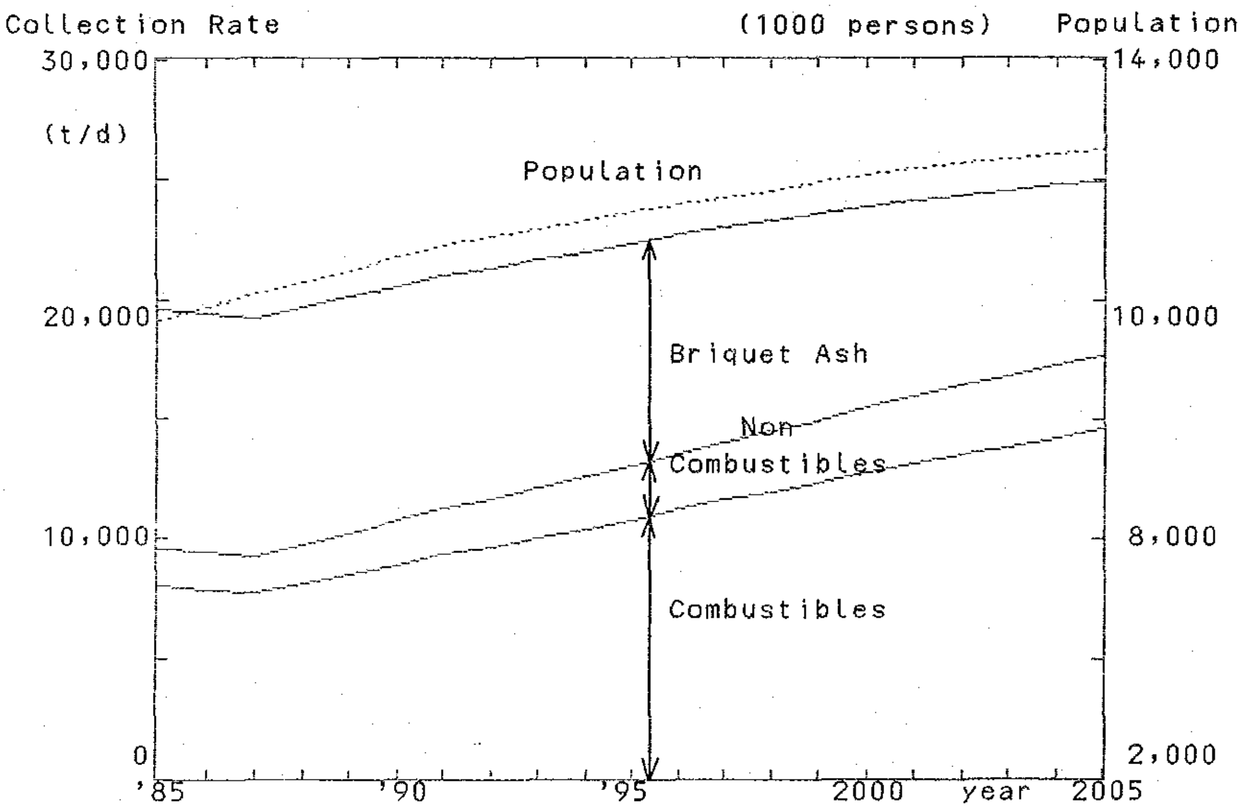


Fig. 5-2-1 Average Collection Rate and Served Population

Table 5-2-1 Population Projections and Average Collection Rates into Components

Year	Generation Rate								Project Framework								Population
	Combustibles		Non Combustibles		Briquet Ash		Total		Combustibles		Non combustibles		Briquet Ash		Total		
	1,000 t/y	ton/day	1,000 t/y	ton/day	1,000 t/y	ton/day	1,000 t/y	ton/day	1,000 t/y	ton/day	1,000 t/y	ton/day	1,000 t/y	ton/day	1,000 t/y	ton/day	(1,000 Persons)
1985	2,940	8,060	550	1,510	3,660	10,040	7,150	19,610	2,940	8,060	550	1,510	3,660	10,040	7,150	19,610	9,660
1986	3,090	8,460	580	1,590	3,670	10,050	7,340	20,100	2,880	7,880	560	1,550	3,650	9,990	7,090	19,420	9,880
1987	3,230	8,860	610	1,670	3,670	10,050	7,510	20,580	2,810	7,710	580	1,580	3,620	9,930	7,010	19,220	10,100
1988	3,390	9,230	640	1,760	3,670	10,040	7,700	21,030	2,970	8,080	610	1,670	3,620	9,920	7,200	19,670	10,300
1989	3,530	9,660	670	1,850	3,640	9,980	7,840	21,490	3,110	8,510	640	1,760	3,590	9,860	7,340	20,130	10,500
1990	3,680	10,070	710	1,940	3,620	9,930	8,010	21,940	3,260	8,920	680	1,850	3,570	9,810	7,510	20,580	10,700
1991	3,820	10,470	740	2,030	3,600	9,880	8,160	22,380	3,400	9,320	710	1,940	3,550	9,760	7,660	21,020	10,900
1992	3,970	10,840	770	2,110	3,570	9,760	8,310	22,710	3,550	9,690	740	2,020	3,520	9,640	7,810	21,350	11,040
1993	4,090	11,210	800	2,190	3,510	9,630	8,400	23,030	3,670	10,060	770	2,100	3,460	9,510	7,900	21,670	11,180
1994	4,230	11,590	830	2,280	3,470	9,500	8,530	23,370	3,810	10,440	800	2,190	3,420	9,380	8,030	22,010	11,320
1995	4,380	11,990	860	2,360	3,420	9,360	8,660	23,710	3,960	10,840	830	2,270	3,370	9,240	8,160	22,350	11,460
1996	4,530	12,390	900	2,450	3,380	9,220	8,810	24,060	4,110	11,240	870	2,360	3,330	9,100	8,310	22,700	11,600
1997	4,660	12,760	920	2,530	3,300	9,050	8,880	24,340	4,240	11,610	890	2,440	3,250	8,930	8,380	22,980	11,720
1998	4,800	13,140	960	2,620	3,240	8,880	9,000	24,640	4,380	11,990	930	2,530	3,190	8,760	8,500	23,280	11,840
1999	4,940	13,540	980	2,690	3,180	8,710	9,100	24,940	4,520	12,390	950	2,600	3,130	8,590	8,600	23,580	11,960
2000	5,080	13,930	1,020	2,790	3,120	8,530	9,220	25,250	4,660	12,780	990	2,700	3,070	8,410	8,720	23,890	12,080
2001	5,230	14,320	1,050	2,880	3,050	8,340	9,330	25,540	4,810	13,170	1,020	2,790	3,000	8,200	8,830	24,180	12,200
2002	5,350	14,670	1,080	2,960	2,960	8,120	9,390	25,750	4,930	13,520	1,050	2,870	2,910	8,000	8,890	24,390	12,280
2003	5,480	15,020	1,110	3,040	2,880	7,890	9,470	25,950	5,060	13,870	1,080	2,950	2,830	7,770	8,970	24,590	12,350
2004	5,630	15,390	1,140	3,110	2,810	7,670	9,580	26,170	5,210	14,240	1,110	3,020	2,760	7,550	9,080	24,810	12,430
2005	5,740	15,730	1,160	3,160	2,710	7,450	9,610	26,340	5,320	14,580	1,130	3,070	2,660	7,330	9,110	24,980	12,500

The waste characteristics for planning intermediate processing are divided into two collection types of two components and three components. Three major components and lower heating values are discussed in Subsection 4-3-2 about low quality waste and medium quality waste. Here, waste composition of high quality waste was also taken into consideration (Table 5-2-2).

Table 5-2-2 Characteristics of Waste by Separation Types

a. Three Major Components and Lower Heating Value

Separation Type	Component	1988 Low Quality	1988 Medium Quality	1988 High Quality	2005 Low Quality	2005 Medium Quality	2005 High Quality
2 * Components	Volatile (%)	23.4	28.9	40.0	27.8	34.1	40.0
	Ash (%)	21.9	26.1	26.0	23.0	25.9	26.0
	Moisture Content(%)	54.7	45.0	34.0	49.2	40.0	34.0
	Lower Heating Value (kcal/kg)	720	1,030	1,600	950	1,290	1,600
3 * Components	Volatile (%)	26.9	32.9	46.0	32.4	39.7	46.0
	Ash (%)	11.5	16.8	14.0	11.5	15.1	14.0
	Moisture Content(%)	61.6	50.2	40.0	56.1	45.2	40.0
	Lower Heating Value (kcal/kg)	840	1,180	2,000	1,120	1,520	2,000

* Including Non-combustibles

b. Non-combustibles (on 3 component separation)

Component		1988	2005
Metals	(%)	16.0	20.0
Glass/Ceramics	(%)	35.0	44.0
Others	(%)	41.0	28.0
Moisture Content	(%)	8	8

Note: Separation is as follows.

2 Component
- Briquet Ash
- Others

3 Component
- Briquet Ash
- Non-combustibles
- Combustibles

5-3 Proposal of Master Plan

5-3-1 Establishment of System Alternatives

(1) Trends in Solid Waste Management

Solid waste Management has always been centered around landfilling. However, difficulties in securing adequate landfill sites in the metropolitan areas have caused municipalities to adopt policies to reduce the load on landfills. As a solution, intermediate processings such as incineration and composting have been implemented.

The situation on solid waste management in various nations around the world is shown in Tables 5-3-1 and 5-3-2. These tables reveal that Japan, Switzerland and the Netherlands have high incineration ratios, followed by France, German Federal Republic and Sweden. Furthermore, heat recovery is popular in Europe, and the United States of America has focused its main management method to landfilling but is carrying out research and development on resource recovery oriented technologies such as pyrolysis and RDF. In this respect, from the landfill-centered principles, solid waste management technologies show trends toward resource recovery with economical use of landfills.

(2) Alternatives for Seoul City

The alternatives for the master plan are established as presented in Fig. 5-3-1 from technical viewpoints. This figure illustrates the waste stream from onsite storage to final disposal for each alternative on the basis of source separation and intermediate processing. The descriptions of each alternative are presented below.

Option I : Completely landfilling type which is the most economical system in the case where acquisition of sufficient landfill sites is easily accomplished. Briquet ash is separately collected for use as cover material.

Table 5-3-1 Collection and Processing/Disposal Rates in Foreign Nations

1000 ton

Nation	Collection Rate	Processing/Disposal Rate					Period
		Mechanical Separation	Composting	Incineration	Landfill	Others	
Canada	12,600	90	-	440	11,844	-	1980
U.S.A.	160,000	-	-	-	-	-	1980
Japan	42,148	-	78	24,847 (15.1)	20,352	933	1979
Australia	10,000	-	-	200	9,900	-	1978
New Zealand	2,106	-	22	-	2,097	-	1982
Austria	1,560	-	313	316 (94.9)	930	-	1982
Belgium	3,082	-	350	720 (29.9)	1,530	482	1980
Denmark	2,046	-	82	655	1,309	-	1980
Finland	1,400	-	-	-	-	-	1980
France	15,500	-	1,395	4,900 (62.0)	9,455	930	1980
G.F.R.	27,000	-	442	6,253	25,794	127	1977
Greece	2,500	-	-	-	2,500	-	1980
Italy	14,041	402	834	2,794 (21.3)	5,286	4,650	1980
Netherlands	5,100	-	827	2,269 (71.7)	-	-	1980
Norway	1,500	-	-	-	-	-	1975
Portugal	1,500	-	64	-	245	-	1980
Spain	8,028	78	905	512 (58.6)	7,075	-	1980
Sweden	2,500	150	180	910 (85.7)	1,500	-	1980
Switzerland	2,146	-	71	1,716 (71.7)	453	-	1979
Great Britain	15,816	-	-	2,780	19,774	5,436	1980

Note : Figures in parentheses denote ratios of energy recovery in percent

Table 5-3-2 Solid Waste Management Systems in Foreign Municipalities

City Name	Collection Rate		Processing/Disposal	Rate	Period	
Greater London (United Kingdom)	11,000 t/yr		Landfill	80%	1975	- After transfer:
			Incineration	20%		Barge 25%
						Vehicle 75% (Capacity $50m^3$)
Westminster (United Kingdom)	Domestic	56,000 t/yr	Landfill	96.7%	1977	
	Commercial	104,000 t/yr	Recycling	3.3%		
	Total	160,000 t/yr				
Paris (France)	Domestic	866,700 t/yr	Incineration	46%	1964	- Refuse of Paris is managed by the Seine Prefectural Government
	Market waste	75,300 t/yr	Material recovery	19%		
	Total	942,000 t/yr	Landfill	35%		
Bonn (G.F.R.)	143,600 t/yr		Landfill	81.4%		
			Incineration	18.6%		
Hamburg (G.F.R.)	Domestic	574,000 t/yr	Incineration		1967	
	Bulky waste	40,000 t/yr	Domestic	40%		
	Total	614,000 t/yr	Bulky waste	100%		
Heidelberg (G.F.R.)	Domestic	44,000 t/yr	Landfill	32.3%	1978	- Recovered materials: glass, paper, ferrous metals, compost
	Commercial/ Industrial	18,000 t/yr	Incineration	35.5%		- Separate collection for paper and glass
	Total	62,000 t/yr	Recovery	32.2%		
Stockholm (Sweden)	Domestic/ Commercial	200,000 t/yr	Landfill	44.4%	1973	
	Industrial	250,000 t/yr	Incineration	55.6%		
	Total	450,000 t/yr				
New York (U.S.A.)	6,468,221 t/yr (in 1978)		Landfill	82.3%	1977	- Separate collection for recoverables is under planning
			Incineration	17.7%		
Dallas (U.S.A.)	1,641,000 t/yr		Landfill	100%	1980	- Three transfer stations
Tokyo (Japan)	Combustibles	2,897,000 t/yr	Incineration	56%	1982	
	Non-combustibles	1,180,000 t/yr				
	Bulky waste	114,000 t/yr	Landfill	44%		
	Others	1,012,000 t/yr				
	Total	5,203,000 t/yr				
Hiroshima (Japan)	Combustibles	64,700 t/yr	Incineration	60%	1983	
	Non-combustibles	16,000 t/yr				
	Recoverables	5,100 t/yr	Material recovery	2%		
	Bulky waste	100 t/yr				
	Hazardous waste	2,600 t/yr	Landfill	38%		
	Total	88,500 t/yr				

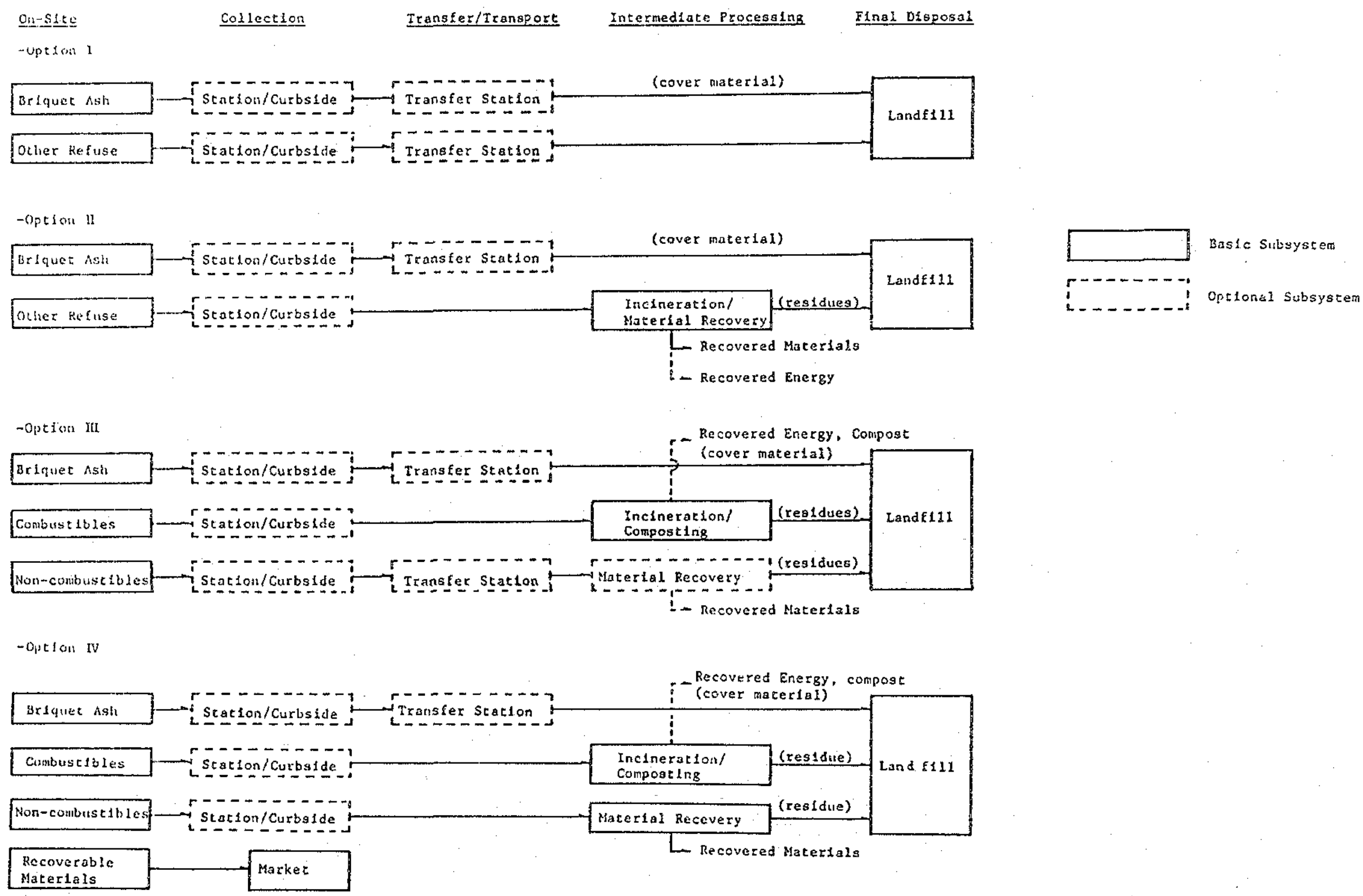


Fig. 5-3-1 Schematic Alternatives for Master Plan

Option II : Two component waste separation option in which intermediate processing for the waste without briquet ash is adopted. Selection of an intermediate processing system is difficult due to factors such as, if composting is chosen, the quality of compost products is poor due to impurities, and if incineration is selected, the amount of residues is large due to mixture of non-combustibles.

Option III : Three component wastes separation option where efficiency and reliability of intermediate processing can be obtained by the separation.

Option IV : Four component wastes separation option which requests a large load on residents due to the separation task required onsite.

The general procedure of an implementation for improvement is divided into three steps. Landfill acquisition must be carried out as the first step and improvement of collection should follow. Then an intermediate processing system should be established after improvement of the collection/transportation system.

5-3-2 Decision of Proposed Master Plan

Among the alternatives considered in the previous subsection 4-2-1, a three component waste separation is appropriate for maintaining the efficiency of intermediate processing due to merits on such matters as up-grading the compost quality, raising heating value and manimizing plant capacity. The costs for collection of 2 and 3 components separation are almost same level as calculated in Table 4-2-6. The appropriateness of the following alternatives are studied:

1. Option I : (Transfer station) + Landfill
2. Option III-a : Incineration + Transfer station + Landfill
3. Option III-b : Compositing + Material Recovery + Transfer station + Landfill
4. Option III-c : Incineration + Material Recovery + Transfer station + Landfill

The cost comparison of the above options is indicated in Table 5-3-3. From view points of costs,

- Option I, with transfer station, is the least expensive, while Option I, without transfer station, is the most expensive. This fact means that transfer station has a large impact to improve collection and transportation efficiency contrary to the costly vehicle collection system, because the distance to Incheon landfill site is considerably long and the transportation cost is high.

- If compost is marketable and is not filled, Option III-b has merits in economics and volume reduction. However, demand for the compost product at present and in future is expected little even if it is distributed free of charge.

- On the other hand, Option III-a and III-c have potential for revenue from activities such as selling steam for heating the surrounding community and generating power when the heating value of refuse becomes sufficient for burning in the future as shown in Table 4-3-5.

Table 5-3-3 Cost Comparison of Alternatives

Item		Option I (L/F)		Option III-a	Option III-b (C+T/S+M/R)		Option III-c
		Without T/S	With T/S	(I/C + T/S)	Marketable	Non-Marketable	(I/C+T/S+M/R)
Investment (billion W)	Compost	-	-	-	470	456	-
	Incineration	-	-	644	-	-	644
	Material Recovery	-	-	-	68	68	68
	Transfer Station	-	17	8	8	8	8
	Operation Vehicles	261	177	186	195	243	182
	Total	261	294	838	741	775	902
O/M + Depreciation (million W/day)	Collection/Transport	430	258	181	194	249	172
	Intermediate Processing	-	-	162	138	134	186
	Landfill	35	35	15	19	27	14
	Total	465	293	358	351	410	372
Revenue	(million W/day)	-	-	-	1	1	1
Net Expenditure	(million W/day)	465	293	358	350	409	371
Filling Rate (t/day)	Incineration Ash	-	-	2,190	-	-	2,190
	Combustibles	14,580	14,580	-	5,100	10,210	-
	Non-combustibles	3,070	3,070	3,070	2,610	2,160	2,160(-RETURN-)
	Briquet Ash	7,330	7,330	7,330	7,330	7,330	7,330
Landfill Volume (m3/day)	Incineration Ash	-	-	1,530	-	-	1,530
	Combustibles	13,120	13,120	-	4,590	9,190	-
	Non-Combustibles	2,460	2,460	2,460	2,090	2,090	2,090
	Briquet Ash	4,400	4,400	4,400	4,400	4,400	4,400
	Total	19,980	19,980	8,390	11,080	15,680	8,020
Reduction Effect	(₩/M3) $\left(\frac{\text{Net Expenditure}}{\text{Reduced Volume}}\right)$	-	-	30,900	39,400	95,100	31,000

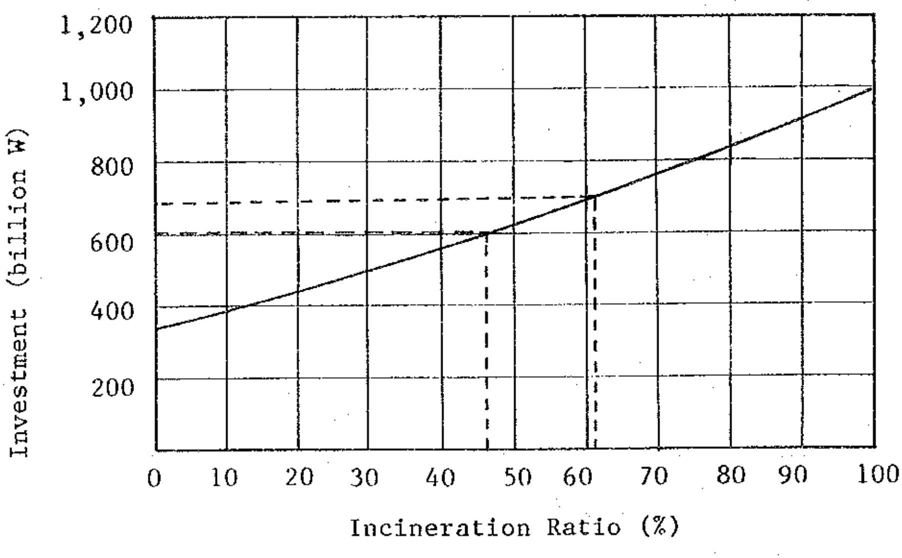
Note ; (L/F): Landfilling, (I/C): Incinerating, (C): Composting, (M/R): Material Recovery
Reduced Volume = [Landfill Volume of Option I] - [Landfill Volume of each Option]
Mass Balance of each alternative is shown in Fig. 4-3-1

Therefore, in consideration of study results of chapter 4 and the following factors, Option III-c is recommended as the most appropriate option, and thus is proposed as the optimum master plan for Seoul City.

1. Most effective process for waste volume reduction (Refer to Table 5-5-3)
2. Improvement of collection and transportation system to promote collection efficiency
3. Technology is proven world-wide
4. Appropriate for waste processing in metropolitan areas (from view-points of environmental aspects, processing rate, etc.)
5. Has possibilities for energy and material recovery

The evaluation table for selection of the optimum alternative is given in Table 5-3-4.

Nevertheless, Option III-c needs a large investment for implementation. Since total processing of waste is a target for the master plan, the available amount of investment should be evaluated. Therefore, the optimum master plan is established on the processing ratio of the projected waste generation rate, based on the results of the economic evaluation in the following section. The relationship between incineration ratio and investment is shown in Fig. 5-3-2.



Note : Investment for landfill includes Incheon landfill and Nanjido Mounding.

Fig. 5-3-2 Correlation between Investment and Incineration Ratio

Table 5-3-4

Evaluation of Master Plan Alternatives

Factor	Option: I Landfill	III-a Incineration	III-b Composting + Material Recovery: Marketable	III-b: Non-marketable	III-c Incineration + Material Recovery	Comment
Economic						
Costs	0	X	Δ	Δ	X	Initial + operation and maintanance costs
Revenue	X	X	0	Δ	Δ	Marketability of output is determinant
Environmental						
Potential to Pollute	X	Δ	Δ	Δ	Δ	Water contamination, air pollution, odor, noise, etc.
Aesthetics	X	Δ	Δ	Δ	Δ	Waste scatter, vectors, appearance, etc.
Technical						
Provenness	0	0	0	0	0	Provenness on a large scale, world-wide
Volume Reduction*	X (0%)	0 (74%)	Δ (60%)	X (34%)	0 (77%)	Critical factor for Seoul City
Administrative	0	Δ	X	X	Δ	Handling, operation, maintenance, etc.
Score	6	7	8	6	8	See note below for point
Rank	4	2	3		1	III-b ranking considered an in-between score

Note : X : 0 point Δ : 1 point 0 : 2 points

* The percentages in parentheses are possible waste volume reduction ratios for each option (on total waste excluding briquet ash).
* Reduced volume:

Option I -------------- 0 m3
III-a -------------- 4,229,000
III-b(Marketable)--- 3,434,000
III-b(Non-marketable)1,944,000
III-c -------------- 4,365,000

* Input volume: 2,692,000 m3

5-4 Viability of Investments

5-4-1 Methodology

Solid waste management is indispensable to the society. In particular, a number of big cities in the world endeavor to seek the best solution for solid waste disposal. Seoul City is not without exception and is working out several alternatives in this field. On the other hand, the problem is that capital is not always sufficient to the economy. Investment in one sector may lead to giving up something in another sector. There may exist trade-offs between competing social needs. This capital constraint implies that it will be necessary to establish Priorities for alternative use of capital.

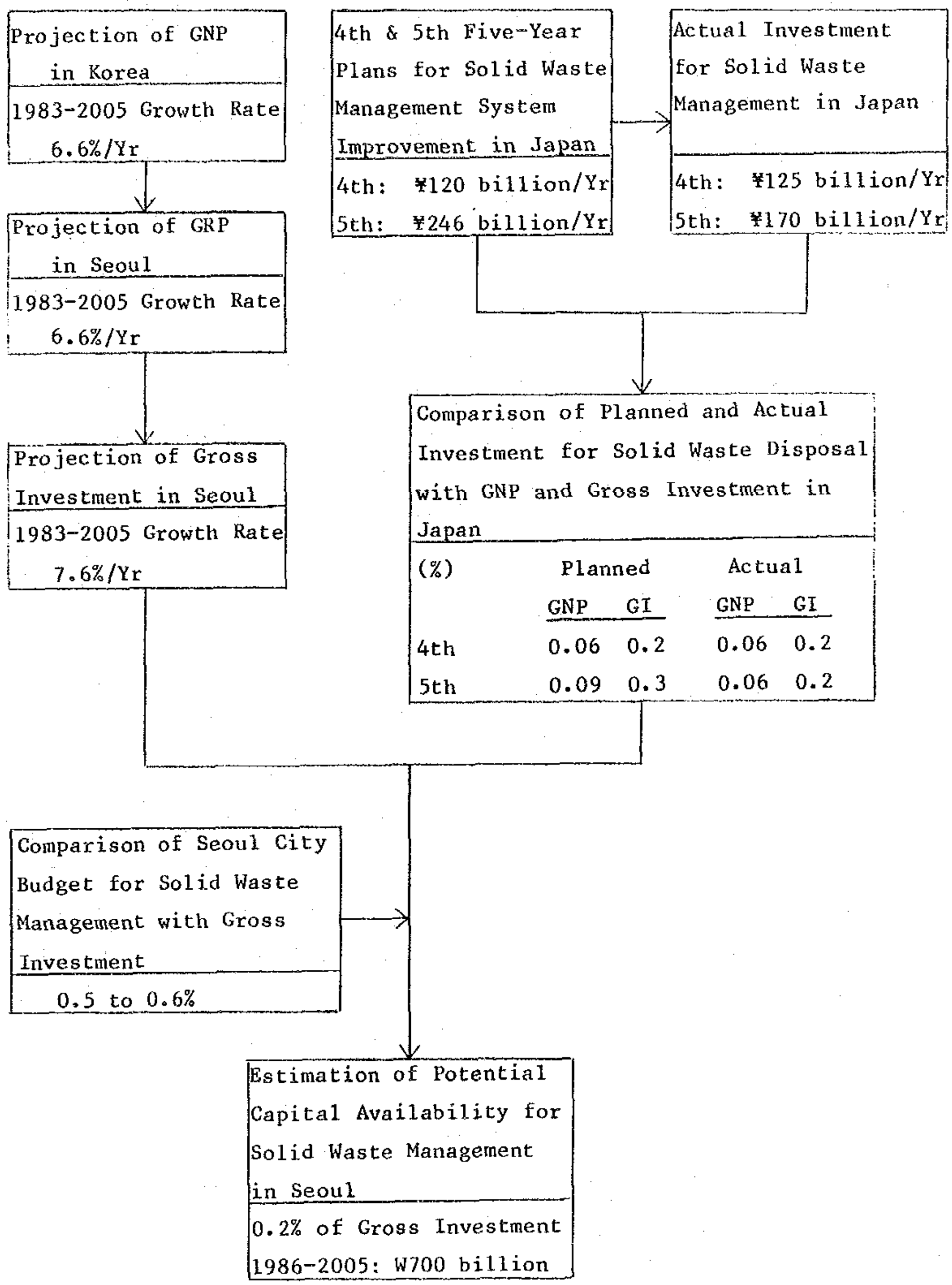
Taking these into account, efforts will be, in this section, mostly directed to provide information for the Government to establish priorities for solid waste management. For this purpose, potential aviliability of capital for solid waste management in Seoul City will be assessed in consideration of practices in Seoul City as well as other countries. Then, the estimated potential availability of capital will be compared with the capital requirements for the alternatives proposed in the Master Plan throughout the planning period up to 2005. When capital shortage exists, another alternative with lower costs shall be elaborated although its service level may be deteriorated.

The assessment of potential availability of capital for solid waste management here is not the results from detail sector analysis for economic planning. This will be, however, informative to the Government when establishing priorities.
The work flow is summarized in Fig. 5-4-1.

5-4-2 Capital Availability

According to the Feasibility Report on Han River Basin Environmental Master Plan, typical level of investment in pollution control in the industrialized countries have ranged from approximately 0.5 percent to 2.0 percent of GNP. This pollution control investment includes not only solid waste disposal but also water and air pollution control.

Fig. 5-4-1 Work Flow for Estimation of Capital Availability



Based upon the experiences in the industrialized countries, the Feasibility Report concludes that the 1 percent allocation of GNP to investment in pollution control seems reasonable.

Investment in pollution control in Japan increased to 2 percent of GNP in 1975. Investment in solid waste disposal was expected to reach ¥600 billion during 1976 to 1980 under the Fourth Five-Year Plan for Solid Waste Management System Improvement. In 1981, the Government of Japan approved the Fifth Five-Year Plan amounting to ¥1,230 billion during the planning period from 1981 to 1985. Table 5-4-1 presents the comparison between the Fourth and Fifth Five-Year Plans.

Table 5-4-1 The 4th and 5th Five-Year Plans for Solid Waste Management System Improvement of Japan

	The 4th Five-Year Plan (1976-1980)		The 5th Five Year Plan (1981-1985)	
	Volume	Amount (billion Yen)	Volume	Amount (billion Yen)
Incineration Facilities	42,000 t/d	472.9	59,850 t/d	772.7
Bulky Waste Processing Facilities	80 units	18.3	85 units	35.0
Facilities Improvement Works	-	23.5	-	20.1
Disposal Facilities	728 sites	59.5	168,250,000m^2	209.8
Landfill Site Acquisition	-	-	17,123,000m^2	109.3
Collection Vehicles, etc.	-	25.8*	-	83.1
Total		600.0		1,230.0

Note : * estimated

Source : City and Waste, Vol. 12, No. 1

An annual average disbursement comes to ¥120 billion for the Fourth Five-Year Plan and ¥246 billion for the Fifth Five-Year Plan which are compared with the GNP and gross investment in Japan during the comparable years. The percentage of annual average disbursement is 0.06 percent against GNP and 0.2 percent against gross investment in the case of the Fourth Five-Year Plan, while the percentage against GNP and gross investment is 0.09 percent and 0.3 percent, respectively, in the case of the Fifth Five-Year Plan. The capital requirements proposed by the Fourth as well as Fifth Five-Year Plan will be regarded as an optimum level of investment for solid waste management improvement.

On the other hand, the actual budgets of the Central Government for solid waste management were approximately ¥36 billion per annum during the Fourth Five-Year Plan and ¥49 billion from 1981 to 1984. The total investment for solid waste management in Japan is estimated on the basis of those budget scales. During the Fourth Five-Year Plan from 1976 to 1980, the actual annual investment is estimated to reach ¥125 billion which is the same level of investment proposed by the Fourth Five-Year Plan. This may be partly due to the price hike after the oil crisis. The estimated annual investment during 1981 to 1984 amounts to ¥170 billion, 30 percent* lower than that expected by the Fifth Five-Year Plan. This estimated investment is also compared with the GNP and gross investment. The percentage of the investment is 0.06 percent against GNP and 0.2 percent against gross investment. This level of investment will be regarded as the minimum requirement to keep a sound solid waste management. * : (1-170/246)=30

Meanwhile, the budget for solid waste management in Seoul City was 0.17 to 0.18 percent of Seoul GRP and 0.5 to 0.6 percent of gross investment from 1983 to 1984. At this budget scale, 30 to 50 percent of the total budget shall be allocated to meet such an investment level as described in the foregoing paragraph. On the other hand, the total budget of Seoul City is a little higher than 10 percent of GRP in these year. The budget for solid waste management, therefore, is around 1.5 to 1.6 percent of the total budget. The limited space for landfill will make solid waste disposal costly and may use more budget in the future.

Needless to say, the availability of capital for solid waste management in Seoul City largely depends upon the priorities that the Seoul Metropolitan Government and the Central Government will assign to this field. From the experiences of the industrialized countries, investment in pollution control increases in accordance with economic development. In Korea, investment in this field will grow fast in the future as a member of the industrialized countries. The city budget for solid waste management is expected to increase accordingly in the future.

5-4-3 Potential Availability of Capital

For the purpose of considering the viability of investments for the proposed Master Plan, this report relies on the Japanese experiences to project the potential availability of capital for solid waste management in the future. The percentages of the investment in solid waste management against GNP and gross investment in Japan were applied to the GRP and gross investment in Seoul City for this purpose. Projections of the total capital available during the planning period in Seoul City range from W985 billion in the case of 0.3 percent of gross investment to W530 billion in the case of 0.06 percent of GRP, as shown in Table 5-4-2.

The greatest availability of capital in the case of 0.3 percent of gross investment can be considered as an optimum or idealistic level of investment in solid waste management that Japan aimed at but could not attain due to capital shortage. On the contrary, Japan actually expended 0.2 percent of gross investment in solid waste management during the Fourth and Fifth Five-Year Plans. This was also the goal of the Fourth Five-Year Plan. Applying this investment level to Seoul City, approximately W660 billion will be available for solid waste management during the planning period. This amount corresponds to the investment level in the case that 0.074 percent of Seoul GRP is allocated to solid waste disposal during 1986 to 2005. In terms of GRP, therefore, the investment amounting to W660 billion is just

Table 5-4-2 Potential Availability of Capital

(Unit: billion Won at 1984 constant prices)

Year	Seoul GRP				Gross Investment			
	0.09%	Cumulative	0.06%	Cumulative	0.3%	Cumulative	0.2%	Cumulative
1986	20.3	20.3	13.6	13.6	23.1	23.1	15.4	15.4
1987	21.8	42.1	14.5	28.1	25.2	48.3	16.8	32.2
1988	23.3	65.4	15.5	43.6	27.3	75.6	18.2	50.4
1989	24.8	90.2	16.6	60.2	29.7	105.3	19.8	70.2
1990	26.5	116.7	17.6	77.8	31.5	136.8	21.0	91.2
1991	28.3	145.0	18.8	96.6	33.9	170.7	22.6	113.8
1992	30.2	175.2	20.1	116.7	36.6	207.3	24.4	138.2
1993	32.3	207.5	21.5	138.2	39.3	246.6	26.2	164.4
1994	34.4	241.9	22.9	161.1	42.3	288.9	28.2	192.6
1995	36.5	278.4	24.4	185.5	45.0	333.9	30.0	222.6
1996	38.9	317.3	25.9	211.4	48.0	381.9	32.0	254.6
1997	41.4	358.7	27.6	239.0	51.6	433.5	34.4	289.0
1998	44.2	402.9	29.5	268.5	55.2	488.7	36.8	325.8
1999	46.8	449.7	31.2	299.7	58.8	547.5	39.2	365.0
2000	49.7	499.4	33.1	332.8	62.4	609.9	41.6	406.6
2001	52.7	552.1	35.1	367.9	66.3	676.2	44.2	450.8
2002	55.8	607.9	37.2	405.1	70.5	746.7	47.0	497.8
2003	59.1	667.0	39.4	444.5	75.0	821.7	50.0	547.8
2004	62.5	729.5	41.6	486.1	79.2	900.9	52.8	600.6
2005	65.7	795.2	43.8	529.9	84.0	984.9	56.0	656.6

in the middle between the optimum 0.09-percent investment and the actual investment of 0.06-percent level. This suggests the necessity of effort to approach the optimum investment level to a certain extent.

Again, available capital for solid waste management in Seoul City depends upon the priorities that the Government will assign to this field. However, given the experiences in industrialized countries and the future economic development in Korea, the potential capital availability will be expected to reach around W700 billion in total for the whole period of the Master Plan, which approximately corresponds to the 0.2 percent allocation of gross investment, i.e. the actual investment level in Japan for these 9 years under the Fourth and Fifth Five-Year Plans. On the other hand, from the viewpoint of GRP allocation, this amount is higher than that from the actual investment level in Japan but will not be unrealistically high as a goal to attain when compared with the optimum investment level of 0.09-percent GRP allocation and 0.3-percent gross investment allocation amounting to W800 billion and W1,000 billion.

Taking these into account, W700 billion seems reasonable as the potential availability of capital for solid waste management during the planning period in Seoul City from the economic point of view. This scale of investment in solid waste management will make it possible to incinerate 50 to 60 percent of combustibles to be generated in Seoul City in the year of 2005, the target year of the Master Plan.

5-5 Implementation

5-5-1 Strategy

(1) General Aspects

Sufficient acquisition of landfill sites is a major problem for solid waste management in Seoul City. To combat this situation, effective use of intermediate processing to reduce the load on landfills is considered as the most rational countermeasure.

As a consequence, the master plan proposed incineration for high volume reduction along with reasonable landfill planning. Furthermore, separate collection is also proposed in accordance with the adoption of incineration and intentions for improvement of the collection and transportation system. The basic strategy of the master plan is described hereinafter.

(2) Introduction of Separate Collection

Separate collection is a basic matter for the proposed master plan since efficient and adequate collection and processing are carried out according to appropriate solid waste characteristics. In addition, separating refuse onsite will give a motive for changing residents' consciousness towards solid waste management and resultant recognition of the necessities for waste reduction and resource recovery.

Separating into three components of briquet ash, combustibles and non-combustibles is proposed in the master plan. The success of proper separation depends greatly on residents' cooperation. It is proposed that model areas are established where incinerations are put into operation. For the establishment of separate collection, public relations activities such as distribution of pamphlets should be fully utilized.

Material recovery will be performed after establishment of new system.

(3) Improvement of Collection and Transportation

The traditional collection system using hand carts and manual transfer stations has many problems resulting from environment disruptions, unaesthetics, non-sanitation and bad working conditions are taken into account, the system may prove otherwise. Furthermore, the modernization of collection and transportation will be inevitable from long term viewpoints, because labor costs and residents' demand for better environment, aesthetics and sanitation are expected to rise, and the traffic conditions will change making the use of hand carts and present transfer system difficult to continue.

The costs for collection systems by hand carts with manual transfer stations, and by vehicle with mechanical transfer stations differ only slightly at present as calculated in Table 4-2-17 in previous subsection 4-2-4. However, hand carts collection system will be costly in future because of escalation of personal expense.

Therefore, adoption of vehicle collection system with 2 ton and 4 ton compactors for combustibles, 2 ton and 4 ton dump trucks for non-combustibles and briquet ash is proposed as a collection improvement measure taking into account collection efficiency. Moreover since the haul distance will become longer than the existing one when the Incheon coastal landfill is started, mechanical transfer stations are necessary for economical transportation. Residual combustibles which cannot be processed, due to the limited incineration capacity, are also transferred to the above transfer stations.

(4) Adoption of Intermediate Processing

The intentions of intermediate processing can be given as listed below.

- Volume reduction for economical use of landfill

- Processing refuse to produce a stable and harmless output to maintain sanitary conditions and preserve the environment.

- Weight and volume reduction for economical transportation

- Resource recovery of materials and energy to conserve the depleting natural resources

In Seoul City, the major problem can be specified as the acquisition of landfill sites at both the present and future even if the Incheon coastal landfilling starts, and therefore volume reduction of the filling waste becomes an effective solution for this situation. As a result, incineration for combustibles and material recovery for non-combustibles are proposed.

However, since the investment for incineration is high, the feasible incineration ratio for year 2005 can be evaluated to be 50-60 % from an economic viewpoint. For selecting the served area for incineration of combustibles, the effects on reduction of transportation costs as a result of waste reduction by incineration need to be considered. In this respect, the effectiveness will be apparent if the farthest areas away from disposal site (Incheon) are selected first. It complies that the areas in the eastern part of Seoul are highly probable candidates. Accordingly, the incineration served area in 2005 is established as Dobong-Gu, Dongdaemun-Gu, Seongdong-Gu, Seongbug-Gu, Gangnam-Gu and Gangdong-Gu on the basis of a Gu as unit, because the transportation distance is longer in these Gu's than others.

As the first step of the incineration program, a 600 ton per day facility with power recovery is to be constructed as a demonstration. With this facility, incineration technology for Korea can be established, and personnel training and accumulation of information such as seasonal waste characteristics and generation rates can be carried out for developing intermediate processing technology.

On the other hand, material recovery is proposed to be carried out at the transfer station. The introduction of the recovery facilities is set for year 1996 after construction of the transfer station as a demonstration unit for further developement.

(5) Establishment of Landfill Planning

It is necessary to recognize that landfills are inevitable for a solid waste management system and that they are limited natural resources when considered as land. Since candidate sites for new landfills are scarce in Seoul City, the Nanjido Mounding is obliged to be planned as a temporary step.

Programmed acquisition of landfill sites is desirable due to the above situation. The master plan estimates that Nanjido Mounding will be completed in 1994 and proposes that Incheon Coastal landfilling should start thereafter. Therefore before 1990, the Seoul Metropolitan Government should make preparations for the Incheon landfill site.

(6) Cooperation of Residents

Residents' cooperation is always a basic matter for improvement of solid waste management from the administrative side, but is not always a welcomed subject from the residents' side. This cooperation is especially needed for source separation and curbside and station storage since these will change the customs of the citizens. Therefore, the solid waste management administrators should carry out campaigns to evoke residents' consciousness towards the significance implied.

(7) Personnel and Institutional Reinforcement

According to implementation of the master plan, the solid waste management workload will increase and its responsibilities will become complex. Institutional and organizational arrangements and resultant personnel reinforcement is needed for increased duties such as facility planning, facility operation and collection vehicle control. Especially, since considerate planning and information accumulation for developing and advancing the master plan are required, education of personnel in charge of these operations should be carried out immediately.

5-5-2 Proposed Master Plan

From consideration of the evaluations on technical and economic aspects, the proposed master plan is described for each subsystem as follows.

Source separation	:	Three component wastes separation into briquet ash, combustibles and non-combustibles
Collection/on site storage	:	Mainly adoption of station collection, container box collection for briquet ash, and baggage collection for other wastes by dump truck and compactor truck according to road conditions
Transfer/Transportation	:	Mechanical transfer stations and large size transportation vehicles
Intermediate Processing	:	Incineration for combustibles and Materials recovery for non-combustibles
Final Disposal	:	Mounded Nanjido, Incheon coastal landfill and subsidiary landfill sites in Seoul

The flow of materials for the proposed system is depicted in Fig. 5-5-1. The proposed system is centered around intermediate processing due to the fact that disposal potential for Seoul is low. However, to effectively process the characteristic waste of Seoul, three component source separation is recommended to grade up the heating value and the level of material recovery. The proposed intermediate processing system will greatly reduce the waste volume to be landfilled, which in turn will extend the life of the landfill. The revenues obtainable from the recovered materials, though not much, can be used to partially offset the running cost. The recovered power from incineration can give benefits to both the processing plant and the surrounding community. Though briquet ash cannot be processed to an advantage, the ash itself can be useful as cover material for landfill operations when sanitary landfilling is considered.

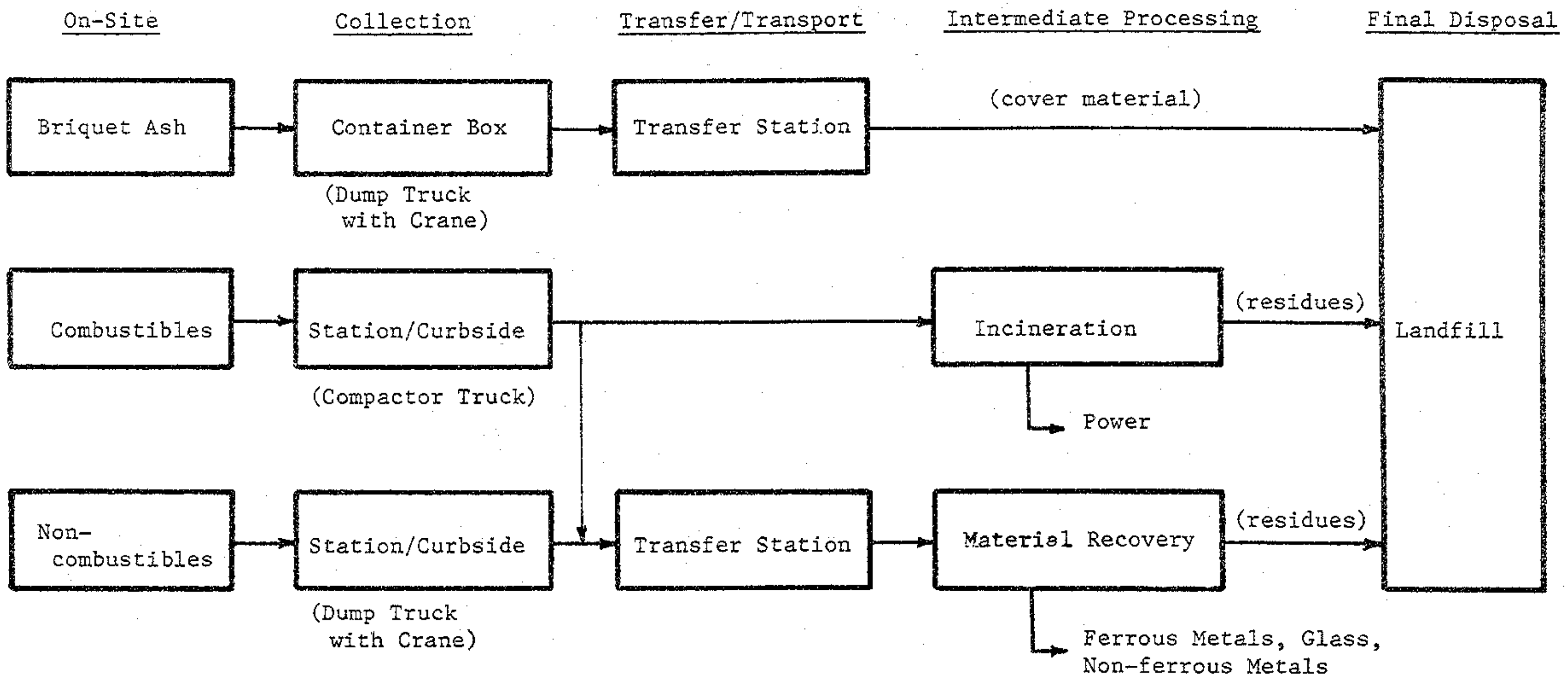


Fig. 5-5-1 Flow Diagram of Proposed System