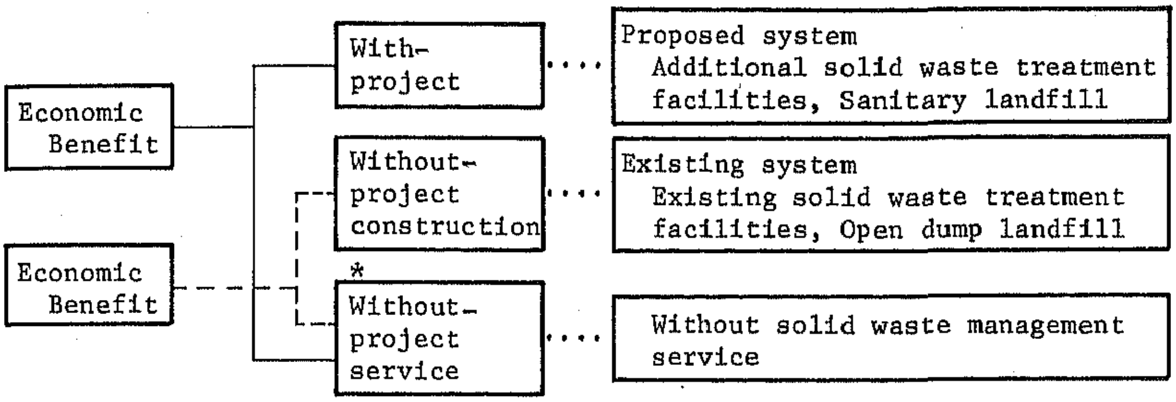
Fig. 6.2 Outline of benefit estimation method




* This concept has been used only for this section to clarify the benefit of solid waste management enterprise.

——— main work flow

---- sub work flow

### 6.2.2 Economic benefit

In this study, the benefit of executing solid waste management by the administration is considered as equal to the cost which will occur if the administration does not execute solid waste management work. Economic viability of each proposed Master Plan alternative was examined in comparison between the total project cost (including the effect of cost savings) and direct benefits added to the indirect benefits described in section (2) below.

The benefit to execute the solid waste management enterprise was subdivided into two categories as described below:

(1) Primary direct benefit

The primary direct benefit covers the reduction in costs which would otherwise be incurred if the solid waste management work was not executed. These costs can be quantified by considering what it would cost citizens to individually perform the disposal of solid waste to prevent disease, rank odor, and maintain personal safety and welfare. Such costs can all be considered as benefits since the sole purpose for individuals to perform such disposal activity is to obtain the environmental benefits listed above. In this sense, the environmental aspects of sanitation work are the most important to consider; hence the designation primary direct benefit.

The main cost to individual householders to perform disposal of solid waste is assumed as the cost of acquiring the land to do it. Therefore in this study, the cost of such land to individual households was calculated as the quantification of primary direct benefit.

In fact, a metropolitan administration manages solid waste as a collective public representative, so that better treatment is made cheaper than the individual household treatment of the waste.

For reference it should be noted that the necessary area for landfilling the solid waste volume discharged in the year 2000 (5,540 t/d day) is approximately 20 ha. The necessary funds for acquiring this area are estimated at about 150 million Baht. This amount is about 50 percent of present budget of BMA's sanitation work.

(2) Secondary direct benefit and indirect benefit

Secondary direct benefit covers direct benefits produced by the project such as reduction of solid waste collection and transport cost by adoption of proposed solid waste management system, recovery of energy from conversion products such as electricity generation by the incineration of solid waste and reutilize solid waste to charge the process of producing composting products.

In this chapter, benefits have been calculated for both (1) Primary direct benefit and (2) Secondary direct benefit. They were then analyzed to evaluate the efficiency ot the proposed solid waste management enterprise.

In addition to these benefits, indirect benefits also were considered.

(3) Estimation of the benefit

i) Primary direct benefit

For estimation of the direct benefit, the following two cases were examined.

Case 1 : Each household acquires the land to dispose of their own household waste so that the height of the landfill is 15 m, the same as a large scale landfill site like at On-Nooch.

Case 2 : Same as the above case, except the height of the landfill is changed to only 3 m.

The landfill shape here was assumed as a cube and the conversion factor from metric ton to cubic meter was settled as 0.8 $m^3/t$. The annual amount of land required for solid waste landfill was calculated by the following formula:

$$Lac = \sum_{n=1}^{24} (Gn \cdot \alpha \cdot \beta \cdot Ln)$$

| | | | | |
|---|---|---|---|---|
| Where, | Lac | : | Annually required land acquisition cost | (Baht/year) |
| | Gn | : | Amount of solid waste discharged from households in "n" districts | (t/year) |
| | $\alpha$ | : | Conversion factor for solid waste volume | ($m^3/t$) |
| | $\beta$ | : | Conversion factor from landfill volume to landfill area | ($m^2/m^3$) |
| | Ln | : | Average unit land acquisition cost in "n" district | (Baht/$m^2$) |

The average land cost in 1980 for 24 districts is shown in Table 6.1.

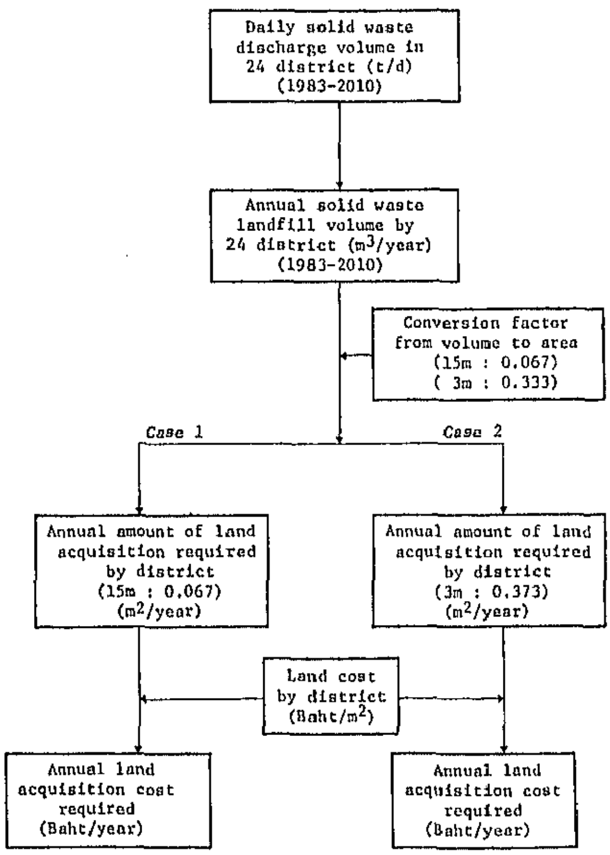
Table 6.1 Average land cost, 1980

(Unit: Baht/$m^2$)

| District No. | Land cost | District No. | Land cost | District No. | Land cost |
|---|---|---|---|---|---|
| 1 | 4,440 | 9 | 1,420 | 17 | 820 |
| 2 | 3,245 | 10 | 1,480 | 18 | 740 |
| 3 | 2,580 | 11 | 530 | 19 | 670 |
| 4 | 5,840 | 12 | 790 | 20 | 90 |
| 5 | 4,270 | 13 | 50 | 21 | 300 |
| 6 | 2,356 | 14 | 130 | 22 | 610 |
| 7 | 1,310 | 15 | 80 | 23 | 100 |
| 8 | 1,960 | 16 | 820 | 24 | 120 |

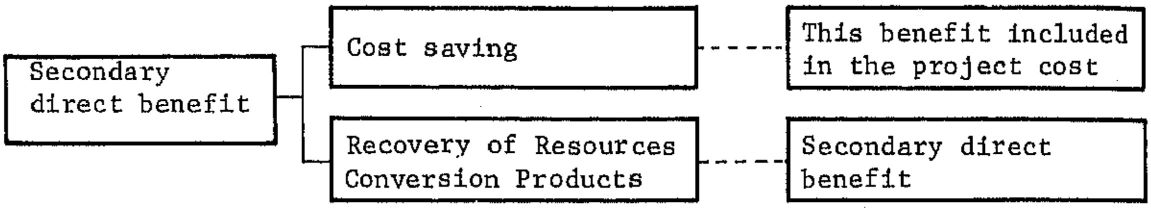
A summary of the method of estimation of direct benefit is shown in Fig. 6.3. The results are as follows: 4,422.3 million Baht for 15 m landfill-height and 21,980.0 million Baht for 3 m landfill-height in total, during the period 1983 to 2010. Direct benefit by year is shown in Appendix 6.2.

Fig. 6.3 Summary of primary direct benefit estimation method



ii) Secondary direct benefit

Secondary direct benefit from the application of a new solid waste management facilities (incinerator, aerated compost plant) are categorized as follows:




Cost saving benefits were estimated and quantified as below. Since these benefits constitute an alternative cost, these benefits were included in the cost side of the evaluation.

Benefit from recovery of resources and conversion products was estimated as a secondary direct benefit.

Indirect benefits which are unquantifiable benefits were excluded from the Benefit-Cost analysis. They are described in detail in a later chapter.

Cost saving benefits from the application of the proposed solid waste management system are described below;

- Reduction of collection and transport costs of the solid waste collection trucks
- Reduction of the purchase costs of the solid waste collection trucks
- Reduction of the personnel expenses (salary and wages) of solid waste collection truck drivers and workers
- Savings in land acquisition cost at the landfill site by reduction of incoming solid waste volume by construction of the solid waste intermediate treatment facilities
- Reduction of facilities construction, maintenance and operation costs at the final disposal sites by reduction of incoming solid waste volume

The benefits from recovery of resources and conversion of products from the application of the proposed solid waste management system are summarized as follows.

- Electric power generation from facilities attached to the incineration plant
- Conversion the solid waste to compost products
- Retrieved ferrous metal
- Use the incineration ash as reclamation of land

The quantification of each secondary benefit is as follows:

a. Cost saving benefit

- Reduction of collection and transport cost of the solid waste collection trucks

  Solid waste collection cost was estimated based on the simulation model discussed in Chapter 4. In this model, solid waste collection truck purchasing cost was excluded since it is estimated in the next paragraph. The estimated transport cost during project life span, that is, between 1983 and 2010, is summarized in Table 6.2.

Table 6.2 Solid waste collection and transport cost by alternative case (1983 - 2010 total)

(Unit : million Baht)

| | Collection and transportation cost of trucks | Savings from without-project case | Index (without-project case = 100) |
|---|---|---|---|
| Case No. 9 | 6,704.4 | 212.7 | 96.9 |
| Case No. 13 | 5,755.2 | 1,161.9 | 83.2 |
| Case No.19-(2) | 6,030.7 | 886.4 | 87.2 |
| Without-project case | 6,917.1 | - | 100 |

- Reduction of the purchase cost of the solid waste collection trucks

  Purchase cost of the solid waste collection trucks is based on the collection truck purchase plan established in Chapter 5. The purchase cost of the collection trucks for each type is summarized in Table 6.3 in 1980 prices. The total solid waste collection trucks purchase cost calculated during 1983 and 2010 is shown in Table 6.4.

Table 6.3 Solid waste collection trucks purchase cost, 1980

(Unit : Baht/vehicle)

| Type of truck | Purchase cost (economic cost) |
|---|---|
| Compactor | 486,000 |
| Non-compactor | 153,700 |
| Container truck | 697,000 |
| Dump truck | 240,000 |

Table 6.4 Total solid waste collection trucks purchase cost by alternative case

(Unit : million Baht)

| | Trucks purchase cost (1983-2010) | Savings from the without-project case | Index (the without-project case=100) |
|---|---|---|---|
| Case No. 9 | 1,441.4 | 33.1 | 97.8 |
| Case No. 13 | 1,173.0 | 301.5 | 79.6 |
| Case No.19-(2) | 1,230.3 | 244.2 | 83.4 |
| Without-project case | 1,474.5 | - | 100 |

- Reduction of the personnel expenses for solid waste collection truck drivers and workers

  Personnel expenses for solid waste collection truck drivers and workers were included in the simulation model described in the solid waste collection and transport cost estimation. In the personnel cost calculation, the crew was assumed to be composed of one driver and three solid waste collection workers which is crew planned in the year 2000. The salary of the driver and workers were fixed as 100 Baht/d and 80 Baht/d, respectively.

- Savings in land acquisition cost at the landfill site

  Since the intermediate treatment capacity is increased, the total incoming volume to the landfill sites will decrease. The savings of the land acquisition cost at the landfill sties in each alternative case are shown in Table 6.5.

Table 6.5 Total savings in land acquisition cost at the landfill sites

(Unit : million Baht)

| | Land acquisition cost (1983-2010) | Savings from the without-project case | Index (the without-project case=100) |
|---|---|---|---|
| Case No. 9 | 281.5 | 34.7 | 89.0 |
| Case No. 13 | 42.1 | 274.1 | 13.3 |
| Case No.19-(2) | 114.7 | 201.5 | 36.3 |
| *Without-project case | 316.2 | - | 100 |

* In this table, to clearly show the efficiency among alternative cases, sanitary landfill method was assumed to be also applied to the without-project case

- Reduction of facilities construction, maintenance and operation costs for the final disposal sites

  By reduction of the incoming solid waste volume to the landfill sites by the expansion of the intermediate treatment capacity, facilities construction cost and maintenance operation cost for the final disposal sites were estimated as shown in Tables 6.6 and 6.7, respectively.

Table 6.6 Total facilities construction cost at the final disposal sites by alternative case

(Unit : million Baht)

| | Facilities construct cost (1983-2010) | Savings from without-project case | Index (without-project case=100) |
|---|---|---|---|
| Case No. 9 | 1,365.7 | 34.1 | 97.6 |
| Case No. 13 | 774.5 | 625.3 | 55.3 |
| Case No.19-(2) | 1,009.7 | 390.1 | 72.1 |
| *Without-project case | 1,399.8 | - | 100 |

* See Note: Table 6.5.

Table 6.7 Total maintenance and operation cost at the final disposal sites by alternative case

(Unit : million Baht)

| | Maintenance and operation cost (1983-2010) | Savings from without-project case | Index (without-project case=100) |
|---|---|---|---|
| Case No. 9 | 189.9 | 93.4 | 67.0 |
| Case No. 13 | 62.7 | 220.6 | 22.1 |
| Case No.19-(2) | 73.2 | 210.1 | 25.8 |
| *Without-project case | 283.3 | - | 100 |

* See Note: Table 6.5

b. Benefits from recovery of resources and conversion of products

. Electric power generation benefit

Electric power generation by utilizing the waste heat of the incineration plant is expected to reduce the need for construction of a new power plant and importation of crude oil. In addition, the generated electricity will contribute to upgrading the standard of livings and to the development of the national economy of Thailand. (Refer to Appendix 6.3) Electric power generation from the generator attached to the incineration plant will produce cost saving with which investment to a new power plant will be minimized.

In estimation of the benefit from electric power generation, benefit was calculated as a construction, maintenance and operation cost savings of a new power plant which has the same electricity generation capacity as the proposed incineration plants of this study. In this case, a hydro-type power plant, of which total cost is low, was selected as the calculation base of the benefit. In the sensitivity analysis which will be mentioned later, a thermal-type power plant was considered.

For the calculation of the construction cost of the power plant, only the surplus power for sale (total power generation minus power for internal consumption in the plant) was counted. Electricity for sale in the proposed incineration plants and construction cost of the power plant with the same power production capacity as the above-mentioned were estimated as shown in Table 6.8.

Table 6.8 Electricity power for sale and the construction cost of an equivalent power plant

| Plant | Power for sale (kW) | Equivalent plant construction cost: 1980 price (unit: million Baht) |
|---|---|---|
| Yannawa | 6,200 | 350 |
| Dusit | 6,200 | 350 |
| Bang Kapi | 5,100 | 280 |
| Bangkok Noi | 4,500 | 240 |
| Phasi Charoen | 4,500 | 240 |

The annual expenditure was estimated calculating annual cost items such as depreciation, interest, wages, operation and maintenance cost, etc. which are needed for construction of hydro-type power plant by year, and distributing these costs evenly to 20 years (ref. Appendix 6.4).

Consequently, the annual expenditure ratio against the total investment cost was calculated as 10.3 percent. The calculation results are shown in Table 6.9.

Table 6.9 Annual expenditure for the power plant operation by capacity

(Unit : million Baht)

| | Annual expenditure |
|---|---|
| 6,200 kW plant | 35.9 |
| 5,100 kW plant | 28.7 |
| 4,500 kW plant | 24.6 |

Consequently, the cost saving benefit of each incineration plant derived from the power generation was calculated as shown in Table 6.10, which was further classified by year by case according to the construction year of each incineration plant. (Ref. Appendix 6.2.)

Table 6.10 Cost saving benefit by incineration plant

(Unit : million Baht)

| Incineration plant | Benefit |
|---|---|
| Yannawa | 35.9 |
| Dusit | 35.9 |
| Bang Kapi | 28.7 |
| Bangkok Noi | 24.6 |
| Phasi Charoen | 24.6 |

- Compost production benefit

Production of compost from solid waste contributes to resource recovery and restoration, and the use of compost will make the permanent disposal of solid waste possible. In this section, the benefit of compost production in the following two method is discussed. (Ref. Appendix 6.5)

- Evaluation of the chemical composition of the compost product
- Production cost of fertilizer similar to the existing compost product

1) Evaluation of the chemical composition of compost

Based on the investigation of chemical composition at the Nong Khaem compost plant, evaluation of existing compost product was made. From the results, components of N-P-K of the Nong Khaem compost product were

0.92 - 1.04 - 1.06 and the Ca of the same was 7.74 percent. By conversion of these components in the compost product to the market price of chemical fertilizer, the equivalent compost price was determined as 410 Baht per ton. (Appendix 6.6)

Increase in agricultural productivity due to use of the compost product is included in the selling price of the compost; therefore, this benefit was excluded from benefit calculation in this study.

Total benefit from use of the compost product was calculated by subtracting effect of the fertilizing components by the transport cost of the compost product and labor cost for sowing the compost.

Transport cost of the compost product was based on the transport cost data of existing compost product (90 Baht). The labor cost of sowing the compost was determined to be 74 Baht from the difference between labor cost of sowing compost (86 Baht/t) and the labor cost of sowing chemical fertilizer (12 Baht/t). (Appendix 6.7) Consequently, the benefit evaluated from the comparison with chemical fertizer was calculated by the following formula.

$$410 - (90 + 74) = 246 \text{ Baht/t}$$

2) Production cost of similar fertilizer (farm compost)

From the viewpoint of the quality and characteristics of the compost, farm compost (such as rice plants and barnyard manure) is similar to the compost from solid waste. In this paragraph, the time required to produce farm compost was converted to cost, which was thought equivalent to benefit of compost.

The process to produce the farm compost includes collection of materials, transport and turn over the materials. From the estimation of the time required to carry out these work items and of the working efficiency of labor, the total processing cost of farm compost was estimated to be 235 Baht/t. (Appendix 6.8)

Other expenses such as transport cost which is expected to be 5 percent of the total processing cost was added to the processing cost. Thus, the total production cost of farm compost was calculated by the following formula:

$$235 + (235 \times 0.05) = 247 \text{ Baht/t}$$

Based on result 1) and 2) above, the benefit of producing compost was determined to be 250 Baht/t. Annual benefit from compost products is shown in Appendix 6.2.

. Benefit from retrieved ferrous metal

Tonnage of retrieved ferrous metal at the existing compost plant was 3,675 tons in 1980 (Approximately 10 tons per day). In the future, after establishment of additional compost plants at Bang Khun Tian and Taling Chan, retrieved volume of ferrous metal will increase about 30 percent over the existing tonnage : 4,745 t/year (Approximately 13 tons per day).

In Thailand, about 70 percent of demand for ferrous metal is satisfied by importation; therefore, retrieval of ferrous metal contributes not only to recovery of resources, but also reduction of the foreign exchange loss which occurs on importation of ferrous metal from abroad.

In addition, retrieval of ferrous metal at the stage of intermediate treatment will save cost compared with retrieval made at the stage of collection.

Estimation of benefit by rerieval of ferrous metal was based on the market price of ferrous metal in 1980; that is, the tendered price of retrieved ferrous metal from existing compost plant. The average tender price was 0.43 Baht/kg. This price reflects the economic cost of the ferrous metal in Thailand. Based on this price, annual benefit was estimated and the results are shown in Appendix 6.2.

. Ash for reclamation land

Ash from the incinerator will basically be used for overlay material at the landfill site together with compost residue. In Chapter 4, the necessary overlay volume was estimated to be 10 percent of the incoming solid waste volume. Therefore, if ash produced in the incineration plant is more than the demand of overlay volume, the ash can be used for land reclamation. Some investigation results indicate that the ground level of Bangkok is subsiding about 10 cm every year. Therefore, use of the ash for land reclamation will produce some benefits. Therefore, in this Study, the ash volume used for overlay of landfill was subtracted from the ash generation volume of every year and, for the rest ash volume, the effect in the case of being used as land reclamation material was evaluated.

The value of ash for land reclamation was calculated based on the price of soil in Bangkok, considering the leachate treatment cost which was subtracted from the value. Leachate treatment cost was estimated to be 15 Baht/$m^3$ based on the leachate treatment facilities construction, operation and maintenance costs. Since economic price of soil in Bangkok was calculated as 130 Baht/$m^3$, the benefit in use of ash as land reclamation material was estimated as follows:

$$130 - 15 = 115 \text{ Baht}/m^3$$

Applying this figure to the surplus ash volume by year, annual benefit was calculated and is shown in Appendix 6.2. In the case No. 9, there is no incineration plant considered, and the ash from the incinerator attached to existing compost plant will be used as overlay material at the landfill site; thus, no surplus ash or benefit from it can be expected.

iii) Indirect benefit

Indirect benefit which can be expected by adopting one of the proposed Master Plan alternatives is listed in Table 6.11 and Appendix 6.9. Some indirect benefit which is included in the environmental impact assessment is excluded from this paragraph.

Table 6.11 Indirect benefit by alternative case

| Indirect Benefit | Items | Case No. 9 | Case No. 13 | Case No. 19–(2) | Without-project case |
|---|---|---|---|---|---|
| Effect to the related industries | · Effect to local industries | Min. (Project cost is 11,309.1 million Baht.) | Max. (Project cost is 18,155.4 million Baht) | Med. (Project cost is 15,191.2 million Baht.) | Nil |
| | · Effect to the civil and archtectural material supplyers, commercial enterprises, etc. | Effective | Effective | Effective | Nil |
| Increase of opportunity of employment | · Employment efficiency<br>Total number of employee during construction. | Min.<br>(1,100,000 persons) | Max.<br>(4,600,000 persons) | Med.<br>(3,200,000 persons) | Hiring of retired employees only |
| | Total number of workers for operation during a period from 1983 to 2010. | (7,700 persons) | (6,300 persons) | (6,500persons) | |
| Rise of land cost | · The treatment and disposal system will be modernized and level of the sanitation system will be upgraded. | Nil | Nil<br>·Land cost at Bang Kapi and Phasi Charoen will rise owing to improvement of the infrastructure | Nil | Max.<br>Leachate, rank odor, dust and waste diffusion, etc. will cause decrease of the land cost |
| Improvement of safety and convenience by adoption of the solid waste management system | · Increase of the traffic safety and decrease of traffic congestion | Min. | Max.<br>· Convenience in the surrounding area owing to the improvement of infrastructure at Bang Kapi and Phasi Charoen incineration plants | Med. | Nil |
| Possibility to utilize the surplus heat from the incineration plant | · Hot water supply<br>· Air-conditioning | Not Available | Available | Available | Not Available |
| Improvement of moral of solid waste workers and residents | | Med. | Max. | Max. | Nil |

iv) Annual benefit flow

Based on the project implementation schedule which was determined in Chapter 5, annual direct benefit flow was established for each alternative case. Total benefit by each case is summarized in Table 6.12 and annual benefit flow is shown in Appendix 6.2.

Table 6.12 Total direct benefit by alternative case (1983-2010)

(Unit : million Baht)

| | | Case No. 9 | Case No. 13 | Case No. 19-(2) |
|---|---|---|---|---|
| Primary direct benefit | (15 m)* | 4,422.3 | 4,422.3 | 4,422.3 |
| | (3 m) | 21,980.0 | 21,980.0 | 21,980.0 |
| Secondary direct benefit | Electricity | - | 1,763.5 | 1,256.5 |
| | Compost** | 506.2 | 463.0 | 463.0 |
| | Ash | - | 464.5 | 289.3 |
| | Ferrous Metal | 46.6 | 43.6 | 43.6 |
| | Subtotal | 552.8 | 2,734.6 | 2,052.4 |
| Total direct benefit | (15 m) | 4,975.1 | 7,156.9 | 6,474.7 |
| | ( 3 m) | 22,532.8 | 24,714.6 | 24,032.4 |

* Parentheses indicate the height of landfill of a household garden

** Total benefit from compost products is not the same for every case because each implementation program is not same.

### 6.2.3 Economic cost

The total project cost for the economic analysis includes all of the solid waste management costs, as follows:

1. Facilities construction cost
2. Land acquisition cost
3. Operation and maintenance cost
4. Collection and transport cost
5. Solid waste collection truck purchase cost

(1) Facilities construction cost

Economic construction cost of each proposed facility was estimated in Chapter 5. Annual investment cost for the facilities was estimated after adding a contingency fee of 15 percent to this estimated cost and after considering the facilities construction schedule. In this estimation, following costs were included.

i) Construction cost of new incineration plant

ii) Construction cost of new compost plant

iii) Thorough repairs for existing compost plant (in the years 1990 and 2000)

iv) Construction cost of landfill sites

Total construction cost during the period 1983 to 2010 by case is summarized in Table 6.13.

Table 6.13 Total construction cost (1983-2010)

(Unit : million Baht)

| | *Case No. 9 | Case No. 13 | Case No. 19-(2) |
|---|---|---|---|
| Incineration Plant | - | 6,447.0 | 3,569.5 |
| New Compost Plant | 776.0 | 648.8 | 648.8 |
| Existing Compost Plant | 507.4 | 507.4 | 507.4 |
| Landfill | 1,371.4 | 787.6 | 1,009.7 |
| Total | 2,654.8 | 8,390.8 | 5,735.4 |

* Collection trucks parking lots were included. (127.2 million Baht)

(2) Land acquisition cost

Land acquisition costs for the following items were estimated.

i) Incineration plant

ii) New compost plant

iii) Landfill sites

Land acquisition cost for the landfill sites was considered until the year 2010 and annual land acquisition was estimated in accordance with landfill plan. Moreover, compensation and contingency cost of land acquisition were considered as 10 percent of economic land acquisition cost and 15 percent of the sum of economic land acquisition cost plus compensation cost, respectively. Total land acquisition cost during the 28 year project life (1983 - 2010) is summarized in Table 6.14 below.

Table 6.14 Total land acquisition cost (1983 - 2010)

(Unit : million Baht)

| | Case No. 9 | Case No. 13 | Case No. 19-(2) |
|---|---|---|---|
| Incineration plant | - | 353.3 | 417.1 |
| New compost plant | 138.2 | 72.0 | 72.0 |
| Landfill site | 281.5 | 42.1 | 114.7 |
| Total | 419.7 | 467.4 | 603.8 |

* Land acquisition cost for collection trucks parking lots are included in case No. 9. (66.2 million Baht)

(3) Operation and maintenance costs

Based on the operation and maintenance costs of each facility estimated in Chapter 5, annual operation and maintenance costs by case were estimated. The main items consist of personnel expenses, fuel and light expenses, water supply charges, parts and machinery cost and other items necessary to maintain and operate the facilities. Total operation and maintenance costs during 28 year project life (1983 - 2010) by case are summarized in Table 6.15.

Table 6.15 Total operation and maintenance costs (1983 - 2010)

(Unit : million Baht)

| | Case No. 9 | Case No. 13 | Case No. 19-(2) |
|---|---|---|---|
| Incineration plant | - | 2,371.3 | 1,570.8 |
| New compost plant | 474.6 | 329.4 | 329.4 |
| Existing compost plant | 3,020.4 | 3,020.4 | 3,020.4 |
| Landfill sites | 189.9 | 62.7 | 73.2 |
| Total | 3,684.9 | 5,783.8 | 4,993.8 |

(4) Solid waste collection, transport and collection-truck purchase cost

Based on the discussion in Section 6.2.1, the total solid waste collection transport and collection-truck purchase cost are summarized in table 6.16

Table 6.16 Solid waste collection, transport and truck purchase cost (1983 - 2010)

(Unit : million Baht)

| | Case No. 9 | Case No. 13 | Case No. 19-(2) |
|---|---|---|---|
| Collection & transport | 6,704.4 | 5,755.2 | 6,030.7 |
| Truck purchase | 1,441.4 | 1,173.0 | 1,230.3 |
| Total | 8,145.8 | 6,928.2 | 7,261.0 |

(5) Total project cost for economic analysis

Total project cost during the 28 year project life span (1983 - 2010) by case is summarized in Table 6.17 and annual cost flow is shown in Appendix 6.10. Annual benefit and cost flow is summarized and shown in Table 6.18.

Table 6.17 Total economic cost (1983-2010)

(Unit : million Baht)

| | Case No. 9 | Case No. 13 | Case No. 19-(2) |
|---|---|---|---|
| Construction cost*1 | 2,654.8 | 8,390.8 | 5,735.4 |
| Land Acq. cost | 419.7 | 467.4 | 603.8 |
| Oper. & Maint. cost | 3,684.9 | 5,783.8 | 4,993.8 |
| Collection and Transport cost | 6,704.4 | 5,755.2 | 6,030.7 |
| Truck purchase cost | 1,441.4 | 1,173.0 | 1,230.3 |
| General Management cost*2 | 1,774.6 | 1,906.8 | 1,838.2 |
| Subtotal | 16,679.8 | 23,477.0 | 20,432.2 |
| Salvage value*3 | - 612.4 | - 2,196.8 | - 1,110.3 |
| Total | 16,067.4 | 21,280.2 | 19,321.9 |

* 1 Including thorough repair cost for existing compost plant

* 2 15 percent of operation, maintenance, collection, transport and truck purchase cost

* 3 The salvage value after the year 2010 of new incineration plants, new compost plants and purchased collection trucks

Table 6.18 Cost-benefit flow by case

(Unit: million Baht)

| Project year | Fiscal year | Case No. 9 | | Case No. 13 | | Case No. 19-(2) | |
|---|---|---|---|---|---|---|---|
| | | Cost* | Benefit | Cost* | Benefit | Cost* | Benefit |
| 0 | 1983 | 379.1 | 411.8 | 417.1 | 411.8 | 403.1 | 411.8 |
| 1 | 1984 | 283.8 | 428.0 | 281.4 | 428.0 | 281.4 | 428.0 |
| 2 | 1985 | 305.7 | 447.3 | 352.0 | 447.3 | 352.5 | 447.3 |
| 3 | 1986 | 382.8 | 471.5 | 544.2 | 471.5 | 549.9 | 471.5 |
| 4 | 1987 | 366.6 | 497.1 | 576.2 | 497.1 | 575.4 | 497.1 |
| 5 | 1988 | 432.2 | 524.1 | 1,147.7 | 524.1 | 1,130.1 | 524.1 |
| 6 | 1989 | 355.0 | 551.1 | 1,018.2 | 551.1 | 1,018.2 | 551.1 |
| 7 | 1990 | 654.9 | 581.0 | 785.0 | 581.0 | 780.5 | 581.0 |
| 8 | 1991 | 484.6 | 609.2 | 484.6 | 654.0 | 556.9 | 654.0 |
| 9 | 1992 | 596.7 | 638.8 | 774.4 | 683.1 | 610.0 | 683.1 |
| 10 | 1993 | 744.7 | 671.4 | 1,792.0 | 711.2 | 1,295.9 | 711.2 |
| 11 | 1994 | 560.5 | 703.8 | 1,672.7 | 743.0 | 1,161.8 | 743.0 |
| 12 | 1995 | 610.4 | 737.6 | 809.5 | 776.2 | 673.9 | 776.2 |
| 13 | 1996 | 927.1 | 771.2 | 555.1 | 881.2 | 533.4 | 857.8 |
| 14 | 1997 | 504.4 | 814.6 | 890.8 | 917.5 | 680.9 | 893.8 |
| 15 | 1998 | 667.0 | 852.4 | 1,398.1 | 954.9 | 810.9 | 931.1 |
| 16 | 1999 | 532.6 | 889.9 | 1,301.0 | 995.6 | 685.7 | 972.2 |
| 17 | 2000 | 1,551.3 | 931.9 | 1,406.6 | 1,037.1 | 1,511.1 | 1,013.9 |
| 18 | 2001 | 564.9 | 962.0 | 618.8 | 1,107.3 | 610.8 | 1,051.9 |
| 19 | 2002 | 581.6 | 992.4 | 665.5 | 1,137.7 | 628.6 | 1,082.1 |
| 20 | 2003 | 593.7 | 1,023.9 | 686.3 | 1,169.2 | 644.3 | 1,113.4 |
| 21 | 2004 | 609.2 | 1,057.1 | 705.1 | 1,202.4 | 659.5 | 1,146.3 |
| 22 | 2005 | 621.3 | 1,090.9 | 720.8 | 1,236.0 | 672.3 | 1,179.7 |
| 23 | 2006 | 631.1 | 1,117.4 | 731.4 | 1,262.3 | 683.4 | 1,205.8 |
| 24 | 2007 | 663.4 | 1,145.8 | 766.5 | 1,290.5 | 710.7 | 1,233.7 |
| 25 | 2008 | 679.3 | 1,173.8 | 779.0 | 1,318.3 | 724.5 | 1,261.2 |
| 26 | 2009 | 689.8 | 1,203.0 | 792.0 | 1,347.3 | 736.1 | 1,289.9 |
| 27 | 2010 | 88.2 | 1,233.8 | -1,392.3 | 1,377.9 | -359.8 | 1,320.2 |

* Including land acquisition cost.

### 6.2.4 Economic analysis

(1) Methodology

The purpose of the economic analysis of this study is to verify the economic viability and rank the proposed Master Plan alternatives. Since the operation and maintenance cost of the proposed solid waste management system are tremendous compared with the capital investment cost, the B/C (Benefit-Cost ratio) and NPV (Net Present Value) methods were adopted for this study but the IRR method of analysis was not applied. In addition, indirect benefits were also considered in the overall economic evaluation.

(2) Base case

For economic analysis, the base case for costs and benefits was fixed as follows:

- Cost : Total project cost (including land acquisition cost)
- Benefit : Primary and secondary direct benefit (indirect benefits were excluded from B/C analysis)

In this analysis, the discount rates (i) were taken as 8%, 10% and 15% considering the opportunity cost of capital in Thailand.

(3) Results of analysis

Economic analysis results are summarized in the tables shown below.

i) B/C analysis

- In the case of 15 m height landfill at each household

| Case No. | Discount rate | | |
|---|---|---|---|
| | 8% | 10% | 15% |
| 9 | 0.32 | 0.31 | 0.31 |
| 13 | 0.28 | 0.27 | 0.24 |
| 19-(2) | 0.29 | 0.28 | 0.25 |

- In the case of 3 m height landfill at each household

| Case No. | Discount rate | | |
|---|---|---|---|
| | 8% | 10% | 15% |
| 9 | 1.44 | 1.42 | 1.39 |
| 13 | 1.04 | 1.00 | 0.95 |
| 19-(2) | 1.11 | 1.08 | 1.02 |

ii) NPV analysis

- In the case of 15 m height landfill at each household.

(Unit : NPV compared to base case)

| Case | Discount rate | | |
|---|---|---|---|
| | 8% | 10% | 15% |
| 9 | -3,714.9 | -3,109.7 | -2,136.2 |
| 13 | -5,797.3 | -4,983.9 | -3,556.1 |
| 19-(2) | -5,246.4 | -4,520.5 | -3,268.0 |

- In the case of 3 m height landfill at each household

(Unit : NPV compared to base case)

| Case No. | Discount rate | | |
|---|---|---|---|
| | 8% | 10% | 15% |
| 9 | 2,169.3 | 1,712.2 | 1,079.1 |
| 13 | 293.1 | 9.9 | - 221.5 |
| 19-(2) | 844.0 | 473.3 | 66.6 |

When the primary direct benefit is estimated based on the case of 15 m height landfill at each household, the benefit-cost ratio of every alternative case is under 1.0 and NPV is minus. These facts indicate that the economic indicators, under the assumption of 15 m height landfill at each household, do not show efficient return, therefore, it is not realistic assessment of individual value of the benefit by the 15 m landfill height. Based on this consideration, the economic evaluation of this study has been made only for the case of 3 meter landfill height.

(4) Sensitivity analysis

For the purpose of making the economic evaluation of the project, the magnitude of both cost and benefit elements were confirmed. In this analysis, the discount rate was set the same as in the base case; that is, 8%, 10% and 15%.

- Testing the magnitude of the benefit

  1) To the assumption that solid waste discharged from every household be disposed of as garden landfill, an addition was made that each household buy a small incinerator to reduce the landfill volume.

  2) Benefit estimation was made based on the electricity generated by a thermal-type power plant

- Testing the magnitude of the cost

  1) Project cost excluding land acquisition cost

i) Benefit for the case of applying a small incinerator for each household

To reduce the land acquisition of landfill to dispose the discharged solid waste from each household, it was assumed that each household would buy a small incinerator. The total cost then included both the land acquisition for landfill of incinerated ash and the purchase cost of a small incinerator.

An assumption was made that the volume-reducibility of the small incinerator was 20 percent. The conversion ratio of ash was determined as 1.0 $m^3/t$. The height of landfill at each household's garden was adopted as 3 m since 15 m is not realistic.

Purchase cost and the life of the small incinerator for each household were assumed as 100 Baht/kg.d and 2 years, respectively. Number of households in Bangkok by year was described in the Financial Analysis and based on the solid waste discharging unit per household estimated in Chapter 2, total purchase cost of the small incinerator in Bangkok was estimated. Based on the assumption that the execution of solid waste management enterprise will eliminate the cost for purchasing the small incinerator and land acquisition for ash, the benefit was examined as one case for the purpose of confirming its magnitude.

ii) Benefit for the case of thermal-type power plant

Instead of benefit from electricity generated by hydro-type power plant, the benefit was estimated based on thermal-type incineration plant. The thermal-type power plant facilities construction cost for a plant which has the equivalent electricity generation capacity as the generator attached to the proposed incineration plant is summarized in Table 6.19.

Table 6.19 Thermal-type power plant construction cost by generating capacity

(Unit : million Baht)

| | Construction cost |
|---|---|
| 6,200 kW plant | 220 |
| 5,100 kW plant | 180 |
| 4,500 kW plant | 160 |

Annual expenditure was estimated as the total cost of fuel (0.98 Baht/kW.h) for a thermal-type power plant plus the annual operating costs such as depreciation, interest, operation cost maintenance cost and general management cost (Appendices 6.11 and 6.12). The annual costs for each capacity is summarized in Table 6.20.

Table 6.20 Annual cost of electricity generation plant by capacity

(Unit : million Baht)

| | Annual sales volume of electricity (thousand kW.h) | Fuel cost | Other investment cost | Total |
|---|---|---|---|---|
| 6,200 kW plant | 43,099 | 42.2 | 25.9 | 68.1 |
| 5,100 kW plant | 35,741 | 35.0 | 21.2 | 56.2 |
| 4,500 kW plant | 31,189 | 30.6 | 18.8 | 49.4 |

Applying this data to each proposed incineration plant, annual benefit for each plant was estimated as shown in Table 6.21. Benefit from 1 kW.h electricity generation was estimated at about 1.6 Baht.

Table 6.21 Annual benefit for electricity generation in the case of thermal-type power plant

(Unit : million Baht)

| Incineration plant | Benefit |
|---|---|
| Yannawa | 68.1 |
| Dusit | 68.1 |
| Bang Kapi | 56.2 |
| Bangkok Noi | 49.4 |
| Phasi Charoen | 49.4 |

The benefit and cost stream for sensitivity analysis by year is shown in Table 6.22.

iii) Results of sensitivity analysis

a. Effect of small incinerator for households

The benefit-cost ratio for the assumption that every household buy a small incinerator was under 1.0 in every alternative case. Since it is not realistic to invest in a solid waste management enterprise where the benefit do not exceed the cost of the enterprise, this proposal was rejected. In addition, in this analysis, the environmental effect such as air pollution by a small incineration plant was not included.

b. Benefit for thermal-type power plant

In comparison with the hydro-type power plant, benefit from the thermal-type power plant increases the benefit-

Table 6.22 Benefit flow for sensitivity analysis

(Unit: million Baht)

| Project year | Fiscal year | Primary direct benefit | | Secondary direct benefit (Thermal-type power plant) | | | Total direct benefit | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Landfill of incineration ash | Small incinerator | Case No. 9 | Case No. 13 | Case No. 19-(2) | Case No. 9 | Case No. 13 | Case No. 19-(2) |
| 0 | 1983 | 99.4 | 269.4 | 14.3 | 14.3 | 14.3 | 383.1 | 383.1 | 383.1 |
| 1 | 1984 | 103.4 | 7.8 | 14.3 | 14.3 | 14.3 | 125.5 | 125.5 | 125.5 |
| 2 | 1985 | 108.3 | 282.9 | 14.3 | 14.3 | 14.3 | 405.5 | 405.5 | 405.5 |
| 3 | 1986 | 114.3 | 15.7 | 14.3 | 14.3 | 14.3 | 144.3 | 144.3 | 144.3 |
| 4 | 1987 | 120.7 | 296.8 | 14.3 | 14.3 | 14.3 | 431.8 | 431.8 | 431.8 |
| 5 | 1988 | 127.5 | 24.0 | 14.3 | 14.3 | 14.3 | 165.8 | 165.8 | 165.8 |
| 6 | 1989 | 134.2 | 305.1 | 14.3 | 14.3 | 14.3 | 453.6 | 453.6 | 453.6 |
| 7 | 1990 | 141.7 | 46.7 | 14.3 | 14.3 | 14.3 | 202.7 | 202.7 | 202.7 |
| 8 | 1991 | 148.7 | 313.7 | 14.3 | 91.3 | 91.3 | 476.7 | 553.7 | 553.7 |
| 9 | 1992 | 156.1 | 55.3 | 14.3 | 90.8 | 90.8 | 225.7 | 302.2 | 302.2 |
| 10 | 1993 | 163.5 | 323.1 | 17.4 | 89.4 | 89.4 | 504.0 | 576.0 | 576.0 |
| 11 | 1994 | 171.6 | 64.7 | 17.4 | 88.8 | 88.8 | 836.0 | 907.4 | 907.4 |
| 12 | 1995 | 180.1 | 350.8 | 17.4 | 88.2 | 88.2 | 548.3 | 619.1 | 619.1 |
| 13 | 1996 | 188.5 | 74.1 | 17.4 | 211.9 | 168.4 | 280.0 | 474.5 | 431.0 |
| 14 | 1997 | 197.6 | 359.8 | 24.3 | 211.7 | 167.9 | 581.7 | 769.1 | 725.3 |
| 15 | 1998 | 207.0 | 83.5 | 24.3 | 211.3 | 167.4 | 314.8 | 501.8 | 457.9 |
| 16 | 1999 | 216.4 | 369.6 | 24.3 | 211.4 | 167.9 | 610.3 | 797.4 | 753.9 |
| 17 | 2000 | 226.9 | 116.3 | 24.3 | 210.9 | 167.6 | 367.5 | 554.1 | 510.8 |
| 18 | 2001 | 234.4 | 378.8 | 24.3 | 278.9 | 178.6 | 637.5 | 892.1 | 791.8 |
| 19 | 2002 | 242.0 | 125.5 | 24.3 | 278.9 | 178.4 | 391.8 | 646.4 | 545.9 |
| 20 | 2003 | 249.9 | 388.0 | 24.3 | 278.9 | 178.2 | 662.2 | 916.8 | 816.1 |
| 21 | 2004 | 258.2 | 134.7 | 24.3 | 278.9 | 177.9 | 417.2 | 671.8 | 570.8 |
| 22 | 2005 | 266.7 | 426.3 | 24.3 | 278.7 | 177.5 | 717.3 | 971.7 | 870.5 |
| 23 | 2006 | 273.3 | 152.9 | 24.3 | 278.5 | 177.1 | 450.5 | 704.7 | 603.3 |
| 24 | 2007 | 280.4 | 435.8 | 24.3 | 278.3 | 176.6 | 740.5 | 994.5 | 892.8 |
| 25 | 2008 | 280.4 | 161.5 | 24.3 | 278.1 | 176.1 | 473.2 | 727.0 | 625.0 |
| 26 | 2009 | 294.7 | 445.3 | 24.3 | 277.9 | 175.6 | 764.3 | 1,017.9 | 915.6 |
| 27 | 2010 | 302.4 | 202.9 | 24.3 | 277.7 | 175.1 | 529.6 | 783.0 | 680.4 |

cost ratio approximately 3% to 5%. Since the benefit for a hydro-type power plant does not include the cost for transmission of electricity, this estimation is overstated to some degree. However, since the incineration plant will be constructed near the central area of Bangkok, it seems realistic to calculate the benefits by thermal-type power plant.

Thus, the economic evaluation will be done based on the thermal-type of incineration plant. Since Case No. 9 has no incineration plants, the benefit-cost ratio does not change in either the case of hydro or thermal-type incineration plant.

c. Without land acquisition case

Share of land acquisition cost among the total capital investment cost (construction cost plus land acquisition cost) in each alternative case (Case No. 9, No. 13, No. 19-(2)) was 13.7%, 5.2% and 9.5%, respectively. Benefit-cost ratio increased about 3.5% to 5% from the case of without land acquisition.

Economic evaluation is basically executed by "with land acquisition cost case" because the proposed facilities will be constructed in comparatively low land cost areas and the component of land acquisition cost in the total project cost is only about 3 percent.

d. In the analysis of NPV, the results indicate a similar tendency to benefit-cost ratio. Only in the case of landfill height being 3 m, there a plus NPV. In comparison with Case No. 9, NPV is reduced about 1,500 million Baht for Case No. 13 and 500 million Baht for Case No. 19-(2).

e. Based on these results of sensitivity analysis, the economic evaluation should be done for the case indicated in Table 6.23; that is, 3 m landfill height at each household, electricity generation by thermal-type power plant and inclusion of land acquisition cost.

(5) Economic viability

The results of economic analysis are summarized as follows:

i) Based on the assumptions for the estimate of benefit of solid waste management enterprise that discharge of solid waste will be made in the household garden and electricity generation will be calculated based on the case of thermal-type power plant, the benefit-cost ratio was more than 1.0 in almost all the cases except Case No. 13 with a discount rate of 15%.

Through this analysis, the economic viability of each proposed Master Plan alternative was proven.

ii) Alternative Case No. 9 has the highest B/C ratio among the proposed three appropriate Master Plan alternatives based on the limited benefits quantified.

Table 6.23 Sensitivity analysis (B/C·NPV)

| Sensitivity variable | | | | | | | | | | | | Results of magnitude analysis | | | | | | Adopted Case |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Primary direct benefit | | | | | Sec. direct benefit | | Cost | | Discount rate | | | B/C Ratio | | | NPV (million Baht) | | | |
| Self-disposal | | Solid waste | | Ash | | | | | | | | Case No. | | | Case No. | | | |
| Landfill | Incine-ration | 15 m | 3 m | 3 m | Hydro | Termal | Total | Excl. Land Acq. | 8% | 10% | 15% | 9 | 13 | 19-(2) | 9 | 13 | 19-(2) | |
| ○ | | ○ | | | ○ | | ○ | | ○ | | | 0.32 | 0.28 | 0.29 | Δ3,714.9 | Δ5,797.3 | Δ5,246.4 | |
| ○ | | ○ | | | ○ | | ○ | | | ○ | | 0.31 | 0.27 | 0.28 | Δ3,109.7 | Δ4,983.9 | Δ4,520.5 | |
| ○ | | ○ | | | ○ | | ○ | | | | ○ | 0.31 | 0.24 | 0.25 | Δ2,136.2 | Δ3,556.1 | Δ3,268.0 | |
| ○ | | | ○ | | ○ | | ○ | | ○ | | | 1.44 | 1.04 | 1.11 | Δ2,375.4 | 293.1 | 844.0 | |
| ○ | | | ○ | | ○ | | ○ | | | ○ | | 1.42 | 1.00 | 1.08 | 1,884.1 | 9.9 | 473.3 | |
| ○ | | | ○ | | ○ | | ○ | | | | ○ | 1.39 | 0.95 | 1.02 | 1,198.4 | Δ221.5 | 66.6 | |
| ○ | | ○ | | | ○ | | | ○ | ○ | | | 0.33 | 0.29 | 0.30 | Δ3,519.1 | Δ5,495.5 | Δ4,882.9 | |
| ○ | | ○ | | | ○ | | | ○ | | ○ | | 0.33 | 0.28 | 0.29 | Δ2,944.5 | Δ4,708.8 | Δ4,193.4 | |
| ○ | | ○ | | | ○ | | | ○ | | | ○ | 0.32 | 0.26 | 0.27 | Δ2,024.7 | Δ3,332.5 | Δ3,009.5 | |
| ○ | | | ○ | | ○ | | | ○ | ○ | | | 1.49 | 1.08 | 1.17 | 2,571.3 | 594.8 | 1,207.5 | |
| ○ | | | ○ | | ○ | | | ○ | | ○ | | 1.47 | 1.04 | 1.14 | 2,049.3 | 285.0 | 800.5 | |
| ○ | | | ○ | | ○ | | | ○ | | | ○ | 1.44 | 1.00 | 1.08 | 1,309.9 | 2.1 | 325.1 | |
| ○ | | ○ | | | | ○ | ○ | | ○ | | | 0.32 | 0.33 | 0.33 | Δ3,714.9 | Δ5,390.0 | Δ4,952.4 | |
| ○ | | ○ | | | | ○ | ○ | | | ○ | | 0.31 | 0.31 | 0.31 | Δ3,109.7 | Δ4,686.4 | Δ4,301.8 | |
| ○ | | ○ | | | | ○ | ○ | | | | ○ | 0.31 | 0.27 | 0.28 | Δ2,136.2 | Δ3,411.6 | Δ3,157.0 | |
| ○ | | | ○ | | | ○ | ○ | | ○ | | | 1.44 | 1.09 | 1.15 | 2,375.4 | 700.3 | 1,137.9 | ○ |
| ○ | | | ○ | | | ○ | ○ | | | ○ | | 1.42 | 1.05 | 1.11 | 1,884.1 | 307.5 | 692.0 | ○ |
| ○ | | | ○ | | | ○ | ○ | | | | ○ | 1.39 | 0.98 | 1.04 | 1,198.4 | Δ77.0 | 177.6 | ◎ |
| ○ | | ○ | | | | ○ | | ○ | ○ | | | 0.33 | 0.35 | 0.35 | Δ3,519.1 | Δ5,088.3 | Δ4,588.9 | |
| ○ | | ○ | | | | ○ | | ○ | | ○ | | 0.33 | 0.32 | 0.33 | Δ2,944.5 | Δ4,411.2 | Δ3,974.6 | |
| ○ | | ○ | | | | ○ | | ○ | | | ○ | 0.32 | 0.29 | 0.30 | Δ2,024.7 | Δ3,188.0 | Δ2,898.5 | |
| ○ | | | ○ | | | ○ | | ○ | ○ | | | 1.49 | 1.13 | 1.21 | 2,571.3 | 1,002.0 | 1,501.4 | |
| ○ | | | ○ | | | ○ | | ○ | | ○ | | 1.47 | 1.09 | 1.17 | 2,049.3 | 582.6 | 1,019.2 | |
| ○ | | | ○ | | | ○ | | ○ | | | ○ | 1.44 | 1.03 | 1.11 | 1,309.9 | 146.6 | 436.1 | |
| | ○ | | | ○ | ○ | | ○ | | ○ | | | 0.82 | 0.62 | 0.66 | Δ996.7 | Δ3,077.8 | Δ2,528.7 | |
| | ○ | | | ○ | ○ | | ○ | | | ○ | | 0.82 | 0.60 | 0.64 | Δ840.3 | Δ2,713.6 | Δ2,251.4 | |
| | ○ | | | ○ | ○ | | ○ | | | | ○ | 0.82 | 0.58 | 0.61 | Δ555.5 | Δ1,974.8 | Δ1,687.3 | |
| | ○ | | | ○ | | ○ | ○ | | ○ | | | 0.82 | 0.67 | 0.70 | Δ996.7 | Δ2,673.5 | Δ2,236.0 | |
| | ○ | | | ○ | | ○ | ○ | | | ○ | | 0.82 | 0.64 | 0.67 | Δ840.3 | Δ2,418.3 | Δ2,033.7 | |
| | ○ | | | ○ | | ○ | ○ | | | | ○ | 0.82 | 0.61 | 0.64 | Δ555.5 | Δ1,831.5 | Δ1,576.9 | |
| | ○ | | | ○ | ○ | | | ○ | ○ | | | 0.85 | 0.64 | 0.69 | Δ800.8 | Δ2,776.1 | Δ2,165.2 | |
| | ○ | | | ○ | ○ | | | ○ | | ○ | | 0.85 | 0.63 | 0.67 | Δ675.1 | Δ2,438.4 | Δ1,924.3 | |
| | ○ | | | ○ | ○ | | | ○ | | | ○ | 0.85 | 0.61 | 0.65 | Δ444.0 | Δ1,751.2 | Δ1,428.8 | |
| | ○ | | | ○ | | ○ | | ○ | ○ | | | 0.85 | 0.69 | 0.73 | Δ800.8 | Δ2,371.8 | Δ1,872.4 | |
| | ○ | | | ○ | | ○ | | ○ | | ○ | | 0.85 | 0.67 | 0.71 | Δ675.1 | Δ2,143.1 | Δ1,706.6 | |
| | ○ | | | ○ | | ○ | | ○ | | | ○ | 0.85 | 0.64 | 0.68 | Δ444.0 | Δ1,607.9 | Δ1,318.4 | |

iii) In accordance with the analyzed results of sensitivity analysis, the benefit-cost ratio will increase by exclusion of land acquisition cost about 3.5% in the Case No. 9 and No. 13, and 5% in the Case No. 19-(2). The reason for this difference is that in the Case No. 19-(2), two incineration plants will be constructed near the city center and land acquisition cost in the area is higher than the costs for plants at other locations.

iv) For reference, benefit-cost ratio for the existing solid waste management system (without-project) was estimated; that is, using the three existing compost plants and three existing landfill sites and achieving the same solid waste collection ratio as proposed in Master Plan alternatives (in the year 2000: 97%). Primary direct benefit was estimated for 3 m landfill height of household waste including land acquisition cost. The results are shown in the Table 6.24 below.

Table 6.24 Benefit-Cost ratio in without-project case

| Discount rate | 8% | 10% | 15% |
|---|---|---|---|
| B/C | 1.53 | 1.51 | 1.48 |

The benefit-cost ratios of the without-project case are higher than that of the proposed three Master Plan alternatives since only quantifiable benefits and costs were considered. Hence, for the determination of project viability for this type of sanitation project from the viewpoint of national economy, additional consideration should be made for environmental influence as described in Chapter 7 since these effects will last over the entire project life span.

v) For the economic analysis of the solid waste management project which involves the environmental economy, evaluation should be made not only by the quantifiable direct benefits and costs but also include the influence of indirect benefit. The final decision should be made from the viewpoint of social economy and long-term influence of the proposed project.

In this sense, in order to establish the optimum solid waste management system, it is necessary to execute a comprehensive evaluation which includes environmental impact assessment and technology evaluation which are described in Chapter 8.

## 6.3 Financial Analysis

From the financial point of view, a solid waste management project is difficult to be self-supporting in constrast to a tollway project; therefore, based on the solid waste collection fee and the revenue generated by the sale of retrieved materials, analysis was made whether the financial viability of the project is good or not from the viewpoint of existing and future available planning funds of BMA and BOS.

### 6.3.1 Investment cost and financing plan

(1) Annual fixed investment costs

Annual fixed investment costs were calculated applying the method mentioned below. The investment costs include land acquisition cost.

i) Incineration plant

The period needed for construction of an incineration plant was estimated to be 68 months for the first plant construction, and 64 months for the succeeding plants since experience obtained through the first plant construction was thought to contribute to shorten the time needed for succeeding preparation of the implementation plan and the detailed design.

- The first plant construction -

- Land acquisition cost ..... The first year 20%, the second year 80%
- Land reclamation & access road construction cost ..... The second year 20%, the third year 80%
- The main facilities construction cost ..... The third year 10%, the forth year 40%, the fifth year 40% and the sixth year 10%
- The external facilities construction cost ..... The sixth year 100%

- The succeeding plant construction -

- Land acquisition cost ..... The second year 100%
- Land reclamation & access road construction cost ..... The second year 20%, the third year 80%
- The main facilities construction cost ..... The third year 10%, the fourth year 40%, the fifth year 40%, the sixth year 10%
- The external facilities construction cost ..... The sixth year 100%

ii) New compost plant

A period needed for construction of a new compost plant was estimated 42 months for the smaller plant in Bang Khun Tian and 48 months for the larger plant in Taling Chan.

- Bang Khun Tian plant -
  - Land acquisition cost ..... The first year 60%, the second year 40%
  - Land reclamation & access road construction cost ..... The second year 70%, the third year 30%
  - The main facilities construction cost ..... The third year 50%, the fourth year 50%
  - The external facilities construction cost ..... The fourth year 100%
- Taling Chan plant -
  - Land acquisition cost ..... The first year 100%
  - Land reclamation & access road construction cost ..... The first year 30%, the second year 70%
  - The main facilities construction cost ..... The second year 10%, the third year 40%, the fourth year 50%
  - The external facilities construction cost ..... The fourth year 100%

iii) Final disposal site

Construction of facilities in the existing final disposal sites On-Nooch and Nong Khaem was assumed to be implemented every five years starting from fiscal 1983. Facilities needed in the period from the year 2001 to 2010 were assumed to be constructed in the year 2000. As for construction of new final disposal facilities at Ram Intra, the land acquisition and planning of the facilities would be made in fiscal 1986 and the construction would be carried out in the following year. The facilities attached to Ram Intra plant were planned to be constructed in accordance with progress of construction of other final disposal sites.

iv) Major repair of the existing compost plant

In order to maintain the normal operation, major repair of the existing compost plant was assumed to be implemented in fiscal 1990 and 2000.

As the result, the annual fixed investment costs were calculated as shown in table 6.25. The annual flow of fixed investment costs by facilities are shown in Appendix 6.13.

Table 6.25 Annual fixed investment costs

(Unit : million Baht)

| | Appropriate Master Plan alternatives | | |
|---|---|---|---|
| | No. 9 | No. 13 | No. 19-(2) |
| 1983 | 134.6 | 170.4 | 155.1 |
| 1984 | — | — | — |
| 1985 | — | 75.6 | 75.6 |
| 1986 | 81.7 | 340.9 | 349.7 |
| 1987 | 51.0 | 289.3 | 288.3 |
| 1988 | 117.7 | 941.9 | 922.8 |
| 1989 | 23.2 | 797.4 | 797.4 |
| 1990 | 337.7 | 498.6 | 494.0 |
| 1991 | 119.3 | 198.5 | 317.7 |
| 1992 | 237.3 | 426.1 | 240.3 |
| 1993 | 414.4 | 1,576.3 | 1,004.9 |
| 1994 | 100.1 | 1,390.6 | 796.5 |
| 1995 | 145.4 | 386.3 | 230.0 |
| 1996 | 575.0 | 83.1 | 53.1 |
| 1997 | — | 438.5 | 218.9 |
| 1998 | 164.8 | 966.1 | 300.7 |
| 1999 | — | 836.4 | 145.4 |
| 2000 | 1,017.5 | 888.2 | 1,033.4 |
| Total | 3.519.7 | 10.299.2 | 7,423.8 |

(2) Financing plan

i) Facilities construction fund

The following conditions were applied as means to raise fund for the facilities construction.

a. For the existing compost plant, the total amount of major repair cost was assumed to be financed from BMA's own fund.

b. For construction of the facilities, excluding the cost for major repair of the existing compost plant, exactly 20% of total cost was assumed to be financed by BMA's own funds. The foreign currency portion except the study and design fees in construction of incineration plant and a little foreign currency in construction of final disposal site and parking lots involved in Case No. 9 were assumed to be financed by overseas financial agencies. The rest of total construction cost was assumed to be financed by the local commercial banks.

As a result, the means of raising the facilities construction funds in each appropriate Master Plan alternative were planned as follows (Ref. Tables 6.26 ∿ 6.29):

- In Case No.9,

  The total construction cost of Case No.9 is 3,519.7 million Baht, 1,159.3 million Baht of which is planned to be financed by BMA's own funds, 268.9 million Baht by overseas financial agencies and the balance of 2,091.5 million Baht by the commercial banks in the country.

- In Case No. 13,

  The total construction cost of Case No. 13 is 10,299.2 million Baht, 2,515.2 million Baht of which is planned to be financed by BMA's own funds, 5,622.1 million Baht by overseas financial agencies and the balance of 2,161.9 million Baht by the commercial banks in the country.

- In Case No. 19-(2),

  The total construction cost of Case No. 19-(2) is 7,423.8 million Baht, 1,940.1 million Baht of which is planned to be financed by BMA's own funds, 3,182.3 million Baht by overseas financial agencies and the balance of 2,301.4 million Baht by the commercial banks in the country.

  The annual funding plan by the financial source is shown in Appendix 6.15.

The loan conditions were assumed as follows;

- For the loans from overseas financial agencies,
  - rate of interest : 3% per annum
  - the terms of repayment : 30 years with a ten-year grace period
- For the loans from the local commercial banks,
  - rate of interest : 15% per annum
  - the terms of repayment : 10 years after the final loan is made.

ii) Working capital

Working capital of each appropriate Master Plan alternative was estimated on the basis of the following assumptions:

Materials (chemicals, etc.) and products (compost and ferrous metal) equivallent to one month's supply are stocked. Compost equivallent to two months product is secured as work in process. An equivallent amount to one month operation cost is assumed as cash in hand.

There is no accounts receivable or payable as the payment was assumed to be made by cash.

Table 6.26 Fixed investment costs (Case No. 9)

(Unit: million Baht)

| Facility | Foreign currency | Local currency | Total |
|---|---|---|---|
| Fixed investment costs | | | |
| 1. Compost plant | 268.9 | 552.7(115.4) | 821.6 |
| (a) Bang Khun Tian | 97.2 | 195.7( 38.6) | 292.9 |
| (b) Taling Chan | 171.7 | 357.0( 76.8) | 528.7 |
| 2. Landfill site | 84.3 | 1,805.4(450.3) | 1,889.7 |
| (a) On-Nooch | 34.9 | 866.6(292.2) | 901.5 |
| (b) Nong Khaem | 34.3 | 641.2( 82.2) | 675.5 |
| (c) Ram Intra | 15.1 | 297.6( 75.9) | 312.7 |
| 3. Parking lot | 6.2 | 233.0(105.5) | 239.2 |
| (a) Yannawa | 3.1 | 136.9( 71.2) | 140.0 |
| (b) Bangkok Noi | 3.1 | 96.1( 34.3) | 99.2 |
| 4. Major repair of the existing compost plant | 373.4 | 195.8( - ) | 569.2 |
| Total | 732.8 | 2,786.9(671.2) | 3,519.7 |

Note: Parentheses indicate land acquisition costs.

Table 6.27 Fixed investment costs (Case No. 13)

(Unit: million Baht)

| Facility | Foreign currency | Local currency | Total |
|---|---|---|---|
| Fixed investment costs | | | |
| 1. Compost plant | 268.9 | 552.7(115.4) | 821.6 |
| (a) Bang Khun Tian | 97.2 | 195.7( 38.6) | 292.9 |
| (b) Taling Chan | 171.7 | 357.0( 76.8) | 528.7 |
| 2. Incineration plant | 5,368.0 | 2,640.5(565.0) | 8,008.5 |
| (a) Yannawa | 1,460.4 | 961.4(354.8) | 2,421.8 |
| (b) Bangkok Noi | 1,301.3 | 613.2(136.0) | 1,914.5 |
| (c) Bang Kapi | 1,304.9 | 554.1( 51.5) | 1,859.0 |
| (d) Phasi Charoen | 1,301.4 | 511.8( 22.7) | 1,813.2 |
| 2. Landfill site | 52.3 | 847.6( 67.5) | 899.9 |
| (a) On-Nooch | 19.6 | 294.0( - ) | 313.6 |
| (b) Nong Khaem | 23.7 | 387.0( 23.4) | 410.7 |
| (c) Ram Intra | 9.0 | 166.6( 44.1) | 175.6 |
| 4. Major repair of the existing compost plant | 373.4 | 195.8( - ) | 569.2 |
| Total | 6,062.6 | 4,236.6(747.9) | 10,299.2 |

Note: Parentheses indicate land acquisition costs.

Table 6.28 Fixed investment costs (Case No. 19-(2))

(Unit: million Baht)

| Facility | Foreign currency | Local currency | Total |
|---|---|---|---|
| Fixed investment costs | | | |
| 1. Compost plant | 268.9 | 552.7(115.4) | 821.6 |
| (a) Bang Khun Tian | 97.2 | 195.7( 38.6) | 292.9 |
| (b) Taling Chan | 171.7 | 357.0( 76.8) | 528.7 |
| 2. Incineration plant | 2,920.8 | 1,863.4(667.3) | 4,784.2 |
| (a) Yannawa | 1,460.4 | 961.4(354.8) | 2,421.8 |
| (b) Dusit | 1,460.4 | 902.0(312.5) | 2,362.4 |
| 3. Landfill site | 65.2 | 1,183.6(183.5) | 1,248.8 |
| (a) On-Nooch | 26.0 | 490.2( 86.3) | 516.2 |
| (b) Nong Khaem | 28.6 | 493.0( 45.0) | 521.6 |
| (c) Ram Intra | 10.6 | 200.4( 52.2) | 211.0 |
| 4. Major repair of the existing compost plant | 373.4 | 195.8( - ) | 569.2 |
| Total | 3,628.3 | 3,795.5(966.2) | 7,423.8 |

Note: Parentheses indicate land acquisition costs.

Table 6.29 Source of finance

(Unit: million Baht)

| Source of finance | | Case No. 9 | Case No. 13 | Case No. 19-(2) |
|---|---|---|---|---|
| BMA's fund or subsidy | Foreign currency | 373.4 | 373.4 | 373.4 |
| | Local currency | 785.9 | 2,141.8 | 1,566.7 |
| | Total | 1,159.3 | 2,515.2 | 1,940.1 |
| Foreign loan (Foreign currency) | | 268.9 | 5,622.1 | 3,182.3 |
| Local loan (Local currency) | | 2,091.5 | 2,161.9 | 2,301.4 |
| Subtotal (Local currency) | | 3,250.8 | 4,677.1 | 4,241.5 |
| Total | | 3,519.7 | 10,299.2 | 7,423.8 |

Accordingly, as increase of the operation cost, working capital requirements also increases so that, in the year 2010, they reach the following (Ref. Table 6.30):

| | million Baht |
|---|---|
| Case No. 9 | 69.4 |
| Case No. 13 | 79.8 |
| Case No. 19-(2) | 74.1 |

The working capital will be loaned from the local commercial banks with a 15% per annum rate of interest.

Table 6.30 Working capital requirements

| Case No. | Year | | | |
|---|---|---|---|---|
| | 1983 | 1990 | 2000 | 2010 |
| 9 | 25.4 | 35.8 | 57.1 | 69.4 |
| 13 | 25.2 | 34.8 | 59.7 | 79.8 |
| 19-(2) | 25.2 | 34.8 | 57.1 | 74.1 |

The management cost is assumed to be financed from the revenue of solid waste management and the rest from BMA's fund.

### 6.3.2 Revenue plan

(1) BMA revenue

BMA revenue in fiscal 1980 was 3,340 million Baht, 79.4% of which was shared by general revenue (mainly tax revenue) and the rest (20.6%) by special revenue composed of accumulated funds and subsidy. Tax revenue shared more than 80% of general revenue. Taxes are all indirect taxes; there is no direct tax system. Three main sources of tax revenue are business tax, vehicle tax, and household and land tax which share about 90% of the total tax revenue. 531 million Baht of special revenue in fiscal 1980 was subsidy, most of which was allocated to elementary education: no subsidy was given to public utility facilities except 8 million Baht for construction and maintenance of roads and bridges.

Elasticity of BMA revenue to GPP of Bangkok city (1974 ∿ 1979) was calculated to be 0.95. This figure agrees with the hypothesis that the elasticity may be around one since BMA revenue mainly consists of indirect taxes.

Based on the hypotheses, BMA revenue is assumed to grow at the same rate as GPP: in the year 2000, it may become more than 3.5 times as large as that in 1980 and, in the year 2010, nearly 5.5 times as large. (Ref. Table 6.31)

Table 6.31 Forecast of BMA revenue

(Unit : million Baht. 1980 constant prices)

| Year | Annual Revenue |
|---|---|
| 1980 | 3,339.625 - |
| 1985 | 4,929.760 (8.1) |
| 1990 | 6,946.620 (7.1) |
| 1995 | 9,122.060 (5.6) |
| 2000 | 11,753.620 (5.2) |
| 2010 | 18,253.010 (4.5) |

Note: parentheses indicate average annual growth rate

(2) Cost for solid waste management

A total cost spent for solid waste management and its relating activities in fiscal 1980 was 351 million Baht, 9% of BMA's annual expenditure (3,911 million Baht) (Ref. Appendix 6.14). Of the total cost for solid waste management 93.3% (328 million Baht) was earned from tax and only 6.7% was raised from solid waste management revenue such as collection fee, compost sales, and recovered ferrous metal sales. Thus, solid waste management can be said to be a low revenue enterprises based on its revenue/cost ratio.

Solid waste management cost is composed of collection and transportation cost (66.2%), treatment and disposal cost including cost for compost secondary treatment (31.9%), and the rest (1.9%) general management cost. Cost for compost secondary treatment in fiscal 1980 included 16 million Baht of subsidy given by BMA for construction of facilities. Therefore, the net percentage of compost sales revenue in the ordinary expenditure excluding the subsidy was 56.5%. (Ref. Table 6.32)

Table 6.32 Cost and revenue of solid waste management

(Unit : Baht)

| Cost | | Revenue | |
|---|---|---|---|
| General management cost | 6,609,276 | Collection fee | 14,206,631 |
| Collection & transportation | 232,565,927 | Compost sales | 7,692,768 |
| (Bureau of sanitation | 15,769,200) | Recovered ferrous metal sales | 1,583,337 |
| (Districts | 132,402,840) | Total | 23,482,736 |
| (Canals cleaning cost | 37,288,600) | | |
| (Collection trucks purchase cost | 6,630,337) | | |
| (Collection trucks | 40,474,950) | | |
| Treatment and disposal cost | 82,551,430 | | |
| Compost secondary treatment cost | 29,720,500 | | |
| Total | 351,447,133 | | |

(3) Revenue from solid waste collection fees

In fiscal 1980, a total of 14,206,631 Baht of solid waste collection fees was collected from 97,752 household which is only 11.8% of the total number of households (825,011) in Bangkok city, whereas 1,966 t/d of solid waste - equivalent to 82.6% of the total generation volume in Bangkok city - was collected.

To increase of revenue, an increase in the fee collection rate should be implemented before any other measure. As for the solid waste collection fee itself, some people assert that it should be increased since it has been fixed at a low rate for a long time even though solid waste management cost has been increasing. Compared with other public utilities charges such as electricity and water supply, however, solid waste collection fees cannot be said to be too low. (Ref. Table 6.33) Accordingly, in forecasting revenue from solid waste collection fees, the current fee rate was taken as the calculation basis. The fee collection rate was assumed in the forecast to reach to hundred percent by the year 2000, that is to say, the collection fees can be collected from all households who benefit from solid waste collection.

Table 6.33 Public utilities charges

| Public utility | Charge |
|---|---|
| Solid waste collection Fee (20 L/d or less) | 4 Baht/month |
| Electricity (minimum charge) | 5 Baht/month |
| Water supply (no more than 6 $m^3$/month) | Free |

Source : Public Health Act, MEA, MWWA.

The revenue from the collection fee is estimated to grow at the rate of 14.4% per annum and due to an increase in the number of pay households reach to 209,090 thousand Baht in the year 2000. From the year 2000 onwards, increase in the revenue will be proportional to increase the number of household (Ref. Table 6.34).

Table 6.34 Forecast of solid waste collection fee revenues

| Year | No. of household paying collection fee | Collection fee revenues (thousand Baht) |
|---|---|---|
| 1980 | 97,752 | 14,207 |
| 1985 | 192,000 | 27,840 |
| 1990 | 375,000 | 54,375 |
| 1995 | 736,000 | 106,720 |
| 2000 | 1,442,000 | 209,090 |
| 2005 | 1,613,000 | 233,885 |
| 2010 | 1,781,000 | 258,245 |

(4) Revenue from compost sales

Revenue from compost sales in fiscal 1980 was 7,692,768 Baht. Assuming that the stock volume was constant throughout the year, compost sold in fiscal 1980 was estimated at 16,507 tons; the average sales price of compost was 466 Baht per ton. At present, nearly the total volume of the processed compost for-sale was said to be sold out. Since the demand for compost has expanded in the 1970's at an annual growth rate of 11% (Ref. Table 6.35), it seems reasonable to expand compost sales up to approximately 90,000 tons per annum by the year 2000, provided that the compost price is reduced to about 300 Baht/t so as to balance with the expected benefit.

Table 6.35 Estimated compost sales volume

| Year | Tonnage (t/year) | Annual growth rate |
|---|---|---|
| 1970 | 5,657 | |
| 1975 | 10,199 | 12.5% |
| 1980 | 16,507 | 10.1% |
| 2000 | 89,425 | 8.8% |

Full operation of the existing compost plants will bring in 15,659 thousand Baht per year of compost sales revenue to BMA. In addition, operation of two more new compost plants (Bang Khun Tian and Taling Chan) will earn another 11,169 thousand Baht per year. Therefore, 26,828 thousand Baht per year in total of compost sales revenue can be expected when all the plants commence full operation. (Ref. Table 6.36)

Table 6.36 Compost sales

| Plant | Production capacity under normal operation (t/d) | Revenue (thousand Baht/year) |
|---|---|---|
| The existing plant | 143 | 15,659 |
| Newly established plant | 102 | 11,169 |
| Bang Khun Tian | 33 | 3,614 |
| Taling Chan | 69 | 7,556 |

(5) Revenue from sales of recovered ferrous metal

Ferrous metal recovered in four compost plants in fiscal 1980 was 3,675 tons, which was sold at auctions with an average sales price of 0.43 Baht/kg. Revenue from sales of recovered ferrous metal in fiscal 1980 was 1,583,337 Baht.

There are about 50 steelworks in Thailand: five electric furnace plants with the total production capacity of 500,000 tons per year, eleven major steel mills containing the above electric furnace plants and about 40 medium and minor steel mills. The electric furnace plants produce steel ingot mainly from scrap iron using pig iron as auxiliary material. Their steel production volume in 1979 was estimated about 600,000 tons. Steel mills produce steel products such as bars and wire from scrap iron. Volume of scrap iron used for steel production in 1979 was estimated to be about 400,000 tons.

Owing to establishment of two more compost plants in Bang Khun Tian and Taling Chan, the tonnage of recovered ferrous metal will be increased to 4,745 tons per year. Based on the present consumption volume of scrap iron (about 400,000 tons a year), there will be a market for the sale of scrap iron recovered in the compost plants. To formulate the revenue, the price of recovered ferrous metal in fiscal 1980 (0.43 Baht/kg) was taken, although the price fluctuates according to the relation between demand and supply of steel products. As a result, the revenue from the recovered ferrous metal in the year 2000 was estimated to be 2,040 thousand Baht. (Ref. Table 6.37)

Table 6.37 Sales of recovered ferrous metal

| Year | Sales tonnage (t) | Revenue (thousand Baht) |
|---|---|---|
| 1980 | 3,675 | 1,583 |
| 2000 | 4,745 | 2,040 |

(6) Revenue from power supply

Power (electricity) supply system in Thailand is maintained by three different authorities: Electricity Generating Authority of Thailand (EGAT) takes charge of power generation and transmission up to the primary transformer substation, then Metropolitan Electricity Authority (MEA) or Provincial Electricity Authority (PEA) handles the further transmission and delivery to the consumers.

Annual growth rate of power consumption in the period from 1974 to 1978 was 11.2% during which power consumption levelled off due to the influence of the first oil crisis.

PEA presently endeavours to extend the power delivery network in rural districts since electrification in these districts has been achieved in only 20% of the area. The progress of the power consumption in the rural districts should expand with the progress of electrification. In the urban areas also, economic development may stimulate higher growth of power consumption.

A forecast by EGAT indicates that the peak power generation volume will reach to 7,534 MW in 1993 and that an average power generation volume of the same year will be 45,585 GW.h (Ref. Table 6.38). To satisfy this forecast demand, development of new power supply sources by 1993 is needed. These new sources should be capable of generating 5,117 MW as the peak generation volume and 30,831 GW.h as an average generation volume per year. Power generation by solid waste incineration plant may contribute a bit to satisfy this demand.

Table 6.38 Forecast of total generation requirements

| Year | Energy generation (GW.h) | Peak generation (MW) |
|---|---|---|
| 1980 | 14,754 | 2,417 |
| 1985 | 25,252 | 4,195 |
| 1990 | 37,211 | 6,150 |
| 1993 | 45,585 | 7,534 |

Source : System planning division, EGAT (July 1981)

Power generation capacity of the planned incineration plant is 157 ∿ 162 kW.h per ton of solid waste incineration. Deducting the part consumed in the plant, salable power out of the above figure will be 97 ∿ 102 kW.h. Salable power volume generated in each incineration plant is shown in Table 6.39. The sales price of electricity to MEA generated in the incineration plant was assumed to be 50% (0.6 Baht/kW.h) of EGAT sales price to MEA considering costs borne by MEA for power transmission to the primary transformer substation. Revenue from supply of power is also shown in Table 6.39. The revenue in the year 2010 will be 84,730 thousand Baht/year with Case No. 13, or 51,720 thousand Baht/year with Case No. 19-(2).

Table 6.39 Revenue from power supply

| Plant | Treatment capacity (t/d) | Supply of power (kW.h/d) | Revenue per annum (thousand Baht) |
|---|---|---|---|
| Yannawa | 1,500 | 118,080 | 25,860 |
| Bang Kapi | 1,200 | 97,920 | 21,444 |
| Bangkok Noi | 1,100 | 85,448 | 18,713 |
| Phasi Charoen | 1,100 | 85,448 | 18,713 |
| Dusit | 1,500 | 118,080 | 25,860 |

(7) Revenue plan

Table 6.40 shows revenue of each appropriate Master Plan alternative in fiscal 2010. In every case, revenue from solid waste collection fee shares the largest part: 90% of the total revenue with Case No. 9, 69% with Case No. 13, and 76% with Case No. 19-(2).

Table 6.40 Planned revenue in fiscal 2010

(Unit : million Baht)

| Source of revenue | Appropriate Master Plan alternatives | | |
|---|---|---|---|
| | No. 9 | No. 13 | No. 19-(2) |
| Solid waste collection fee | 258.2 | 258.2 | 258.2 |
| Compost sales | 26.8 | 26.8 | 26.8 |
| Recovered ferrous metal sales | 2.0 | 2.0 | 2.0 |
| Electricity supply | - | 84.7 | 51.7 |
| Total | 287.0 | 371.7 | 338.7 |

The revenue by year is shown in Table 6.41.

The revenue in each case is constant until 1990 since new intermediate treatment facilities are not yet in operation till then. Differences in revenue by case appears from 1991 onward as incineration plants commence operation.

Based on the total revenue during 28 years from fiscal 1983 to 2010 of Case No. 9 as 1.0, Case No. 13 will be 1.28 and Case No. 19-(2), 1.19. Since solid waste collection fee forms the largest part in total revenue of each case, difference of total revenue among the cases is relatively small.

### 6.3.3 Financial expense

(1) Management cost

The word management cost used in this paragraph means the cost required for solid waste management. It consists of solid waste collection and transportation cost including expense for purchase of collection trucks, operation and maintenance costs for intermediate treatment by the existing and planned compost plants and incineration plants, operation and maintenance costs for final disposal facilities, and general management cost. The total management costs during 28 years from fiscal 1983 till 2010 in each case are shown in Table 6.42. For convenience of comparison, the management cost for the without-project case (ie, the case that no intermediate treatment facilities are established) was calculated and shown in the same table.

The cost savings in each case is measured as stated below.

- Case No. 9 : Owing to establishment of two additional compost plants, collection and transportation cost will be reduced 3.1% below the without-project case during 28 years, and collection trucks purchase cost will be 2.2% less. Nevertheless, as a whole, management cost of Case No. 9 is 3.4% more than that of without-project case because operation costs of the additional compost plants and final disposal sites are larger than the cost saving.
- Case No. 13 : Establishment of incineration plants contributes to cost savings in collection and transportation. In the same manner as the above Case No. 9, reduction of collection and

Table 6.41 Planned annual revenue

(Unit: million Baht)

| | Appropriate Master Plan alternatives | | |
|---|---|---|---|
| | No. 9 | No. 13 | No. 19-(2) |
| 1983 | | 30.2 | |
| 1984 | | 33.2 | |
| 1985 | | 38.0 | |
| 1986 | | 45.9 | |
| 1987 | | 53.4 | |
| 1988 | | 58.6 | |
| 1989 | | 64.6 | |
| 1990 | | 71.4 | |
| 1991 | 79.4 | 105.3 | 105.3 |
| 1992 | 88.2 | 114.1 | 114.1 |
| 1993 | 102.1 | 124.4 | 124.4 |
| 1994 | 113.8 | 136.1 | 136.1 |
| 1995 | 127.3 | 149.6 | 149.6 |
| 1996 | 142.7 | 205.1 | 190.8 |
| 1997 | 168.4 | 222.6 | 208.3 |
| 1998 | 188.6 | 242.8 | 228.5 |
| 1999 | 211.5 | 269.3 | 255.0 |
| 2000 | 237.9 | 295.7 | 281.4 |
| 2001 | 241.1 | 325.8 | 292.8 |
| 2002 | 244.1 | 328.8 | 295.8 |
| 2003 | 247.6 | 332.3 | 299.3 |
| 2004 | 250.8 | 335.5 | 302.5 |
| 2005 | 262.7 | 347.4 | 314.4 |
| 2006 | 265.6 | 350.3 | 317.3 |
| 2007 | 268.5 | 353.2 | 320.2 |
| 2008 | 271.1 | 355.8 | 322.8 |
| 2009 | 274.1 | 358.8 | 325.8 |
| 2010 | 287.0 | 371.7 | 338.7 |
| Total | 4,467.8 | 5,719.9 | 5,318.4 |
| Relative Index | 1.0 | 1.28 | 1.19 |

transportation cost and collection trucks purchase cost reach 17.0% and 20.4% respectively. However, operation cost of incineration plants also exceeds the cost saving so that management cost in this case will be 11.4% larger than that in without-project case.

- Case No. 19-(2) : This case has two less incineration plants than Case No. 13, therefore, the cost savings in collection and transportation cost and collection trucks purchase cost are also small : they are 12.9% and 16.5% of the without-project case, respectively. On the other hand, operation cost of incineration plants is two-thirds of Case No. 13, so that management cost in this case is increased to only 7% over that in without-project case.

In every case, only small cost savings is expected. Management cost of Case No. 9 is the smallest, followed by Case No. 19-(2) with Case No. 13 last. However, difference of the amounts of these three cases are not large in terms of difference of facilities construction cost in each plan.

Financial project cost in each case of appropriate Master Plan alternatives is shown Table 6.43 as reference.

Table 6.42 Management cost (fiscal 1983 ∿ 2010)

(Unit : million Baht)

| | Case No. 9 | Case No. 13 | Case No.19-(2) | without-project case |
|---|---|---|---|---|
| General management cost | 1,889.8 | 2,037.0 | 1,956.3 | 1,828.3 |
| Collection and transport cost | 6,785.4 | 5,814.5 | 6,103.7 | 7,004.3 |
| Collection trucks purchase cost | 1,847.1 | 1,503.9 | 1,576.9 | 1,889.5 |
| Operation and maintenance costs | | | | |
| for existing compost plants | 3,259.7 | 3,259.7 | 3,259.7 | 3,259.7 |
| for additional compost plants | 516.0 | 358.2 | 358.2 | - |
| for incineration plants | - | 2,580.0 | 1,670.6 | - |
| for final disposal sites | 189.9 | 62.7 | 73.2 | 33.8 |
| Total | 14,487.9 | 15,616.0 | 14,998.6 | 14,015.6 |

Table 6.43 Financial project cost (fiscal 1983 ∿ 2010)

(Unit : million Baht)

| | Case No. 9 | Case No. 13 | Case No.19-(2) | without-project case |
|---|---|---|---|---|
| Management cost | 14,487.9 | 15,616.0 | 14,998.6 | 14,015.6 |
| Facilities construction cost | 2,848.5 | 9,551.3 | 6,457.6 | 569.2 |
| Land acquisition cost | 671.2 | 747.9 | 966.2 | 455.3 |
| Total | 18,007.6 | 25,915.2 | 22,422.4 | 15,040.1 |

(2) Cost accounting of intermediate treatment facilities

1) Newly established compost plants

Management cost, construction cost, and depreciation of the two newly established compost plants are estimated as shown in Table 6.44.

Table 6.44 Cost accounting of newly established compost plants

(Unit : thousand Baht/year)

| | Bang Khun Tian | Taling Chan |
|---|---|---|
| Management cost | 12,090 | 21,340 |
| Depreciation cost | + 12,715 | + 22,595 |
| Total | 24,805 | 43,935 |
| Sales revenue | - 3,614 | - 7,556 |
| Financing burden | 21,191 | 36,379 |

Note: Depreciation cost was calculated with straight line method on assumption that the useful life span of the facilities is 20 years and with the construction costs of 254.3 million Baht for Bang Khun Tian and 451.9 million Baht for Taling Chan excluding land acquisition cost.

If revenue from compost sales, though not much, is taken into account, the financing burden caused by composting treatment in two plants (Compost sales revenue - Composting treatment cost) will be 57.6 million Baht per year (Ref. Table 6.44).

Since the solid waste treatment tonnage of Bang Khun Tian compost plant is 221 t/d and that of Taling Chan plant is 459 t/d, the solid waste treatment cost per unit ton is calculated 308 Baht for Bang Khun Tian and 262 Baht for Taling Chan.

ii) Incineration plants

Management cost of incineration plant may expand year after year. For convenience of financial analysis, the management cost of 10th year counting from the year of commencement of the plant operation was adopted in calculation since this was thought near to the average management cost. The cost was estimated in the range from 47.2 to 55.2 million Baht in the year.

Depreciation was estimated by straight line method assuming the useful life span of the plant to be 20 years: the depreciation cost will be 88.9 ∿ 103.4 million Baht per year. As a result, annual management cost of each incineration plant including depreciation was estimated to lie in the range from 136.1 (Bangkok Noi incineration plant) to 157.7 million Baht (Dusit incineration plant).

Subtracting power supply revenue from the management cost, the financing burden caused by incineration treatment was calculated and is shown in Table 6.45. Total financing burden for incineration plants are then calculated as 479.2 million Baht per year in Case No. 13 and 258.4 million Baht per year in Case No. 19-(2).

Solid waste treatment tonnage of each incineration plant is 880 ∿ 1,200 t/d. Therefore, the treatment cost per ton of solid waste was calculated as 348 Baht in Yannawa incineration plant as the lowest and 426 Baht in Phasi Charoen plant as the highest. The treatment cost per ton of solid waste of incineration is 1.3 times greater than that of composting in the newly established plant. For reference, the unit production cost of electricity generated in incineration plant was calculated on assumption that the incineration plant functions as a power generation plant. The production cost of each plant lies in the range from 3.5 Baht/kW.h (Yannawa) to 4.4 Baht/kW.h (Phasi Charoen).

Table 6.45 Cost accounting of incineration plants

(Unit : thousand Baht/year)

| | Yannawa | Bang Kapi | Bangkok Noi | Phasi Charoen | Dusit |
|---|---|---|---|---|---|
| Revenue from power supply | 25,860 | 21,444 | 18,713 | 18,713 | 25,860 |
| Management cost | 49,100 | 48,100 | 47,200 | 47,400 | 55,200 |
| Depreciation cost | 103,350 | 90,375 | 88,925 | 89,525 | 102,495 |
| Total cost | 152,450 | 138,475 | 136,125 | 136,925 | 157,695 |
| Financing burden | 126,590 | 117,031 | 117,412 | 118,212 | 131,835 |

### 6.3.4 Financial analysis

(1) Analysis method

As solid waste management enterprise is an unprofitable enterprise with a low ratio of the revenue to the cost, application of common analysis methods such as R/C (Revenue-Cost ratio) and R-C (Net Present Value) may not fully satisfy the purpose. Therefore in the analysis, results by these methods were taken as references and, instead, a sort of standard for the amount of financing burden was formulated and applied to evaluation of each appropriate Master Plan alternative.

(2) Results of the analysis

BMA's financing burden in each case in a 28-years period from 1983 till 2010 obtained from cash flow analysis is summarized in Table 6.46. Cash flow statement by year is shown in Appendix 6.15.

BMA's own funds needed for the construction of facilities of Case No. 9 will be equivalent to 1,159.3 million Baht. Current financing burden of Case No. 9 during 28 years defined as the difference of applications and sources of funding was estimated 14,725.5 million Baht. As a result, the total financing burden of Case No. 9 will be 15,884.8 million Baht. As the principal to be repaid by fiscal 2010 is 2,170.3 million Baht, the outstanding principal at the end of 2010 is 190.1 million Baht.

In the same manner, total financing burden and outstanding principal in Case No. 13 are 21,718.0 million Baht and 3,305.6 million Baht respectively, and that in Case No. 19-(2) are 19,528.3 million Baht and 1,578.3 million Baht. Difference of the total financing burden among the cases is caused mostly by payment of interest.

From the above evaluation, a conclusion was drawn that Case No. 9 has the smallest financing burden and outstanding principal whereas Case No. 13 has the largest figures in both. This evaluation, however, cannot clarify feasibility of each case, but only reveals relative superiority. Therefore, an attempt was made hereafter to formulate a 'Financing burden standard' upon which financial feasibility of each appropriate Master Plan alternative could be examined.

When obstruction to feasibility were found, the best way to eliminate them was sought.

Table 6.46 BMA's financing burden (fiscal 1983 ∿ 2010)

(Unit : million Baht)

| | Appropriate Master Plan alternatives | | |
|---|---|---|---|
| | No. 9 | No. 13 | No. 19-(2) |
| BMA's fund | 1,159.3 | 2,515.2 | 1,940.1 |
| Current financing burden | 14,725.5 | 19,202.8 | 17,588.2 |
| Total financing burden | 15,884.8 | 21,718.0 | 19,528.3 |
| Outstanding principal (at the end of 2010) | 190.1 | 3,305.6 | 1,578.3 |

The 'Financing burden standard' was based on the budget of fiscal 1980. In that year, the budget relating to solid waste management was 351.4 million Baht. Canal and road cleaning was excluded from the scope of economic and financial analysis, therefore, the budget for these items should also be excluded; hence the budget of fiscal 1980 relating to solid waste management was estimated 244.2 million Baht. Subtracting revenue obtained from solid waste management enterprise from the budget, BMA's financing burden caused by solid waste management was calculated as 220.7 million Baht. BMA's revenue of the same year was 3,339.6 million Baht; hence the rate of financing burden of solid waste management to BMA's revenue is 6.6%. This rate 6.6% was taken as a standard for evaluation of each case, though the rate would fluctuate somewhat by year.

Applying 6.6% as a standard, the feasibility of each appropriate Master Plan alternative was examined. The financing burden of each alternative derived from cash flow statement by year is shown in Figs. 6.4∿6.6. In the figures, line a-a shows the 6.6% standard.

In Case No. 9, BMA's current financing burden satisfies the 6.6% standard through the whole period. Except two years in fiscal 1990 and 2000 when the large amount of BMA's fund for major repair of the existing compost plant is needed, BMA's total financing burden roughly satisfies the 6.6% standard. Thus, this case can be implemented by BMA since BMA must bear the funding for this major repair whether an appropriate Master Plan alternative is implemented or not.

On the other hand, the current financing burden in Cases No. 13 and 19-(2) exceed the 6.6% standard: thirteen years with Case No. 13 and nine years with Case No. 19-(2); however, the excess is not large and can be borne by BMA. These cases can be implemented by BMA provided BMA furnishes funds for facilities construction 2,515.2 million Baht in Case No. 13 and 1,940.1 million Baht in Case No. 19-(2) respectively, however, allocation of fund only for solid waste management enterprise with high priority seems rather difficult since there are various items requiring finance. For implementation of these cases, subsidy of Government for construction of facilities should be essential condition.

Incidentally, in Japan, 50% of the construction cost of solid waste management facilities is subsidized by the Government.

If the Thai Government subsidize 20% of the facilities construction cost excluding the cost for major repair of the existing compost plant, these appropriate Master Plan alternatives become as feasible as Case No. 9 in terms of BMA's financing. The amount of the required subsidy in each case will be as follows:

Case No. 13 1,946.0 million Baht

Case No. 19-(2) 1,370.9 million Baht

In short, when BMA implements one of these alternatives as its independent project, Case No. 9 can be said to be financially the most feasible one. However, if results of overall evaluation suggest adoption of the other cases, the Government must subsidize the construction of the facilities.

Finally, the R/C and R-C of each appropriate Master Plan alternative are shown in Table 6.47 as a reference. Case No. 9 is best in terms of both R/C and R-C. Case No. 13 and 19-(2) have nearly the same R/C value but Case 19-(2) is better since its R-C value is lower.

Table 6.47 R/C and R-C

| | Appropriate Master Plan alternatives | | | without-project case |
|---|---|---|---|---|
| | No. 9 | No. 13 | No. 19-(2) | |
| R/C | 0.16 | 0.12 | 0.13 | 0.19 |
| R-C (million Baht) | -3,179 | -5,095 | -4,604 | -2,499 |

Fig. 6.4 BMA's financing burden for solid waste management
(Case No. 9)

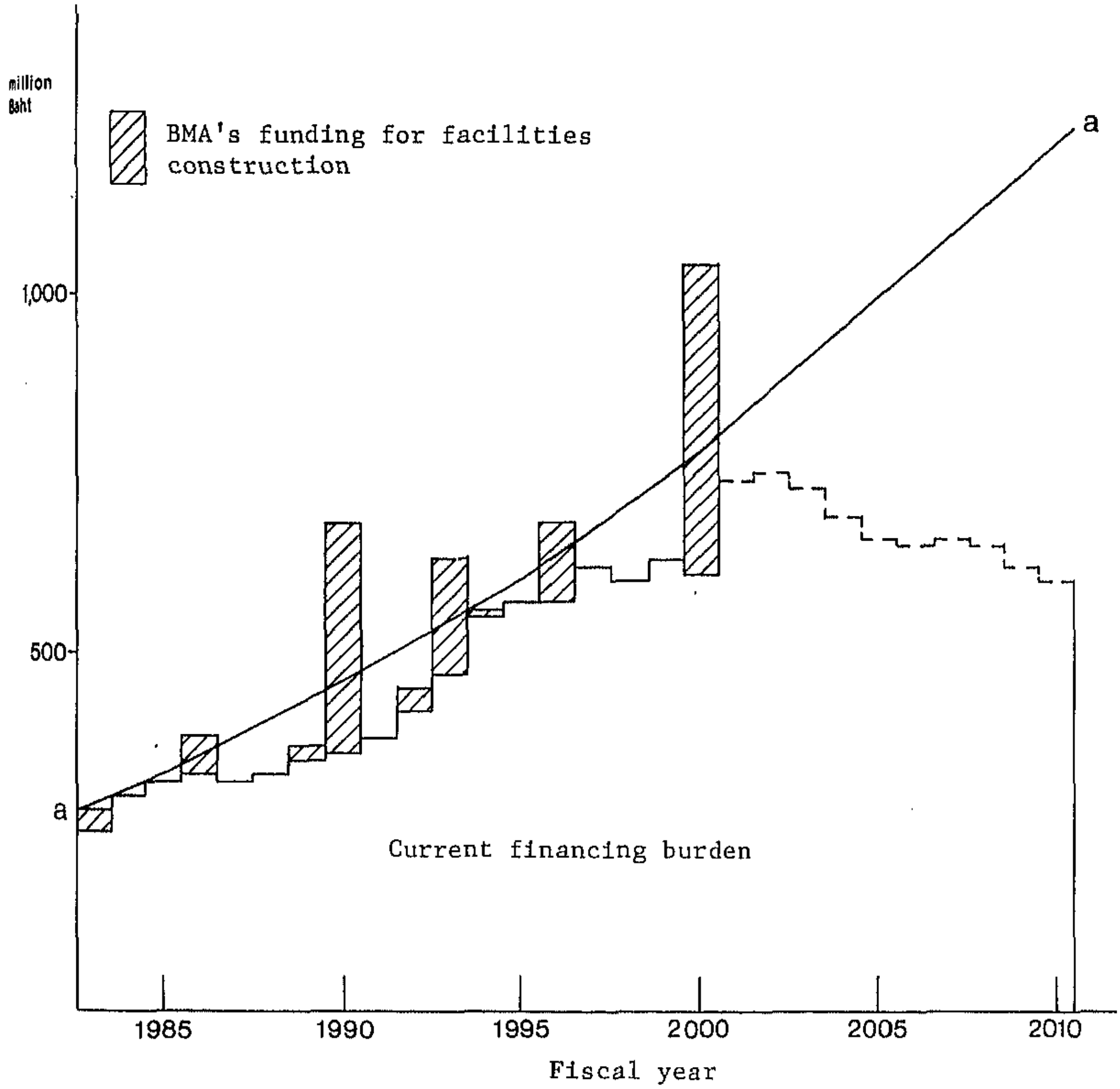


Fig. 6.5 BMA's financing burden for solid waste management
(Case No. 13)

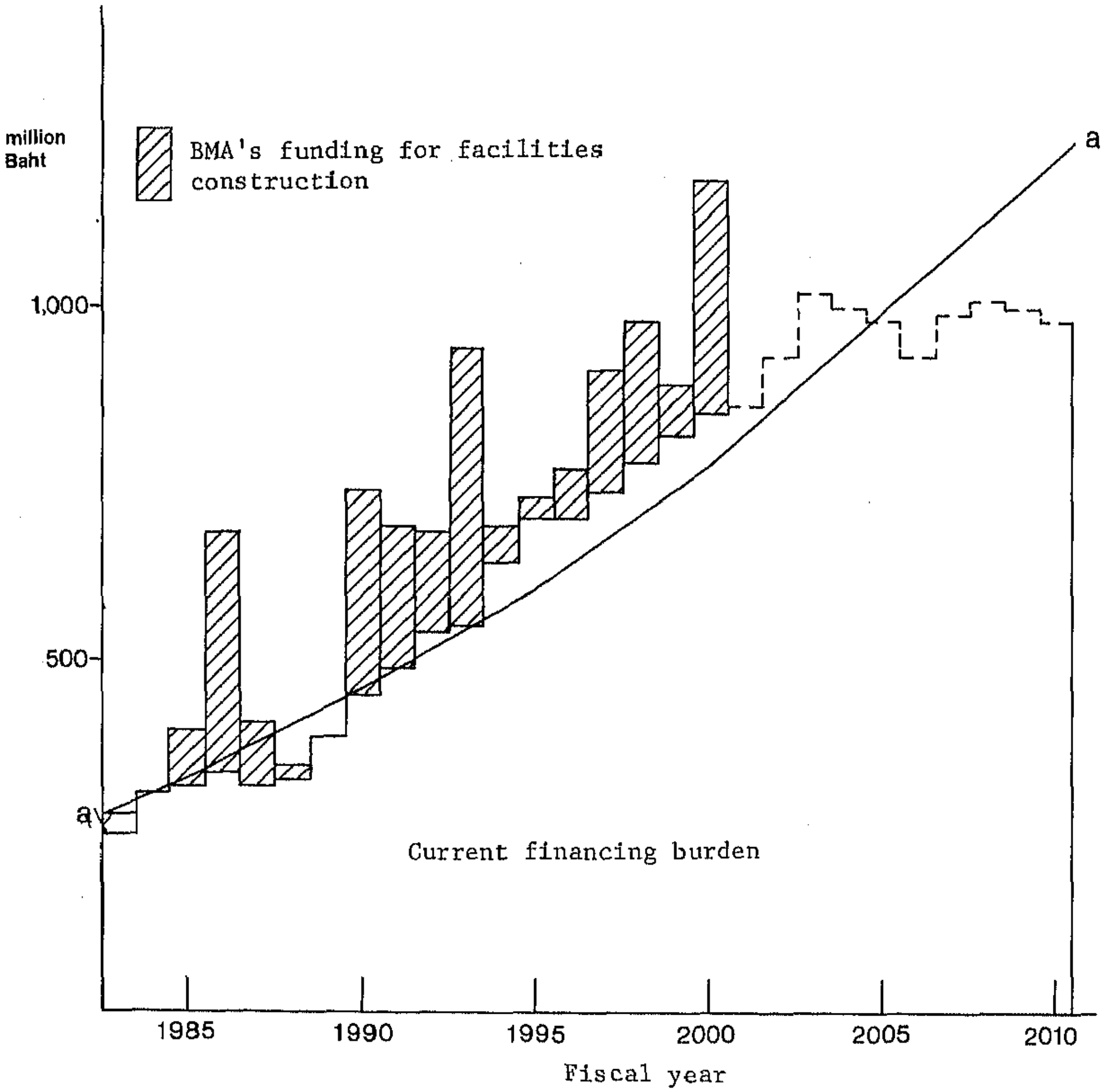
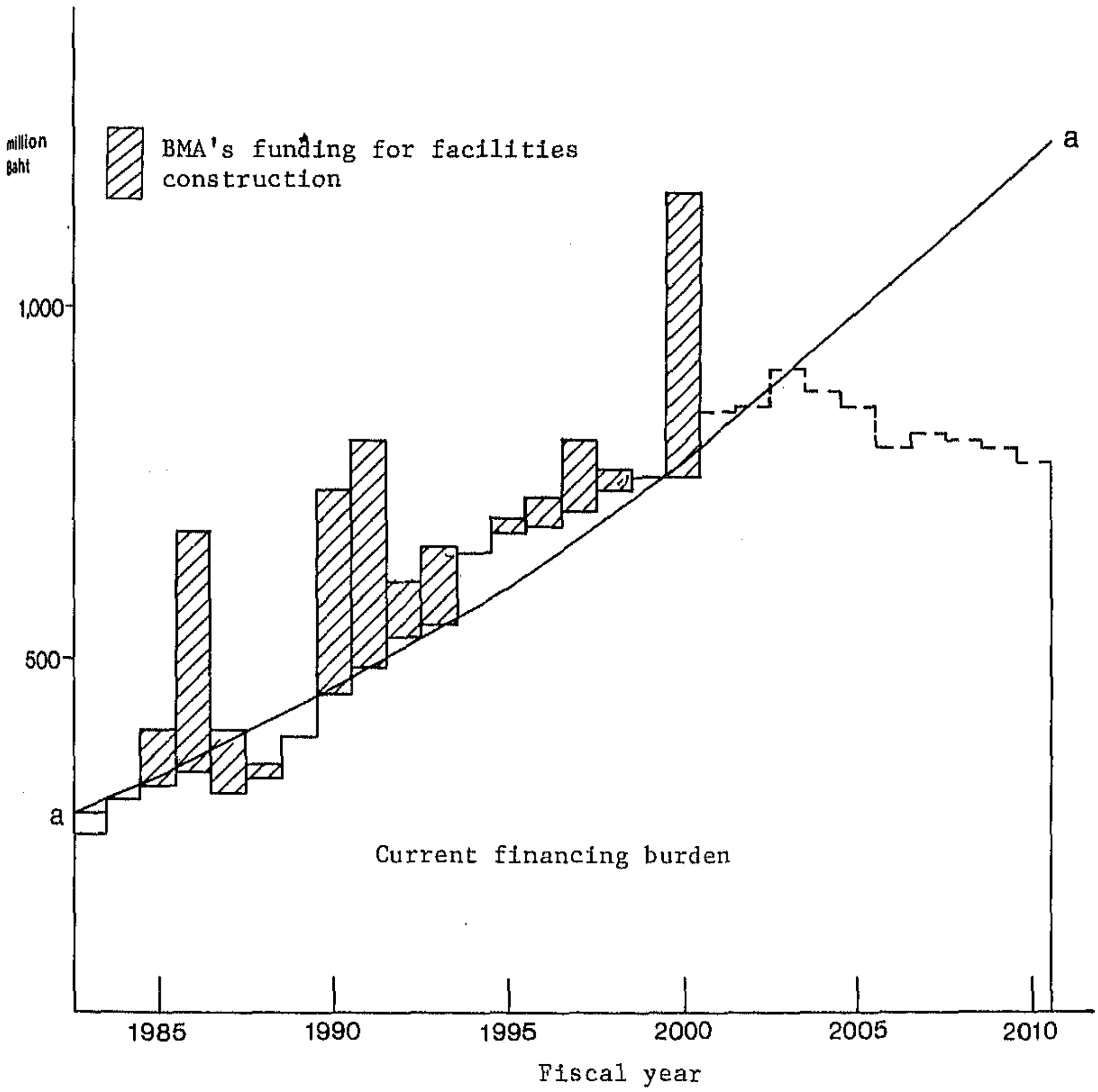


Fig. 6.6 BMA's financing burden for solid waste management
(Case No. 19–(2) )



## 6.4 Comprehensive Evaluation of Economic and Financial Analyses

(1) Benefit - cost ratios at 15% discount rate for the proposed appropriate Master Plan alternatives based on quantifiable benefits and costs are shown below:

| | Case No. | | | |
|---|---|---|---|---|
| | 9 | 13 | 19-(2) | Without-project |
| B/C Ratio | 1.39 | 0.98 | 1.04 | 1.48 |

Compared with Cases No. 13 and 19-(2), the benefit-cost ratio is higher in Case No. 9 and the without-project.

(2) In this study, it was tried to quantify as many benefits as possible. Some of the unquantifiable benefits have been discussed previously in Chapter 6, but in this paragraph, further discussion is made.

It is necessary to recognize the limitation of countermeasures which can be executed for solid waste management to cope with the large amount of discharged solid waste volume and the solid waste characteristics in the future over the entire project life span (1983 - 2010).

The effects on final disposal expected by the adoption of one of the proposed appropriate Master Plan alternatives are summarized as landfill volume reduction and extension of life expectancy landfill in Tables 6.48 and 6.49, respectively.

Table 6.48 Total landfill volume by case (1983-2010)

(Unit : 1,000 $m^3$)

| Case No. | Disposal volume | | | | | Index against without-project case | |
|---|---|---|---|---|---|---|---|
| | Solid waste | Compost residue | Ash from existing compost plant incinerator | Incineration residue | Total | Total | Solid waste and compost residue |
| 9 | 27,686 (91.6) | 1,970 (6.5) | 583 (1.9) | - | 30,239 (100.0) | 94.7 | 94.6 |
| 13 | 10,867 (61.7) | 1,740 (9.9) | 583 (3.3) | 4,409 (25.1) | 17,599 (100.0) | 55.1 | 40.2 |
| 19-(2) | 16,170 (75.0) | 1,740 (8.1) | 583 (2.7) | 3,066 (14.2) | 21,559 (100.0) | 67.5 | 57.1 |
| Without-project | 30,152 (94.4) | 1,212 (3.8) | 583 (1.8) | - | 31,947 (100.0) | 100 | 100 |

Table 6.49 Year of maximum landfill capacity

| Case No. | Maximum usable landfill year | | | Extension of life of landfill against without-project case (years) | | |
|---|---|---|---|---|---|---|
| | On-Nooch | Nong Khaem | Ram Intra | On-Nooch | Nong Khaem | Ram Intra |
| 9 | 1999 | 1995 | 1988 | same | same | same |
| 13 | 2012 | 1996 | 1988 | + 13 | + 1 | same |
| 19-(2) | 2006 | 1996 | 1988 | + 7 | + 1 | same |
| Without-project | 1999 | 1995 | 1988 | - | - | - |

These effects were quantified during the project life span and included in the economic evaluation. Some type of final disposal site will be necessary no matter what solid waste management system is adopted and it will be used over the project life span.

(3) There are still vacant parcels of land in the suburban area of Bangkok; however, low residential mixed use areas in the year 2000 will expand significantly to about 2.3 times (86,500 ha) of 1977. Considering these facts, it is impossible to use existing landfill sites and expand them to the surrounding areas forever without limitation. This indicates the necessity of reducing the total solid waste volume discharged and increasing the solid waste inactivity (harmlessness). This means increase of the incoming ash volume to the landfill site. To increase the incoming ash volume will produce benefits such as shorter time of inactivation of the stored solid waste (converted to soil) at the landfill site, use of landfill for land reclamation, etc. and prevention of the occurrence of pollution from landfill. Compared with case No. 9, it is clear from Table 6.48 that adoption of Case No. 13 or 19-(2) will reduce the total landfill volume and harmful raw waste volume almost by half. This benefit will be increase if the project life span is prolonged.

(4) For reference, project costs of the proposed appropriate Master Plan alternatives are summarized in Table 6.50. Project costs by year are shown in Appendix 6.16.

Table 6.50 Project cost (Financial) (1983 - 2000)

(Unit : million Baht)

| | No. 9 | No. 13 | No. 19-(2) |
|---|---|---|---|
| Facilities construction cost | 2,848.5 | 9,551.3 | 6,457.6 |
| Incineration & Compost plant | 706.2 | 8,149.7 | 4,823.1 |
| Landfill site | 1,439.4 | 832.4 | 1,065.3 |
| Parking lots | 133.7 | - | - |
| Thorough repair of existing compost plant | 569.2 | 569.2 | 569.2 |
| Land acquisition cost | 671.2 | 747.9 | 966.2 |
| Incineration & Compost plant | 115.4 | 680.4 | 782.7 |
| Landfill site | 450.3 | 67.5 | 183.5 |
| Parking lots | 105.5 | - | - |
| *1 Management cost | 7,789.4 | 7,856.2 | 7,767.4 |
| Project-cost | 11,309.1 | 18,155.4 | 15,191.2 |
| *2 Without-project | 8,596.3 | 8,596.3 | 8,596.3 |
| Additional investment | 2,712.8 | 9,559.1 | 6,594.9 |

*1 Management cost : Including general management cost, collection and transport cost, collection trucks purchase cost, operation and maintenance costs

*2 Without project : Total investment cost including operation and maintenance costs in without-project case

(5) The financing burden, shown in the following table, is calculated by subtracting total revenue and loaned funds from total financial cost for execution of the project.

(Unit : million Baht)

| Case No. | 9 | 13 | 19-(2) | Without-project |
|---|---|---|---|---|
| Financing burden | 15,884.8 | 21,718.0 | 19,528.3 | 10,751.9 |
| Index (without=100) | (148) | (202) | (182) | (100) |

Due to the peculiarity of solid waste management enterprise, it is unable to run it on a self-supporting basis; thus, every alternative case has some financing burden. The range of financing burden is quite different among these alternative cases but, in all cases, it is necessary to appreciate the benefit in the long range and give priority to this project as a national level project.

In order to realize the project Cases No. 13 and No. 19-(2) from the financial viewpoint, many measures can be considered such as a national government subsidy of about 20 percent of the total facilities construction cost or the government bearing the interest. By these measures, not only Case No. 9, but also Cases No. 13 and 19-(2) can be executed within the limitation of BMA's own budget. Economic viability is proven in every Master Plan alternative, therefore, it is recommended that the optimum solid waste management system should be determined not only by the amount of financing burden, but also by appropriateness of the system for Bangkok as the capital of Thailand and the need for environmental protection. In this sense, this project should have the same high priority as water supply, sewerage or drainage projects. Due to the financing burden to BMA, this project is recommended to be executed as a national project.

(6) The final decision for selection of an optimum Master Plan should be comprehensively made considering the following items as well as the limit of the environmental burden.

1) Maintain and improve the welfare of residents
2) Increase economic efficiency and reduce financing burden
3) Promote resources recovery (conserve natural resources)
4) Improve the welfare of sanitation workers

# Chapter 7 ENVIRONMENTAL IMPACT ASSESSMENT

# CHAPTER 7 ENVIRONMENTAL IMPACT ASSESSMENT

## 7.1 Method of Environmental Impact Assessment

### 7.1.1 Objective of the study

The objective of this study is to assess the environmental effect of establishment and utilization of the solid waste treatment facilities included in three appropriate Master Plan alternatives. The effect of without-project case was also studied for reference. Assessement was made in comparison with the predicted impact of the project with assessement criteria established for this study. The results were used to make a relative comparison of three plans applying a scoring system which reflects the relative importance of the envivonmental factors.

### 7.1.2 Scope of the study

(1) Appropriate Master Plan alternatives and their facilities

The alternatives, their facilities and proposed sites are shown in Table 7.1.

Table 7.1 Alternatives, their facilities and proposed sites

| Alternatives | Case No. 9 | | | Case No. 13 | | | | Case No. 19-(2) | | | | Case No. W/O | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Proposed site for facilities | Compost plant New | Compost plant Existing | Landfill site | Compost plant New | Compost plant Existing | Landfill site | Incineration plant | Compost plant New | Compost plant Existing | Landfill site | Incineration plant | Exist. comp. plant | Landfill site |
| On-Nooch | | o | o | | o | o | | | o | o | | o | o |
| Nong Khaem | | o | o | | o | o | | | o | o | | o | o |
| Ram Intra | | o | o | | o | o | | | o | o | | o | o |
| Talin Chan | o | | | o | | | | o | | | | | |
| Bang Khun Tian | o | | | o | | | | o | | | | | |
| Yannawa | | | | | | | o | | | | o | | |
| Dusit | | | | | | | | | | | o | | |
| Bangkok Noi | | | | | | | o | | | | | | |
| Bang Kapi | | | | | | | o | | | | | | |
| Phasi Charoen | | | | | | | o | | | | | | |
| No. of facilities | 2 | 3 | 3 | 2 | 3 | 3 | 4 | 2 | 3 | 3 | 2 | 3 | 3 |
| Total | 8 | | | 12 | | | | 10 | | | | 6 | |

Note: 1. The mark "o" indicates the objective facilities for assessment.

2. Influence caused by operation of collection trucks is a subject for assessment for all alternatives.

3. Number of existing compost plants of On-Nooch is counted here as one, though actually there are two plants.

(2) Base year of assessment

The year 2000 was taken as the base year of assessment, in which the facilities are scheduled to be in normal operation.

(3) Study areas of assessment

The study areas of assessment were determined for each environmental factor (Ref. Table 7.2).

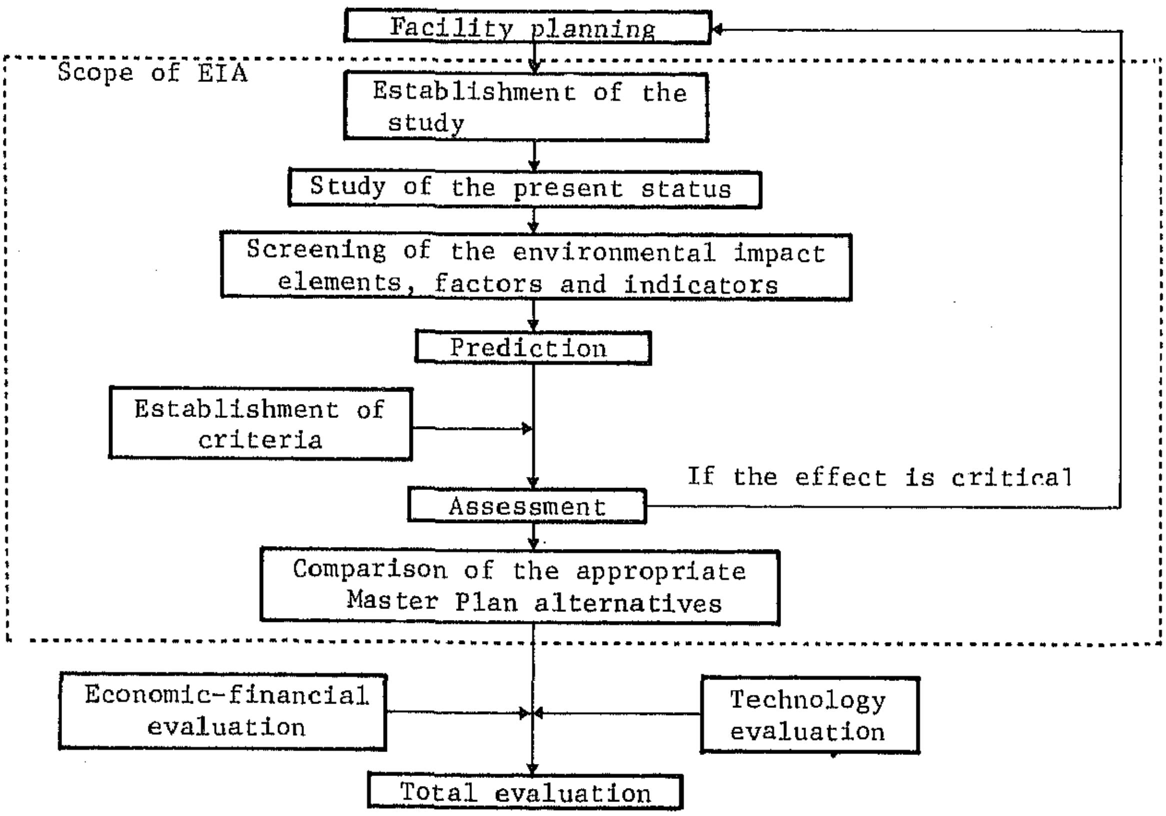
Table 7.2 Study areas for assessment

| Environmental factor | Study area |
|---|---|
| Living environment | The area outside the site where the effect of establishment and utilization is anticipated |
| Natural environment | Inside and adjacent area to the site where the effect is anticipated |
| Socio-economic environment | The area where the effect of utilization of the facilities is anticipated |

### 7.1.3 Procedure of the study

The environmental impact assessment was carried out using the procedure shown in Figure 7.1.

Fig. 7.1 Procedure of environmental impact assessment



### 7.1.4 Definitions and terminology

Environmental impact element: The facilities which constitute the solid waste management system.

Environmental factor: A factor of phenomena which reflects the effect of human activities.

Environmental indicator: An element of the environmental factor which indicates the scale of the impact.

## 7.2 Study of the Present Status

### 7.2.1 Socio-economic environment

(1) Population

The population of Bangkok in 1980 was 5.15 million. (Ref. Table 7.3)

Table 7.3 Population characteristics

| Population (1980) | | | Districts of max. and min. density | | | |
|---|---|---|---|---|---|---|
| Sex | Thailand | Bangkok | Name of district | Density (person/km$^2$) | Household | Person per household |
| Male | 23,627,727 | 2,618,224 | (max.) Pom Prap | 98,974 | 18,900 | 10.1 |
| Female | 23,333,611 | 2,535,678 | (min.) Nong Chok | 217 | 6,908 | 7.4 |
| Total | 46,961,338 | 5,153,902 | Bangkok | 3,280 | 824,011 | 6.2 |

Source: Registration Section, Office of Under-Secretary of State for BMA.

(2) Industry

The total number of employed persons was 2.14 million in 1978 as shown in Table 7.4.

Table 7.4 Employed persons in Bangkok by occupation (1978)

(Unit: 1,000 persons)

| Sex | Occupation | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | Agricul-ture | Mining | Manufac-turing | Construc-tion | Elec-tricity | Commerce | Transport | Service | |
| Male | 116.6 | 1.0 | 343.5 | 74.4 | 17.1 | 326.4 | 106.4 | 229.7 | 1,215.1 |
| Female | 123.2 | 0.0 | 248.9 | 12.6 | 3.7 | 226.9 | 10.0 | 298.3 | 923.6 |
| Total | 239.8 | 1.0 | 592.4 | 87.0 | 20.8 | 553.3 | 116.4 | 528.0 | 2,138.7 |

Source: Report of the Labor Force Survey, 1978, National Statistical Office

(3) Land use

The land use of Bangkok in 1979 was as follows: 77% open space, 15% for residential, and the rest as shown in Table 7.5.

Table 7.5 Land use in Bangkok (1979)

| Land use | Open space | Residential | Institute | Commercial | Industry | Others | Total |
|---|---|---|---|---|---|---|---|
| Area ($km^2$) | 1,209.4 | 228.9 | 29.4 | 27.0 | 16.7 | 57.3 | 1,568.7 |
| Percentage | 77.1 | 14.6 | 1.9 | 1.7 | 1.1 | 3.6 | 100.0 |

(4) Transportation

The number of registered vehicles in Thailand in 1978 was 1.52 million, 0.5 million of which was registered in Bangkok. (Ref. Table 7.6)

Table 7.6 Number of registered vehicles (1978)

(Unit: vehicle)

| Area | Type | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | Seat car | Motorcycle | Tricycle | Passenger car | Truck | Others | |
| Thailand | 362,396 | 714,080 | 8,635 | 28,127 | 368,373 | 37,502 | 1,519,113 |
| Bangkok | 251,331 | 129,078 | 6,886 | 24,205 | 71,203 | 19,613 | 502,316 |

Source: Vehicle registration section, Police Department

The traffic volume on the main roads was surveyed in 1977 as shown in Table 7.7.

Table 7.7 Traffic volume of main roads (1977)

| Road Number | Name | Daily traffic volume (vehicle per day) | Remark |
|---|---|---|---|
| National Road No.3 | Sukhumvit Rd. | 25,700 | Urban main road for On-Nooch |
| National Road No.4 | Petchkasem Rd. | 27,300 | Urban main road for Nong Khaem |
| National Road No.34 | Bangna Trad Rd. | 13,800 | Inter city road for Pataya |
| National Road No.35 | Thonburi-Pakto Rd. | 6,800 | Inter city road for Samut Sakarn |

Source: The comprehensive study for Bangkok suburban Transportation Project, 1979 JICA

(5) Historical sites and cultural assets

Bangkok, with a 200-year long history as a capital of Thailand, has many religious facilities pertaining to Buddhism.

## 7.2.2 Natural environment

(1) Geography and geology

Thailand extends from 6 to 20 degrees north in latitude (1,500 km in length), and from 97 to 106 degrees east in longitude; The total area is 514,000 $km^2$. Bangkok lies 13 degrees north in latitude and 100 degrees east in longitude.

The ground surface elevation varies from 0.8 to 1.0 meters above sea level.

Subsurface soils in the city area are alluvium deposits consisting of clay and sand, and the stratum from 20 to 30 meters below the ground surface is called the Bangkok clay.

(2) Groundwater

In Bangkok city area, four aquifers lie within 200 meters below the ground surface. Their characteristics are shown in Table 7.8.

Table 7.8 Characteristics of groundwater

| Name of aquifer | Depth (m) | Thickness (m) | Water quality (chloride) | |
|---|---|---|---|---|
| | | | Concentration (ppm) | Distribution |
| Bangkok | 20 - 30 | 1 - 80 | 5 - 1,160 | Increase toward southwest(SW) |
| Phra Pradaeng | 60 - 100 | 15 - 80 | 5 - 2,840 | Increase toward NW and SW |
| Nakhorn Luang | 110 - 160 | 15 - 75 | 2 - 8,850 | Increase toward W |
| Nonthaburi | 180 - 200 | 5 - 60 | 1 - 4,100 | Increase toward W and SW |

Source: Analysis of sedimentary facies and groundwater potential of some quarternary deposits Bangkok area, Chulalongkorn University, 1980

(3) Climate

Climate of Thailand can be divided into three seasons: cold season, hot season and rainy season. The temperature of Bangkok city shows little fluctuation throughout the year: its average is 28 degrees centigrade. (Ref. Table 7.9)

Table 7.9 Climate in Bangkok

| Item | Dry season Nov. – Feb. | Hot season Mar. – Jun. | Rainy season July – Oct. | Average/ Total | Monthly Max. | Monthly Min. | Remark |
|---|---|---|---|---|---|---|---|
| Temperature (°C) | 26 | 29 | 28 | Ave. 28 | 35 (Apr.) | 20 (Jan.) | – |
| Rainfall (mm) | 96 | 434 | 1,014 | Total 1,544 | 402 (Sep.) | 9 (Jan.) | (Daily Max.)154 |
| Humidity (%) | 73 – 84 | | | Ave. 79 | – | – | – |
| Wind | North (Oct.–Jan.), South (Feb.–Sep.) | | | Ave. 2.5m/s | 2.9m/s (Mar.) | 1.8m/s(Dec.) | – |

Source: Meteorological Department, Ministry of Communications

(4) Fauna

i) Birds

Thailand belongs to a tropical climate zone. There are various types of insects and plants, and more than 840 species of birds have been identified. Thailand is located at the connection point of Indochina peninsula and Malay peninsula where migrating birds pass.

In Thailand, three species of birds are designated to be preserved, though they do not live around the proposed sites. They are Giant Ibis, Chinese Egret, and White Winged Wood Duck.

ii) Fish

Commercially caught fish live in the rivers in Bangkok. The record of fish landed at Bangkok in 1979 are as follows.

| | |
|---|---|
| ° Catfish (Pla Duk) | 1,212 t |
| ° Catfish (Pla Sawai) | 106 t |
| ° Carp (Pla Tapien) and others | 15 t |
| ° Snake-head fish | 859 t |
| ° Climbing perch | 26 t |
| Total | 2,218 t |

Source: Fisheries record of Thailand 1979, Department of Fisheries, Ministry of Agriculture and Cooperatives

(5) Flora

According to classification by plant distribution, Bangkok is located in the rain green forest district.

The proposed sites are surrounded by palm trees and bananas which are regarded economically valuable.

7.2.3 Living environment

(1) Air pollution

Air pollution in Bangkok is extensive particularly in the central districts. It is caused mainly by the operation of around 500,000 vehicles in the city area. The main pollutant is carbon monoxide gas; its hourly average concentration was surveyed between 19-40 ppm. (Ref. Table 7.10) Air pollution in Bangkok has increased due to the dominant windless condition and inversion phenomenon.

Table 7.10 Air pollution in Bangkok

| Item | Pollutant | | |
|---|---|---|---|
| | Carbon monoxide (ppm) | | Lead |
| | Hourly average | 8-h average | (μg/m³) |
| Observed value | 19 - 40 | 14 - 33 | 6.2 - 22.5 |
| Year | 1977 | | 1975 |
| Standard in Thailand (Draft) | 40 | 16 | 10 |

Source: Environmental condition in Thailand, NEB 1980

(2) Water pollution

Agriculture, fishery and industry in Thailand benefit greatly from Khlongs and Chao Phraya river which flows at 50 - 1,000 $m^3$/sec of water through the year. Water in these Khlongs and rivers has been polluted according to the increase of waste water discharged from industries and houses. Pollutant contents of water sampled from some of them exceed the allowable limit specified in the Factory Act B.E. 2512. (Ref. Table 7.11)

Table 7.11 Water pollution in Bangkok

| | Regulated item | | | | | | |
|---|---|---|---|---|---|---|---|
| | DO (mg/L) | BOD (mg/L) | COD (mg/L) | SS (mg/L) | Cℓ (mg/L) | Temperature (°C) | pH - |
| Chao Phraya | 0-5.3 | 1.1-7.9 | - | - | 20-42 | 24 - 39 | - |
| Khlong | 0-6.7 | 2-240 | 5-303 | 2-339 | 32-5,423 | 28 - 32 | 6.8 - 7.8 |
| Standard in Factory Act | - | 20- 60 | - | 30-150 | 1 | 40 | 5 - 9 |

Source: Feasibility study of Bangkok sewerage system project in Kingdom of Thailand, 1982 JICA

(3) Noise

The main sources of noise in Bangkok are factories, river boats, aircrafts, construction and especially vehicles. (Ref. Table 7.12)

Table 7.12 Noise in Bangkok

[dB(A)]

| | Noise source | | | | | | |
|---|---|---|---|---|---|---|---|
| | Truck | Taxi | Motor-cycle | Tri-cycle | Boat | Aircraft | Factory |
| Survey | 81-98 | 91-96 | 88-101 | 88-97 | 90 | 90-118 | 84-118 |
| Standard | 95 | | | | 90 | - | 80 |

Source: Environmental condition in Thailand, NEB 1980

(4) Soil contamination

Soil in Bangkok is said to be contaminated as the results of accumulation of toxic substances discharged from the vehicles, factories, farms and houses. (Ref. Table 7.13)

Table 7.13 Soil contamination in Bangkok

(ppm)

| Location | Lead | Zinc | Cadmium |
|---|---|---|---|
| Road median | 49 - 3,655 | 16 - 485 | 0.21 - 1.83 |
| Roadside | 14 - 63 | 10 - 42 | 0.53 - 1.24 |
| General | 0 - 200 | 10 - 300 | 0.1 - 7.0 |

Source: The study of the probable polluted characteristics of soil in Bangkok Metropolitan area, Chulalongkorn university

(5) Complaints concerning the environmental problems

Miscellaneous complaints addressed to BMA in 1979 reached to 980 cases, 243 of which relate to environmental problems. (Ref. Table 7.14)

Table 7.14 Complaints concerning environment in Bangkok

| | Matter of complaint | | | | | Total |
|---|---|---|---|---|---|---|
| | Air | Noise | Water | Refuse | Others | |
| Number of complaints | 44 | 89 | 31 | 79 | 937 | 980 |

Source: Environmental condition to Thailand, NEB 1980

### 7.2.4 Features of the proposed sites

The proposed sites are presently used as farmland, or orchard, or left as swamps. Except Dusit and Bangkok Noi, around 90% of the site areas and the surroundings is unused and left as open space. Features of the proposed sites are shown in Table 7.15.

### 7.2.5 Present status of the existing compost plants

Survey of the refuse and emission gas from incineration plant attached to Nong Khaem compost plant were conducted in June and July of 1981. (Ref. Field Investigation Report) (Ref. Appendix 7.1 for summary)

### 7.2.6 Laws and regulations relating to environment in Thailand

The basic act concerning environment in Thailand is the National Environment Promotion and Preservation Act. (Ref. Appendix 7.2 list of laws and regulations)

The quality standards of air, water and noise were set up in 1980 by the Office of the National Environment Board.

The Notification of the Ministry of Industry No. 11 (1979), based on the Factory Act 1969, prescribes the criteria with respect to waste water disposal system.

The Notification No. 4 (1971) prescribes allowable limit of odour, noise, vibration, dust, fume, ash and smoke.

Act for Wild Life Conservation and Protection was enacted in 1960. Land use is prescribed by Town and Country Planning Act.

Preservation of historical assets is regulated by act for Ancient Remain, Antique, Art Works and National Museum.

Table 7.15 Features of the proposed sites

| Proposed site | Location | Land use | | Buildings (Number/ha) | Open space (%) | Flood at full tide |
|---|---|---|---|---|---|---|
| | | Regulation | Present Status | | | |
| 1. Yannawa | Between Rujjadapi Seag Rd. (50 m wide) Chao Phraya | Buildings are regulated | Mainly orchard with houses, factories and temples. | 4.2 | 89 | Yes |
| 2. Dusit | Between Pibon Song Karm Rd. (15 m wide) and Chao Phraya | No | Mainly houses, with factories, schools, temples, orchard. Developing. | 13.5 | 44 | Yes |
| 3. Bang Kapi | 1 km south of Ladphrao Rd. | No | Mainly farms and swamps. Near a school. Developing. | 3.4 | 89 | No |
| 4. Bangkok Noi | Between Charan Sanit Wong Rd. (22 m wide) and Chao Phraya | No | Orchard. Mainly houses, factories, stores, temples and schools. Densely mixed. | 21.0 | 41 | Yes |
| 5. Phasi Charoen | 0.5 km south of Petkasem Rd. Along Phasicharoen Bang Khae Rd. | No | Mainly orchard. Schools, temples and houses to the north. | 5.4 | 89 | Unknown |
| 6. Bang Khun Tian | Between Pakto-Thonburi Rd. and Mahachai Railway | No | Mainly rice field. Houses are increasing | 1.3 | 94 | No |
| 7. Taling Chan | Near Outer Ring Rd. and Pinkrao-Nakornclaisri Rd. | Agricultural area | Farms and swamps | 1.1 | 98 | No |
| 8. On-Nooch | Between Soi Sukhumvit Rd. 77 and 103 | No | Mainly orchard, farms and swamps. Houses along the road to the north | 2.7 | 92 | No |
| 9. Nong Khaem | 0.6 km north of Petkasem Rd. | No | Mainly farms with houses and a school. TV station to the north. | 1.1 | 96 | No |

## 7.3 Screening of the Environmental Impact Elements, Environmental Factors and Environmental Indicators

### 7.3.1 Screening of the environmental impact elements

The following items are taken as environmental impact elements: incineration plant, final disposal site, new and existing compost plant, and collection truck. (Ref. Table 7.16)

Table 7.16 Features of environmental impact elements

| Facility | Environmental impact element | Materials to be handled | Treatment method | Equipment | Location | Capacity or planned disposal volume (t/d) |
|---|---|---|---|---|---|---|
| New compost plant | Plant | Solid waste | Aerated composting | Handsorting building, fermentation yard | Taling Chan | 540 |
| | | | | | Bang Khun Tian | 260 |
| | Landfill site | Solid waste | Bank filling (without cover soil) | Waste water treatment facility, Vehicle | Taling Chan | 65 |
| | | | | | Bang Khun Tian | 30 |
| Final disposal site & existing compost plant | Landfill site | Solid waste compost residue | Sanitary land-fill | Landfill area and control office, waste water treatment facility, car washing facility, Vehicle | Case No. | |
| | | | | | On-Nooch 9 | 2,120 |
| | | | | | On-Nooch 13 | 370 |
| | | | | | On-Nooch 19-(2) | 790 |
| | | | | | Nong Khaem 9 | 1,805 |
| | | | | | Nong Khaem 13 | 900 |
| | | | | | Nong Khaem 19-(2) | 1,125 |
| | | | | | Ram Intra 9 | 640 |
| | | | | | Ram Intra 13 | 280 |
| | | | | | Ram Intra 19-(2) | 385 |
| | Existing compost plant | Solid waste | High rate composting | Primary fermentation plant, secondary fermentation yard, attached incineration plant, stack, selection plant | On-Nooch | 640 |
| | | | | | Nong Khaem | 160 |
| | | | | | Ram Intra | 320 |
| Incineration plant | Plant | Solid waste | 24 hour-continuous-incinerator | Incinerator, waste water treatment facility, electric precipitator, stack, control office, electric generator | Yannawa | 1,500 |
| | | | | | Dusit | 1,500 |
| | | | | | Bang Kapi | 1,200 |
| | | | | | Bangkok Noi | 1,100 |
| | | | | | Phasi Charoen | 1,100 |
| | Attached facilities | – | – | Truck weigher, car washing facility, warehouse | – | – |
| Collection and transport trucks | Collection and transport trucks | Solid waste, ash, compost product | – | Compactor, dump-truck | Case No. | No. of trucks (veh.) |
| | | | | | 9 | 1,374 |
| | | | | | 13 | 1,139 |
| | | | | | 19-(2) | 1,164 |

### 7.3.2 Screening of the environmental factors and environmental indicators

General environmental factors and indicators have been studied relation to the environmental impact, then the specific factors and indicators for the detail examination were selected as shown in Table 7.17. (Ref. Appendix 7.3 General factors)

Table 7.17 Environmental factors and environmental indicators

| Environmental category | Environmental factor | Environmental indicator | |
|---|---|---|---|
| Living environment | Air pollution | Ambient quality | Concentration of $NO_X$, $SO_X$, $HC\ell$, and Dust |
| | | Total emission | Volume of $SO_X$ |
| | Water pollution | Effluent quality | pH, BOD, SS, Zn, Cr, Hg, Cd |
| | | Effluent volume | BOD, SS |
| | Noise | Noise level | |
| | Vibration | Vibration level | |
| | Rank odor | Concentration of odor substances | |
| | Soil contamination | Concentration change of soil contaminator | |
| | Land subsidence | Amount of subsidence | |
| | Low frequency air vibration | Sound pressure level | |
| | Obstruction against sunshine | Shadow of structure | |
| | Wind damage | Wind damage | |
| | Electric wave obstruction | Electric wave obstruction | |
| | Treatment residue | Secondary influence | |
| | Traffic | Traffic | |
| | Fire | Fire | |
| Natural environment | Topography and geology | Topography and geology | |
| | Groundwater | Groundwater | |
| | Aesthetics | Landscape | |
| | Flora | Loss of vegitable | |
| | Fauna | Loss of wild animal | |
| | Aquatic life | Loss of aquatic life | |
| Socio-economic environment | Historical site and cultural assets | Destruction or deformation of historical site and cultural assets | |
| | Land use | Restriction on land use, Land cost | |
| | Industry | Industrial structure | |
| | Employment | Condition of employment | |

## 7.4 Forecast of the Environmental Impacts

### 7.4.1 Environmental factors to be used for forecast

(1) Quantitative forecast

Environmental factors used for quantitative forecast were determined as shown in Table 7.18.

Table 7.18 Environmental factors for quantitative forecast

| Environmental impact element | Element facility | Air pollution | Water pollution | Noise | Rank odor | Land subsidence |
|---|---|---|---|---|---|---|
| Incineration plant | Stack | (1) | | | | |
| | Plant | | | (2) | | |
| Final disposal site | Landfill site | | | | (3) | (4) |
| | Waste water treatment facilities | | (5) | | | |
| Compost plant | Stack | (6) | | | | |
| Collection truck | Operation | (7) | | (8) | | |

Note: Number in a parenthesis indicates the paragraph number of Section 7.4.2.

(2) Qualitative forecast

The factors to be used for qualitative forecast were determined as follows.

| | | |
|---|---|---|
| Living environment | : | Soil contamination, Low frequency air vibration, Vibration, Obstruction against sunshine, Wind damage, Electric wave obstruction, Treatment residue, Traffic and Fire |
| Natural environment | : | Topography and geology, Groundwater, Aesthetics, Flora, Fauna and Aquatic life |
| Socio-economic Environment | : | Historical sites and cultural assets, Land use, Industry and Employment |

### 7.4.2 Forecast of the environmental impacts

(1) Air pollution (Incineration plant)

i) Forecast model

Diffusion of gas discharged from stacks of the incineration plants was forecast applying the following equations.

a. Plume Model for windy condition (U > 0 m/s)

$$C(x, y, z) = \frac{Q}{2\pi U \sigma y \sigma z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \left[\exp\left\{-\frac{(H+z)^2}{2\sigma_z^2}\right\} + \exp\left\{-\frac{(H-z)^2}{2\sigma_z^2}\right\}\right]$$

where, C(x, y, z) : Concentration at point (x, y, z), (ppm)

x : Leeward distance from the emission source, (m)

y : Horizontal distance from X line, (m)

z : Vertical distance from X line, (m)

Q : Emission Intensity, (cc/s)

U : Wind velocity, (m/s)

H : Height of the emission source, (m)

$\sigma y$ : Horizontal diffusion width, (m)

$\sigma z$ : Vertical diffusion width, (m)

b. Puff Model for windless condition (U $\leqq$ 1 m/s)

$$C(x, y, z, T) = \int_0^T \frac{Q}{(2\pi)^{3/2} \cdot \sigma y^2(t) \cdot \sigma_z(t)} \cdot \exp\left\{-\frac{x^2+y^2}{2\sigma y^2(t)}\right\} \left[\exp\left\{-\frac{(H+z)^2}{2\sigma z^2(t)}\right\} + \exp\left\{-\frac{(H-z)^2}{2\sigma y^2(t)}\right\}\right]$$

where, C(x, y, z, T): Concentration at point (x, y, z) T hours after emission, (ppm)

Q : Emission Intensity, (cc/s)

$\sigma y$: Horizontal diffusion width T hours after emission, (m)

$\sigma z$: Vertical diffusion width T hours after emission, (m)

H : Height of the emission source, (m)

ii) Conditions for the forecast

a. Theoretical air volume (Lo) and emission gas volume ($Q_1$)

Lo = 8.89c + 26.7 (h - o/8) + 3.33s

$Q_1$ = ($\lambda$ - 0.21) Lo + 1.867c + 11.2h + 0.7s + 0.8n + 1.244w

where, c, h, o, s, n and w : Chemical composition ratio of carbon, hydrogen, oxygen, sulpher, nitrogen and water

$\lambda$ : Excessive air ratio

b. Concentration of gas at stack outlet (Ref. Table 7.19)

Table 7.19 Concentration of gas at stack outlet

| Pollutants | Concentration |
|---|---|
| Hydrogen chloride (HCl) | 750 (ppm) |
| Sulfur oxides ($SO_x$) | 60 (ppm) |
| Nitrogen oxides ($NO_x$) | 150 (ppm) |
| Carbon monoxide (CO) | 50 (ppm) |
| Dust | 0.1 ($g/Nm^3$) |

These figures were estimated from the forecast characteristics of solid waste in the year 2000.

c. Stack and characteristics of gas

Stack height 60 m

Gas temperature 200°C

Gas emission speed 15 m/s.

d. Objective incineration plants

Case No. 13 Yannawa (1,500 t/d), Bang Kapi (1,200 t/d), Bangkok Noi (1,100 t/d), Phasi Charoen (1,100 t/d)

Case No. 19-(2) Yannawa (1,500 t/d), Dusit (1,500 t/d)

iii) Results of forecast

The maximum pollutants concentration on the ground was forecast on assumption that the maximum quantity of low-quality solid waste was incinerated under the ordinary climate. (Ref. Table 7.20) (Ref. Appendix 7.4 for the contour line maps of pollutants concentration)

Table 7.20 Maximum concentration on the ground

| Case No. | Pollutants | | | | | Location of occurrence |
|---|---|---|---|---|---|---|
| | HCℓ (ppm) | SOx (ppm) | NOx (ppm) | CO (ppm) | Dust ($mg/m^3$) | |
| 13 | 0.029 | 0.002 | 0.006 | 0.002 | 0.004 | 2 km north of Yannawa |
| 19-(2) | 0.029 | 0.002 | 0.006 | 0.002 | 0.004 | - do - |

iv) Total emission volume of sulfur dioxide ($SO_2$).

a. Forecast model

The total emission volume of $SO_2$ was estimated from the following equation. (Ref. Table 7.21)

$$Q_s = q_s V 10^{-6}$$

where, $Q_s$ : Total emission volume of $SO_2$, ($Nm^3/h$)

$q_s$ : Concentration of emitted $SO_2$ gas, (ppm)

V : Emission gas volume, ($Nm^3/h$)

b. Condition for forecast

Incineration plant $q_s$ = 60 (ppm)

Existing compost plant $q_s$ = 35 (ppm)

Table 7.21 Emission gas volume

| Treatment capacity (t/d) | 1,500 | 1,200 | 1,100 | Exist. comp. plant |
|---|---|---|---|---|
| Emission gas volume (v = $Nm^3/h$) | 315,000 | 252,000 | 231,000 | 42,000 |

c. Results of the forecast

Total emission of $SO_2$ gas was forecast as in Table 7.22.

Table 7.22 Total emission of $SO_2$ gas

| Treatment capacity (t/d) | 1500 | 1200 | 1100 | 100 |
|---|---|---|---|---|
| $SO_2$ gas ($Nm^3/h$) | 18.9 | 15.1 | 13.9 | 1.5 |

| Case No. | 13 | 19-(2) |
|---|---|---|
| Total volume of $SO_2$ ($Nm^3/h$) | 61.8 | 37.8 |

(2) Noise (Incineration plant)

i) Forecast model

◦ Attenuation owing to accoustic shielding obtained from the Flennel number (N)

$$N = \frac{2\delta}{\lambda} = \frac{\delta f}{170}$$

where, $\lambda$: Wave length (m)

f: Frequency (Hz)

$\delta$: A+B-d (See Fig. 7.2)

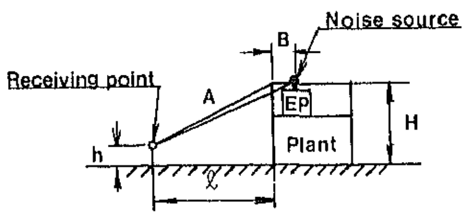



Fig. 7.2 Noise source of plant

° Attenuation owing to distance was obtained from the following equation:

$$L_A = L_W - 8 - 20 \log r$$

where, $L_A$ : Sound level at the receiving point, [dB(A)]

$L_W$ : Power level of the noise source, [dB(A)]

r : Distance from the noise source to the receiving point, (m)

ii) Conditions for the forecast

a. Dimension of the plant (Ref. Fig. 7.2)

Height of noise source H = 31.5 m (B = 5 m)

Height of receiving point h = 1.5 m

Distance to the boundary line $\ell$ = 39 m

b. Noise source of the plant

The noise levels of the electric precipitaters (EP) and the cooling tower was forecast as in Table 7.23.

Table 7.23 Noise of incineration plant equipment

[dB(A)]

| Noise source | Frequency (Hz) | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 | |
| E P | 58 | 68 | 74 | 82 | 82 | 75 | 69 | 86 |
| Cooling tower | 60 | 64 | 77 | 77 | 74 | 65 | 52 | 81 |

iii) Results of the forecast

Noise from the plant to be received at the boundary line of the site was estimated as follows. (Ref. Table 7.24)

Table 7.24 Noise of incineration plant

| Noise source | Sound level on the boundary, [dB(A)] |
|---|---|
| EP (3 pieces) | 21 |
| Cooling tower | 14 |
| Total | 22 |

(3) Rank Odor (Final disposal site)

i) Forecast model

a. Gas generation volume

The gas generates as the result of unaerobic decomposition of solid waste. Its volume was estimated applying the following chemical equation.

$$CHaObNc + \frac{1}{4}(4-a-2b+3c)H_2O \rightarrow \frac{1}{8}(4-a+2b+3c)CO_2 + \frac{1}{8}(4+a-2b-3c)CH_4 + cNH_3$$

b. Diffusion Model of rank odor

$$C = \frac{2(1+e)Q}{(2\pi)^{3/2}\cdot\gamma\cdot d^2}\{1 - \exp(-\frac{d^2}{2\sigma_{yo}^2})\}$$

where, C : Substance concentration on the ground, (ppm)

Q : Volume of rank odour gas, (cc/s)

$\gamma$ : Vertical diffusion speed, $\gamma = 1.0$ (m/s)

$\sigma_{yo}$ : Initial horizontal diffusion width, $\sigma_{yo} = 20$ (m)

d : Distance from the generation source, d = 10 (m)

ii) Conditions for the forecast

a. Solid waste chemical composition

C : 18.9%, H : 2.89%, O : 11.09% and N : 0.38%

b. Change of gas generation rate

Half of the gas volume was assumed to be generated in the first year after landfill.

c. Landfill volume

The maximum landfill volume of On-Nooch (Case No. 9) in the year 2000 was adopted as 1,814 t/d.

d. Concentration of the generated rank odor at the landfill site:

| | |
|---|---|
| Hydrogen sulfide | 40 (ppm) |
| Methyl mercaptan | 15 (ppm) |
| Methyl sulfide | 30 (ppm) |
| Ammonia | 1.7 (%) |
| Trimethylamine | (negligible) |

iii) Results of forecast

Concentration of the offensive substances on the boundary of the sites under the windless condition was forecast as shown in Table 7.25 (the windless condition is the worst conditions when the source is close to the ground).

Table 7.25 Diffusion of rank odour

| | Substance | | | |
|---|---|---|---|---|
| | Ammonia | Methyl mercaptan | Hydrogen sulfide | Methyl sulfide |
| Generation volume (cc/s) | 522.47 | 0.465 | 1.24 | 0.93 |
| Concentration (ppm) | 0.29 | $2.57 \times 10^{-4}$ | $6.85 \times 10^{-4}$ | $5.14 \times 10^{-4}$ |

(4) Land subsidence (Landfill site)

i) Forecast model

a. Amount of subsidence

$$S = \frac{e_0 + e}{1 + e_0} h_0$$

where, S : Total amount of subsidence, (m)

$e_0$ : Initial void ratio

e : Final void ratio (Quick load of 15 m high waste was assumed)

$h_0$ : Depth of consolidation stratum

b. Time required for consolidation

$$t = \frac{T D^2}{C_v}$$

where, t : Time required for consolidation

T : Time factor relating to consolidation rate

$C_v$ : Consolidation factor

D : Maximum permeation distance of the consolidation stratum

ii) Condition of the forecast

The values applied in the forecast were shown in Table 7.26.

Table 7.26 Data used for forecast of land subsidence

| ho (m) | Cv ($cm^2/s$) | °C | Load ($t/m^2$) | | Void ratio | |
|---|---|---|---|---|---|---|
| | | | Landfill site | Boundary | Landfill site | Boundary |
| 14 | $8.96 \times 10^{-4}$ | 2.08 | 17.1 | 0.09 | 1.47 | 2.07 |

iii) Results of the forecast

Results of the forecast were shown in Table 7.27.

Table 7.27 Subsidence

| Location | Subsidence (m) | Period (years) |
|---|---|---|
| Landfill site | 2.50 | 60 (90% consolidation) |
| Boundary | 0.04 | - do - |

(5) Water pollution (Final disposal site)

i) Forecast model

a. Discharge volume

$$Q = (C_1A_1 + C_2A_2)I \cdot /(1{,}000\alpha)$$

where, Q : Discharged volume, $(m^3/d)$

$C_1, C_2$ : Coefficients of leachate discharge from the landfill site; $C_1$ under landfill work, and $C_2$ after completion of landfill.

$A_1, A_2$ : Drainage area in a landfill site; $A_1$ landfilling area, and $A_2$ completed area.

I : Inflow water (= Rainfall - evaporation), (mm/year)

$\alpha$ : Number of operating days in a year

b. Volume of pollutants

Pollutant volume = (Discharged volume) x (Pollutans concentration)

ii) Conditions for the forecast

Conditions for the forecast of water pollution are shown in Table 7.28.

Table 7.28 Conditions for forecast of water pollution

| | | | Case No. 9 | 13 | 19-(2) | Without-project |
|---|---|---|---|---|---|---|
| Drainage area in a landfill site (1,000 $m^2$) | On-Nooch | $A_1$ | 189.4 | 92.2 | 80.6 | 189.4 |
| | | $A_2$ | 157.5 | 0.0 | 76.9 | 157.5 |
| | Nong Khaem | $A_1$ | 199.0 | 118.0 | 140.0 | 199.0 |
| | | $A_2$ | 240.0 | 126.0 | 115.0 | 240.0 |
| | Ram Intra | $A_1$ | 88.8 | 59.1 | 50.8 | 88.8 |
| | | $A_2$ | 70.4 | 0.0 | 59.5 | 70.4 |
| Operating days (d) | | α | 310 | | | 180 |
| Effluent quality | BOD ($g/m^3$) | | 20 | | | 200 |
| | SS ($g/m^3$) | | 30 | | | 200 |
| Coefficient of leachate discharge | | $C_1$ | 1.0 | | | |
| | | $C_2$ | 0.4 | | | |
| Inflow water (mm/year) | | I | 912 | | | |

iii) Results of the forecast

Results of the forecast are shown in Table 7.29.

Table 7.29 Water pollution of landfill sites

| | | Case No. 9 | 13 | 19-(2) | Without-project |
|---|---|---|---|---|---|
| On-Nooch | | | | | |
| Discharge volume ($m^3/d$) | | 750 | 280 | 330 | 1,280 |
| Pollutants volume | BOD | 15.0 | 5.6 | 6.6 | 256 |
| (kg/d) | SS | 22.5 | 8.4 | 9.9 | 256 |
| Nong Khaem | | | | | |
| Discharge volume ($m^3/d$) | | 870 | 500 | 550 | 1,500 |
| Pollutants volume | BOD | 17.4 | 10.0 | 11.0 | 300 |
| (kg/d) | SS | 26.1 | 15.0 | 16.5 | 300 |
| Ram Intra | | | | | |
| Discharge volume ($m^3/d$) | | 350 | 180 | 220 | 600 |
| Pollutants volume | BOD | 7.0 | 3.6 | 4.4 | 120 |
| (kg/d) | SS | 10.5 | 5.4 | 6.6 | 120 |

(6) Air pollution (Existing compost plant)

i) Forecast model

Diffusion of gas from stack of incineration plant attached to the existing compost plant forecast from the following equation.

$$C_{max} = \frac{2q}{\pi eUHe^2} \left( \frac{Cz}{Cy} \right)$$

where, $C_{max}$ : Maximum concentration of pollutants on the ground, $(m^3/m^3)$

q : Emission gas volume, $(m^3/s)$

U : Wind velocity, (m/s)

Cz,Cy : Diffusion parameters, Cz vertical and Cy horizontal

He : Effective stack height, (m) (actual stack height plus height of smoke ascent)

ii) Conditions for the forecast

q = 11.7 $(m^3/s)$, U = 6 (m/s), Cz = Cy = 0.12

Actual stack height : 24.4 (m)

Gas temperature : 150°C

Incineration volume : 100 t/16h

Pollutants concentration of emission gas : HCl 100 (ppm), $SO_X$ 35 (ppm), $NO_X$ 60 (ppm), CO 15 (ppm), Dust 0.04 $(g/Nm^3)$

Assumptions were made that carbonate calcium is mixed into the refuse hopper to reduce hydrogen chloride, and that water spray gas cooling method is applied.

iii) Results of the forecast

Table 7.30 Air pollution by the existing compost plant

| | Pollutant | | | | |
|---|---|---|---|---|---|
| | HCℓ | $SO_X$ | $NO_X$ | CO | Dust |
| Maximum concentration on the ground | 0.037 (ppm) | 0.013 (ppm) | 0.022 (ppm) | 0.006 (ppm) | 0.015 $(mg/m^3)$ |

The maximum concentration is expected to occur 550 meters leeward of the stack.

(7) Air pollution (Collection trucks)

Diffusion of carbon monoxide, the dominant pollutant of exhaust gas, was forecast.

i) Forecast model

a. Emission rate of CO

$E = 287\ S^{-0.75}$

where, E : CO emission rate, (g/kg)

S : Running speed, (km/h)

Source: Vehicle emissions and air pollution in Bangkok streets, AIT-Shell Research, 1975

b. Diffusion model

The same as the equation used for rank odour forecast.

ii) Conditions for the forecast

a. Running speed S = 20 (km/h) (Slower the speed, thicker the concentration)

b. Number of collection trucks N = 300 (vehicle/h) (261 trucks at the peak hour is estimated at On-Nooch in the alternative Case No. 9)

c. The initial diffusion width $\sigma_{yo}$ = 15 (m)

iii) Results of forecast

Results of forecast are shown in Table 7.31.

Table 7.31 Air pollution by collection trucks

| Distance from the trucks (m) | 5 | 10 | 20 | 30 | 40 |
|---|---|---|---|---|---|
| Concentration (ppm) | 2.1 | 1.9 | 1.4 | 0.9 | 0.6 |

(8) Noise (collection trucks)

i) Forecast model

$$L = Lw - 8 - 20 \log_{10} \ell + 10 \log_{10} (\pi\frac{\ell}{d} \tanh 2\pi\frac{\ell}{d}) + \alpha$$

where, L : Average noise level [dB(A)]

LW : Average power level of a vehicle, [dB(A)]

$Lw = 87 + 0.2V + 10 \log_{10} (a_1 + 10 a_2)$

$a_1$ : Composition of small vehicles

$a_2$ : Composition of large vehicles whereas $a_1 + a_2 = 1.0$

$\ell$ : Distance between source and receiver, (m)

d : Average headway, (m) : d = 1,000 v/N v : Average running speed, (km/h)

N : Traffic volume, (vehicle/h)

$\alpha$ : Adjustment to account for the road type and the height of receiver, [dB(A)]

ii) Conditions for the forecast

a. $V = 60$ (km/h), $\ell = 10$ (m), $\alpha = -4$ [dB(A)]

b. Traffic volume and heavy vehicle ratio

$N = 1,000$ (vehicle/h), $a_2 = 0.30$ (Collection trucks excluded)

$N = 1,300$ (vehicle/h), $a_2 = 0.46$ (Collection trucks included)

iii) Results of forecast

Table 7.32 Noise of collection trucks

| Case | Sound level [dB(A)] | Increase due to the collection trucks |
|---|---|---|
| Including collection trucks | 69 | 3[dB(A)] |
| Excluding collection trucks | 72 | |

## 7.5 Assessment Criteria

An environmental impact assessment will be prepared according to the assessment criteria shown in Table 7.33. The assessment criteria were formulated making reference to laws and regulations in Thailand relating to pollution and other concerned material of the foreign countries.

Table 7.33 Criteria for environmental impact assessment

| Environmental factor | | Environmental indicator | | | Assessment standards | Basis for the standardization |
|---|---|---|---|---|---|---|
| Living environment | Air pollution | Ambient air quality | $NO_2$ | | Maximum hourly value 0.32 $mg/m^3$ (0.16 ppm) *1 | Environmental Quality Standards in Thailand (Draft) 1980 NEB |
| | | | $SO_2$ | | Annual average hourly value 0.1 $mg/m^3$ (0.04 ppm) *2 | – do – |
| | | | CO | | 8–hour average hourly value 20 $mg/m^3$ (16 ppm) *3 | – do – |
| | | | SPM (dust) | | Annual average hourly value 0.1 $mg/m^3$ | – do – |
| | | | HC1 | | Annual average hourly value 0.05 ppm | 1/100 of permissible concentration during work (5 ppm) by ACGIH Guideline |
| | | Total emission volume | $SO_2$ | | Plant capacity: 1,500 (t/d) / 1,200 / 1,100; Allowable emission: 56 ($Nm^3/h$) / 46 / 43 | $SO_2$ total volume suppression (Japan)<br>Tokyo Metropolitan Government (TMG) bulletin No. 674 |
| | Water pollution | Concentration of effluent substance | pH | | Between 6.5 and 8.5 | Environmental standards concerning water pollution (Japan).<br>Bureau of Environment bulletin No. 3 |
| | | | BOD | | 20 ppm | Factory Act 1969 MOI, Thailand. |
| | | | SS | | 30 ppm | – do – |
| | | | Heavy metals | Zn | 5 ppm | – do – |
| | | | | Cr | 0.5 ppm | |
| | | | | Hg | 0.005 ppm | |
| | | | | Cd | 0.03 ppm | |
| | | Total effluent volume | BOD | | 19 kg/d | TMG Pollution Prevention Ordinance (Japan) |
| | | | SS | | 28.5 kg/d | The Study team |
| | Noise | Noise level | Daytime | | 55 dB(A) (50% value acceptable inside the typical office buildings) | Environmental Quality Standards for Noise (Japan) |
| | | | Night time | | 50 dB(A) (50% value acceptable at quiet residential areas) | |
| | Vibration | Vibration level | | | 55 dB (insensible earthquake, upper end of the 80% range) | Vibration Regulation Law (Japan)<br>Bureau of Environment bulletin No. 90 |
| | Rank odour | Density of rank odour | Ammonia | | 1 ppm (Odour strength factor 2.5 (sensible density)) | Offensive Odour Control Law (Japan) |
| | | | Methyl mercaptan | | 0.002 ppm | |
| | | | Hydrogen sulfide | | 0.02 ppm | |
| | | | Methyl sulfide | | 0.01 ppm | |
| | | | Trimethylamine | | 0.005 ppm | |
| | Soil pollution | Density of heavy metals in soil | Cd | | 1 mg per 1 kg of rice (6 mg per 1 kg of soil) | The Law concerning prevention of soil pollution of agricultural land (Japan) |
| | | | Cu | | 125 mg per 1 kg of soil | |
| | | | As | | 15 mg per 1 kg of soil | |
| | Land subsidence | Amount of land subsidence | | | Shall not cause additional land subsidence. | The Study team |
| | Low frequency air vibration | Sound pressure level | | | 50 dB(A) (an extent within which daily life is not affected) | The Study team |
| | Obstruction against sunshine | Shadow of structure | | | Shadow of the structure shall not remain longer than two hours at the places distant at least 10 meters from boundary line of the site. | Architectural Standards (Japan) |
| | Electric wave obstruction | Electric wave obstruction | | | Shall not cause new electric wave obstruction. | The Study team |
| | Wind damage | Wind damage | | | Shall not affect the living environment with turbulence such as down wash and down draft. (Approximate wind velocity: 5 m/s or less) | Wind force grading by Meteorological Agency, Japan. |
| | Treatment residue | Secondary influence | | | Secondary influence such as decomposition, fermentation, rank odour, and breeding of vector shall be small. (Targeted ignition loss: 7%) | Guideline by Ministry of Public Welfare, Japan. |
| | Traffic | Traffic (surroundings) | | | Shall not give serious trouble to passersby attending school or the handicapped. Shall not affect the environment of residential areas. | The Study team |
| | Fire | Fire | | | Spontaneous fire shall not affect the surroundings. | The Study team |
| Natural environment | Topography & geology | Topography & geology | | | Topographical or geological change shall not affect the living environment. | The Study team |
| | Aesthetics | Landscape | | | Change of flow and quality of ground-water shall not affect the living environment. | The Study team |
| | Flora | Loss of vegetation | | | There shall be little loss of plants. | The Study team |
| | Fauna | Loss of wild animal | | | There shall be little loss of wild animals. | The Study team |
| | Aquatic life | Loss of aquatic life | | | Shall not give serious influence to aquatic life. | The Study team |
| Socio-economic environment | Historical site and cultural assets | Destruction or deformation of historical site and cultural assets | | | The existing shape and value of historic sites and cultural spots shall not be degraded. | The Study team |
| | Landuse | Restriction on landuse | | | Shall be coordinated with the future landuse plan of the surroundings with little adjustment of the existing regulations. | The Study team |
| | | Land cost | | | Shall not reduce land value of the surroundings | The Study team |
| | Industry | Industrial structure | | | Shall not cause particular damage to the existing industries. | The Study team |
| | Employment | Employment opportunity | | | Shall not seriously reduce employment opportunities. | The Study team |

Note: *1) Equivalent to annual average hourly value of 0.03 ppm of NOx.
*2 $SO_2$ is regarded as $SO_X$.
*3 Equivalent to annual average hourly value of 8 ppm.