3.3.3 Compost plant

The first compost plant of BOS built in Din Daeng started operations in 1961. This plant, however, stopped operating in 1976 due to the urbanization which occurred surrounding the plant. At present, four compost plants of BOS located at On-Nooch (two plants), Nong Khaem and Ram Intra are operating with a total daily treatment capacity of 1,120 tons.

An incinerator is attached to the existing compost plants to incinerate the waste classified as unsuitable-waste for composting.

The compost facilities are all equipped with British equipment which uses a drop door method. The four compost plants were constructed under a blanket contract with the John Thompson Company, and the contract value was 289,091,878 Baht.

The outline of the compost facilities is shown in Table AP 3.27.

The production process for composting consists of impact pulverization of the solid waste carried into the plant, classification of the solid waste after impact pulverization, five-day indoor primary fermentation, and two-month outdoor secondary fermentation using an open-air storage method. Thereafter, the compost is sieved finely by trommel and packed for sale.

The operation and control of the compost plants is carried out by the Bureau of Sanitation. The operation and control of the Trommel, however, is carried out by the Revenue Division of BOF. The operating time for these facilities, as shown in Table 3.3, varies with each of the facilities.

The compost plant is entirely shutdown for 6 days every 2 months to carry out a periodic inspection and repair work for the equipment.

In the case of the On-Nooch Compost Plant, the operating rate is 90% because the number of annual operating days from September 1979 to August 1980 was 329 days. In such a plant, an operating rate of 90% is considered very good.

Table 3.3 Operating hours of compost facilities

		Compost facilities			
		On-Nooch		Nong Khaem	Ram Intra
		No. 1	No. 2		
Operating time	Compost plant	8:00 - 12:00 13:00 - 17:00 (8 hours run)		8:00 - 12:00 13:00 - 17:00 (8 hours run)	8:00 - 12:00 13:00 - 16:30 (7 hours run)
	Incinerator	8:00 - 24:00 (continuous run)		8:30 - 23:30 (continuous run)	8:00 - 22:00 (continuous run)
	Trommel	-		-	8:00 - 16:00 (first shift) 17:00 - 24:00 (second shift) (15 hours run)

Regarding the breakdown of plants, a survey result of Nong Khaem Compost Plant is shown in Fig. 3.3. The result reveals that the breakdown of the hammer mill accounts for 60% of the total breakdowns. This breakdown is caused mainly by clogging of foreign substances between the hammer and the casing.

The electric power consumption varies with each compost plant; 8.7 kW·h per ton of solid waste in the case of On-Nooch Compost Plant, 9.3 kW·h per ton of solid waste in the case of Nong Khaem Compost Plant, and 10.0 kW·h per ton of solid waste in the case of Ram Intra Compost Plant. The water consumption does not change greatly with each plant; being approximately 30 m^3/d·compost plant.

The volumes of solid waste carried into the compost plants are shown in Table AP 3.30, and the material balance for composting is shown in Fig. AP 3.9. According to the material balance, about 16 tons per 100 tons of solid waste can be recovered as compost for sale. Compared with 8 to 10% compost recovery from city waste in Tokyo, the above percentage can be said to mean a higher productivity.

Presently, only Nong Khaem Compost Plant manufactures compost for sale.

The number of Trommels in Nong Khaem Compost Plant is 12; five are installed indoors, and the other seven outdoors. They can process 100 tons of compost after secondary fermentation by operating 15 hours a day, and can recover 60 tons of compost as a product for sale. The compost for sale is manufactured mainly during the dry season (from November to April) from about 70% of the yearly production (according to the records in 1980). The fine classifying mesh of trommel consists of 2 types; one which is coarse, and the other fine. The compost manufactured through the former is sold as Compost Type-1, and the compost manufactured through the latter is sold as Fine Compost Type-1. The product made by adding night soil sludge to Compost Type-1 is sold as Compost Type-2. These composts are put in bags for shipment.

The amounts of compost manufactured annually for sale are given in Table AP 3.31.

(1) Quality of compost

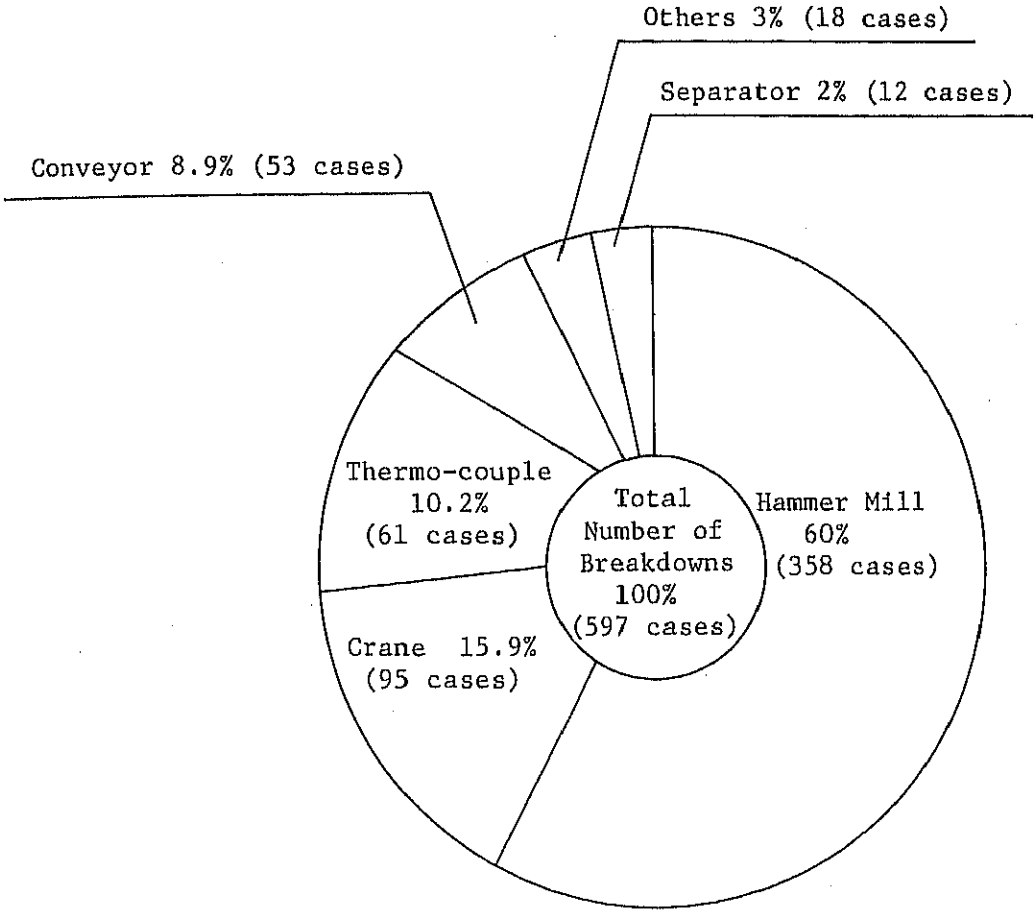
The study team carried out various surveys on the quality of compost, and the conclusion is summarized below.

There is a tendency that COD, T-C, T-N and ignition loss decrease with the passage of time because organics escape to the air or soluble components flow out during the secondary fermentation. Contrary to this tendency, Carbon/Nitrogen (C/N) ratio increases. Increase of the C/N ratio suppresses generation of nitrogen which is effective for improvement of physical composition of soil.

As compared to the criteria in Japan for compost quality, the nitrogen content of BMA compost is extremely small so that the method used for Compost Type-2 is appropriate.

Abnormally high electrical conductivity of the compost has a bad

Fig. 3.3 Record of breakdown of equipment in Nong Khaem compost plant from March 1979 to August 1980 (18 months)



effect on the germination of crops, but BMA compost is characterized by low electric conductivity so that there is no problem.

The chemical components of BMA compost are shown in Table 3.4. Compared the chemical components of BMA compost (Table 3.5) with that of city compost in Japan, the N-P-K content of BMA compost is lower than that of city compost in Japan whereas Calcium content is particularly high. Ca is effective for acid neutralization of soil and the maintenance of the effect is better than from inorganic lime. According to the results studied for BMA compost (i.e. comparison of heavy metal content), the heavy metal content of BMA compost is higher than that of city compost in Japan, especially high in Cd and Cu contents: Cd content is approximately 5 times higher and Cu is approximately 7 times higher. It is indispensable to eliminate contents of Cd and Hg in order

Table 3.4 Chemical components of BMA compost

	Range	Mean	S.D.	C.V.
Total nitrogen (N) (%)	(0.56 ∿ 1.35) 0.08 ∿ 1.32	(1.00) 0.918	(0.346) 0.567	(34.7) 61.8
Total phosphorus (P_2O_5)(%)	(0.57 ∿ 0.82) 0.9 ∿ 1.14	(0.72) 1.04	(0.111) 0.108	(15.5) 10.4
Potassium (K_2O) (%)	(0.95 ∿ 1.40) 0.81 ∿ 1.29	(1.12) 1.06	(0.212) 0.198	(19.0) 18.6
Calcium (CaO) (%)	(2.42 ∿ 9.16) 3.41 ∿14.2	(5.8) 7.74	(2.83) 4.60	(48.4) 59.4
Magnesium (MgO) (%)	(0.16 ∿ 0.51) 0.20 ∿ 0.86	(0.34) 0.523	(0.147) 0.276	(43.1) 52.9
CaO/MgO		(17.1) 14.8		
Zinc (Zn) ppm	(220 ∿ 1,180) 120 ∿ 1,660	(610) 902	(45.8) 63.2	(75.0) 70.0
Copper (Cu) ppm	(120 ∿ 860) 970 ∿ 2,110	(415) 1,332	(33.7) 52.9	(81.3) 39.7
Lead (Pb) ppm	(119 ∿ 212) 242 ∿ 603	(167.5) 359.5	(43.8) 164.7	(26.1) 45.8
Cadmium (Cd) ppm	(3.37 ∿ 10.30) 9.61 ∿ 21.1	(6.00) 14.4	(3.16) 4.91	(52.7) 34.2
Mercury (Hg) ppm	(3.50 ∿ 15.40) 2.80 ∿ 5.32	(6.56) 3.50	(5.89) 1.22	(89.8) 34.9
Arsenic (As) ppm	(2.97 ∿ 8.49) 2.52 ∿ 7.36	(6.69) 4.87	(2.51) 2.17	(37.5) 44.6
Zn/Cd		(101) 62.6		
PCB ppm	(0.27 ∿ 1.66) 0.23 ∿ 0.81	(0.76) 0.433	(0.615) 0.258	(80.9) 59.6

Note: Figures in ( ) are samples from On-Nooch.
Figures in the lower row are of samples after Trommel processing (Nong Khaem).

Table 3.5 Chemical composition of city compost (11 samples from 8 facilities) and barnyard manure (6 samples) in Japan

Item	City Compost			Barnyard Manure		
	Range	Mean	C V(%)	Range	Mean	C V(%)
Total nitrogen (N) (%)	1.24 ∿ 2.30	1.73	9.0	0.96 ∿ 2.30	1.50	33.6
Total phosphorus (P_2O_2)(%)	0.48 ∿ 3.57	1.13	78.5	0.27 ∿ 0.86	0.55	36.6
Potossium (K_2O)(%)	0.61 ∿ 3.13	1.89	37.0	1.42 ∿ 3.92	2.85	35.6
Calcium (CaO)(%)	3.24 ∿ 9.49	5.44	32.5	0.73 ∿ 2.73	1.70	42.0
Magnesium (MgO)(%)	0.31 ∿ 2.82	0.64	114.9	0.25 ∿ 0.88	0.58	45.7
CaO/MgO	2 ∿ 22	12.1	38.7	2 ∿ 6	3.3	45.2
Lead (Pb)(ppm)	64 ∿ 911	232	104.3	15 ∿ 34	24	32.5
Cadmium (Cd)(ppm)	1.6 ∿ 6.0	2.9	51.8	1.3 ∿ 4.9	2.1	68.4
Zinc (Zn)(ppm)	274 ∿ 1,670	674	61.8	48 ∿ 165	99	42.6
Copper (Cu)(ppm)	52 ∿ 429	189	64.1	14 ∿ 31	21	29.6
Nickel (Ni)(ppm)	14 ∿ 49	29	42.8	14 ∿ 39	25	34.9
Chrome (Cr)(ppm)	29 ∿ 202	83	62.3	33 ∿ 120	67	53.8
Mercury (Hg)(ppm)	0.5 ∿ 4.2	1.7	63.5	0.1 ∿ 0.7	0.26	90.8
Arsenic (As)(ppm)	0.1 ∿ 6.0	2.8	67.8	1.1 ∿ 5.2	2.7	54.3
Zn/Cd	161 ∿ 316	224	19.8	25 ∿ 97	56	48.7

Note: Analysis on foreign material-eliminated samples, on dry basis.

to prevent contamination by heavy metals contained in compost.

Although it is true that Cu and Zn are indispensable elements for plant nutrition, it is unclear what influence will have on plants when continuously compost with a large content of Cu and Zn is applied in large amounts to farmland.

BMA compost contains about 1 to 2 ppm of PCB which is considered to accumulate in soil; however, the half-life period of PCB is comparatively short, so that there is little possibility of occurrence of soil contamination or PCB migration to crops as far as the normal amount of compost is applied.

The results of the exclusion test for heavy metals are shown in Table 3.6. The results of the exclusion test was examined according to the landfill standards for compost in Japan revealing that the exclusion of mercury is 0.03 mg/L to 0.18 mg/L, exceeding the total standard value (less than 0.005 mg/L), which is 6 times to 36 times as high as the standard limit.

Table 3.7 gives the mean values of particle size distribution. Compost before trommelling contains particle sizes 30 mm or more which accounts for 20 to 30% of the total, but compost after trommelling does not contain sizes more than 30 mm.

After trommelling, particle sizes are normally distributed.

The mixing rate of foreign materials in the compost before trommelling is approximately 18 to 20%. The main foreign material is plastic. The mixing rate after trommelling decreases to 1.6%, showing the remarkable effect of trommelling. The main foreign material after trommelling is glass: since mixing of glass even in a small amount is dangerous when the compost is applied to paddy field, it should be removed.

The upper permissible limit for foreign materials contained in compost is 5% on a dry base. The quality of BMA compost after passing through trommel is quite acceptable.

(2) Marketing of compost

The selling prices for compost and the sales amount are given in Tables AP 3.32 and AP 3.33.

The compost sales amount in fiscal 1980 was 692,767 Baht for the volume of 16,507 tons. Therefore, the price per ton of compost was 466 Baht. Since the manufacturing cost of compost was 1,132 Baht per ton (including the depreciation of the compost plant), the income from compost sales was about 40% of the manufacturing cost.

There are 3 routes for marketing compost: through sales agents (160 persons) in Bangkok Metropolis, through farmers groups in the prefectures near Bangkok and through governmental agencies (such as State Railways of Thailand, Ministry of Agriculture, BMA).

(3) Recovery and sale of utilizable ferrous metals

The amount of ferrous metal recovered by the magnetic separator from the raw waste entering the compost plants is approximately 0.8 tons for each 100 tons of raw waste. The recovered ferrous metal is compressed into blocks weighing 25 to 40 kg for sale. There were about 3,675 tons of ferrous metal recovered by the 4 compost plants in fiscal 1980.

The recovered ferrous metal consists mainly of various metal products and empty cans discharged from households. The amount of foreign material on a weight basis adhering to the compressed metal blocks is about 6% of the amount of metal blocks. The results of the investigation reveal that the attached foreign material decreases in quantity during open air storage. It is considered, however, that the open air storage for a long period of time will reduce the quality of recovered metal.

The recovered ferrous metal is sold at auction through agents 2 or 3 times a year. At the auctions in 1980, the price offered by the highest bidder was 0.42 to 0.45 Baht/kg. The total value of sales was 1,583,337 Baht.

Table 3.6 Result of exclusion test

Exclusion material \ Location	On-Nooch		Ram Intra		Nong Khaem (before classification)		Nong Khaem (after classification)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Hazardous material								
Hg (mg/L)	0.04∿0.16	0.09	0.03∿0.18	0.07	0.07∿0.18	0.10	0.03∿0.07	0.05
Cd (mg/L)	0.03∿0.08	0.06	ND	ND	0.03∿0.08	0.05	0.04∿0.08	0.24
Pb (mg/L)	0.37∿1.40	1.03	0.46∿1.05	0.84	0.73∿1.50	1.00	0.46∿1.25	0.83
Organic phosphorus comp.,								
- Methyl parathione (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND
- Paratione, EPN (mg/L)	ND, ND	ND	ND, ND	ND	ND, ND	ND	ND, ND	ND
Cr^{+6} (mg/L)	ND∿0.10	0.05	ND∿0.55	0.23	ND∿0.65	0.19	ND∿0.40	0.10
As (mg/L)	0.02∿0.12	0.07	0.01∿0.11	0.05	ND∿0.06	0.04	ND∿0.03	0.01
CN (mg/L)	0.008∿0.04	0.017	0.002∿1.00	0.280	0.007∿0.05	0.024	0.002∿0.07	0.036
PCB (mg/L)	ND	ND	ND∿2.48×10^{-3}	6.2×10^{-4}	ND∿1.4×10^{-2}	3.5×10^{-3}	ND	ND

Note: The number of samples was four and they were taken in September, October, November and December, 1980.

Table 3.7 Compost size grading distribution (mean value)

(Unit: %)

	Compost Brand Name	>100 mm	100∿50 mm	50∿30 mm	30∿10 mm	10∿5 mm	57 mm	Total
Wet Basis	On-Nooch	8.4	9.6	12.0	41.1	15.1	13.8	100.0
	Ram Intra	2.1	6.6	10.6	48.9	15.5	16.3	100.0
	Nong Khaem *1	3.8	7.5	14.6	49.6	12.9	11.6	100.0
	Nong Khaem *2	0.0	0.0	0.0	14.1	23.7	62.2	100.0
Dry Basis	On-Nooch	8.2	9.7	11.8	40.3	15.2	14.8	100.0
	Ram Intra	2.1	7.1	11.4	47.1	15.1	17.2	100.0
	Nong Khaem *1	4.1	7.7	14.2	48.8	13.2	12.0	100.0
	Nong Khaem *2	0.0	0.0	0.0	14.1	23.2	62.7	100.0
Moisture Content	On-Nooch	37.7	40.4	42.8	42.9	41.4	38.8	42.2
	Ram Intra	41.2	40.3	39.7	47.8	46.8	40.1	46.2
	Nong Khaem *1	32.0	37.9	41.1	41.0	37.8	32.2	39.9
	Nong Khaem *2	-	-	-	33.3	34.4	28.1	33.1

*1 : before Trommel
*2 : after Trommel

I(10) Classification of delivered solid waste by interview

Solid waste such as glass, plastic, rubber, leather, battery and flourescent lamp is harmful to compost while the market waste is useful for composting because it contains a large amount of garbage. At the time of weighing the delivered solid waste, therefore, drivers should be interviewed in order that the collection trucks loaded with solid waste unsuitable for compost are instructed to go directly to the final disposal site and the collection trucks loading the solid waste such as market waste which is useful for composting are instructed to go to the compost plant.

It is recommended to set up a collection transport plan to deliver the market waste directly to the compost plants without mixing it with other waste because a large amount of the market waste useful for composting is discharged from the market place.

I(11) Incineration of unsuitable waste for composting mixing with combustible waste

The solid waste to be incinerated is an unstable material for composting which is rejected by the classifier at the compost

plant. Hospital waste is also disposed by incineration. These types of solid waste are difficult to be incinerated particularly when incineration control is not performed satisfactorily for the following reasons:

a. Sufficient combustion is not performed because the calorific value of these solid wastes are low but the incinerator is designed for high calorie input.

b. The solid waste to be incinerated mainly consists of plastic which is apt to be melted and become a lump in the incinerator under the present incinerator combustion conditions, thus hindering combustion.

c. The calorific value of the solid waste in the rainy season is low because of its high moisture content.

In order to solve these problems, the best way is to install an air preheater and auxiliary burner to the existing incinerator as explained in item S(16).

As an urgent measure to be taken for the easy incineration of solid waste difficult to burn, it should be mixed with combustible waste such as wood waste, bamboo baskets and business waste whose calorific value is high. Solid waste difficult to burn can be mixed with dried solid waste collected from the landfill site in the dry season to plan easy burning.

In such a case, use of a simple sieve is recommended to remove fine organic waste which has become soil, and plastics as much as possible. This method is worthy of study because it contributes to the prolonged life of landfill site.

To perform combustion control, the incineration temperature should be kept at least 700°C or higher. If solid waste is incinerated lower than this temperature, not only incineration will be performed satisfactorily but also organic acid, ammonia and rank odour will be discharged from the stack.

I(12) Drain of leachate from the reception pit

The moisture content of the solid waste for composting should generally be less than 60%; raw solid waste with a moisture content of more than 60% cannot generally raise fermentation temperature sufficiently, where the C/N ratio of compost tends to increase.

In order to prevent these disadvantages, many methods are applicable to reduce the moisture content in advance such as compression, heating, and heating of the fermentation through by heat insulation. Any of these methods, however, requires a considerable amount of expense which in return results in an increase in the manufacturing cost of compost.

Therefore, as the simplest method although it is not a perfect method, draining of the water remaining at the bottom of the reception pit should be carried out. Especially, during the rainy season when 87% of the total rainfall is concentrated (approximately 1,350 mm), it is necessary to always drain water in the pit thoroughly because rainwater is apt to collect in the pit.

S(12) Roofing of secondary fermentation yard

Since the secondary fermentation is carried out by open air storage method, the fertilizing components are apt to flow out with storm water and an aerobic fermentation is apt to occur.

In the dry season, on the other hand, it is feared that when organic mercury contained in compost is exposed to the sun, methyl mercuration occurs, which is extremely dangerous. In any case, the secondary fermentation with an open air storage system is undersirable.

On the assumption that the secondary fermentation yard of the On-Nooch compost plant is to be enclosed, a roofed area of 18,750 m^2 which is divided into 3 block yards and can store the compost for 60 days (secondary fermentation period) can be obtained in the site area of 32,550 m^2 as shown in Fig. 3.4. The construction cost necessary for roofing shown in Fig. 3.4 is estimated to be about 40 million Baht.

It may be possible to roof the yard at a lower cost by a method which is designed simply to protect the compost against rain-water and direct sun rays. In this case, however, a sufficient height for ceiling and sufficient distance between supports should be provided so as not to hinder the work and operation of equipment.

In case the roofing facilities as shown in Fig. 3.4 are installed in Nong Khaem and Ram Intra, the construction costs are estimated to be 10 million Baht and 20 million Baht respectively.

S(13) Roofing of outdoor trommel of Nong Khaem compost plant

The purpose of roofing is to operate the trommels even in the rainy season.

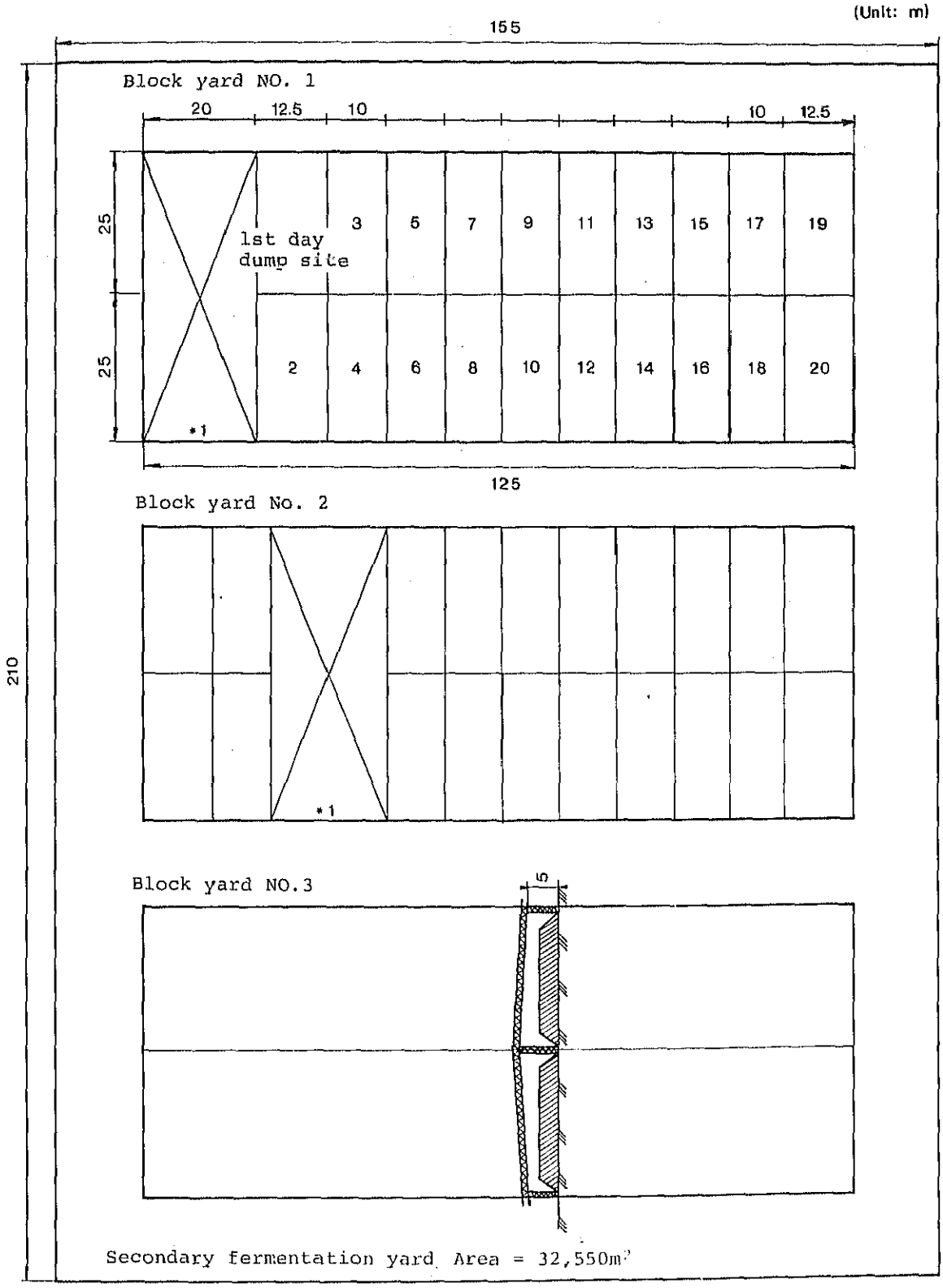
A building should be constructed to house 7 trommels installed outdoors at the Nong Khaem compost plant. (Fig. 3.5)

Necessary area for the building is 1,890 m^2 (63 m x 30 m) and the construction cost is estimated to be approximately 200 million Baht.

S(14) Installation of trommels at On-Nooch and Ram Intra compost plants

The marketing results of compost for sale which is finely classified by trommel are satisfactory, and compost for sale presently tends to fall in short supply. In addition, the results of a marketing research by the study team reveals that the demand for compost for sale will increase in the future. Therefore, the production capacity of compost for sale can be expanded to meet the increased demand. Appropriate scale to be recommended is to install 20 trommels at the On-Nooch compost plant, and 10 trommels at the Ram Intra compost plant respectively. The marketing volume of compost, however, cannot be determined only by the relation between the demand and the supply. It is also greatly affected by other factors, especially, the selling price.

Fig. 3.4 Roofing facilities of the secondary fermentation yard (On–Nooch)

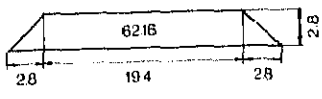


Rough specifications

Area of building : 125m x 50m x 3 bldg. = 18,750m²

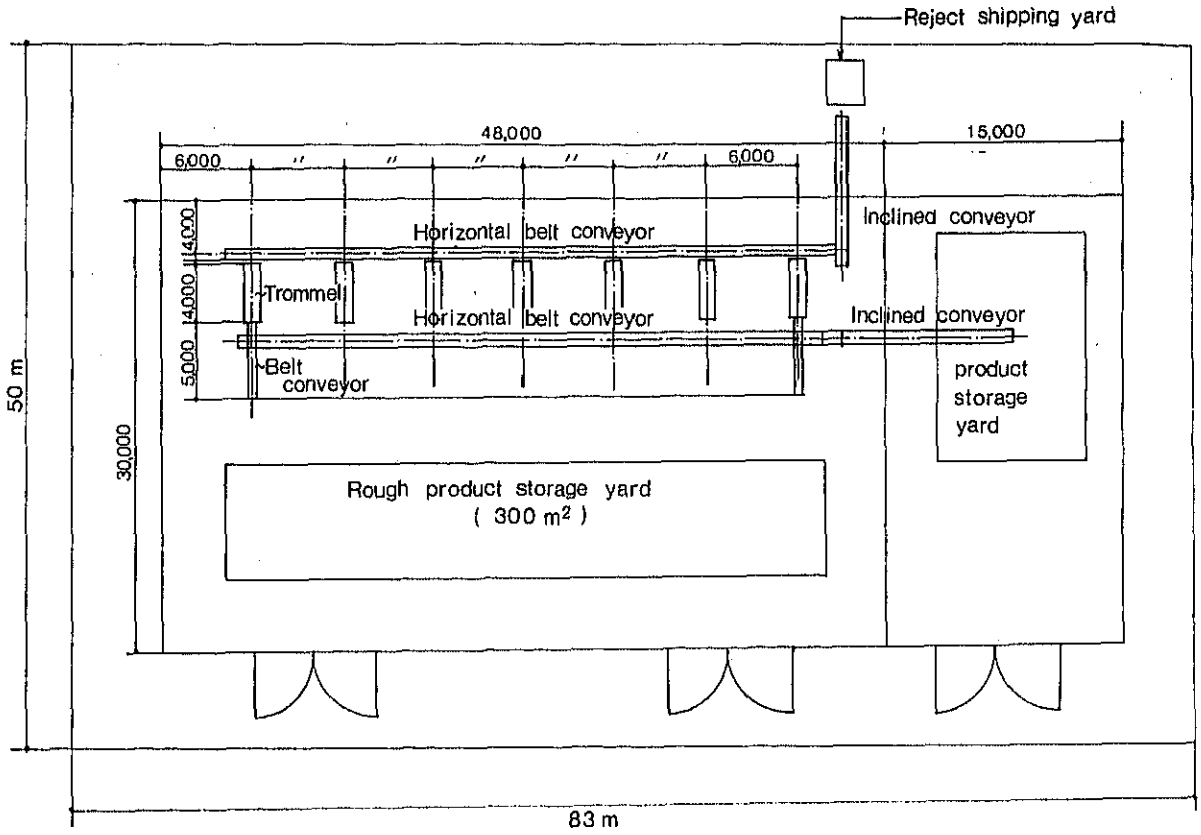
Area of site : 210m x 155m = 32,550m²

Note : *1 Work space



Piling method of compost

Fig. 3.5 Plan of the trommel installation
(Unit: m)



(Rough specifications)
. Area of building : 63 m x 30 m = 1,890 m²
. Structure : Steel structure, slate, one-storey building, effective height of 5 m
. Area of site : 83 m x 50 m = 4,150 m²
. Construction cost : 200 million Baht

Whether or not the low price policy described in S(15) can be taken is an important key to an increase in the sales of compost, and when the compost is sold at high price by which users are not attracted to buy, the sales of compost will decrease no matter how the quality of compost is improved. When the manufacturing capacity is expanded, therefore, it is safe to install about 10 trommels by stages, while studying the influence of price policy and effect of public relation activities.

Installation of trommel of an appropriate scale recommended above requires the construction cost of 37 million Baht in the case of On-Nooch (10 units), and 13 million Baht in the case of Ram Intra (5 units). The calculation was made on the assumption that the processing capacity of trommel is 16t/16h per unit.

S(15) Compost sales promotion measures

The solid waste management enterprise is fundamentally an enterprise on an economical expenditure basis. The sales of compost and retrieved ferrous metal are to pormote reuse of utilizable materials, and are not aimed at gaining profits. Since a public organization naturally has the limit of financial undertaking even for the public benefits, they are unable to carry out the enterprise beyond this limit.

At present, BMA is already bearing approximately 60 percent of the total production cost of compost.

The amount of annual expenditure by BMA is not so large, but the fact that defrayment of 60 percent of the total production cost indicates that it is close to the limit of expenditure by BMA. Based on this fact, therefore, there is little room for reduction of the present price.

The beneficiaries should bear reasonable burden for the benefits they received, and the amount of money to be borne by the beneficiaries is the present selling price of about 470 Baht/t.

The price of compost, however, is high compared with the selling price of crops so that general farmers cannot use the compost on a profitable basis.

The present situation indicates that the compost is an unattainable objective for general farmers although BMA is bearing the maximum limit of cost. It would be premature to think, however, judging from the present situation, that manufacturing of the compost is unsuitable as a public enterprise.

Since there are many latent consumers for the compost, it is possible to tie it in with the substantial demands of the compost by changing them to the actual consumers by means of public relations activities related to the necessity and effect of compost, and setting a price reasonable for the benefits they receive.

It may be said in this connection that the Nong Khaem compost plant only is now producing compost for sale, and if all expenses of other 3 plants which do not have an income from sales of the compost are charged to the manufacturing cost of the compost of the Nong Khaem compost plant, the manufacturing cost of compost for sale will become about 4,500 Baht per ton.

However, the fact that BMA is now operating the compost plants which have no income from sales of the compost means that the main purpose of operating the compost plants is for intermediate treatment of the solid waste, and accordingly, the expenses incurred for these plants can be treated as an expense for the intermediate treatment of the solid waste.

Based on this concept, therefore, the production cost of compost for sale when it is produced using the solid waste which is intermediately treated at these 3 plants, can be looked

upon as an expense related to the trommel which classifies the material to produce the compost for sale. Since the depreciation expense and operation expense of trommel is very small as compared to the total operation expense of compost plant, it can be said in general terms that with the present cost, it is possible to increase the production volume of compost for sale about 3 times as high as the present volume and reduce the gross manufacturing cost of compost substantially to about 1/3 of the present level (not considering the financial aspects).

Manufacturing and marketing of compost is a public enterprise which should be promoted from a national view point of reuse of resources. When the price of the compost is examined based on this assumption, the following 3 conditions should be taken into consideration for establishing the price.

i) It should be a price which gives users more benefit than they pay for.

ii) It should be a price which is tied in with increase in demand.

iii) It should be a price which provides an income which will not press hard on operation of compost plants even though it is a public enterprise.

According to the calculation made by the Study team, the primary economic benefit only of the compost can be converted to about 240 Baht/t.

If the compost is priced at a value lower than the above listed value, it means that users enjoy the benefit of the difference between the values.

It is a theoretical benefit and the actual benefit should be determined from the contribution of the compost to the yield of crops.

There are many ways to deepen interest and heighten understanding of farmers about compost; the public relations activities such as distribution of printed matter, effective use of compost in the agricultural project, cooperation with an agricultural experiment station and practical use test through an agricultural cooperative body. Furthermore, when the administrative organizations positively carry out effective use of the compost such as fertilization of trees in parks and on roads, the reliability of the compost is firmly fixed in the mind of people, which will become a silent and strong weapon for public relations activities.

In order to increase the demand for the compost, it is necessary to spread use of the compost to general dry field farmers. In order to do so, it is essential to reduce the selling price of the compost. Although the relation between the price and the demand volume is not defined, it is estimated that if the price of compost is reduced to a reasonable price, the compost will attract the interest of dry field farmers.

When the operation cost of the compost plant becomes a subject of discussion, an essential factor is how to evaluate the intermediate treatment functions of compost plant. The calculation base of production cost of the compost charges depending on its evaluation.

The compost plant may be divided into two functions: reducing of volume of the solid waste, making it harmless and its inactivation through the intermediate treatment, and manufacturing of the compost using the treated solid waste.

The intermediate treatment of solid waste is an expenditure management and on the other hand, manufacturing of the compost is an profit making management, therefore it is difficult to define a distinction for the compost plant between the function of intermediate treatment and the function of compost production.

The compost production cost of 1,132 Baht/t is a cost which is calculated on the basis that all processes in the compost plant are regarded as production processes for the compost, including the evaluation of the intermediate treatment function.

A factor to be considered in the evaluation of intermediate treatment function should be determined by policy. Recently, there has been an international tendency that stress is placed on the intermediate treatment function of the compost plant, the plant management is regarded as an outgoing enterprise, and the expenditure portion by a public organization is increasing.

It is possible to regard the process up to completion of the secondary fermentation as intermediate treatment of solid waste. If the process of after trommel is assumed to be the production process of compost, the production cost of the compost is calculated to be a little more than 160 Baht/t.

In conclusion, the success of increase of compost sales is dependent upon a policy of administrative organization to decide their portion of the expense to be borne in order to spread use of the compost. If the profitability of compost enterprise is discussed independently, it will omit one important role that the compost enterprise plays in the solid waste management system.

Recognizing that composting of solid waste is an indispensable function in the overall solid waste management system, and grasping how the compost, a by-product of solid waste management system, contributes to the public, the scope of administrative and financial assistance to the compost enterprise will be determined as a matter of course, where the policy of plant management (selling price of the compost and scope of dissemination and public relations activities for spread of compost) will be determined accordingly. When the cost control is to be conducted, it should be kept in mind that the compost is after all a by-product produced in the process of the solid waste management and that the manufacturing cost to produce a by-product does not have much meaning in the cost control.

S(16) Additional installation of burners in the existing incinerators

As mentioned already in I(11), the existing incinerators are not suitable for incineration of solid waste unsuitable for composting and hospital waste because these incinerators are designed for high calorie input.

In addition, the existing incinerators have other problem points, and it is considered doubtful whether or not it is practical and economical to solve these problems with equipment by complementary means.

Although the incineration performance of the existing incinerators can be improved greatly with installation of an air preheater or auxiliary burner, it is not a final countermeasure against various defects.

A shortcut to solving the problem drastically is to replace the existing incinerators with new incinerators which are suitable for the present incineration input, and to install a new incinerator to be used exclusively for hospital waste.

Under the present circumstances where a proper treatment and disposal system for hospital waste is urged to be established, there is no time to wait for construction of incinerator to be used exclusively for hospital waste, which will be described in R(8).

Incineration is a safe and reliable method to treat the hospital waste. It is necessary, therefore, to incinerate the hospital waste in the existing incinerators until such a time when construction of incinerator exclusively for use of hospital waste becomes practical.

A shorter way to allow for incineration of hospital waste in the existing incinerators is to attach the auxiliary burners to the existing incinerators. The expense for this installation is estimated to be about 2.5 million Baht including the associated facilities and construction cost.

R(7) Addition of new classification process

Removal of foreign material in the compost is essential for improvement of the quality of compost.

There are many types of equipment available to classify a specific substance such as metal and plastic from the solid waste. However, such equipment is unsatisfactory for removal of the solid waste unsuitable for composting because all the equipment is designed and manufactured for the purpose of recovery of resources.

In order to satisfactorily classify the solid waste unsuitable for composting, the following two methods can be considered to incorporate a new classifying process in the existing work flow.

One method is to provide work benches and an appropriate number of workers (about 7 workers for 1 stage) along the existing No. 1 conveyor (right after the magnetic separator) and No. 2 conveyor (right after roto disc separator) to carry out the manual classifying work.

Another method is to classify the compost with trommel after the primary fermentation. This method is more practical than the former method; however, in consideration of a precondition that the compost for sale is to be classified after the secondary fermentation (even though trommelling more than twice may have an effect in its own way), it may be effective to incorporate the manual classifying system which can classify a foreign material passing mesh of trommel.

R(8) New installation of incinerator used exclusively for hospital waste

In order to ensure complete management of hospital waste, it is recommended that the hospital waste be incinerated in an incinerator used exclusively for the hospital waste without mixing it with other solid waste.

Since the hospital waste consists of various matter (combustible matter such as disposed clothing and bedding, flame-resisting matter such as waste after operations and carcasses of animals from experiments, as well as noncombustible matter such as medicine bottles and metallic medical tools), it is difficult to control the combustion of hospital waste.

There are many types of incinerators available to be used exclusively for hospital waste. It is essential, however, to control combustion satisfactorily for any incinerator adopted.

In the case of hospital waste, special care should be exercised to prevent scattering of the solid waste and direct contact of the solid waste with workers' hands during operations from carry-in to incineration, and at the same time, the associated facilities should be provided to maintain sanitation and safety satisfactorily.

On the assumption that large hospitals are obliged to incinerate their own solid waste by themselves, the appropriate capacity of new incinerator to be installed will be about 10t/8h.

When a batch combustion-type incinerator of this size is to be installed for exclusive use for hospital waste, the required site area and construction cost are calculated to be about 600 m^2 and about 18 million Baht, respectively.

R(9) Preparation of an operation control manual and maintenance control manual

- Operation control manual

  This manual is to secure the safety of the workers, explain the functions and capacity of the facilities as designed, and carry out proper maintenance of the facilities for a regular continuous operation.

- Maintenance control manual

  This manual is to maintain the functions and capability of the facilities and carry out proper maintenance so as not shorten the life of the facilities.

A sample of both manuals is shown in Appendix 3.6 and Appendix 3.7 respectively for reference.

3.3.4 Final disposal system

At present, there are 6 final disposal sites in the Metropolitan area of Bangkok to dispose of raw waste, incineration residue and solid waste unsuitable for composting by means of landfill. (Ref. Table 3.8)

Table 3.8 The present status of the final disposal site

	On-Nooch	Nong Khaem	Ram Intra	Tung Kru	Bung Tanode	Bung Phra-yasalum
Total site area (incl. compost plant) m^2	929,600	588,800	89,600	64,000	8,000	8,000
Start of land-filling	1964	October 1972	October 1972	1977	Not known	Not known
Landfill volume t/d	415	590	197	72	50	30
Total landfill volume (as of the end of 1980)	m^2 12,552,092	m^2 2,935,794	m^2 1,028,252	m^2 332,453	Not known	Not known

All final disposal sites are located in a low, swampy place in inland areas.

A portion of the final disposal sites at Tung Kru and Bung Phrayasalum is private land which is offered free of charge by the land owner with intention that his worthless low, swampy land is reclaimed by landfill with the solid waste.

The landfill method adopted on all disposal sites is an aerobic, non-sanitary landfill system or the so-called "open dump system".

The equipment now in service at three disposal sites (On-Nooch, Nong Khaem and Ram Intra) includes bulldozers, front-end loaders, drag-lines, excavators and dump trucks.

It can be said that the quantity of the working equipment delivered to the disposal sites of On-Nooch, Nong Khaem and Ram Intra is sufficient. On the other hand, no working equipment is delivered to other disposal sites. Especially, in the case of Tung Kru final disposal site where disposal of about 70 tons of solid waste is carried out daily, the shortage of working equipment poses a serious problem. In the disposal site having no working equipment, the waste received is levelled by manpower.

At present, only the On-Nooch disposal site treats the leachate from the final disposal site. The treatment system involves biological treatment. The results of the analysis of the leachate reveal that COD is higher than BOD, which indicates that an aerobic decomposition of the waste for landfill occurs. A treatment system mainly depending on the biological treatment cannot cope with COD; however, biological treatment is indispensable since control of BOD in waste water is important.

In the case of On-Nooch disposal site, there are houses, schools, factories, etc. surrounding the site except on the southwest. Consequently, complaints have been received about odor and leachate.

On the south side of Nong Khaem disposal site is a TV station, and the east side of the site is dotted with houses.

Ram Intra disposal site is dotted with newly built houses only in the northwest portion.

At present, almost no environmental improvement around these disposal sites is carried out. Therefore, it is assumed that the number of complaints will increase as houses are built more closely around the disposal sites in the near future.

I(13) Transfer of control of both Tung Kru and Bung Phrayasalum final disposal sites to BOS

At present, the Tung Kru final disposal site is under the jurisdiction of Rat Burana district, and the Bung Phrayasalum disposal site is under the jurisdiction of Minburi district. Both administrative districts are utilizing the respective sites for landfill with solid waste collected by themselves. Both final disposal sites are located at a convenient place for transport of the solid waste, even from other administrative districts. It is recommended, therefore, that control of both final disposal sites be transferred to BOS to receive the solid waste from other administrative districts.

Private land occupies a large area of both disposal sites (3,200 m^2 of 64,000 m^2 in Tung Kru, and all 8,000 m^2 site area in Bung Phrayasalum). These private lands have been offered free-of-charge by land owners based on the condition that the lands are returned to the owners after completion of landfill.

Because these low, swampy lands which are of little value under the present conditions exist widely in the city of Bangkok and its environs, it is considered that there are many land owners who are willing to offer their property under the condition that the land will be returned to them after completion of landfill. It is desired, therefore, to utilize these private lands effectively.

In this case, however, full consideration should be paid to the effect on the surrounding environment.

In addition, a study should be made carefully in advance whether the landfill work can be implemented to satisfy the utilization plan of reclaimed land and landfill period of land owners in mind, and the owners approval should be obtained.

I(14) Even laying and compacting of solid waste layers

Solid waste dumped at landfill site should be placed evenly and compacted to prevent partial subsidence or permeation of rain water, and also to secure the safety of the workers and improve the work efficiency by rearranging the working environment.

In addition, the work of levelling and compacting the waste layers is indispensable for effective utilization of reclaimed lands. A thickness of one layer laid evenly should be 3 meters, as a standard. The landfill should be started from the perimeter to the center of a landfill site, and surrounding the landfill a constant slope of approximately 1:3 should be maintained.

The even placement and compaction of waste can be performed efficiently and effectively when a bulldozer is used. In the case of 3 final disposal sites of On-Nooch, Nong Khaem and Ram Intra, even placement and compaction of waste can be performed with the present field work equipment in service (Table 3.9), but in the case of both final disposal sites of Tung Kru and Bung Phrayasalum where the landfill volume is comparatively large and the work is done manually, it is necessary to allocate one each bulldozer.

The even placement and compaction ability of a bulldozer is 76 m^3/h in the case of 11-ton class. In Tung Kru, the volume of waste to be placed evenly is 133 m^3 per day so that the work time of an 11-ton class bulldozer is a little less than 2 h/d.

The cost required for distribution of one each bulldozer (11 tons) to both disposal sites is calculated to be 2.6 million Baht.

Table 3.9 Field work equipment at disposal sites

(As of the end of Dec. 1980)

Final Disposal Sites		On-Nooch	Nong Khaem	Ram Intra	Tung Kru	Bung Tanode	Bung Phrayasalum
Field Work Equipment	Bulldozer	5	4	3	–	–	–
	Front-end Loader	4	3	2	–	–	–
	Drag-Line	1	–	–	–	–	–
	Excavator	1	–	–	–	–	–
	Dump Truck	–	5	2	–	–	–

(Including equipment for compost plants)

I(15) Circulation spray of leachate during dry season

The leachate collected in side ditches around the landfill site should be pumped up to be sprayed over a solid waste mound by circulation spray method during the dry season to allow it to evaporate under the sun's heat in order to reduce the volume of waste water. This method is effective in the dry season but not so effective in the rainy season because the volume of leachate increases and the evaporation power decreases. Therefore, the leachate which cannot be disposed of during the rainy season will be tentatively stored in the yard of landfill site and used for a circulation spray in the dry season to reduce the volume of waste water to be treated.

A set of movable self-suction pump (with an engine) for circulation spray will cost 52,600 Baht (aperture 100 mm, output 5 PS, pumping volume 500 L/min, head 17 meters and pumping distance 120 meters). The number of pumps required are 4 units for On-Nooch and Nong Khaem respecively, and 1 unit for Tung Kru. The total purchasing expense of the pumps is 473,400 Baht. In addition, the material expense for operation of 9 pumps is estimated to be about 85,000 Baht a year. Utilization of a vacuum car can be considered as a short-term tentative measure until the pumps are purchased.

I(16) Continuous 24-hour operation of leachate treatment system

At present, the leachate treatment system at On-Nooch employs an activated sludge process. When the operation is stopped for many hours,the activated sludge is destroyed, and its processing ability is not recovered after restart of operation, and leachate is discharged without treatment. In order to prevent destruction or lowered function of activated sludge, it is recommended to keep the treatment system in 24-hour continuous operation.

I(17) Spray of insecticide for extermination of vermin and insects

Insects such as flies and mosquitoes are liable to breed and vermin such as rats are apt to live in landfill site because of their nature. The existance of such vermin and insects to some degree is unavoidable. When they are left without control, however, it will result in breeding and living of a large number of vermin and insects, which cause not only direct harm but also bring infection and contamination to the surrounding areas. In order to prevent this, it is essential to exterminate vermin and insects by spraying with insecticide. However, spraying of insecticide should be done carefully because it involves other dangers.

When an insecticide is sprayed over a wide landfill site, the sprayed insecticide may be scattered to the surrounding area depending on the wind direction or weather conditions, causing damage to animals and plants.

If the insecticide is sprayed carelessly over the landfill site at the stage of breeding for vermin and insects in large number, they will be chased out from the landfill site to the neighbouring areas, resulting in the spread of damage.

Accordingly, it is necessary to constantly surpress breeding and living of vermin and insects through the periodical spray of insecticide as well as using the insecticide spray temporarily when necessary according to the conditions, especially in the rainy season when their breeding and living conditions are complete. It is recommended, therefore, that the spray of large amount of insecticide at one time be avoided based on a consideration of its effect on the surrounding areas and the safety of workers. The spray area should be divided into sections and the insecticide be sprayed by section.

When there is a sign that vermin and insects will breed in large numbers, it is important to carry out a concentrated extermination in order to prevent such large scale breeding from occurring.

Since the periodic spraying of insecticide is apt to render vermin and insects immune against insecticides, the effect of spray, and change of the type of insecticide if necessary must be examined.

It is essential that when an insecticide is to be sprayed, full consideration should be paid to the health of residents and avoiding damage to animals and plants in the surrounding areas, as well as the safety of the workers. An insecticide and spray method which is free of environmental danger should be selected.

Use of a disinfection truck (about 2-tons capacity) with an insecticide tank (400 liter) is effective for a wide disposal site such as On-Nooch and Nong Khaem. The unit price for a disinfection truck is about 360,000 Baht (one each to the above two disposal sites), and the expense for insecticide (one can of oil insecticide covers 900 m^2 provided that it is diluted to 1/100) to be sprayed over 6 final disposal sites in total is calculated to be about 300,000 Baht a year. With the expansion of final disposal site areas, however, the consumption of insecticide will increase, and the expense is estimated to increase to about 350,000 Baht a year in 1987.

I(18) Clarification of control territory of landfill site

Landfill site is apt to cause problem of environmental pollution such as discharge of rank odors, and leachate effluents. In order to prevent this, it is necessary to carry out a complete work control program, and at the same time, to establish a system and organization which clarifies who is responsible for it. As the first step, it is recommended to clarify the control territory of a disposal landfill site and make the residents of surrounding areas aware of the name of the responsible person in charge of control. One of simplest methods is to provide a fence with barbed wire around the perimeter of the landfill site and put up a bulletin board at important locations to indicate the name and contact place for the person in charge of control. When this method is applied to the existing 6 landfill sites, the expense (fence, barbed wire and bulletin board) is estimated to be about 640,000 Baht.

S(17) Establishment of a reclaimed land utilization plan

The future status of landfill areas ideally should be determined prior to starting the landfill operations at a disposal landfill site and the landfill operation should be carried out according to a configuration suitable for utilization. For a disposal site which starts new landfill, it is recommended to establish the reclaimed land utilization plan and carry out the landfill operations to form a configuration suitable for utilization purposes. In many cases, however, the reclaimed land utilization plan is not established because it usually takes many years from the start of landfill operations until a landfill area becomes usable, and there are many unforeseeable factors during the period such as change of surrounding environment and change of social situation.

In such a case, it is not necessary to establish a reclaimed land utilization plan with much effort but is recommended to carry out a landfill operation aimed at a general-purpose configuration, that is a levelled configuration. The same should apply to the existing disposal landfill sites when it is difficult to establish a reclaimed land utilization plan.

S(18) Pre-embanked sectional sanitary landfill method (Ref. Fig. 3.6 and 3.7)

Pre-embanked sectional sanitary landfill method should be applied to the large size disposal sites of On-Nooch and Nong Khaem, and this system should be employed at other disposal sites when the circumstances permit.

The embankment should be built mainly with surplus compost and solid waste taken from the landfill mound which has become soil, and the surface of the embankment should be covered with clayey soil obtained by digging in the yard.

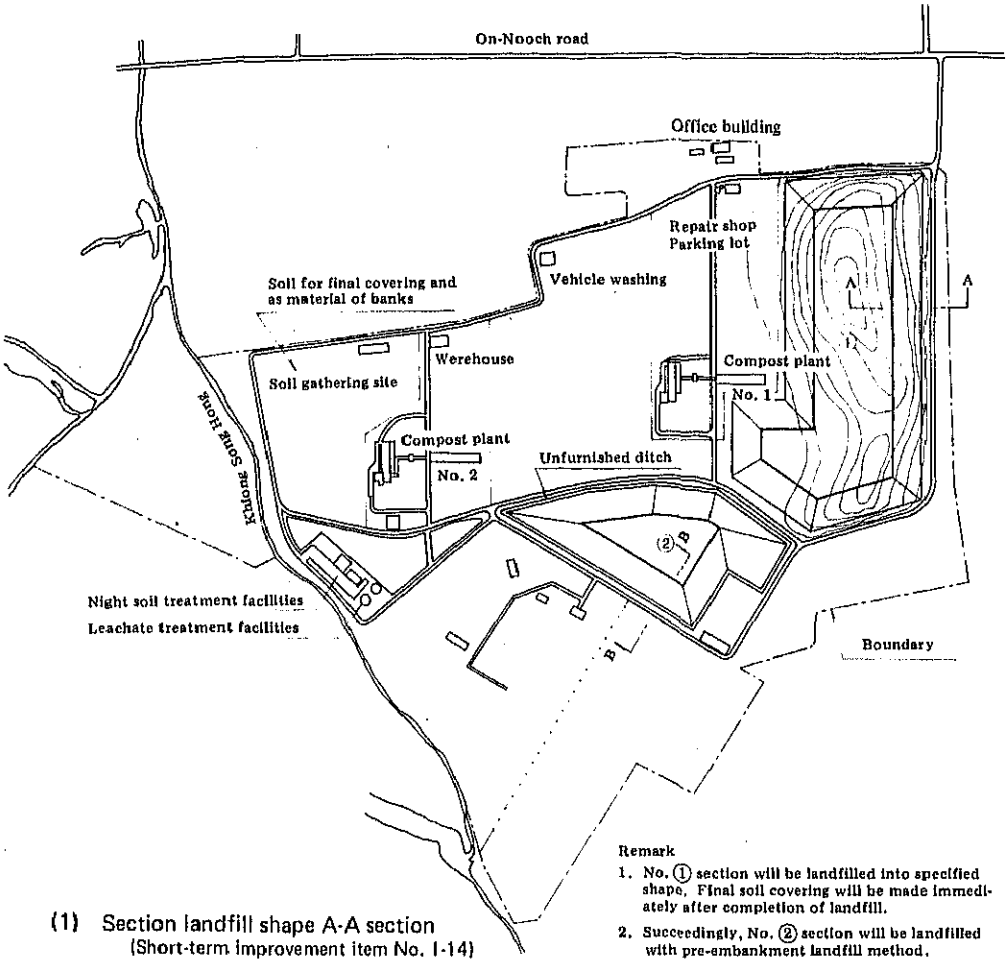
For landfill, solid waste should be placed from the Perimeter of the site along the embankment toward its center, and each layer should be covered with an overlay. Surplus compost is to be used as the overlay. When the thickness of the layer reaches 2.7 meters, the surface of each layer should be covered with an overlay thickness of 30 cm.

Each block upon completion of the landfill should immediately be covered with an overlay to a thickness of more than 1 meter to control penetration of rain water and to reduce the leachate effluent.

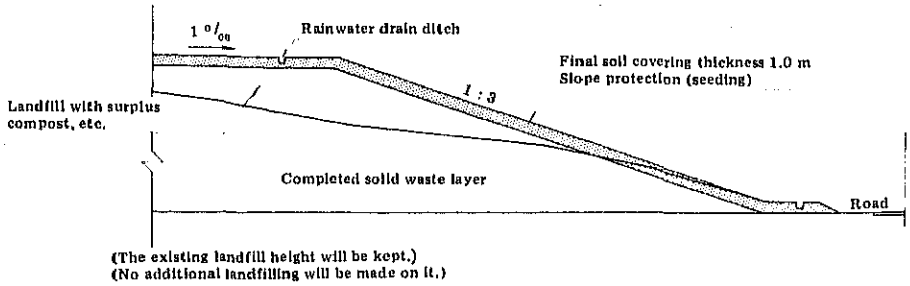
The overlay of the landfill area is designed to protect the environment against discharge of rank odors, scattering of solid waste and breeding of vermin and insects.

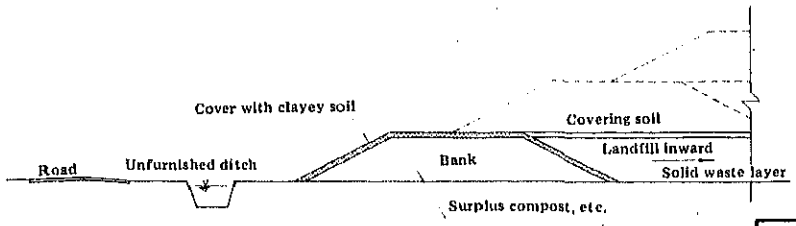
When the landfill is completed, planting of seeds should be done, especially over the overlay surface of embankment and slope of solid waste mound to increase the strength of the slope surface.

Planting improves the landscope and prevents scattering of waste from the surface of the reclaimed land, in addition to strengthening the overlay surface.



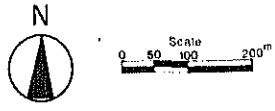
(1) Section landfill shape A-A section
(Short-term improvement item No. I-14)

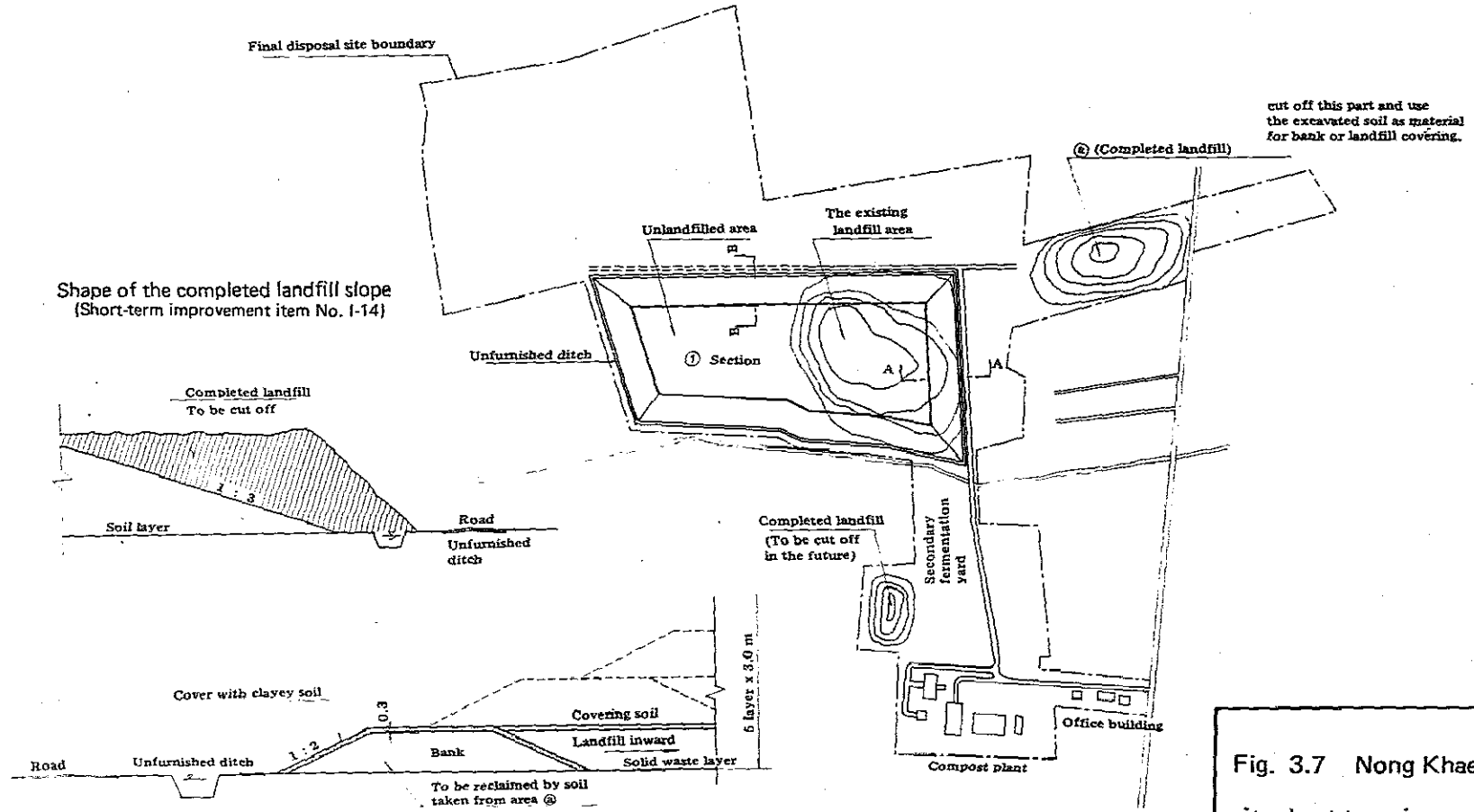




(2) Section Bank shape B-B section
(Short-term improvement item No. S-18)

Fig. 3.6 On-Nooch landfill site short-term improvement plan





Shape of the completed landfill slope
(Short-term improvement item No. I-14)

Shape of bank at unlandfilled area B-B section
(Short term improvement item No. S-18)

Fig. 3.7 Nong Khaem landfill site short-term improvement plan

I(19) Disposal of night soil

When night soil is dumped at landfill site, it should be dumped in the center of the landfill site where the impact of the leachate is least. This is to ensure biological treatment, filtration and dispersion when the night soil passes through the waste layer.

Disposed of night soil is ingested or decomposed to gas by bacteria in the soil of solid waste mound so that it becomes harmless. Solid waste mound functions as a filter bed to absorb the organic matter.

Because of a certain maximum load conditions for biological treatment, however, it is necessary either to dilute the night soil or to expand the contact area if night soil volume to be disposed of is considerable. Where the contamination of ground water is expected, or there is a well in the proximity or the groundwater level is high, disposal of night soil should not be conducted.

It should be noted that the above purification function becomes ineffective when a water channel is formed within the landfill layer. When a disposal place is to be selected, therefore, it is necessary to conduct a test disposal to check that there is no water channel formed within the ladfill layer.

R(10) Strengthening of fire fighting system

Urgent countermeasures should be taken against any fire occurs in the landfill site particularly during each dry season.

For fire fighting, the number of the existing fire pumps is not sufficient, therefore it should be increased. In addition, combination of the water discharge with soil covering will be effective to extinguish a fire, aimed at safe and adequate fire fighting. For this purpose, one dump truck (10 tons) and one power shovel at least should be arranged for the soil covering at each final disposal site. The soil to be used should be prepared separately beforehand.

R(11) Installation of gas bleeding facility

Solid waste landfilled produces gas in the process of decomposition, which containes CO_2 and CH_4 principally, and a small quantity of NH_3, H_2S and CO. Apart from the toxicity ot these components, the most serious problem in the landfill site is remain and accumulation of flammable gas inside the landfill layers which is diffused to the land surface on some occasion which might cause a fire or explosion.

The fermentation gas always contains a large quantity of CO_2 (inert gas) which functions as restrainer against explosion, therefore, danger of explosion could be much reduced compared with the case of combustible gas alone. Substantial countermeasures should however be taken to prevent fire.

In other words, the gas for which the countermeasures should be taken is CH_4 because other flammable gasses contained in small quantities do not pose much of a problem.

As there is a danger of a fire caused by ignition of CH_4 gas blowing out to the surface of landfill site, it is recommemded that a gas bleeding facility be provided in order to prevent the accumulation of the gas and its remaining in the solid waste layer.

A simple gas bleeding facility consists of slotted pipes inserted into the landfill should be sufficient for this purpose. The gas bleeding facility should be installed according as the landfill work progresses.

3.3.5 Management system

The present condition of the administrative management system related to solid waste disposal is described in Appendix 3.1 "Outline of the existing solid waste management system". In order to improve the existing management system on a comprehensive scale, a large reform of the organization and system should be performed and systematic review and revision of the laws and regulations should be conducted; however, it is difficult to carry out these improvement plans on a short term basis. Since a full scale improvement of the administrative system is covered in Chapter 9 "Recommendation for Administrative Organizations and Services" of long-term plan (Master Plan), this section proposes the improvement plans for some of the problems associated with the existing administrative management system, which can be or should be improved for the short term, although there are many other problems associated with the existing management system.

I(20) Complete collection of unpaid solid waste collection fee

According to the estimate made by the Study team based on the date from 1980, about 615,000 tons of household waste and business waste were collected from 82.6% of objective solid waste collection areas, and the collection fee collected amounted to 14 million Baht/year. This amount is nothing but 1/7 of the total amount of collection fee to be collected theoretically.

The unpaid collection fee exceeds 85%. The actual ratio of collectable fee is lower than the above percentage (85%) because it includes the waste collection fee from slums and some parts of the public areas from where fee collection is not possible.

Solid waste collection fee should be completely collected to maintain a fair burden on the beneficiaries and conduct sound financing for the cleaning operations.

I(21) Introduction of cost control system

In a profit making enterprise, the relationship between investment and the profit is clearly defined quantitatively based on judgement in the business operation.

In the case of a sanitation enterprise which is not a profit making venture, it is difficult to accurately grasp the relationship between the investment and the visible and invisible benefits which are brought about by the investment, so

that the cost consiousness of persons concerned is apt to be weakened.

Even in public enterprises, however, the responsible officials should make efforts to gain the maximum effect with the minimum investment. The first thing to be done in this direction is to accurately evaluate essential cost factors such as solid waste disposal cost and compost production cost.

In a more detailed explanation, a cost control system should be introduced, where the cost evaluation is made on the solid waste disposal cost and compost production cost including depreciation, in order to ensure the investment on the above disposal and production to be utilized in accordance with the solid waste administration policy.

I(22) *Complete supply of work clothes and other outfits*

Work clothes and other outfits should be supplied in adequate quantity to the workers as a means of safety and welfare of the workers. In particular, the priority should be placed on workers who handle hazardous hospital waste with an allowance of disinfection period (about 1.5 times of general worker usage). The workers supplied with these items must be responsible for wearing them in order to provide a good image for citizens related to the collection service.

The items to be supplied include work clothes, work cap, a pair of gloves and boots, etc.

S(19) Weighing the total volume of incoming solid waste to compost plants and final disposal sites

The total volume of incoming solid waste is the basic data which is indispensable for operation of the solid waste management system. To obtain this data, it is essential to weigh the total volume of solid waste coming into the final disposal sites in addition to weighing the incoming waste to the compost plants which is now being carried on.

Only the Tung Kru disposal site is not equipped with a weigh-bridge at present. Therefore, if a weigh-bridge (about ten million Baht) is installed at this site, the total volume of incoming solid waste can be weighed.

S(20) Collection, centralized control, analysis and effective use of fundamental data and information

The fundamental data and information can be classified into the following two categories.

One is social and economical indexes to ascertain the results and present status of sanitation enterprise: the number of households for solid waste collection and the collection volume, generation source and collection volume of business waste, the number of collection trucks, trip distance and route, and the number of workers and number of working days.

These data can be classified further into data for each administrative district or by time.

By combining and analyzing these data, useful information can

be obtained, such as operation and collection rates for collection trucks and the future forecast which will provide guidelines for improvement and future planning of sanitation administration.

The other category is technical indexes: solid waste composition, compost component and environmental impact value, etc. These data are indispensable for selection or operation of a solid waste management system, quality control of by-product and protection of the environment.

The collected data and information should be utilized effectively not only as data to be kept under centralized control for use in the solid waste administration, but also as data for publication which is distributed to in and outside of the authorities to deepen the understanding of the parties concerned and used as PR material for the general public.

S(21) Training of workers

The purposes of the training are to uplift the sense of public service, to make the workers acquainted with accurate knowledge of the solid waste business and to give strong motivation to keep the publics living environment clean.

A short-period training course should be established for all field workers including drivers (refer to Appendix 3.8). The training course is desired to be held permanently and managed by about 3 persons.

S(22) Installation of shower facilities

Shower facilities should be installed for use by the workers after the day's work.

S(23) Implementation of measures for labor safety and health

In order to prevent labor disasters and to maintain safe and sanitary work environment, the labor safety and health standards should be established and the labor safety campaign be developed by means of training and education.

First of all, the safety control standards should be formulated and, based on them, the present status should be reviewed and the existing problems or the points to be improved along the future should be clarified. Aiming at uplifting of sense of safety and knowledge concerning safety regulation, training should be made for all people who are engaged in sanitation activities. Through safety discipline at work site, the workers should be trained in performance of safe work according to work manual and the safety control standards.

The labor safety and health campaign is desired to be developed from viewpoints of not only prevention of labor disasters but also establishment of sanitary and pleasant work environment.

S(24) Expansion of the present duty of surveillants

At present, the duty of surveillants is limited to the confirmation of completion of solid waste collection work.

To improve and increase the efficiency of the solid waste management, the following items should be added to the duty of surveillants:

- Guidance of residents concerning the proper methods for waste discharge
- Surveillance against illegal disposal
- Confirmation of operating conditions and trip route of collection trucks
- Guidance and supervision of collection workers in accordance with the manual
- Guidance for treatment and disposal of business waste and surveillance against illegal treatment and disposal of business waste
- Investigation of citizens' complaints and grievance procedure
- Guidance and coordination with the cleaning cooperative associations
- Guidance for responsible persons in charge of collection in slums
- Public relations activities with residents

In order to ensure smooth enforcement of such diversified duties for surveillants, it is necessary to prepare a work manual for surveillants which specifies the scope of guidance and supervision, authority and responsibility of surveillants.

In addition, since the amount of work for surveillants increases as the result of expansion of duty, it is important to re-examine the total work volume, secure the number of surveillants necessary for the total work volume, and assign them to the work properly.

R(12) Establishment of the solid waste management standards

When any trouble happens at any stage of solid waste management procedure from collection to final disposal, it might effect on the overall solid waste management system which may hinder smooth performance of the solid waste operation. Consequently, it is necessary to establish a basic minimum standard to be observed at each stage of solid waste treatment.

- Storage of solid waste ..... Standard for storage of large volume of solid waste
- Collection and transportation ..... Collection, transportation and maintenance control standard
- Intermediate treatment ..... Structural standard and maintenance control standard for intermediate treatment facilities
- Final disposal ..... Solid waste landfill standard, structural standard and maintenance control standard of final disposal site

R(13) Coordination between all authorities concerned

Individual small administrative units including the sanitation administration are a means to receive a policy from the overall administration body, develop it and put it into practice. Each small administrative unit is always responsible to recognize its position in the overall administration and carry out its activities under coordination with other administrative authorities.

The sanitation administration especially has many contact points with other administrative authorities and it is unable to carry out its activities without coordination with other authorities. For instance, the policy of sanitation administration is closely related to the policy of the Ministry of Welfare, and the collection and transportation cannot be performed neglecting the Road Traffic Act set up by the Public Safety Committee.

Above all, the sanitation administration has the closest contact with each administrative organization in BMA, and it is essential first of all to concentrate on promotion of coordination with these organizations.

- Bureau of City Planning, BMA ..... Clarifying position of solid waste management system in the city planning, harmony between the future city plan and the cleaning undertaking plan should be maintained.
- Bureau of Public Health, BMA ..... Maintaining harmony between the public health administration and the sanitation administration, cooperation for public sanitation activities should be promoted.
- Bureau of Education, BMA ..... The understanding about maintenance of living environment should be deepened through education.
- Bureau of Sewage and Drainage, BMA ..... Mutual cooperation should be promoted concerning solid waste collection from rivers and Khlongs and leachate treatment at final disposal sites.
- Bureau of Finance, BMA ..... Mutual cooperation should be promoted concerning maintenance and repair of collection trucks, quality improvement and market development of compost.

R(14) Suppression of solid waste discharge volume

Suppression of solid waste discharge volume enables to reduce solid waste management cost and, needless to say, to improve the living environment.

The solid waste consists of a portion of a certain volume which is inevitable to be discharged, and another portion which does not have to be discharged when certain conditions are met. The purpose of suppression of solid waste discharge volume is to restrain discharge of the latter as much as possible to reduce the total discharge volume.

The first prerequisite to suppress solid waste discharge volume is not to discharge utilizable materials as waste.

In this case, it is necessary to consider a value of utilizable material from both aspects of dischargers and social needs, that is, a material which is not needed to A may be useful to B. However, the material is useless unless the material useless for A is transferred to B. Therefore, the physical distribution system should be established in order to use such material properly. The sanitation cooperative associations (described later) may function as a physical distribution system for utilizable materials.

The second prerequisite is that the manufacturers minimize the waste portions from their products and that they retrieve as much materials which can be utilized for their production as possible from discharged waste. Retrieval of utilizable materials should also be carried out at the consumption stage. For this purpose, a system which is advantageous for consumers also such as buying-back of emptied cans and bottles should be established.

It is recommended to study a system where the retrieval expense is included in the selling price of the product, and instead, the manufacturers are responsible for the collection of disposed containers, and the retrieval expense saved with the cooperation of consumers is returned to consumers. In the course of physical distribution, there are many factors to increase the waste volume; excessive packaging and disposal of packing materials, etc.

The third prerequisite is to create an environment which satisfies the first and second prerequisites, such an environment can be established mainly under the guidance of administrative authorities by means of education of methods to suppress solid waste discharge volume through the dissemination of information and public relations activities, establishment and guidance of sanitation cooperative associations and financial aid to the associations.

Of these three prerequisites, the first prerequisite has the direct and most effect on the suppression of solid waste discharge volume. To this end, consumers should assume a firm attitude to refuse acceptance of unnecessary materials and pick up utilizable materials for reuse. Such reformation of conciousness will not be realized by approaching individual consumers. The effective method is to organize sanitation cooperative associations utilizing the existing organizations such as town associations and self-government associations. The public relations activities to suppress solid waste discharge volume can be performed through these associations.

S(25) Establishment of bonus system

The bonus system should be established to provide recognition or to distribute rewards to workers who have achieved good results and proven themselves worthy of representing good public service. Such a system should be applied to all public service employees including the workers engaged in the solid

waste management operation. It is recommended however, to establish a special bonus system divided into various categories for the field workers who are seldom favored with opportunities for promotion and wage increase. This bonus system, for example, may be given to those who have a good record, or those who are diligent in the work for many years, or those who exercise good conduct related to duty or performance of an act which enhances the reputation of employees or for which social honor is gained, or those drivers who have driven the collection truck without accident for many years, or those who are to be commended for other reasons.

S(26) Introduction of merit certification system for advancement of workers

This system is to keep the door open for promotion, for those who want to change their jobs from field workers to general administrative employees based on the results of merit certification test, provided that one of the qualifications for workers to undergo the test is that they have a good record in their performance as field workers.

S(27) Transfer of control of trommel from BOF to BOS

In an entire process of compost production, BOS presently copes with the serial stages from reception of solid waste until completion of the secondary fermentation, and BOF takes the rest part. BOF refines the secondary fermented compost by trommeling, packs it up, stores and sells it to the consumer.

It is desirable, however, to separate the production function from sales function because improvement and maintenance of compost quality are ensured under a continuous production process controlled by single responsible department. This also enables the sales department to concentrate on the marketing.

For this purpose, work and control of trommeling and packing process should be transferred from BOF to BOS.

BOS is desired to assume all power and responsibility concerning compost production whereas BOF is responsible and empowered to perform compost sales.

S(28) Centralization of authority of sanitation administration

When an organization is grown up too large, it often falls in defective cases such as paralysing its own function due to its largeness or requiring excessive operating cost to maintain its function. A common way to make up for such deficiency is to divide the organization into several small organizations by function and empower them necessary authority to perform respective function. Decentralization of authority made by BMA also belongs to a category of this way.

There are two essential conditions for sucessful achievement of the decentralization: one is to clarify division of duty and power between central and local authorities, and the other is to establish communication channels between central and local authorities in order to maintain the better mutual under-

standings. As far as sanitation administration of BMA is concerned, however, these conditions are thought to be not fully satisfied and, what is more essential, administrative organization of BOS itself does not seem to have been grown up too large so that necessitate division or decentralization. Presently, all districts and departments of BMA are positioned under jurisdiction of Office of Under Secretary of State for BMA, and the departments have no authority to directly order or control the districts or the sections in the districts. When any of the departments necessitates to inform something to the districts, the matter is transmitted to the districts through the above office. This system has also been applied to BOS and caused miscellaneous problems as described below.

- Control power of BOS over the districts has been extremely weakened so that when BOS finds any deficiency in sanitation activities of the district, BOS is unable to directly instruct the district to improve it. Weakness of the control power of BOS also makes it difficult to have the districts obeyed the administrative policy and sanitation project established by BOS.
- A grade of collection service differs by districts and work volume per collection worker is uneven by districts.

In the case of sanitation enterprise or any other similar enterprises which involve field operation in the wider areas, it is indispensable to control the entire organization under a unified control channel which streches from top to every end of the organization. Without such control, satisfactory grade of sanitation services, of which performance is the duty of sanitation administration, cannot be conducted.

In so far as sanitation enterprise of BMA is concerned, therefore, Sanitation Sections which presently belong to the districts should better be separated from the district organization and reorganized into a subordinate organization to BOS, which is directly controlled by BOS.

All authority and power related to sanitation administration should be centralized to BOS. BOS should be the sole authority to control over the Sanitation Sections.

Reorganization of sanitation administration organization as a whole will make BOS resume its control power, that enables to solve or improve the long-pending problems existing among the districts such as unbalance of number of equipment, manpower, work volume and grade of collection service, and, as the result, to realize implementation of appropriate sanitation activities. Due to the reorganization, work volume of BOS Head Office should inevitably be increased; however, on the other hand, rationalization of the organization produces surplus manpower in Sanitation Sections which can be utilized to cope with the increased work volume in BOS Head Office.

According as growth of BOS organization, decentralization of the authority may be discussed again in the future. Even in this case, the discussion should no be carried on the direction to separate Sanitation Sections from BOS since it is an

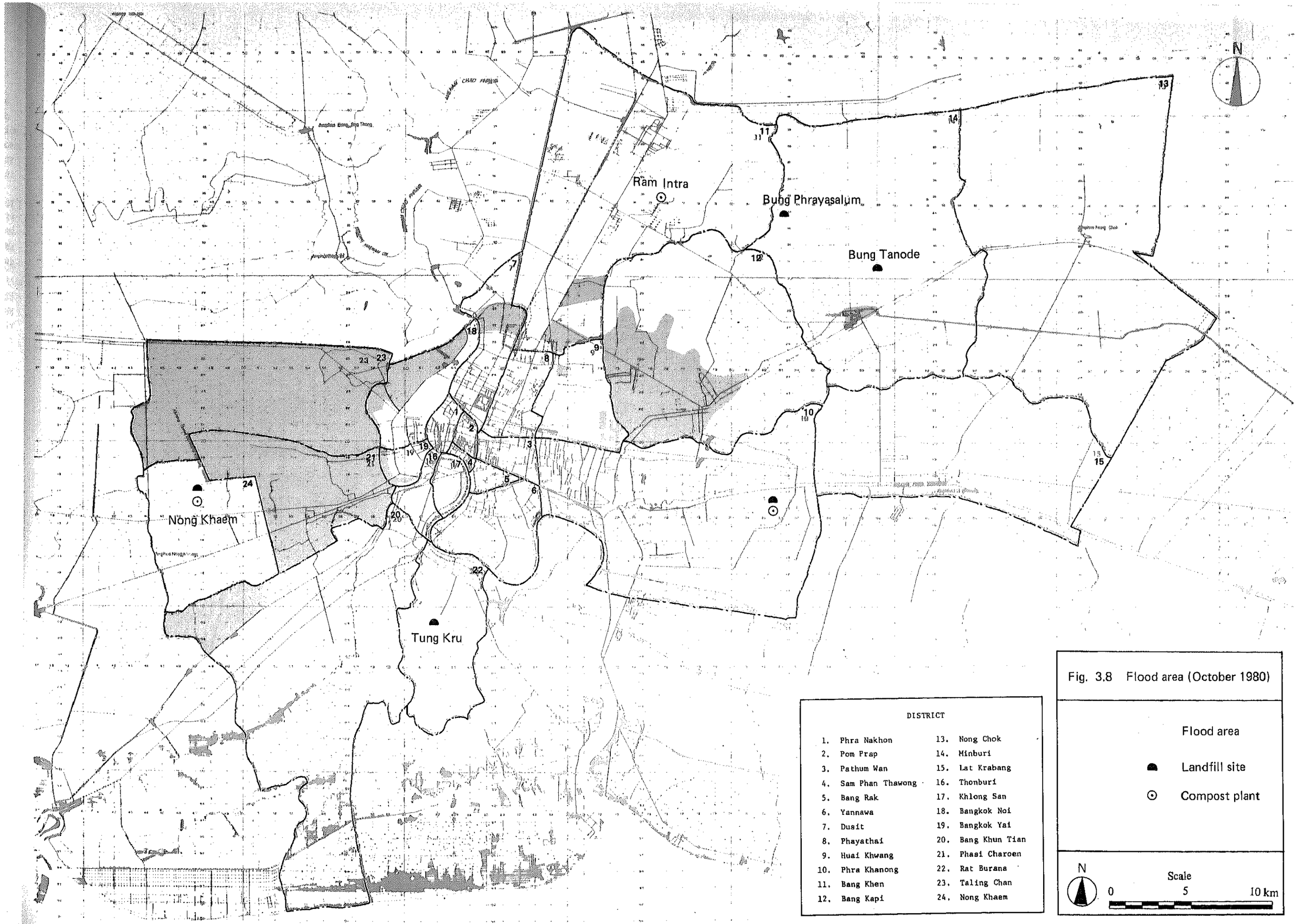
essential necessity for smooth performance of sanitation administration to unite them with single control and order channel. One of the solutions to meet requirement of the decentralization is to establish branch offices of BOS which is composed of several Sanitation Sections under its jurisdiction. The further details of this system is described in Chapter 9.

3.3.6 Recommended solid waste treatment measures during floods

In the rainy season every year (July to October), a wide area, about 20% of the total area in Bangkok Metropolis is covered with water due to squalls or floods.

Fig. 3.8 shows a flooded area in Bangkok in October 1980. As can be seen from this figure, the flooded area in the central part of the Metropolis is smaller than that in the suburbs. This is because the central area is equipped with drainage pump plants. It is very difficult to collect solid waste during floods, especially in the suburbs. Table 3.10 shows the solid waste collection during floods (flood condition in the year 1980).

Even in districts which suffer less damage from floods, roads and other spots are partially covered with water, making it difficult to collect the solid waste.



DISTRICT

1.	Phra Nakhon	13.	Nong Chok
2.	Pom Prap	14.	Minburi
3.	Pathum Wan	15.	Lat Krabang
4.	Sam Phan Thawong	16.	Thonburi
5.	Bang Rak	17.	Khlong San
6.	Yannawa	18.	Bangkok Noi
7.	Dusit	19.	Bangkok Yai
8.	Phayathai	20.	Bang Khun Tian
9.	Huai Khwang	21.	Phasi Charoen
10.	Phra Khanong	22.	Rat Burana
11.	Bang Khen	23.	Taling Chan
12.	Bang Kapi	24.	Nong Khaem

Fig. 3.8 Flood area (October 1980)

Flood area

Landfill site

Compost plant

N

Scale 0 5 10 km

Table 3.10 Solid waste collection during floods (flood condition in the year 1980)

District	No Trouble with Solid Waste Collection	Unable to Collect	Unabled Period of Collection
1 Phra Nakhon	O		
2 Pom Prap	O		
3 Pathum Wan	O		
4 San Phan Thawong	O		
5 Bang Rak	O		
6 Yannawa		O	30 days
7 Dusit	O		
8 Phayathai	O		
9 Huai Khwang		O	30 days
10 Phra Khanong		O	60 days
11 Bang Khen		O	60 days
12 Bang Kapi		O	60 days
13 Nong Chok	O		
14 Minburi	O		
15 Lat Krabang	O		
16 Thonburi	O		
17 Khlong San	O		
18 Bangkok Noi	O		
19 Bangkok Yai		O	30 days
20 Bang Khun Tian	O		
21 Phasi Charoen		O	60 days
22 Rat Burana	O		
23 Taling Chan	O		
24 Nong Khaem	O		

Source: Sanitation Section of each District.

It becomes difficult to carry the solid waste delivery inside the intermediate treatment and final disposal sites, many of which are located in a low, swampy place, because roads in the disposal site are covered with water and the areas around the disposal sites are contaminated with leachate. The quality of compost deteriorates (outflow of fertilizing component) because the secondary fermentation yard of the compost plant is covered with water.

I(23) Storage of solid waste during floods

Because of heavy rain or floods, solid waste cannot be collected; therefore, dischargers have to store solid waste for a considerably long time. The stored waste becomes decomposed and fermented, producing germs or parasites and rank odour. Garbage starts to decompose four hours after being disposed, presenting unsanitary and an environmentally undesirable state. Progress of decomposition is unavoidable. In order to delay decomposition of waste and isolate decomposed waste from the living environment, it is essential to seal up decomposing matter in a air-tight containers such as vinyl bags or plastic containers. Even when the waste is put in an air-tight container, decomposition of the waste progresses, rank odour due to leak of fermentation gas cannot be prevented and increase of germs and parasites causes danger to the daily living. Thus, there is a time limit for storage of solid waste in households. This time limit is not constant and changes depending on the temperature, humidity and property of the waste. However, in the case of Bangkok which has a high temperature and high humidity environment, it is considered that the time limit for storage of raw waste in households is about 5 days. Accordingly, in flooded areas where the waste collection becomes impossible for more than 5 days, it is necessary to store the solid waste being isolated from the households. In this case, only one method is to provide a waste storage depot by unit of local organization such as sanitation cooperative association mentioned in R(14) to isolate and store the solid waste from households exceeding the storage time limit. The capacity of the storage depot should be determined according to the discharge volume of solid waste and the uncollectable period for the area. The storage depot should be of such construction that it is protective against floods and preventive to outflow of leachate from the waste. In addition, it will be necessary to provide a roof on the depot to prevent rain water from coming in.

There is another method to utilize unused buildings in the district temporarily as a depot. In this case, however, strict sanitation control is necessary for storage of solid waste. In districts where it is difficult to carry the solid waste from each household to a depot because houses are remote from it and the surrounding areas are under deep water, it is recommended that the door-to-door waste collection be carried out by a boat which is purchased or leased by a unit of sanitation cooperative association and the boats deliver the solid waste to a depot. In flooded areas which are near roads which will allow the collection trucks to have access, the solid waste stations will be provided along the roads to store the waste collected by

door-to-door method by boat or solid waste carried on foot from each house and allow for pick up by the collection trucks.

I(24) Priority arrangement of diesel collection trucks to flooded areas

Collection trucks frequently encounter engine trouble when operating in flooded districts or in heavy rain. In many cases, a malfunction of the engine is caused because the ignition system of truck becomes saturated with water. Since a gasoline engine uses an ignition system to ignite the fuel with a high-voltage electric spark, the electric system to discharge the high-voltage spark is mounted on the outside of the engine, the engine may stop due to electric leak or faulty contact when the wires, connection parts and contacts become wet.

A diesel engine on the contrary, employs so called a compression combustion system where the fuel is sprayed into the air which is at a high temperature and high pressure due to high compression, so that it does not require the electric system for ignition and it is more resistant to water compared to a gasoline engine.

It is therefore considered desirable to arrange for diesel-engine collection trucks to be used the flooded areas on a priority basis.

S(29) Various measures to continue the collection and transportation of solid waste during floods

The normal collection and transportation plan connot be applied during floods because the road conditions change completely. Consequently, it is necessary to set up a work plan case by case based on the flood conditions. In order to do so, the road conditions during floods must be ascertained accurately.

. Preparation of a route map showing road conditions during floods

The flooded areas should be grouped into about 3 stages: submerged road conditions in each stage shoud be divided into 3 levels: shallow submerged area (collection trucks can run at low speed), medium submerged area (collection trucks can run at very low speed) and deep submerged area (collection trucks cannot access). Such information should be described on presently available route maps. The investigation of submersion degree and entry in route map should be done by collection truck drivers, and the results should be reported to the Collection and Transportation Countermeasure Headquarters for Floods which will be explained later. The investigation of submersion degree should be made more than 3 times per year at each stage of flood degree. The basic route map should be prepared based on the results of investigation for at least 3 years, and the route map should be distributed to drivers. Thereafter, investigation of submersion degree should be carried out every year and the data obtained should be used for revision of the route map.

· Installation of guide signs showing the submerged road conditions

The route map can be used as a guide to show the general flood

conditions, but it does not show the road conditions in detail. It is, therefore, recommended that guide signs as shown in Fig. 3.9 be put up on the road shoulder to warn drivers of the depth of submersion water, condition of road submerged under water and running speed, etc. It should be noted however, that installation of guide signs must be subject to the approval of the authorities concerned such as road management authority and Public Safety Committee.

- Installation of temporary stations

  In flooded areas where the collection trucks can run, the station system should be adopted temporarily regardless of the normal collection method. A place where collection trucks have good access should be clearly marked with signs as collecting place (station), and dischargers should be instructed to discharge the solid waste in the station by themselves.

- Collection and transportation of solid waste by boats

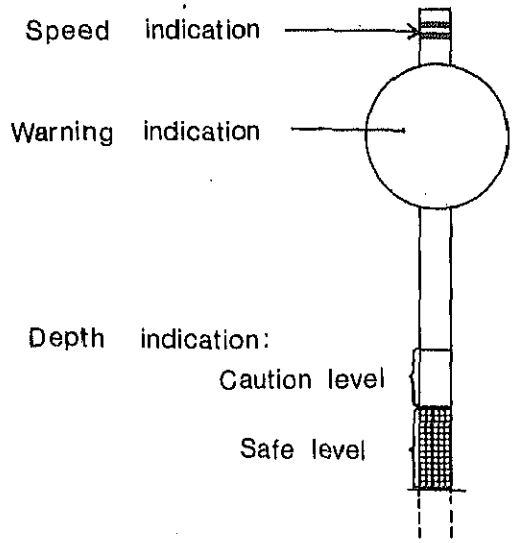
  Solid waste collection by boats to be carried out by the sanitation cooperative associations is described in I(23). Separately from the above waste collection system, it is worth while to study the utilization of solid waste collection organization from Khlongs recommended in I(7) for collection and transportation of solid waste from flooded areas along Khlongs. It may be possible to use the Khlong cleaning boats for collection and transportation of solid waste from some deeply submerged areas.

- Establishment of Collection and Transportation Countermeasure Headquater for Floods

  In order to carry out the collection and transportation operation effectively and case by case according to the flood condition, the Collection and Transportation Headquaters for Floods (Flood Countermeasure Headquaters) should be established in BOS.

In addition to preparation and distribution of basic route map during floods, the Flood Countermeasure Headquarters is responsible to maintain close contact with the individual administrative districts to collect from drivers road condition information and other flood information, analyze such information, and advise the individual administrative districts of information such as appropriate collection and transportation route and delivery points. Based on information from the Headquarters, the individual administrative districts determine practical collection and transportation routes and issue instructions to the drivers.

Fig. 3.9 Guide signs during flooding

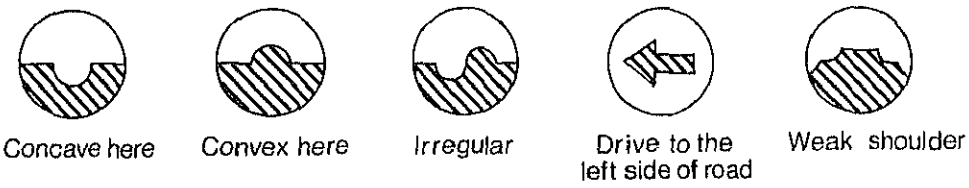


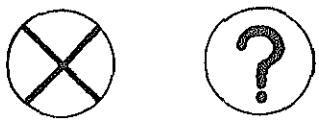
Max Speed indication

less than 10 km/h

less than 20 km/h

Warning indication





3.4 Fund Program for Short-term Improvement Plan

The amounts of funds necessary to implement the recommended short-term improvement plan are shown in the Table 3.11. The fund program was established based on the following conditions.

i) Enforcement of short-term improvement will be carried out for 5 years from 1982 to 1986. Since a part of the plan for fiscal 1982 has already been put into operation, the table covers the fund program on and after fiscal 1983.

ii) The unit price calculation is based on the prices as of 1980. No modification has been made based on price change record and price change forecast.

iii) Harmony with the long-term plan is considered.

iv) The expenses related to so-called software such as education, training and various activities are excluded.

v) Concerning the "recommended items (R items) for implementation, the total amount of cost required is shown in the column of remarks as a reference.

vi) The operating expenses are excluded as a rule; however, items which are to be included in operating expenses but essential to the short-term improvement such as collection trucks purchase cost, vehicle inspection and maintenance cost, etc. are specified in the list with * mark.

vii) Although some items such as vehicle purchase require fixed expenses on and after fiscal 1987, the fund program is limited up to fiscal 1986.

Table 3.11 Fund program for short-term improvement plan

(1/3)

(Unit: 1,000 Baht)

	Code	Expense items	1983	1984	1985	1986	Remarks
Collection	S(7)	Purchase of road cleaning trucks	-	4,210	-	-	2 units
	I(7)	Boats for solid waste collection from Khlongs	320	320	320	320	4 boats every year
	R(3)	Purchase of mechanical river cleaning boats	---	---	---	---	5,620/2 boats
Transport	S(9)	Purchase of collection trucks	16,800* (27 units)	19,900* (32 units)	19,300* (31 units)	19,900* (32 units)	O
	S(9)	Purchase of spare trucks	7,200* (36 units)	1,600* (8 units)	1,600* (8 units)	1,600* (8 units)	O
	R(4)	Installation of auxiliary loading equipment	---	---	---	---	14,000 (150 sets)
	S(11)	Installation of maintenance and minor repair facilities for each district	6,600 (4 districts)	9,300 (5 districts)	10,600 (5 districts)	26,600 (10 districts)	O
	S(11)	Periodic inspection and maintenance of collection trucks	3,370*	3,370*	3,370*	3,370*	500 units every year
	S(10)	Stock control of spare parts for collection trucks	7,800	7,800	7,800	7,800	Spare parts for 500 trucks every year
Compost Plant	S(12)	Roofing of secondary fermentation yard	10,200 (Nong Khaem)	20,000 (On-Nooch	20,000 (On-Nooch)	20,000 (Ram Intra)	O

(Cont'd)(2/3)

(Unit: 1,000 Baht)

	Code	Expense items	1983	1984	1985	1986	Remarks
Compost plant	S(14)	Installation of trommels (incl. buildings)	-	18,500 (On-Nooch)	18,500 (On-Nooch)	13,000 (Ram Intra)	O
	S(16)	Installation of auxiliary burner to incinerator	-	5,000 (2 plants)	5,000 (2 plants)	-	
	R(8)	Introduction of exclusive-use incinerator for hospital waste	---	---	---	---	18,000
Final disposal	I(14)	Purchase of bulldozers	2,600	-	-	-	2 units
	I(15)	Installation of leachate circulating spray system	350	300	100	100	O
	S(18)	Expense related to sectional landfill	-	-	27,000 (On-Nooch)	27,000	Cost for pre-embankment sectional landfill will be borne by ordinary expenditure
	R(11)	Planting and seeding	---	---	---	---	230
	R(10)	Purchase of fire-fighting equipment	---	---	---	---	2,350/7 units
	R(11)	Installation of gas breeding facilities	---	---	---	---	45
	I(17)	Purchase of insecticide and disinfection trucks	300	300	300	300	Insecticide
			360	360	-	-	Each one unit of disinfection truck

(Cont'd)(3/3)

(Unit: 1,000 Baht)

	Code	Expense items	1983	1984	1985	1986	Remarks
Administration system	I(22)	Complete supply of work clothes and other outfits	5,000	5,000	5,000	5,000	
	S(19)	Purchase of solid waste weigh-bridge	10,000	-	-	-	
	S(20)	Analysis of solid waste composition	50	50	50	50	
	S(20)	Compost test	100	100	100	100	Twice a year
	S(20)	Measurement of environment pollution items	15	15	15	15	Twice a year
	S(21)	Installation of training facilities	5,200	-	-	-	
	S(22)	Installation of shower facilities	700	700	700	700	At 5 places every year
Counter-measure during floods	S(29)	Preparation of route map	8,000	7,500	7,500	9,150	
	S(29)	Installation of guide signs	600	600	-	-	2,500 signs every year
		Total	85,565	104,925	127,255	135,005	452,750 (Excluding R items)

R items	40,245
Grand total	492,995

Note: · Collection trucks purchase cost is counted in cost estimation of Master Plan also.

· R-items are recommended to be implemented in any —— marked year.

· Items which have a particularly close relationship with the long-term plan (Master Plan) have a "o" mark in the column of remarks.

· Items such as vehicle purchase expense and vehicle inspection and repair expense which are normally included in the operating expenses but are main subjects of the short-term improvement are shown with an "*" mark.

Chapter 4 SOLID WASTE MANAGEMENT SYSTEM MASTER PLAN ALTERNATIVES

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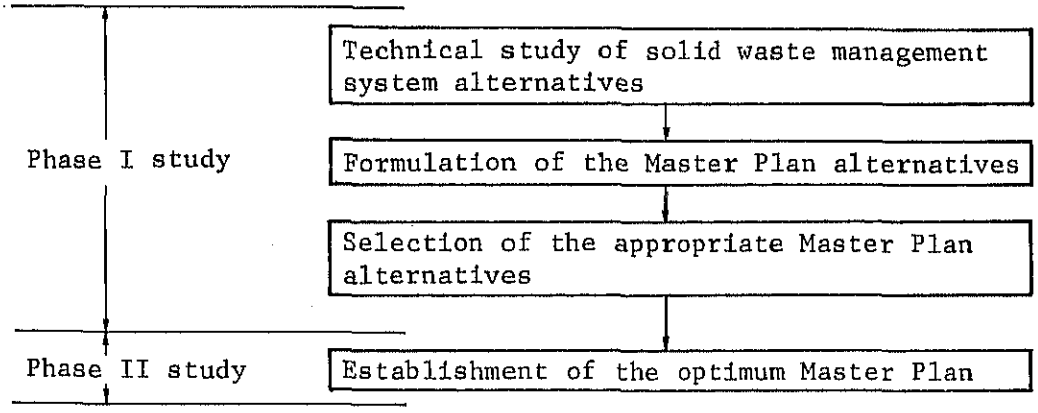
CHAPTER 4 SOLID WASTE MANAGEMENT SYSTEM MASTER PLAN ALTERNATIVES

4.1 Methodology

Aimed at the final establishment of a solid waste management system Master Plan (the optimum Master Plan), the following study items were undertaken:

- technical study of solid waste management system alternatives such as collection, transportation, intermediate treatment and final disposal,
- formulation of Master Plan alternatives, and
- selection of the appropriate Master Plan alternatives.

The process for establishment of the optimum Master Plan is explained in the figure below.



Phase I study includes the selection of the appropriate Master Plan alternatives, and Phase II will establish the optimum Master Plan.

As mentioned before, the Study (Bangkok solid waste management study) has been promoted aimed at four goals of solid waste management: total volume collection, total volume treatment and disposal, establishment of a reliable solid waste management system, and promotion of citizen cooperation.

In addition to these goals, four guidelines were set up and applied to formulation of the Master Plan alternatives: economy of cost, promotion of resource recovery, environmental protection (including maintenance and improvement of public health), and consideration of BMA's administrative conditions.

These guidelines were also considered to be criteria for establishment of the optimum Master Plan.

Technical study of solid waste management system alternatives considered all the necessary items for formulation of the Master Plan alternatives and examined practicalities of miscellaneous technology concerning collection, transportation, intermediate treatment and final

disposal, based on the data and information obtained by the Study team to date.

The technical study was performed and the results were evaluated to select the appropriate management system alternatives for the future conditions in Bangkok.

The selected appropriate management system alternatives with the unit cost of investment, operation and maintenance are presented in this chapter for each system.

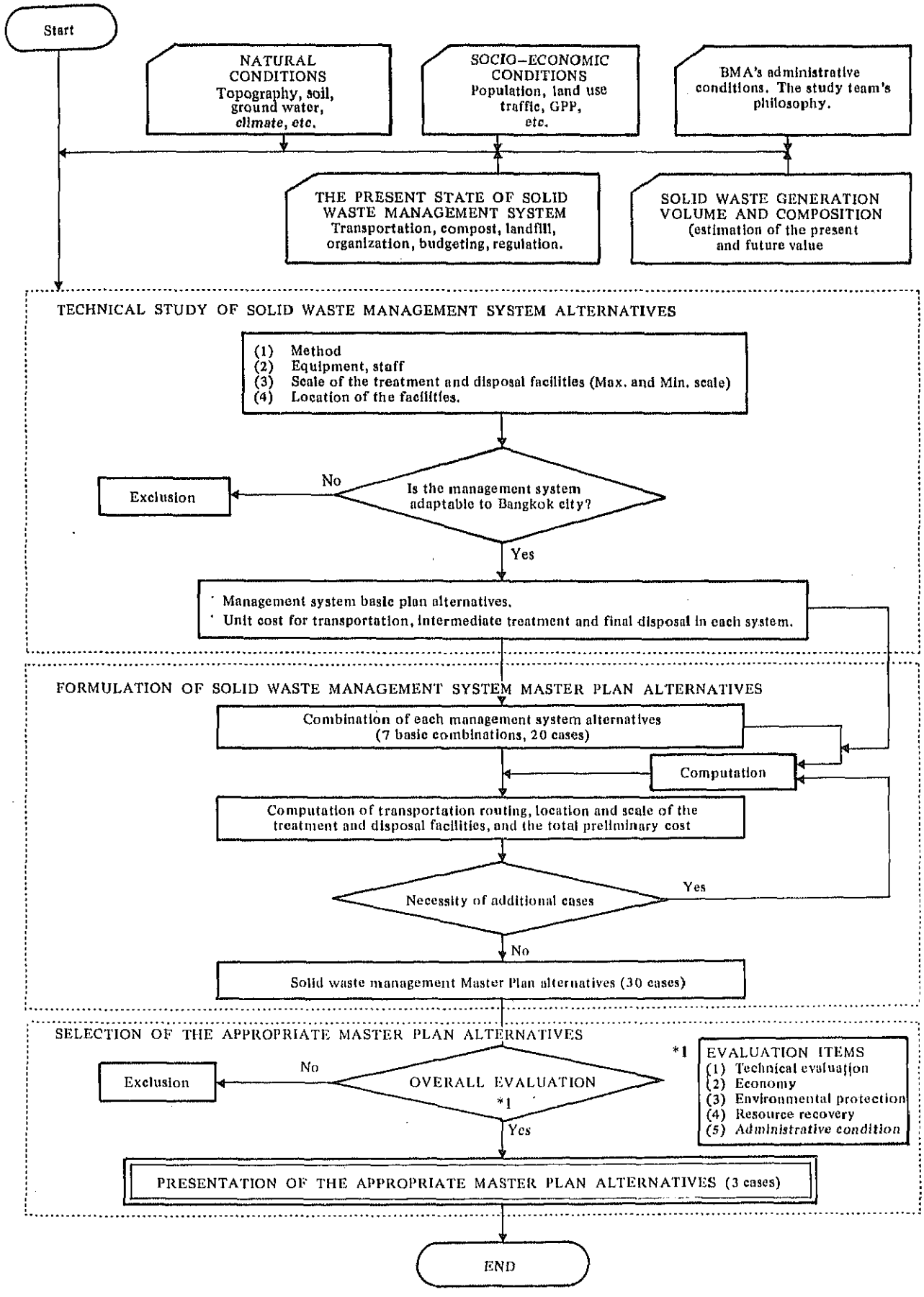
The next step of the Study was the formulation of the Master Plan alternatives. The seven basic combinations of solid waste management systems which were evolved into 20 cases and the other necessary data were input to a computer to determine solid waste transportation routes and location of the treatment and disposal facilities which would minimize the total cost. For each prospective case among the 20 cases, input conditions for a computer were varied to provide the appropriate additional cases. As a result, the original 20 cases were expanded to 30 Master Plan alternatives.

The most appropriate Master Plan alternatives were to be evaluated and selected from the Master Plan alternatives. The four guidelines (economy of costs, environmental protection, resource recovery and administrative conditions) were taken as the evaluation criteria and, in addition, a technical evaluation was adopted as one of the criteria for general and overall evaluation. As a result, three plans were selected from the Master Plan alternatives as 'appropriate' Master Plan alternatives.

Key-information and data were formulated and attached to each of the appropriate Master Plan alternatives, such as the system flow-chart, solid waste management balance sheet, solid waste transportation O-D map, facilities location map, conceptual plan of representative facilities, and the total preliminary cost estimation.

Figure 4.1 shows procedure used to determine the Master Plan alternatives.

Fig. 4.1 Process flow-chart: formulation of the Master Plan alternatives



4.2 Collection and Transportation System

4.2.1 Technical study of collection and transportation

The functions of the solid waste storage, collection and transportation are the most important parts in the solid waste treatment system from a viewpoint of maintenance of public health with removing generated solid waste promptly from the daily living environment.

Various techniques used at the present are summarized in Appendices 4.1 to 4.3. Adaption of various mechanized techniques for solid waste collection and transport are considered, but the main activities of collection and transport still depend upon the cooperation of manpower and vehicles. The next section describes an appropriate plan of the collection and transport system mainly using vehicles.

4.2.2 Appropriate plan of the collection and transport system

(1) Collection

Considering the results of future properties of solid waste, it is not necessary to adopt several intermediate treatment techniques according to the properties of individual solid wastes. Therefore, a separate collection system which may increase the cost should be avoided, and the current system of combined collection is recommended.

i) Collection methods by types of discharger

a. Collection from small-volume dischargers such as households and small shops

(Storage) A container with lid (20 to 100 liters, made of plastic or metal), a polyethylene bag or a paper bag is used. (The polyethylene bag or paper bag is a disposable bag used to pack commodities. However, a paper bag should not be used for wet waste or at a rainy day.)

(Collection method) Station collection

Stations are established along routes of collection trucks in principle. If houses are located along a narrow street, a station is established along the narrow street, and collection workers carry out the solid waste with push carts from the station to the collection truck waiting on a wide street.

(Equipment) Middle-size compactor

A collection truck with compaction equipment (compactor) is recommended for improvement

of the loading efficiency, increase of the loading weight, and release of collection workers from heavy labor or dangerous work. At the present time, about one-third of BMA's collection trucks are compactors of the medium-size (7.5 m^3). It is desirable to use such medium-size compactors in the future according to the overall evaluation on the supply and standarization of spare parts, the collection volume and the mobility of truck required.

(Frequency of collection) Three times a week.

b. Housing compound and estate (flats, apartment house, etc.)

(Storage and collection methods) The following methods are used on occasions:

. Hauled container or stationary container

Dischargers are able to throw solid waste into a container at any time.

. Station collection

A designated container discharge site should be prepared in the area of the housing estate.

. Drop chute system

Chutes are provided in most buildings, and a small container cart is placed under each chute. The small-size container should be designed to join to a compactor with an automatic loader.

The chute and the small-size container should be designed to prevent breakage or scatter of solid waste after dropping. Furthermore, the apartment manager of a housing complex often has to change the small-size full container under the chute with another empty container before solid waste spills over from the container.

The filled small container is moved to a pick-up station in the site and covered with a lid. A collection truck collects solid waste from the small containers at the station.

(Equipment)

. Container loader and large-size container should be used for hauled container system

. Compactor with crane or dump truck with crane should be used for stationary container system.

. Compactor should be used for station collection system.

. Compactor with automatic loader or crane should be used for chute system.

(Frequency of collection) Three times a week

c. Large-volume dischargers (Large markets, large stores, Sunday markets and large buildings)

(Storage and collection) The hauled container system is adopted as much as possible for large-volume dischargers, considering situations of buildings and sites, and the discharge volumes.

If adoption of the hauled container system is difficult, solid waste is stored in small containers (of plastic or metal, about 60 liters), which are kept at a container depot. It is desirable that a collection truck is able to approach the container depot. Otherwise, a station along the road should be appointed to apply the method of station collection.

If paper waste is the majority of solid waste as in the case of office buildings, canvas bags provided with casters are recommendable for storage. If possible, a storage tank with automatic discharger such as dust-drum may be provided at the construction stage of a building.

(Equipment)

. Container loader and large-size container should be used for hauled container system.

. Compactor should be used for container storage or dust-drum.

. Dump truck should be used for canvas bag storage.

(Frequency of collection) More than three times a week depending upon the discharge volume

(Others) Solid waste discharged from markets is suitable for compost treatment. It is better to collect market wastes independently and haul them to a compost plant.

d. Others

(Hospital) The solid waste discharged from hospitals is classified into the following two types:

. Unsanitary waste and hazardous waste ---

Unsanitary waste includes organs and organic materials from operations, used gauze patches, materials potentially contaminated with disease germs, used syringe-needles, ampoules, pieces of broken glass, drugs, etc.

- Sanitary waste and non-hazardous waste ---

Writing paper in a office and food waste in a kitchen which are not contaminated with disease germs.

Wastes of above items should be separately stored. Unsanitary waste should be stored in thick black plastic bags and discharged. Hospitals (including small medical facilities) organize a cooperative, which collects or entrusts an outside service to collect the wastes of items above separately. Water-tight type dump trucks with lids should be used to prevent breakage or scatter of waste.

The collected solid waste should be incinerated at a treatment plant managed by the cooperative or reliably managed by a licensed waste treatment company. The incineration residue should be transported to the landfill site provided by the cooperative or the contracted company for waste treatment. A large hospital with sufficient funds may incinerate the waste at its own plant constructed in the hospital site, and ashes are transported to the landfill site provided by the cooperative.

For the time being, however, until hospitals establish the self-disposal system, it is desirable that the government authorities are responsible for all phases from collection to final disposal. Therefore, BOS should provide a small-size exclusive incinerator to burn the hospital wastes as described in the short-term improvement plan in chapter 3.

(Collection along a waterway)

Solid waste discharged from the places where collection trucks cannot access by road will be collected along canals (where conveniently located) by small boats with outboard motors carrying several polyethylene containers of about 60 liters (This is the station collection in principle, but door-to-door collection trips are made when station collection is difficult.) The waste-filled polyethylene containers are unloaded at a properly selected place

along a canal (where compactor trucks can approach). The containers have lids. The place should be selected on the transport route of a collection truck, and the solid waste is transfered from the polyethylene containers to the compactors. The empty containers are carried back to the boat office (starting point of the boat) by compactors, and again are used for the next solid waste collection (the next day) along canals by small collection boats.

ii) The offices in charge of the collection

The Garbage Collection Division (BOS) should be responsible for collection of solid waste from markets except those in the suburban districts, and each district should be responsible for other solid waste collection.

iii) Working days

Work days should be 298 days per year except Sundays and holidays. However, solid waste collection from markets and shopping quarters should be made daily, even on Sundays and holidays.

iv) Composition of a crew

The crew with a medium-size compactor should be composed of one driver and three collection workers. In the cases the crew for hauled and stationary container system, should be composed of one driver and one collection worker.

(2) Transport

Two transport alternatives are proposed. One involves direct transport to the destination by collection trucks and the other involves transfer transport.

i) Transfer transport

Two kinds of transfer systems were considered: land-river transfer station along Chao Phraya River and a land - land transfer station in the city area.

a. The size of facility, site area, construction cost and maintenance and operating cost

A large capacity transfer station is preferable for gaining the economies of large volume transport, but the capacity must be determined considering the collection volume in the neighboring areas (within 5 to 10 km) of the transfer station. The following table shows the size of transfer station, the required site area, the construction cost and maintenance and operating cost.

Kind of transfer	Capacity (t/d)	Required Area (m^2/(t/d))	Const. cost (Baht/t·d)	Maint. & Oper. cost (Baht/t)
River-land	200 to 600	10	30,000	10
Land-land	150 to 200	5	150,000	45

b. Equipment for transfer transport

- Boats with a capacity of 100 to 200 tons loosely packed.
- Large-size container truck (10 t, 20 m^3).

(3) Others

i) Cleaning of roads

The mechanical or manual cleaning depends upon a type of road. The mechanical cleaning consists of a dump truck to collect relatively large solid waste (wood-chips, stones, etc.), a road-sweeper with brush and swallow-in inlet and a sprinkler truck. The frequency of cleaning is about 2 ∿ 4 times a month. The manual cleaning is performed by workers with brooms and dust pans. The collected solid waste is thrown into small-size containers (about 500 liters), which is always placed at a proper place on the road. A compactor with a crane for a container collects the waste from the container.

ii) Cleaning in canals

Wide canals where a mechanical boat can pass should be cleaned mechanically, while middle and small canals should be cleaned by collection workers with hooks, poles or nets from a boat.

The collected solid waste and weeds should be unloaded on some open spaces (like banks) for several days to dry out under the sun, and then be conveyed to a landfill site by a water-tight dump truck (10 tons).

The frequency of cleaning is 1 ∿ 2 times a month.

iii) Transport of incineration residue (ash)

Incineration residues discharged from a incineration plants should be transported by a water-tight dump truck (10 t) to a landfill site or swampy land which a land-owner requests to reclaim.

iv) Parking lots

By increasing of the number of collection trucks in the future, it will be difficult to park all the collection trucks at the existing parking lots of a district office in the city center. Therefore, it is necessary to establish new parking lots for collection trucks of such districts in the city center or periphery districts of the center.

Parking lots should be established at the places such as the sites of intermediate treatment facilities, which should be constructed near to the city center.

4.2.3 Number of vehicles and collection workers

The formulas to calculate the number of vehicles and collection workers are described below. The number of vehicles is calculated in chapter 5.

(1) Number of vehicles

i) Middle-size compactors

By formulation of a model of collection and transport by compactors, the daily solid waste volume collected and transported by a vehicle is calculated for each collection territory (for example, a district). The required number of compactors is determined from the planned solid waste collection volume and the daily collection and transport volume per vehicle.

The formula to obtain the daily collection volume per vehicle is shown as follows: (see Appendix 4.4 for details of the model and formulation of the formula).

$$Q = \frac{q(T - \bar{To})}{q(\frac{1,000}{60} E1 + Em) + (4.48L - 3.58 + td)} \qquad (4.2 - 1)$$

where, Q : Daily collection and transport volume per vehicle (t/d·vehicle)

q : Loading volume per trip [2.8] (t/trip·vehicle)

E1: Loading efficiency [2.0] (s/kg)

Em: Coefficient of moving [4 ∿ 15] (min/t)

L : Transport distance per trip (km)

td: Unloading time at a destination [10] (min)

T : Length of workday [540] (min/d)

$\bar{To}$: Off-route time including rest, lunch, preparation, fill in the operation record and car washing, etc. [90] (min/d)

(note) The figures in brackets [ ] are actual numbers of the variables in computation.

The required number of vehicles is determined with the following formula:

$$N = G/Q$$

where, N : Required number of trucks (vehicle)

G : Collection volume per workday (t/d) (Value of G is determined by adjusting the planned collection volume in section 2.2.3 considering the number of workdays in a week and collection frequency.)

ii) Container loaders

The number of container loaders is obtained by substituting the volume collected and transported by a container loader per day. The daily solid waste collection and transport volume per container loader is calculated with formula 4.2-3, which can be obtained by adjusting the formula 4.2-1 a little.

$$G = \frac{q(T - \bar{To})}{te + (4.48L - 3.58 + td)} \qquad (4.2 - 3)$$

where, G : The daily volume collected and transported per vehicle (t/d·vehicle)

q : The solid waste volume in a container (t/container) [2]

te: The time for exchanging an empty container for a waste-filled container at a collection site [15] (min)

L, T, $\bar{To}$ and td: as defined previously.

(note) The figures in brackets [ ] show actual number of variables in computation.

iii) Mechanized vehicles for road cleaning

The daily working distance is obtained by dividing the cleaning distance of roads by the frequency of work. The required number of mechanical is obtained by dividing the working distance by the working efficiency. The frequency of work is once a week for a wide road with six lanes or more, and twice a month for a road with four lanes. The working efficiency is determined as 10 km/d·vehicle referring to the survey results in Bangkok and other cities.

For collection and transportation of manually collected road waste, a compactor with a crane for a container is provided for each district.

iv) Boats for canal cleaning and collection trucks for solid waste generated in canals

The number of boats is determined from the total distance of canals to be cleaned, the frequency of work and the working efficiency.

The frequency of work in a wide canal cleaned by a mechanical boat should be once a week, and the frequency of manual work with a small boat in small or middle-size canals should be once or twice a month. The working efficiencies for mechanical cleaning and manual cleaning are fixed at 5 km/d·boat and 120 m/d·boat respectively. A collection truck for solid waste collected from canals should be provided in every district.

v) Ash transport trucks

The daily transport volume per vehicle is obtained from the ash volume generated from an inceneration plant, the loading volume per truck, the distance to the landfill site and the number of work hours each day. The estimate for this was 30 t/d/· vehicle in case of about 20 km of haul distance. The required number of ash transport trucks is obtained by dividing the ash volume generated from the incineration plant by the daily transport volume per vehicle.

vi) Spare trucks

Today, the breakdown rate for collection trucks is 18%, but this is expected to be reduced to lower than 5% with improvement of maintenance service and introduction of new vehicles. Based on the existing breakdown rate of vehicles, the allocation rate for spare vehicles is fixed at 18% of the required number of vehicles at the present time, but will be decreased in the future to 5% by the year 2000.

As the spare trucks for compactors, 10 m^3 dump trucks should be adopted based on consideration of their general use, while the type of spare trucks for other vehicles than a compactor was selected as the same type of vehicle.

(2) Number of collection workers

i) Workers for compactors and container loaders

The basic number of drivers and workers is obtained by multiplying the number of crew members by the required number of vehicles obtained in para (1) i). One crew consists of a driver of a compactor and four collection workers at present, but the number of collection workers will decrease in the future to three in the year 2000 as shown in para 4.2.2 (1) iv). The planned number is 115% of the required number based on consideration of the absenteeism rate for illness or vacation.

ii) Workers for the mechanical road cleaning

A driver operate a mechanical road-sweeper alon but dump trucks and sprinkler trucks with one accompanying worker. The planned number of workers for mechanical cleaning of roads is calculated by multiplying the number in a crew by the required number of vehicles obtained in para (1) iii) and adding a 15% allowance the same as in para (2) i).

iii) Workers for the manual road cleaning

Since the city center and its peripheral districts have been considerably urbanized, the increase in sweepers will be unnecessary in the future, and the number of sweepers in those territories will remain unchanged at the present level. The number of sweepers in districts which are assumed to be urbanized in future will be determined based on the increase of the urbanized areas and the growth rate of the population.

A crew for collection and transport of solid waste collected by sweepers from roads (the crew of a compactor with a crane for a container) consists of a driver and a worker. The total number, therefore, is obtained from the required number of vehicles determined in para (1) iii).

iv) Workers for canal cleaning

The crew of a mechanical boat should consist of five workers. The crew of a small boat should consist of three workers. The number of workers for collection and transport of the unloaded canal waste is 20 including the driver of a dump truck.

The planned number of workers for canal cleaning is obtained by multiplying those crews by the numbers of boats and vehicles determined in para (1) iv) and adding a 15% allowance.

v) Number of drivers for transport of incineration residue

The basic number of drivers for transport of incineration residue is calculated based on the required number of vehicles obtained in para (1) v) alloting one driver per truck for transport of ashes. The planned number of drivers for transport of incineration residue is finally determined with the inclusion of a 15% allowance.

4.2.4 Cost of collection and transport

The formula to obtain the cost of collection and transport is described herein. The calculation of the costs is presented in section 4.5.

The costs are mainly classified in two categories as follows:

- Costs related to collection vehicles:
  1) Maintenance costs for vehicles (oil, tires, spare parts, etc.)
  2) Purchase costs of vehicles
  3) Fuel
- Labour costs for workers
  1) Drivers for collection vehicles
  2) Collection workers

Consequently, the following expression was formulated (see Appendix 4.5 for explanation and derivation of the formula).

$$C_{unit} = 1.32 + \frac{190}{HL} \qquad (4.2 - 4)$$

where, C unit: Cost of collection and transport per ton per km: a unit expense obtained by dividing the total cost

of collection and transport by the total number of tons carried and trip kms. (Baht/t·km)

H : Number of trips per day (trip/d·vehicle)

L : Round-trip-haul distance (km/trip)