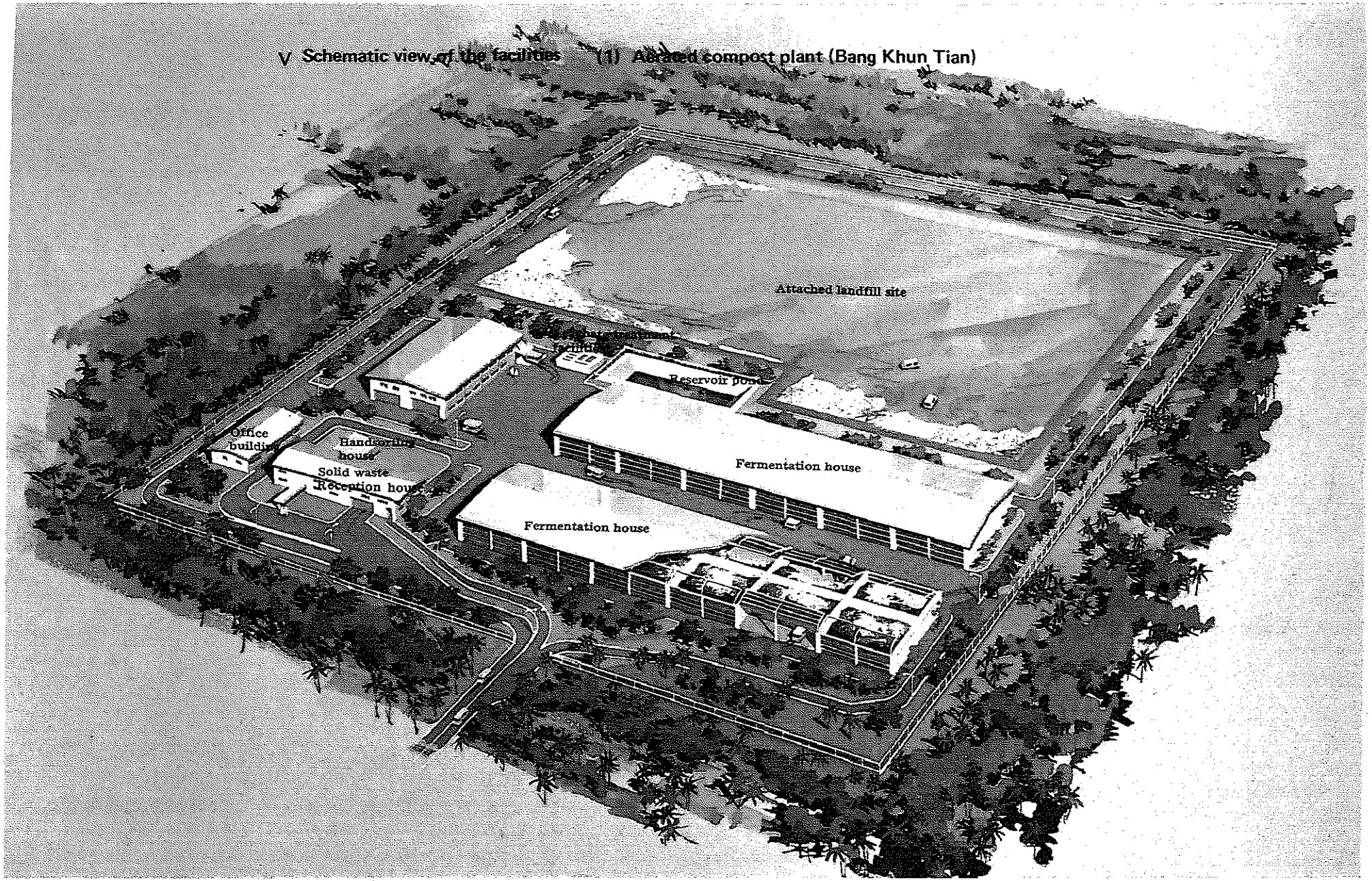
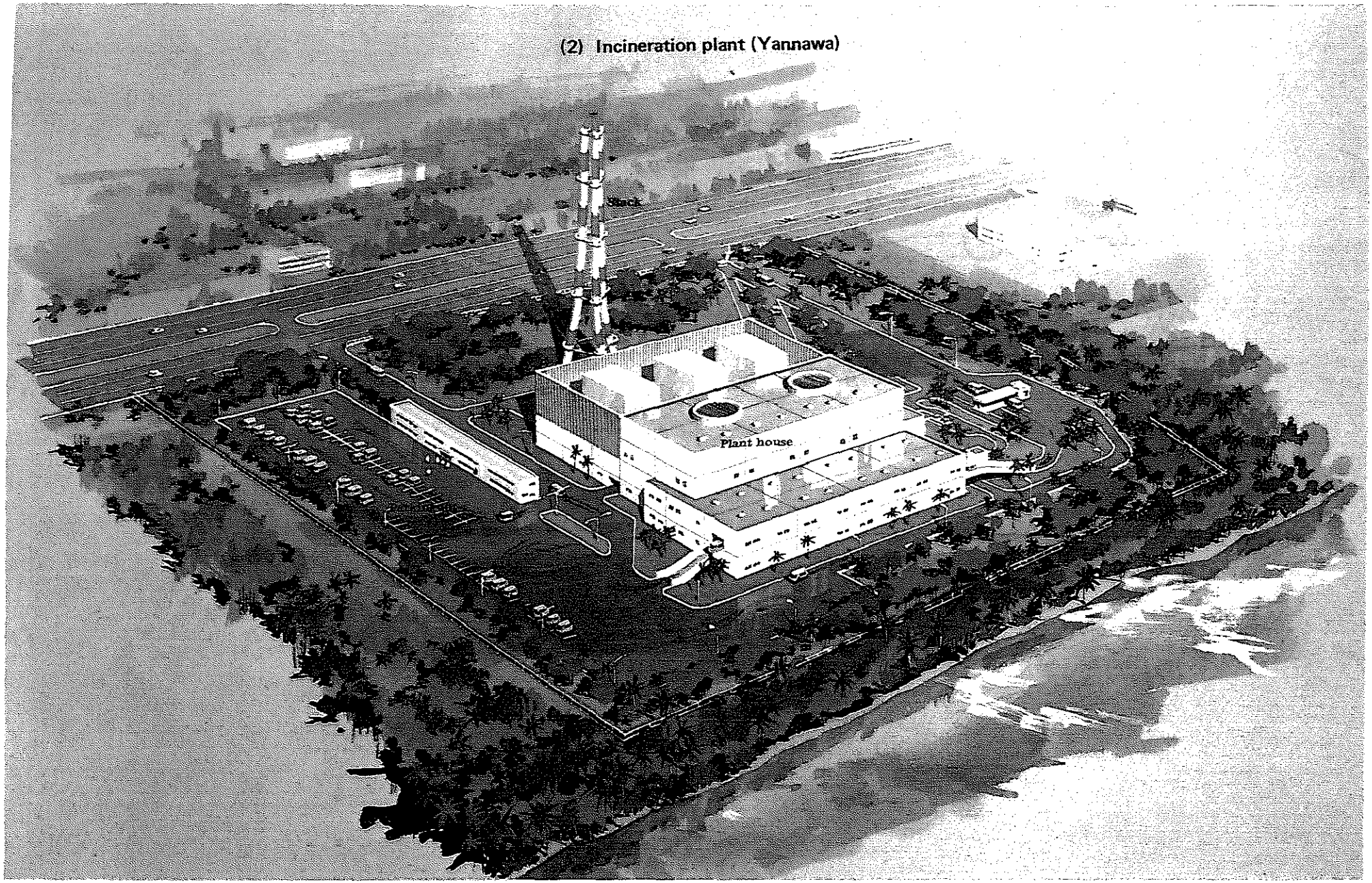
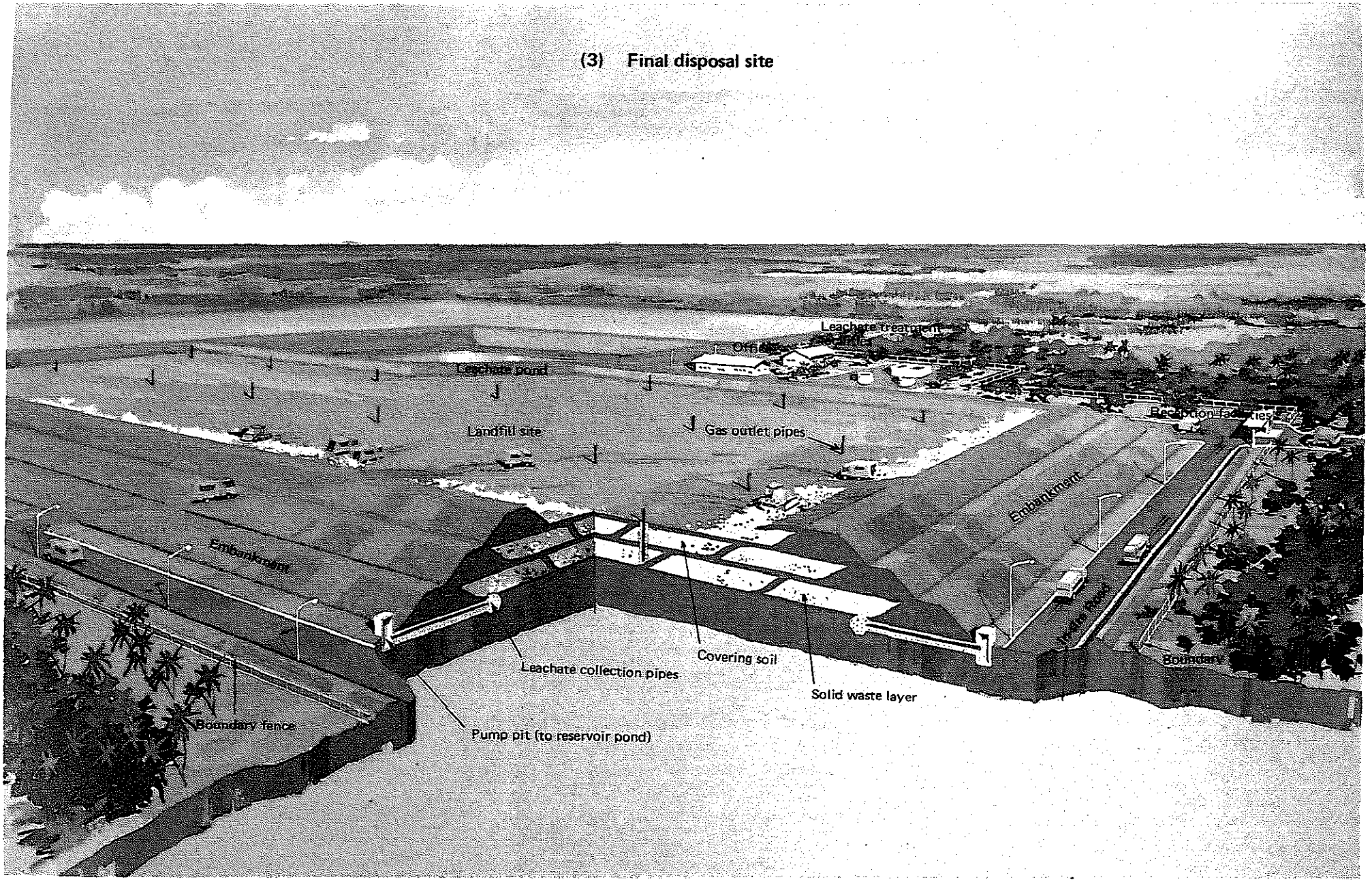
V Schematic view of the facilities (1) Aerated compost plant (Bang Khun Tian)



(2) Incineration plant (Yannawa)



(3) Final disposal site



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CHAPTER 1 INTRODUCTION

1.1 Background and Progress of the Bangkok Solid Waste Management Study

Bangkok city, with an approximate population of 5.1 million, is one of the most prominent cities in the Southeast Asian countries. It has had a long and close relation with Japan in its history. Economic and social development in Thailand has brought a concentration in population to its capital and, as a result, Bangkok city today suffers from miscellaneous urban problems. Above all, solid waste generated from this huge city every day makes it difficult to maintain public health and moderate the living environment. Based on the seriousness of the situation, the Bangkok Metropolitan Administration (BMA) has focused on solid waste management as one of the main priorities for establishment of urban infrastructure in Bangkok city.

Motivated by such background, the Government of Thailand made a request to the Government of Japan for technical cooperation in the study of solid waste management plan in Bangkok city. On acceptance of the request, the Japan International Cooperation Agency (JICA) organized the first preliminary survey team who completed an eight-day field survey in Bangkok city from 28th February, 1979 and formulated a brief implementation plan of the Study. Following the first preliminary survey, JICA organized the second preliminary survey team under the cooperation of Tokyo Metropolitan Government (TMG) and dispatched it to Bangkok during the period from August, 1979 to February, 1980. The second preliminary survey team conducted surveys of solid waste properties and outlined the existing solid waste management system in Bangkok city under supervision of JICA Supervisory Committee. Based on the results of the preliminary surveys, JICA organized the Study team who began the main study in Bangkok in June, 1980. The previous JICA Supervisory Committee was again given the role to supervise the main study. BMA, upon acceptance of the Inception Report from the Study team, organized the Follow-up Committee for cooperation and supervision of the Study, which is headed by the Deputy Governor and composed of 12 high-ranking officials. The Study team has completed 26 months of study and has now reached the stage to present the Final Report. We, the Study team, hereby would like to express our gratitude to the Follow-up Committee members for their hearty cooperation and assistance, and to the excellent counterparts who have made their full effort and collaborated with us for the successful conclusion of the Study.

1.2 Outline of the Study

1.2.1 Goals of the Study

BMA's policy for solid waste management has two targets. One is to realize a clean Bangkok and the other is to promote effective use of city compost, that is to say, promotion of resource recovery from urban solid waste.

The Study team has divided the BMA's policy into four goals at which the future solid waste management system in Bangkok city should aim.

(1) Total volume collection. This goal includes collection of all solid waste generated daily in the metropolitan area, except for properly disposed-of solid waste by the dischargers themselves. According to an estimation by the Study team, the solid waste collection rate in Bangkok city in 1979 was about 77%, and most of the rest (27%) was inferred to have been self-disposed and illegally abandoned.

The collection rate is intended to rise to 97% by the year 2000.

(2) Total volume treatment including sanitary landfill.

This goal aims at the sanitary treatment and disposal of all collected solid waste.

Presently, the collected solid waste other than the part being intermediately treated in compost plants is unsanitarily disposed of in no better way than merely being discarded.

(3) Establishment of a reliable, durable and flexible solid waste management system. This is an indispensable factor for realization of total volume collection and total volume treatment and disposal.

There are many cases in which a sanitary administration was compelled to incur unreasonable expenditures simply because an inadequate system had been adopted based upon poor technical judgement without sufficient experience and adequate knowledge.

Establishment of a reliable management system cannot be achieved only by introducing modern equipment and advanced facilities. It requires the training of highly educated engineers and officers for maintenance of the facilities. As a matter of course, sufficient budget has to be prepared for the management.

(4) Promotion of citizen collaboration. An ultimate goal of solid waste management is to provide the citizens with a beautiful and sanitary living environment. To this end, all possible attempts should be made to obtain the citizen collaboration through promotion of the citizen appreciation of sanitation and solid waste management.

The Study team has undertaken this Study aiming at the goals mentioned above.

A target year and objective areas of the project were fixed as below:

The long term Master Plan aims at the year 2000 as the target whereas the short-term improvement plan intends to improve the existing solid waste management system within the next five years (1982-1986). The scope of the project is limited to 24 districts of Bangkok Metropolis; suburban areas outside Bangkok are not included in the scope.

Concept of solid waste management adopted by the Study team is shown in Appendix 1.1.

Incidentally, Appendix 1.2 "History of solid waste management in Bangkok" was contributed by Mr. Somchitt Trivichien, the director of Technical Division of BOS.

1.2.2 Study work flow and time schedule

The Study consists of Phase I (Masterplan Study Phase) and Phase II (Feasibility Study Phase). Fig. 1.1 shows the Study work flow and titles of reports with dates of respective submission. The time schedule is shown in Fig. 1.2.

Phase I study involves the following study items:

- Survey of the existing solid waste management system
- Establishment of short term improvement plan to urgently improve the existing solid waste management system within a relatively short term (approximately five years)
- Survey of the present solid waste composition and generation volume, and their forecast for the future
- Technical survey concerning solid waste management system alternatives
- Formulation of 30 cases of Master Plan alternatives and selection of 3 cases of appropriate Master Plan alternatives from among the 30 cases

In order to back up the above study, seven auxiliary field surveys were carried out through the Phase I study period and the initial part of the Phase II study period.

In the Phase II study, the facilities (equipment and man power) plans were set up with respect to each of the above said three appropriate Master Plan alternatives and, through overall evaluation made on the results of three kinds of evaluation such as economic and financial analyses, environmental impact assessment, and evaluation from technological viewpoint, an optimum Master Plan was established. At the same time, implementation schedule of the optimum Master Plan and recommendations for the administrative organization concerning implementation of the optimum Master Plan were formulated. The Study was commenced in June, 1980 and completed in September, 1982 with presentation of the Final Report. The total Study period was 28 months.

Fig. 1.1 The Study work flow

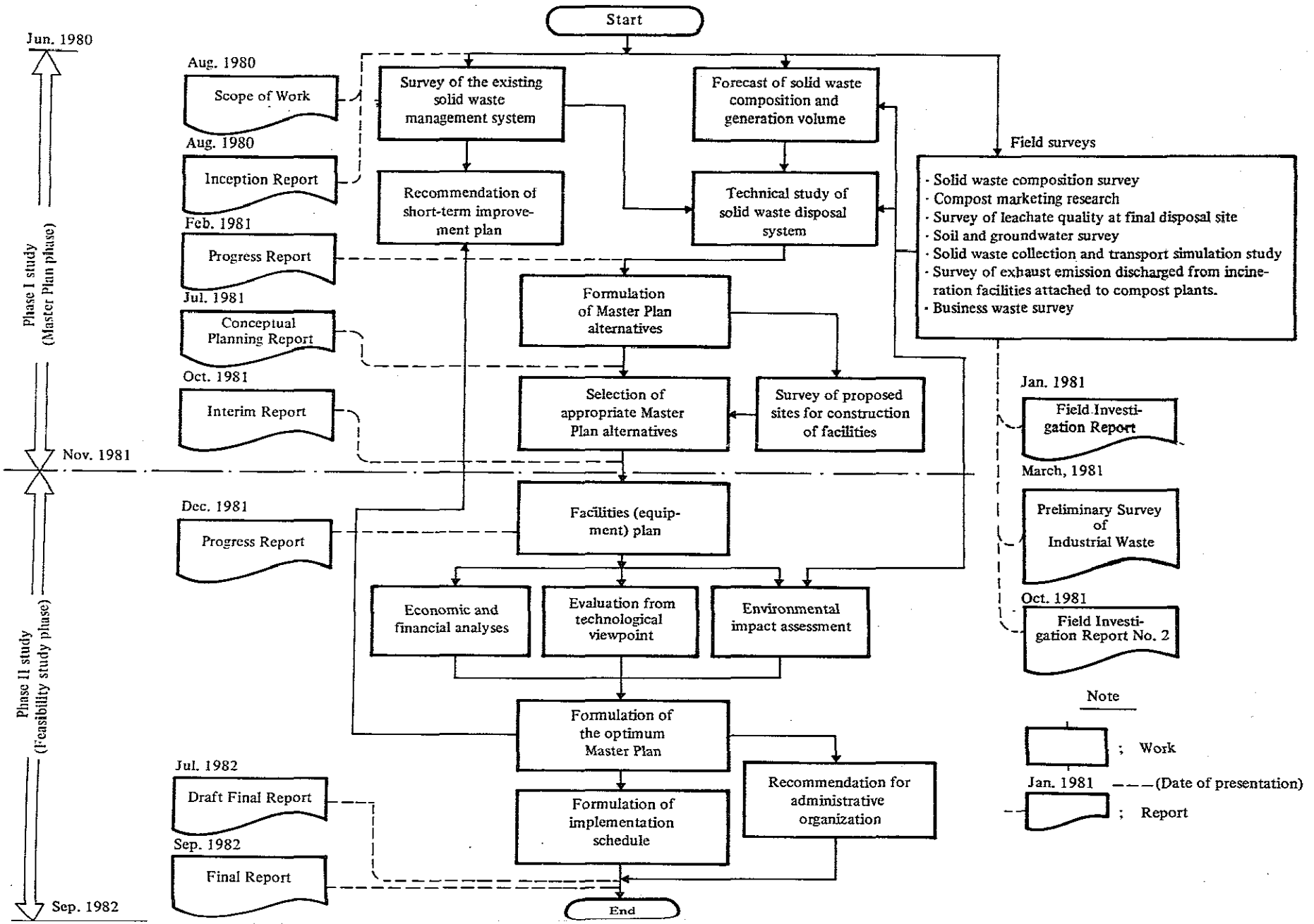
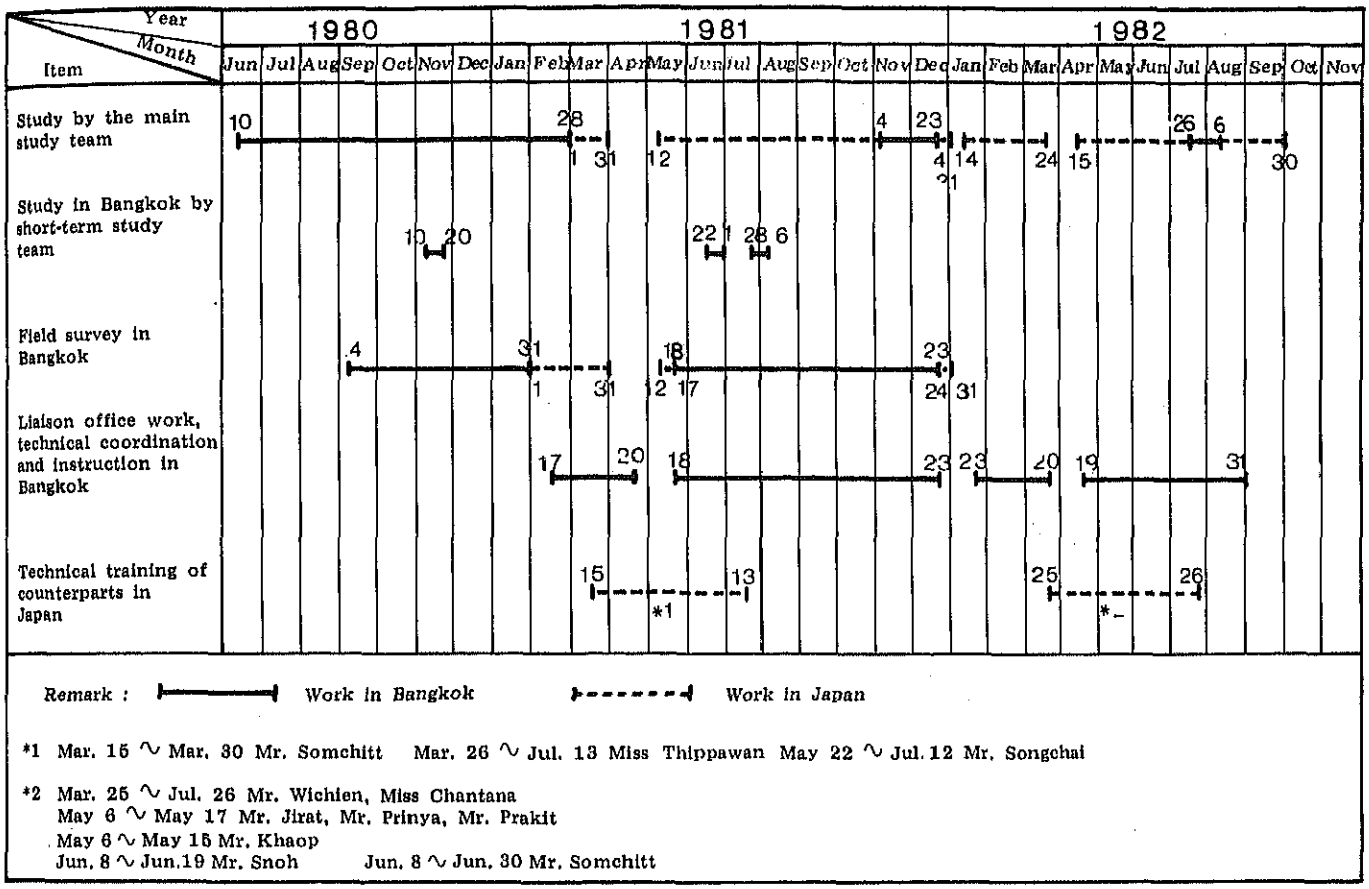


Fig. 1.2 The study schedule



1.2.3 Organizations relating to the Bangkok Solid Waste Management Study

a) JICA Supervisory Committee

1. Dr. Shiro Kawaguchi	Chairman	Prof. Faculty of Engineering, Tokyo Metropolitan University
2. Mr. Akira Ide		Director, Plant Construction Div. Bureau of Public Cleansing, Tokyo Metropolitan Government (TMG)
3. Dr. Masaru Tanaka		Chief, Solid Waste Management Section, Department of Sanitary Engineering, The Institute of Public Health
4. Mr. Kazuyoshi Okazawa		Asst. Chief, Environmental service section, Ministry of Public Health
5. Mr. Masahiro Fujiwara		Asst. Chief, Environmental service section, Ministry of Public Health

b) The Study team

1.	Mr. Jiro Yamai	Team Leader	Bureau of Public Cleansing, TMG
2.	Dr. Ryuji Tsukada	Asst. Team Leader	Tokyo Metropolitan Environmental Service Corporation (TEC)
3.	Mr. Yasuyuki Matsumoto		TMG
4.	Mr. Yoshiaki Ishikawa		TMG
5.	Mr. Tomoyuki Matsumura		TEC (Commission basis)
6.	Mr. Takashi Sasaki		TEC (- do -)
7.	Mr. Yoichi Hanada		TMG
8.	Mr. Yasuo Nemoto		TMG
9.	Mr. Masami Kondo		TEC (Commission basis)
10.	Mr. Noriya Yamiya		TEC (- do -)
11.	Mr. Masashi Hattori		TEC (- do -)
12.	Mr. Takeshi Suzuki		TEC (- do -)
13.	Mr. Kazuhiko Yokojima		TEC (- do -)
	Field Survey Team		
14.	Mr. Shoji Fujii		TEC (Commission basis)
15.	Mr. Mitsuru Omura		TEC
16.	Mr. Kazuo Emura		TEC (Commission basis)
17.	Mr. Osamu Hashimoto		TEC
18.	Mr. Shigehisa Tazaki		TEC (Commission basis)
19.	Mr. Satoshi Watabe		Pacific Consultants International Co.
	Short-term Team		
20.	Mr. Kanichi Arizumi		TEC
21.	Mr. Shuji Shimizu		TMG
22.	Mr. Shigeru Kondo		TMG
23.	Mr. Sadao Matsushima		TMG
24.	Mr. Yoshimi Murakami		TMG
25.	Mr. Hitoshi Terashima		TMG
26.	Mr. Yukio Shikada		TMG
27.	Mr. Ichiro Kojima		TMG
28.	Mr. Tatsuo Makioka		TMG

c) Follow-up Committee, BMA

1.	Dr. Winich Asavasena	Deputy Governor of BMA - Chairman
2.	Mr. Den Bhusuwan	Under Secretary of State for BMA
3.	Dr. Chek Dhanasiri	Deputy Under Secretary of State for BMA

4.	Mr. Snoh Iam - Opas	Director, Bureau of Sanitation
5.	Mr. Jirat Rujirat	Deputy Director, Bureau of Sanitation
6.	Miss Arporn Chanchareonsook	Director, Policy and Planning Division 1., BPP.
7.	Mr. Nakorn Sakornsinthu	Director, Compost Plant Division, BOS
8.	Mr. Prinya B. Banyong	Director, Garbage Collection Division, BOS
9.	Mr. Boonyakit S. Tanskul	Chief, Foreign Relation Section, Public Relation Division
10.	Mr. Somchitt Trivichien	Director, Technical Division, BOS - Secretary
11.	Mr. Chob Soommanas	Chief, Planning and Project Section, Technical Division, BOS - Assistant Secretary
12.	Miss Sarinporn Leemaharoungruang	Chief, Survey and Research Section, Technical Division, BOS - Assistant Secretary

d) Counterparts BMA

1.	Mr. Somchitt Trivichien	Director of Technical Division BOS
2.	Miss Sarinporn Leemaharoungreaung	Sanitation Researcher, Chief of Survey and Research Sect., Technical Div. BOS
3.	Mr. Saneh Wayuprab	Sanitation Researcher, Chief of Environmental Sanitation Sect. Technical Div. BOS
4.	Miss Tippawan Paesakool	Sanitation Researcher, Technical Div. BOS
5.	Miss Chantana Nivataphund	- do -
6.	Mr. Utid Mahakittikun	- do -
7.	Mr. Wisit Amornkitbamrung	- do -
8.	Mr. Abhichart Kong-arth	Artist, Technical Div. BOS
9.	Miss Siriwan Pensangiam	Statistics, - do -
10.	Mr. Kompol Hoitong	Sanitation Researcher, - do -
11.	Mr. Phijit Wangsanuwath	- do -
12.	Miss La-iad Klubsazng	Officer, - do -
13.	Mr. Compee Srithuth	- do -
14.	Mr. Anuwatt Dendi	- do -

15.	Miss Apinya Pongseankae	Officer, Technical Div. BOS
16.	Miss Titinun Boonsongseang	- do -
17.	Mr. Surawongse Swangbumrung	Mechanical Engineer, Waste Disposal Div. BOS
18.	Mr. Thawatchai Phuddee	Officer, - do -
19.	Mr. Samruay Amattaykul	- do -
20.	Mr. Yuttidham Srisawade	- do -
21.	Mrs. Parichat Sanghiran	- do -
22.	Mr. Wicha Wongpradit	Engineer, Chief of On - Nooch Compost plant No. 2 Control Sect. BOS
23.	Mr. Songchai Payomyaam	Engineer, Chief of Nong - Khaem Compost plant Control Sect. BOS
24.	Mr. Wichian Punnatrakool	Engineer, On - Nooch Compost plant No. 2 Control Sect. BOS
25.	Mr. Pramote Khemtis	Engineer, Chief of On - Nooch Repair & Maintenance Sect. BOS
26.	Mr. Kanchit Kururattapun	Engineer, Chief of On - Nooch Compost plant No. 1 Control Sect. BOS
27.	Mr. Chalong Suthapradit	Engineer, Chief of Ram - Intra Compost plant Control Sect. BOS

Cahpter 2 VOLUME AND PROPERTIES OF SOLID WASTE

CHAPTER 2 VOLUME AND PROPERTIES OF SOLID WASTE

2.1 Present State of Solid Waste Generation Volume and Composition

2.1.1 Collected volume of solid waste

Solid waste generated in Bangkok metropolis is collected by Sanitation Sections of 24 districts and Garbage Collection Division, Bureau of Sanitation (hereinafter referred to as "GCD"). These offices collect not only solid waste discharged from small volume discharges such as general households and petty shop-attached residences but also business waste discharged from business establishments such as hotels, markets, offices and factories. Further, these offices collect road sweeping waste whereas Bureau of Sewage and Drainage collects solid waste in rivers and canals. The collected waste is transported to compost plants and landfill sites for treatment and disposal. Table AP2.1 shows statistics of solid waste disposal volume. Based on it, volumes of collected waste and disposed-of waste were estimated by weight with reference to volume measuring method, missing value and so forth. The results obtained through such estimating process are shown in Table 2.1. Statistics of solid waste collected volume by districts and by GCD are shown in Table AP2.2 and Table AP2.3 respectively. The measuring method of collected solid waste differs by district. In consideration of this difference, collected volume of solid waste by these offices (District Sanitation Sections and GCD) and collected volume in districts are converted to estimated weight. The results thus obtained are shown in Table 2.2.

2.1.2 Solid waste generation unit

The survey of the properties and generation of solid waste from households and some business establishments was made from 1979 to 1981 (hereinafter referred to as "The Survey of the Properties and Generation of Solid Waste"). The investigations focused on households (residences, petty shop-attached residences, etc.), markets, hotels, offices, large-scaled retailers and factories (textile factories, automobile assembly factories, and sawmills). As for hospitals, an interview survey was made. From the results of investigations, values for solid waste generation unit were obtained as shown in Table 2.3. In addition, interview surveys were made to other business offices than the above-mentioned in 1981. The values for industrial solid waste generation unit in these surveys are shown in Table AP2.4.

2.1.3 Solid waste collection volume by generation source

The solid waste collection volume of 1,966 tons per day in fiscal year 1980 was distributed to each generation source — household, market, hotel, office, hospital, road, river, park, sunday-market, and so forth. Part of total collection volume that did not fall within the above-mentioned generation source is all summarized in "others", which includes restaurant, supermarket, department store, gay quarter, school, airport, factory and the like. The estimated results of solid waste collection volume are shown in Table 2.4. (Note: for the number of markets and

Table 2.1 Solid waste disposal volume
(1967-1981)

Fiscal Year	Disposal Volume (1)			Collected Volume (2)	
	Excluding Tung Kru & Minburi		Including Tung Kru & Minburi	In a year	In a day (3)
	Dump Site & Din Daeng Compost Plant (m^3) (4)	Compost Plant On-Nooch, Ram Intra & Nong Khaem (t)	(1,000 t)	(1,000 t)	(t/d)
1967	1,248,812	-	417.1	438	
1968	1,313,501	-	437.4	459	
1969	1,230,378	-	408.3	429	
1970	1,341,352	-	443.7	466	
1971	1,269,048	-	418.5	439	
1972	1,250,543	-	411.1	432	
1973	1,408,782	-	461.6	485	
1974	1,320,873	-	431.4	453	
1975	1,221,237	-	397.5	417	1,140
1976	1,429,557	-	476.0	500	1,370
1977	1,624,120	-	527.5	554	1,520
1978	1,337,886	118,245	570.4	599	1,640
1979	824,056	310,673	608.0	638	1,750
1980	776,621	405,040	683.3	717	1,966
1981	386,005 t	285,322	697.9	737	2,008

Note: (1) Disposal volume by weight was determined by the Study team based upon the records at the processing and disposal sites in Bangkok and upon the estimated bulk density of the solid waste.

(2) Collected volume is estimated as 5% up of the disposal volume based on the recovery of materials at collection sites.

(3) Collected volume in a day was obtained by dividing the annual collected volume by 365 days.

(4) Except for 1981.

Table 2.2 Collection volume

(Unit : t/d)

District Name	Fiscal year					
	1979		1980		1981	
	per office	per district	per office	per district	per office	per district
Phra Nakhon	122.9	122.9	117.1	117.1	126.2	126.2
Pom Prap	80.4	85.8	89.9	96.2	91.5	95.9
Pathum Wan	83.7	93.2	90.7	100.8	107.5	116.0
Sam Phan Thawong	66.4	66.4	60.1	60.1	52.2	52.2
Bang Rak	74.9	78.3	100.2	104.3	91.0	94.4
Yannawa	110.3	110.7	120.1	121.1	121.6	122.6
Dusit	155.7	156.7	241.3	241.8	233.1	233.6
Phayathai	154.9	169.7	177.5	187.5	178.4	189.9
Huai Khwang	59.3	60.2	71.6	72.1	72.0	72.5
Phra Khanong	233.9	240.3	246.4	251.5	238.5	246.3
Bang Khen	101.5	107.9	93.1	98.2	96.0	105.9
Bang Kapi	69.4	69.4	73.2	73.2	74.1	74.1
Nong Chok	3.2	3.2	4.0	4.0	4.2	4.2
Minburi	23.9	23.9	33.1	33.1	25.4	25.4
Lat Krabang	8.2	8.2	6.6	6.6	5.5	5.5
Thonburi	63.1	69.3	68.8	76.2	77.2	80.4
Khlong San	54.5	58.5	54.8	59.6	53.1	57.9
Bangkok Noi	78.4	82.2	91.1	95.7	109.4	115.3
Bangkok Yai	30.5	32.4	32.9	35.1	38.8	40.1
Bang Khun Tian	31.2	31.2	37.0	37.0	48.7	48.7
Phasi Charoen	32.9	35.9	38.6	40.8	46.6	49.3
Rat Burana	34.5	34.5	38.5	38.5	37.6	37.6
Taling Chan	3.9	3.9	7.5	7.5	7.7	7.7
Nong Khaem	5.3	5.3	8.0	8.0	6.3	6.3
BOS	67.1	-	63.9		65.4	
Grand Total	1,750.0	1,750.0	1,966.0	1,966.0	2,008.0	2,008.0

Note : The figures were determined by the study team on the basis of the data reported by each office and the bulk density of solid waste determined from analysis of the On-Nooch weighing record, that is, 0.292 t/m^3.

Table 2.3 Generation unit

Type of Discharger	Generation Unit
1. Household*1	315 g/d·person (1.09 L/d·person)
(1) residential	296 g/d·person (1.01 L/d·person)
(2) commercial or industrial	343 g/d·person (1.17 L/d·person)
2. Market*2	17 L/d·store
3. Office	190 g/d·employee
4. Hotel	1.6 kg/d·room
5. Large retail*3 store	0.5 $L/d \cdot m^2$
6. Hospital	660 kg/d·hospital
7. Textile Factory	4 L/d·employee
8. Car Ass'y Factory	21 L/d·employee
9. Sawmill	12 L/d·employee

Estimated by the Study team on the basis of "Survey of Properties and Generation of Solid Waste".

Note: *1 Household in this table means a family or a group of persons who live together in a small house, a flat, a row building, or in some cases, live and work in the same house or the same apartment.

*2 Generation unit is expressed per store in a market.

*3 Generation unit is expressed per unit floor area.

*4 The number of samples examined were as follows:

Household	:	daily samples from about 180 households over a period of six weeks
Market	:	10 samples from 9 markets
Office	:	9 samples from 8 office buildings
Hotel	:	11 samples from 9 hotels
Large retail store	:	9 samples from 8 stores
Hospital	:	18 hospitals from which the solid wastes are collected by Garbage Collection Division in 1980.
Textile factory	:	8 samples from 8 factories
Car assembly factory	:	8 samples from 5 factories
Sawmill	:	3 samples from 3 sawmills

Table 2.4 Collected solid waste volume in 1980 by source

Source	Generation Unit	Size	Volume t/d
1. Household	315 g/d·person	4,176,000 persons *1	1,315
2. Market	17 L/d·store (4.25 kg/d·store)	32,000 stores	135
3. Hotel	1.6 kg/d·room	12,700 rooms	20
4. Office	190 g/d·person	347,100 persons *2	66
5. Hospital	660 kg/d·hospital	60 hospitals *3	40
6. Road			34 *4
7. Khlong			22.5 *5
8. Park		6 parks (1.24 km^2)	2.5 *6
9. Sunday Market			4.3 *7
10. Others			326
Total			1,966

Estimated by the Study team

Note: *1 : The figure is determined from the population and the estimated collection percentage.
*2 : The figure is adapted from the "Labor Force Survey".
*3 : The figure shows the main hospitals.
*4 : Estimated from the number of the sweepers and the machines (Roadsweeper).
*5 : Estimated on the basis of the data in the BSD report.
*6 : Estimated by using the road refuse amount.
*7 : Estimated by the number of the refuse containers and the collection frequency.

solid waste collection volume by district, refer to Appendix 2.4). Most solid waste generated in slums is left uncollected. Its volume was estimated at approximately 52 tons per day by the Study team. (Appendix 2.5 shows process of estimation).

2.1.4 Solid waste generation volume

Some part of solid waste generated in Bangkok city is left uncollected and thrown into vacant lots or into Khlongs or burnt at generation sources. Questionnaires were sent to Sanitation Sections in all districts to determine percentage of solid waste collection. The reply made by each office indicated that a good amount of generated waste was left uncollected in most districts. (refer to Appendix 2.6).

(1) Estimation of solid waste generation volume

The following three estimation methods of solid waste generation volume were prepared and the results by these methods were compared with the answers of the above-mentioned questionnaire in order to select the most accurate figures of solid waste generation volume.

a. Method-1: Estimate of solid waste generation volume based on relation between land-use pattern and solid waste generation density.

b. Method-2: Estimate the generation volume by multiplying solid waste generation unit by population of the areas.

c. Method-3: Estimate the generation volume by adding solid waste generation volume in uncollected areas to present collection volume.

The details of the foregoing three methods are shown in Appendix 2.7. Judging from the preceding three methods and also from the replies to the foregoing questionnaires sent to the Sanitation Sections, solid waste generation volume in 1979 was estimated and the results are shown in Table 2.5.

(2) Generation unit

Generation unit per capita per day on collection volume basis was calculated by dividing collection volume and generation volume by the solid waste-collected population and the generating population respectively.

The solid waste-collected population was estimated from miscellaneous kinds of information such as the collection area map, land-use map, sub district boundary map, sub district population, and representative population density by landuse type (refer to Table AP2.10).

Solid waste generation population was estimated as the population living in urban areas.

In the agricultural area where population density is low, the generated solid waste can be disposed of by the generators themselves in

Table 2.5 Solid waste generation volume and the collection percentage of the generation volume (1979)

District Name	Generation Volume (t/d)	Collection Volume (t/d)	Collection Percentage of the generation volume (%)
Phra Nakhon	124.1	122.9	99.0
Pom Prap	86.7	85.8	99.0
Pathum Wan	94.1	93.2	99.0
Sam Phan Thawong	67.1	66.4	99.0
Bang Rak	79.1	78.3	99.0
Yannawa	165.4	110.7	66.9
Dusit	192.4	156.7	81.4
Phayathai	184.7	169.7	91.9
Huai Khwang	77.0	60.2	78.2
Phra Khanong	269.3	240.3	89.2
Bang Khen	138.5	107.9	77.9
Bang Kapi	100.0	69.4	69.4
Nong Chok	5.4	3.2	59.3
Minburi	30.0	23.9	79.7
Lat Krabang	10.8	8.2	75.9
Thonburi	115.4	69.3	60.0
Khlong San	92.3	58.5	63.4
Bangkok Noi	203.9	82.2	40.3
Bangkok Yai	57.7	32.4	56.2
Bang Khun Tian	52.3	31.2	59.7
Phasi Charoen	52.3	35.9	68.6
Rat Burana	39.2	34.5	88.0
Taling Chan	11.5	3.9	33.9
Nong Khaem	10.8	5.3	49.1
Total	2,260	1,750	77.4

Estimated by the Study team.

their own gardens, and this is a more practical way than developing collection services for door-to-door collection. The solid waste generation unit of Bangkok city is estimated at 470 grams per day per capita. (Note: for solid waste generation unit by district, refer to Table AP2.12).

2.1.5 Solid waste properties

"Survey of the Properties and Generation of Solid Waste" was carried out over a period of two years in the following months: October, November, and December, 1979; October, November, and December, 1980; and June through September, 1981.

In the household waste survey, samples were taken from 150 to 180 households from residences, shop-attached residences, independent houses, flats, row buildings, etc., in order to examine various kinds of use of buildings and building structures in the selected households. In every month of the survey period, the samples were taken from the households every day in a week.

In the business waste composition survey, markets, hotels, offices, large-scale retailers, and factories (textile factories, automobile assemblers, sawmills) were studied and six surveys were performed in each business sector.

As a representative of total solid waste, incoming solid waste to On-Nooch compost plant (referred to as "reception pit waste") was taken and composition surveys were made on it 14 times during the rainy season and 18 times the dry season.

(1) Physical composition

Survey results of solid waste physical composition are shown in Table 2.6. Household waste contains largely vegetables, paper and plastics while market waste contains vegetables and plants. Paper forms a large part of office waste, large-store waste and hotel waste. Solid waste from textile factories contains considerable textile and waste from sawmills has sawdust and synthetic glue. Automobile assemblers' waste includes a large part of wasted packing materials (paper and plastics).

(2) Bulk density and moisture content

Table 2.7 shows survey results for bulk density and moisture content.

(3) Ultimate analysis, pH and calorific value

Combustibles and miscellaneous of the samples used in the physical composition analysis were further analyzed to chemical components. The results are shown in Table 2.7.

Solid waste containing a considerable volume of plastics shows higher rates of C (carbon) and H (hydrogen) contents. This tendency is conspicuous with solid waste samples from large stores and automobile assemblers.

Table 2.6 Physical composition

Component	Source of Generation (Unit: Percent on dry weight basis)								Incoming Solid Waste	
	Household	Market	Large Store	Hotel	Office	Textile Factory	Automobile Factory	Sawmill	Percent on dry weight basis	Percent on wet weight basis
1. Paper	24.7	9.8	59.0	45.1	63.6	5.7	42.0	0.0	18.0	18.3
2. Textile	4.7	1.1	1.4	3.5	1.5	81.7	6.5	0.2	4.4	3.6
3. Garbage	25.0	41.7	7.3	11.5	4.9	0.9	1.6	0.0	16.5	29.9
4. Grass and Wood	7.6	29.7	2.6	5.1	3.5	1.6	4.2	86.5	19.6	23.2
5. Plastics	11.2	4.7	19.8	9.8	10.1	5.2	18.2	1.4	10.3	7.5
6. Synthetic Glue	-	-	-	-	-	-	-	11.6	-	-
7. Rubber and Leather	1.2	0.4	0.6	0.9	0.7	0.5	5.5	0.0	2.7	1.4
8. Ferrous Metal	5.0	1.2	2.0	5.7	4.1	3.0	10.1	0.2	4.5	2.0
9. Non-Ferrous Metal	0.3	0.1	0.2	0.7	0.2	0.0	0.2	0.0	0.3	0.1
10 Glass	5.5	0.9	1.7	7.1	4.2	0.0	0.4	0.0	5.5	2.4
11. Bones, Stones and Ceramics	8.6	8.3	1.6	3.6	2.0	0.3	0.3	0.1	10.3	5.6
12. Dry Cells	0.48	0.0	0.8	0.4	0.2	0.0	-	-	0.4	0.2
13. Sand Paper	-	-	-	-	-	-	5.4	-	-	
14. Miscellaneous	5.9	2.1	3.0	6.6	5.0	1.1	5.6	0.0	7.5	5.8

Note : The figures in the table were determined on the basis of the results of the Surveys of Properties and Generation of Solid Wastes in 1979 to 1981.

Household : Daily samples from about 180 households were compiled into one sample which was analyzed. Total number of analysis samples were 30.
Market : 6 samples from 6 markets
Large store : 6 samples from 6 large stores
Hotel : 6 samples from 6 hotels
Factory : 2 samples from 6 factories of the same kind
Pit : 32 samples

Table 2.7 Chemical properties of solid waste

Category of solid waste	(A) Bulk density and total moisture content		(B) Ultimate analysis of combustible and miscellaneous (dry basis)							(C) Phosphorus and Potassium contents, and pH of combustibles and misc. (dry basis)			(D) Lower calorific value
	Bulk density (kg/L)	Total moisture content (wt%)	C (wt%)	H (wt%)	N (wt%)	O (wt%)	S (wt%)	Cℓ (wt%)	Ash (wt%)	P (wt%)	K (wt%)	pH (wt%)	(kcal/kg)
Household waste	0.22	58.3	46.2	6.90	1.20	32.6	0.14	0.68	12.3	0.20	0.25	6.0	1,160
Market waste	0.22	80.0	39.5	6.70	1.20	32.8	0.25	1.03	18.10	0.21	0.25	6.2	180
Large store waste	0.09	38.1	52.4	8.43	0.30	30.8	0.13	0.85	7.10	0.06	0.16	5.8	2,800
Hotel waste	0.15	44.6	42.8	6.90	0.43	33.9	0.19	0.66	15.11	0.09	0.23	6.4	1,790
Office waste	0.07	26.9	44.0	7.13	0.35	39.4	0.12	0.75	8.30	0.05	0.20	6.2	2,670
Factory waste Textile	0.12	23.6	50.9	6.92	0.18	37.4	0.21	0.24	4.16	0.04	0.16	7.2	3,230
Automobile	0.07	21.6	52.0	8.62	0.58	28.4	0.15	0.64	9.60	0.03	0.13	6.3	3,270
Sawmill	0.30	31.2	48.1	7.44	0.86	28.9	0.06	0.09	14.60	0.09	0.25	5.2	2,450
Pit waste	0.29	57.1	44.2	6.68	1.02	27.5	0.18	0.69	19.73	0.21	0.34	6.2	1,130

Note : The figures in the table are derived from the results of the Surveys of Properties and Generation of Solid Wastes made in 1979 to 1981.
Lower calorific values are of moist solid waste, measured in Bomb value.

The number of samples were as follows:

- Household : Daily samples from about 180 households were compiled into one sample, which was analyzed. Total number of analysis samples were 30.
- Market : 6 samples from 6 markets
- Large store : 6 samples from 6 large stores
- Hotel : 6 samples from 6 hotels
- *Factory* : 2 *samples from 6 factories of the same kind*
- Pit : 32 samples for the column (A), 9 for column (B) and (D) and 6 for column (C)

Market waste was found to contain the largest volume of phosphorus and potassium.

The lower calorific value of the reception pit waste was measured as approximately 1,130 kcal/kg, which is a sufficient value for self-combustion. Considering the facts that the analysis result involves one case of 800 kcal/kg, however, some solid waste might require some additional fuel such as kerosene.

Market waste contains so much water that the lower calorific value is low. On the other hand, solid waste from large stores, offices and factories contains a lot of paper and dried combustibles, so that it has a larger calorific value.

2.1.6 Fluctuation of solid waste generation volume and change of its composition

(1) Fluctuation of solid waste generation volume

i) Fluctuation by day

Fluctuation of household waste generation volume by day was investigated. The results (Table AP2.13) indicate that there is little difference in household waste generation volume between weekdays, however, there is ten to twenty percent increase in generation volume on Saturdays and Sundays.

ii) Fluctuation by month

Judging from monthly solid waste collection volume and difference in solid waste loading volume per collection truck, the ratio of the maximum collection volume per month to the average collection volume per month was calculated to be 1.09 (Refer to Appendix 2.9).

(2) Fluctuation of solid waste composition

A physical composition survey was made on the reception pit waste, which was assumed to be representative and possess the average properties of solid waste in Bangkok. Fourteen samples were examined in the rainy season and eighteen samples were examined in the dry season.

Survey results of solid waste physical composition are shown in Table 2.8(1).

Significant physical composition differences were not perceived in individual composition items, with the exception of the item, "stones, ceramics, bones".

In roughly classified items such as "combustibles, incombustibles, miscellaneous", however, the survey revealed significant difference in that there were somewhat more combustibles and less incombustibles in the rainy season than in the dry season.

The difference of combustibles can be interpreted as an accumulation of slight differences in the composition of individual items while difference of incombustibles can be interpreted as reflection of a large difference in the item, "stones, ceramics, bones".

Table 2.8(1) Solid waste properties in the rainy season and the dry season

- Physical composition of the reception pit waste -

Item	Percent on dry weight basis			Moisture content		
	rainy season (mean)	dry season (mean)	Variance ratio	rainy season (mean)	dry season (mean)	Variance ratio
1.Combustibles	73.7	69.2	6.633*	63.0	64.1	0.319
Paper	18.8	17.2	0.564	57.5	60.0	1.122
Textiles	4.8	4.1	0.617	50.1	46.9	1.032
Vegetables	17.3	15.6	0.943	74.8	77.9	7.424*
Wood & Grass	19.5	19.7	0.004	64.7	63.9	0.153
Plastic	10.2	10.4	0.061	43.9	40.1	1.515
Rubber & Leather	3.1	2.2	0.657	14.2	20.8	2.307
2.Incombustibles	18.0	24.1	15.202**	13.9	11.9	0.734
Metal(ferrous)	4.0	4.9	1.483	4.9	6.0	0.873
Metal (non-ferrous)	0.3	0.4	0.414	0.7	2.2	1.721
Glass	4.8	6.1	2.961	1.8	1.7	0.006
Stones & Bones	8.4	12.3	10.756**	24.1	18.1	3.132
Dry cells	0.5	0.4	-	-	-	-
3.Miscellaneous	8.3	6.7	1.354	46.3	44.7	0.532
4.Total	100.0	100.0		57.5	56.7	0.146

Bulk Density (kg/L) :	0.30	0.28	0.667

Note : Criteria for rejection

* 5% significance level : $F(1.30;0.05) = 4.17$

** 1% significance level : $F(1.30;0.01) = 7.56$

Significant difference was not perceived in moisture content.

Analysis for chemical property was made on the crushed samples of combustibles and miscellaneous items together, which were taken from physical composition samples. Seven samples were analyzed in the dry season, 14 samples in the rainy season. Analysis results are shown in Table 2.8(2).

More contents of C, H, O and combustibles are found in the crushed samples in the dry season than in the rainy season. On the other hand, less ash contents are found in the samples in the rainy season than in the dry season.

A comparison of chemical properties on a wet solid waste basis revealed that there was no significant difference of the contents of C, H, O and combustibles between the rainy season and the dry season. Ash content was significantly higher in the dry season than in rainy season because of the great difference of ash content in incombustibles between the two seasons.

Little difference of calorific value was perceived between the rainy season and the dry season.

Table 2.8(2) Solid waste properties in the rainy season and the dry season

- Chemical composition of the reception pit waste -

(1) Chemical composition of ground sample				(2) Chemical composition of wet solid waste			
Composition (wt%)	rainy season (mean)	dry season (mean)	Variance ratio	Composition (wt%)	rainy season (mean)	dry season (mean)	Variance ratio
Combustibles	83.3	77.3	11.618**	Combustibles	27.8	26.8	0.380
C	45.54	42.86	6.462*	C	15.3	14.3	0.112
H	6.87	6.50	1.982	H	2.29	3.97	0.028
N	1.17	0.877		N	0.39	0.30	
O	28.84	26.17	2.934	O	9.57	8.99	0.989
S	0.213	0.142		S	0.07	0.04	
Cl	0.645	0.739		Cl	0.22	0.26	
Ash	16.7	22.7	11.618**	Ash	14.7	16.5	5.36*
				Moisture content	57.5	56.7	
				Lower calorific value (kcal/kg)	1,133	1,134	0.000

Note: Criteria for rejection

* 5% significance level: $F(1.19; 0.05) = 4.38$
** 1% significance level: $F(1.19; 0.01) = 8.18$