vi. Transport Cost Comparison

Costs of direct transport and transfer transport were examined in each case. In this examination, the direct transport costs consider:

- transport costs from the weighted center of each municipality/district to Nejapa Disposal Site (D/S) by 18yd^3 compactor truck.

The transfer transport costs consist of:

- transport costs from the weighted center of each municipality/district to the transfer station by 18yd^3 compactor truck,
- costs for the transfer station, and
- transport costs from the transfer station to Nejapa Landfill.

From a viewpoint of costs, whether the employment of transfer transport is beneficial or not (i.e., whether the transfer transport in total can be cheaper than the direct transport or not) is examined. The results show that Case 1 leads to the largest cost reduction, the second place is Case 2 and the third one is Case 3, but Case 2 and Case 3 are almost the same.

Case 1

Table K-55: Cost Reduction by Transfer Transport (Case 1; T/S 1-1, 1200t)

Municipality	Direct	Transfer	Direct – Transfer	
	US$/ton	US$/ton	US$/ton	%
T/S 1-1 (1200t)				
011SS	5.20	3.35	1.85	35.6
012SS	4.94	3.88	1.06	21.5
013SS	5.29	4.54	0.75	14.2
014SS	6.00	4.36	1.64	27.3
015SS	5.91	3.79	2.12	35.9
02MJ	4.41	4.05	0.36	8.2
03CD	4.28	4.76	-0.48	-11.2
04CT	3.70	5.02	-1.32	-35.7
05AY	4.10	4.32	-0.22	-5.4
06SM	6.88	4.76	2.12	30.8
07ST	6.31	6.12	0.19	3.0
08AC	6.22	5.11	1.11	17.8
09SY	5.64	4.98	0.66	11.7
10IL	6.35	5.82	0.53	8.3
11SMT	6.66	7.84	-1.18	-17.7
Average	5.46	4.85	0.61	9.6

Case 2

Table K-56: Cost Reduction by Transfer Transport (Case 2; T/S 2-1, 300t; T/S 2-2, 600t; T/S 2-3, 300t)

Municipality	Direct	Transfer	Direct – Transfer	
	US$/ton	US$/ton	US$/ton	%
T/S 2-1 (300t)				
013SS	5.29	5.56	-0.27	-5.1
014SS	6.00	5.70	0.30	5.0
07ST	6.31	5.78	0.53	8.4
08AC	6.22	5.12	1.10	17.7
average	5.96	5.54	0.42	6.5
T/S 2-2 (600t)				
011SS	5.20	3.78	1.42	27.3
012SS	4.94	4.22	0.72	14.6
015SS	5.91	4.35	1.56	26.4
02MJ	4.41	4.35	0.06	1.4
03CD	4.28	5.14	-0.86	-20.1
04CT	3.70	5.32	-1.62	-43.8
05AY	4.10	4.66	-0.56	-13.7
06SM	6.88	5.32	1.56	22.7
average	4.93	4.64	0.29	1.9
T/S 2-3 (300t)				
09SY	5.64	5.23	0.41	7.3
10IL	6.35	5.27	1.08	17.0
11SMT	6.66	7.17	-0.51	-7.7
average	6.22	5.89	0.33	5.5
Average	5.70	5.36	0.35	4.6

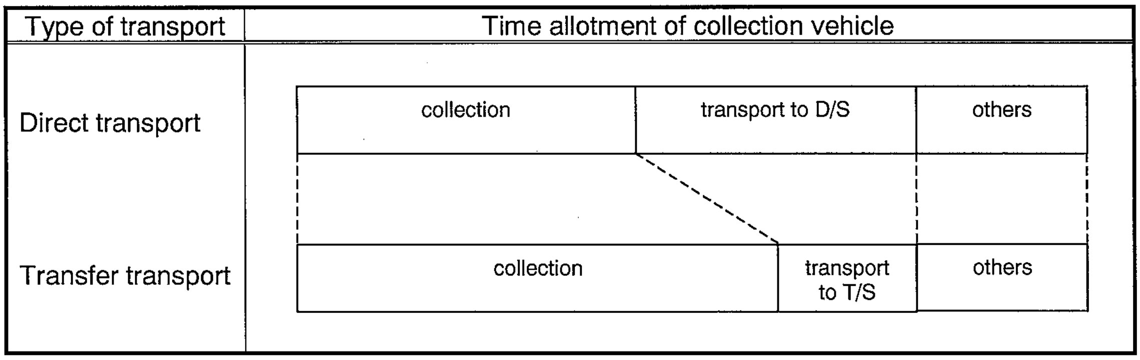
Case 3

Table K-57: Transport Cost Reduction of Transfer Transport (Case 3; T/S 3-1, 300t; T/S 3-2 900T)

Municipality	Direct	Transfer	Direct – Transfer	
	US$/ton	US$/ton	US$/ton	%
T/S 3-1 (300t)				
012SS	4.94	5.66	-0.72	-14.6
013SS	5.29	4.96	0.33	6.2
014SS	6.00	5.36	0.64	10.7
07ST	6.31	6.11	0.20	3.2
08AC	6.22	5.27	0.95	15.3
average	5.75	5.47	0.28	4.2
T/S 3-2 (900)				
011SS	5.20	4.00	1.20	23.1
015SS	5.91	4.44	1.47	24.9
02MJ	4.41	4.53	-0.12	-2.7
03CD	4.28	4.49	-0.21	-4.9
04CT	3.70	5.02	-1.32	-35.7
05AY	4.10	4.75	-0.65	-15.9
06SM	6.88	5.06	1.82	26.5
09SY	5.64	4.31	1.33	23.6
10IL	6.35	5.24	1.11	17.5
11SMT	6.66	7.22	-0.56	-8.4
average	5.31	4.91	0.41	4.8
Average	5.53	5.19	0.35	4.5

vii. Effect on Collection

In case that the transfer transport is adopted, collection vehicles can gain more time for waste collection activity, as the time required for transport is reduced. The following figure schematically shows the difference of time spared for collection vehicle between the direct transport and the transfer one.



As more time is spared for the collection activity, a collection vehicle can collect more waste in a day. Table K-58 shows the increase of collection amount by the employment of the transfer transport in case of the 18yd^3 compactor. Case 1 shows 41% of increase of collection amount, Case 2 and Case 3 are 53% and 48% respectively.

Table K-58: Comparison of Collection Amount by Direct or Transfer Transport

Case	Direct ton/day/vehicle	Transfer ton/day/vehicle	Increase
Case 1	9.0	12.7	41%
Case 2	8.8	13.5	53%
Case 3	9.0	13.3	48%

viii. Collection and Transport Cost Comparison

Transport cost comparison concentrated on the costs of transport, it did not take into account the effect on collection, i.e., more time is spared for the collection activity and a collection vehicle can collect more waste in a day. In this section, taking it into consideration, "collection costs plus transport costs" are compared for the cases of direct transport and transfer transport, i.e., how much in collection and transport cost in total can be reduced if the transfer transport is adopted (see Table K-59 to Table K-61).

In Case 1, 3 municipalities of CD, CT and AY do not get benefit by employing the transfer transport. In Case 2, the same 3 municipalities (CD, CT and AY) do not become beneficial. In Case 3, District 2 of SS is added to them as non-beneficial members.

The results of "collection costs plus transport costs" comparison were almost same as the transport cost comparison carried out in the previous section. 8 municipalities, SS, MJ, SM, ST, AC, SY, IL, SMT, obtain benefit from the transfer transport. However, the justifiable reasons for employing the transfer transport for CD, CT and

AY municipalities, which are relatively close to Nejapa Disposal Site, could not be found in this examination.

Table K-59: Collection and Transport Cost Reduction by Transfer Transport (Case 1; T/S 1-1, 1200t)

Municipality	Direct	Transfer	Direct - Transfer	
	US$/ton	US$/ton	US$/ton	%
T/S 1-1				
011SS	13.53	11.50	2.03	15.0
012SS	13.20	11.86	1.34	10.2
013SS	13.69	12.33	1.36	9.9
014SS	14.95	12.24	2.71	18.1
015SS	14.76	11.79	2.97	20.1
02MJ	12.46	12.01	0.45	3.6
03CD	12.20	12.57	-0.37	-3.0
04CT	11.55	12.75	-1.20	-10.4
05AY	11.94	12.17	-0.23	-1.9
06SM	16.89	12.57	4.32	25.6
07ST	15.55	13.82	1.73	11.1
08AC	15.35	12.84	2.51	16.4
09SY	14.38	12.75	1.63	11.3
10IL	15.75	13.51	2.24	14.2
11SMT	16.42	15.93	0.49	3.0
Average	14.17	12.71	1.47	9.5

Table K-60: Collection and Transport Cost Reduction by Transfer Transport (Case 2; T/S 2-1, 300t; T/S 2-2 600t; T/S 2-3, 300t)

Municipality	Direct	Transfer	Direct - Transfer	
	US$/ton	US$/ton	US$/ton	%
T/S 2-1				
013SS	13.69	13.53	0.16	1.2
014SS	14.95	13.61	1.34	9.0
07ST	15.55	13.69	1.86	12.0
08AC	15.35	13.17	2.18	14.2
average	14.89	13.50	1.39	9.1
T/S 2-2				
011SS	13.53	11.93	1.60	11.8
012SS	13.20	12.22	0.98	7.4
015SS	14.76	12.29	2.47	16.7
02MJ	12.46	12.29	0.17	1.4
03CD	12.20	12.92	-0.72	-5.9
04CT	11.55	13.09	-1.54	-13.3
05AY	11.94	12.52	-0.58	-4.9
06SM	16.89	13.09	3.80	22.5
average	13.32	12.54	0.77	4.5
T/S 2-3				
09SY	14.38	13.28	1.10	7.6
10IL	15.75	13.28	2.47	15.7
11SMT	16.42	14.88	1.54	9.4
average	15.52	13.81	1.70	10.9
Average	14.58	13.28	1.29	8.2

Table K-61: Collection and Transport Cost Reduction by Transfer Transport
(Case 3; T/S 3-1, 300t; T/S 3-2 900t)

Municipality	Direct	Transfer	Direct - Transfer	
	US$/ton	US$/ton	US$/ton	%
T/S 3-1				
012SS	13.20	13.57	-0.37	-2.8
013SS	13.69	13.05	0.64	4.7
014SS	14.95	13.34	1.61	10.8
07ST	15.55	13.89	1.66	10.7
08AC	15.35	13.27	2.08	13.6
average	14.55	13.42	1.12	7.4
T/S 3-2				
011SS	13.53	11.96	1.57	11.6
015SS	14.76	12.33	2.43	16.5
02MJ	12.46	12.41	0.05	0.4
03CD	12.20	12.34	-0.14	-1.1
04CT	11.55	12.75	-1.20	-10.4
05AY	11.94	12.58	-0.64	-5.4
06SM	16.89	12.83	4.06	24.0
09SY	14.38	12.19	2.19	15.2
10IL	15.75	13.01	2.74	17.4
11SMT	16.42	15.02	1.40	8.5
average	13.99	12.74	1.25	7.7
Average	14.27	13.08	1.19	7.6

ix. Consideration Transfer Station Size

The lager size of transfer stations lead to the fewer cost. However, construction of large facility has large impact on traffic, environment, etc. Consideration of such impacts is summarized in Table K-62.

Table K-62: Comparative Evaluation of Transfer Stations by Size

Comparative Evaluation Item	Small T/S (e.g., up to 300 ton/day)	Medium T/S (e.g., 300 to 900 ton/day)	Large T/S (e.g., more than 900 ton/day)
1. Land Acquisition	Easy	← →	Difficult
2. Neighborhood Consensus	Easy	← →	Difficult Consensus with residents along the access road is also necessary.
3. Compatibility with Development Plan, and Construction Permit	Easy Possibly acceptable in many candidate sites	← →	Difficult Numbers and locations of candidate sites will be largely limited.
4. Environmental Impact (Acceptability)			
• impacts of noise, offensive odor	Small	← →	Large Prevention measures e.g., buffer zone is inevitable.
• traffic congestion	Very small	← →	Large Prevention measures will be necessary, or appropriate localization is indispensable (sufficient access to trunk road).
• aesthetic view impact	small mitigation measures	← →	Large mitigation measures
• other impacts	Small	← →	Large

Comparative Evaluation Item	Small T/S (e.g., up to 300 ton/day)	Medium T/S (e.g., 300 to 900 ton/day)	Large T/S (e.g., more than 900 ton/day)
5. Economic Feasibility			
• Land Area Necessary • and • Acquisition Cost	Small, Small	← →	Large (including buffer zone), Large
• Access Road Improvement Cost	Small	← →	Large
• Transport distance by collection vehicles, and its benefit	Shorter, Large	← →	Longer, Small
• Benefit of "Economy of Scale"	Small	← →	Large

x. Examination of the Cases and Recommendation of the Optimum Transfer Transport System

As the cost comparison of the three cases shows, Case 1 is the most beneficial in viewpoint of costs. However, construction and operation of the 1200t T/S must be absolutely difficult in the densely populated city center of SS. Acquiring such large scale of land and getting neighborhood consensus must face severe opposition from the citizens. Moreover, a thorough investigation on its impact on traffic is necessary, as the city is being annoyed about heavy traffic congestion even at present.

Case 2 is the secondly beneficial at the cost comparison, but almost the same as Case 3. Construction and operation of 300ton/day T/Ss in the west and in the east of the Study Area would not give serious adverse impacts on and around the sites due to their small sizes. The weighted center of the west is on AC, and one of the east is on SY. A 600ton/day T/S in the city center of SS would face problems, however, those would not be so serious as ones of 1200ton/day T/S.

Case 3 is with the least benefit. Construction and operation of 300t T/S in the west would not face serious problems as mentioned in the previous paragraph. The 900ton/day T/S in the east has more serious adverse impacts than 300 or 600ton/day T/Ss due to its large size. However, these impacts must be less than those of 1200ton/day T/S in the central part of SS.

As for each municipality, CD, CT and AY would never get benefit from the employment of transfer transport in any 3 cases above, if the final destination were Nejapa Disposal Site. As for CT, its present destination is the ESPIGA Disposal Site. If the final destination were ESPIGA, CT would gain benefit from the transfer transport, as the proposed T/Ss are located on the way south to ESPIGA. However in the assumptive case of Nejapa destination, collection vehicles of CT should go south to a T/S and a transfer vehicle will travel north from such T/S to Nejapa site maybe on the same road again.

Consequently, the Case 3 is recommendable as the optimum transfer transport system for AMSS.

The examination carried out here is based on the several assumptions. Ideally, locations and sizes of T/Ss are determined by weighted centers of waste generation areas and waste amount dealt with. However, the reality is different from the ideal. The locations and sizes of T/Ss depend on actually available lands and their circumstances. Therefore, it would be necessary and recommended that, after selecting candidate sites from several possibly available lands, a more concrete investigation (such as a feasibility study) on them should be executed.

c.2 Type of Transfer Station

Generally, transfer stations are classified into two types; direct-load and storage-load. The direct-load transfer stations means that waste brought by collection vehicles such as compactor trucks is directly discharged into transport vehicles such as tractor-trailers. On the other hand, storage-load transfer stations have a certain capacity to store waste, e.g., one to three days.

Table K-63: Comparative Evaluation of Transfer Stations by Type

Item	Direct-load	Storage-load
Required land size	**Small** space for storing waste is not necessary.	**Larger** large space for storing waste is necessary.
Required equipment	**Few** not necessary for loading waste into transport vehicles.	**Many** wheel loader or equivalent equipment is necessary for loading waste into transport vehicles.
Required prevention measures to environment	**Few** negative impact on environment, such as odor, waste litter, would be small, as waste is directly transshipped to transport vehicles.	**Many** negative environmental impact would be large as waste is placed on storage pits before transferred into transport vehicles. prevention measures to odor, waste litter, etc. and wastewater (leachate from waste) treatment would be necessary.
Reliability. flexibility	**Small** if transport system stops, collection system immediately halts too.	**Large** even though transport system stops, collection system can work until capacity of the storage pit fills.

Applicability

Construction and operation of direct-load would be less costly than that of storage-load, but less reliable to collection system. In the Study Area, round trip travel times of all the present collection routes never exceed three hours on the assumption that the final destination is Nejapa Disposal Site. This means that when the transfer transport system halts, at least one or two collection trips can be carried out in one working shift, which is 6 hours to 8hours, by returning to the direct transport. Therefore, even if the transfer transport system halts one day or two days, the negative impact on the collection system would not be serious. Consequently, direct-load is recommendable to the Study Area.

However, if the transfer station is used in conjunction with MRF, waste needs to be placed on the storage pit to be carried to material recovery process, where sufficient environmental prevention measures will be inevitable.

c.3 Type of Transfer Vehicle

Basically, type of transfer vehicle is determined from an economic point of view. Waste must be transported at minimum cost. The larger capacity of vehicle, generally, results in the fewer unit costs. However, gross vehicle weight (GVW), maximum payload, dimensions of body, etc. should meet with regulations which control vehicles and traffic.

Decree No.86 "Reglamento para el Control de Pesos, Carga y Medidas de Vehiculos Automotores que Circulan por las Carreteras de la Republica" by Ministry of Public Works (Ministerio de Obras Pubulicas) prescribes that:

- Maximum width is 2.50m,
- Maximum height is 3.80m,
- Maximum length is 18.30m, and
- Vehicle weight plus load do not exceed 33,800kg. If a total weight exceeds 33,800kg, it is necessary to obtain a certificate from Dirección General de Caminos.

Proposed Vehicle

The proposed transport vehicle is tractor-trailer that has capacity to load 20 ton of waste and over. The container (trailer) should be open top type as the direct-load transfer station is recommended.

d. Conclusion

Whether the transfer transport should be employed or not is depending on the size of T/Ss that are used. Small T/Ss' unit costs tend to be expensive, contrarily large T/Ss' ones are likely to be inexpensive due to economy of scale. In the examination of breakeven distance and travel time to Nejapa Disposal Site, 100ton/day transfer transport system never became beneficial to the Study Area, 300ton/day or over transfer transport system were advantageous compared with the direct transport.

In order to seek optimum location of T/Ss and their sizes, three cases were set.

- Case 1 is to use one large size of T/S, 1200 ton/day, in the central part of SS,
- Case 2 is to use two small size of T/Ss, 300 ton/day, in the west and in the east of the Study Area and one medium size of T/S, 600 ton/day, in the central part of SS, and
- Case 3 is to use one small size of T/S, 300 ton/day in the west and one large T/S, 900 ton/day in the east.

Case 1 leaded to maximum cost reduction, 9.6% in transport cost and 9.5% in collection and transport cost. Case 2 (4.6%, 8.2%) and Case 3 (4.5%, 7.6%) were the almost same, but Case 2 reduced the cost a little more than Case 3 did. It was thought, however, that Case 1 would be the least realistic as due to its size and the location. Case 2 would be more feasible than Case 1, but it would still be difficult to construct and operate the 600t transfer transport system in the central part of SS. Case 3 would be the most practical as the both T/Ss are out of the densely populated area of the Study Area.

The examination included 11 municipalities except AP, NJ and TN. Any case could not find the justifiable reasons for employing transfer transport for CD, CT and AY.

As for type of T/S, direct-load type is recommendable due to its fewer cost and smaller environmental impacts on and around the site. Although the direct-load type is less reliable than the storage-load type for maintaining the collection system, this would not be a serious problem because waste collection works can temporarily return to the direct transport system that is presently practiced.

20 ton or over tractor-trailers are recommendable as transport vehicles. Smaller capacity vehicles than those are not recommendable because use of a small vehicle for transfer transport raises transport cost.

The examination carried out here were based on several assumptions. More concrete investigation such as feasibility study must be necessary to decide the employment of an optimum transfer transport for AMSS.

K.4.3 Intermediate Processing System

K.4.3.1 Concept of Intermediate Processing Introduction

Objectives and methods of the intermediate processing system in municipal SWM are summarized in the table below. As it could be judged from the table below, the primary objective in the intermediate processing is the volume reduction in general. Subsequent objectives could be in the order of: improvement of waste handling; waste stabilization (e.g., prevention of waste decay); resource recovery; and energy recovery.

Table K-64: Objectives and Methods of Intermediate Processing System

	Improvement of waste handling	Volume reduction	Waste stabilization	Resources recovery	Energy recovery
Separation		X		X	
Baling	X	X			
Composting	X	X	X	X	(X)
Incineration	X	X	X		X

What method of intermediate processing to be selected in municipal SWM will largely depend on the intrinsic local conditions (e.g., geographical, social, economical conditions).

In Japan, as the incineration in municipal SWM is the common and major intermediate processing, the intermediate processing is almost perceived as a synonym of incineration. The reasons are as follows.

- The Japanese summer is humid and hot, therefore organic waste decay and vectors proliferation takes place in a short time. To cope with these problems, municipal wastes (especially perishables) should be frequently collected and be subject to a "stabilization" process before long.
- Although the national economical standard is high, 130 million people live on the narrow territory. Consequently land prices are extremely high, therefore it is required to limit as much as possible the land destined for sanitary landfills.

Therefore, the principal objectives of the incineration process in Japanese municipal SWM are: "waste stabilization" in a sanitary manner and "volume reduction" to economize the use of landfill sites.

For example in the United States of America, as the climate is comparatively dry, risks of vectors proliferation on rotten waste are lesser. Meanwhile extensive territory usable for landfills is generally available. Hence, the incineration process for the municipal SW there normally have a principal objective of energy recovery such as power generation, rather than the objectives of waste stabilization or volume reduction.

Small countries in Europe such as Denmark and Switzerland employ incineration processes widely. The climate there is relatively dry and the winter being freezing. Therefore, incineration objectives are mainly volume reduction and heat energy recovery rather than a Japanese objective of waste stabilization.

Meanwhile, intermediate processing facilities for "resource recovery" from municipal waste are being constructed and operated many recently in many industrialized countries, with an objective of "resource conservation".

As explained above, in introducing an intermediate processing facility, examination for the below aspect is indispensable:

- local conditions (e.g., geographical, social, economical conditions).

Modernity and newness of a facility, its performance and functioning in foreign industrialized countries and such commercial propaganda will not help to examine appropriate solutions in search. On the contrary, they may place confusion in the examination of what intermediate process answers to objectives raised.

Special attentions should be paid to that intermediate processing facilities normally require considerable investment costs for construction as well as significant O&M costs that will be a continuous financial burden.

Therefore, it is essential to introduce an optimum intermediate processing at an optimum time, i.e., the introduction should be when it is really needed.

K.4.3.2 Evaluation of Intermediate Processing System

a. Separation

Objectives of selection plant (S/P) are summarized in the table below. List of target recovery materials will vary a little depending on the S/P objectives. However, the plant structure basically does not change even the list of target recovery materials changes. Meanwhile, list of target recovery materials might be changed due to market price fluctuation of such materials. Therefore, the facility plans for S/P should be such that the plant can cope with changes in target recovery materials.

Table K-65: Objectives and Activities of Selection Plant (S/P)

<table>
<tr><th colspan="2">Objectives</th><th>Target recovery materials</th><th>Activities</th></tr>
<tr><td>Case1</td><td>Recovery of recyclable material from commingled waste</td><td>• Bulky items, cardboard, paper, plastics(PET, HDPE, etc.), glass, aluminum cans, tin cans, other ferrous materials</td><td rowspan="3">• Manual separation of bulky item, cardboard, plastics, glass by color, aluminum cans, and large ferrous items.
• Magnetic separation of magnetism item (tin can, etc.)
• Baling of separated materials for shipping. Storage of baled materials</td></tr>
<tr><td>Case 2</td><td>Recovery of recyclable material from commingled waste and source-separated materials</td><td>• Bulky items, cardboard, paper, plastics(PET, HDPE, etc.), glass, aluminum cans, tin cans, other ferrous materials
• Source-separated materials</td></tr>
<tr><td>Case 3</td><td>Preparation of MSW for use as a feedstock for composting</td><td>• Bulky items, cardboard, plastics, glass, aluminum cans, tin cans, other ferrous materials.</td></tr>
</table>

If a S/P is introduced for AMSS, it should initially be the Case 1 for the time being and will be converted to that for Case 2 in the course of increase in the separate collection for source separated materials.

b. Baling

The baling process is normally employed as a part of process in S/P. There are a few exceptional cases that a baling process without pre-treatment is implemented at the upstream municipal SW flow so that final disposal volume reduction and transport cost cut would be attained. However in such cases, if examination on such as: treatment of residual liquid of waste squeezed by baling; and specification of binding wire; etc is forgotten, original objectives will not be complied with.

Direct baling of municipal SW was attempted in Japan in 1970s. Baled waste was asphalt coated to shape a block, which was intended to be used as construction materials. However, leachate leaked out from the block and baling wire was eroded and broken down. Consequently those blocks did not work as construction materials and polluted the environment. This technique of asphalt coated baled waste was abandoned. Current baling techniques in Japan are mostly used for baling the recovered materials in S/P with an objective of "handling improvement".

As the case above explains, direct baling of municipal SW has the problem. It is suggested that baling should be employed as a part of S/P functions in AMSS.

c. Composting

There are basically two types of composting process for organic fraction of municipal solid waste: "aerobic process" and "anaerobic process". The comparison of the two processes is shown in the table below.

Table K-66: Comparison of Aerobic and Anaerobic Composting for Organic Fraction of Municipal SW

Characteristic	Aerobic process	Anaerobic process
Energy use	Net energy consumer	Net energy producer
End products	Humus, CO_2, H_2O	Sludge, CO_2, CH_4
Volume reduction	Up to 50%	Up to 50%
Processing time	20 to 30 days	20 to 40 days
Curing time	30 to 90 days	30 to 90 days
Primary goal	Volume reduction	Energy production
Secondary goal	Compost production	Volume reduction, waste stabilization

Source : Integrated Solid Waste Management, McGraw-Hill

The table explains that the aerobic process has a primary goal of volume reduction and the anaerobic process requires higher cost of pressure vessel and several instruments in order to recover biogas. Therefore, when an examination on compost introduction takes place, it will be recommended to adopt and/or maintain aerobic process for AMSS so that the volume reduction can be targeted at relatively low cost.

Table K-67 and Figure K-8 outlines comparison of composting methods.

Table K-67: Comparison of Composting Method

	Minimal technology windrow	High-rate windrow	Static pile	In-vessel
Outline	The minimal windrow technology approach involves forming large windrows (e.g., around 3.5m height by 7.3m width) that are turned only once a year with a front-end loader.	A high-rate windrow composting system employs windrow with smaller cross section, typically 1.5 to 2.0 m height by 4 to 5m width. The dimensions of the windrows depend on the type of equipment that will be used to turn the composting waste. Waste is turned twice per week while the temperature is maintained at around 55 Centigrade.	An aerated static pile system consists of a grid of aeration or exhaust piping over which the processed organic fraction of municipal solid waste is placed. Typical pile heights are 2 to 2.5 m. A layer of screened compost is often placed on top of the newly formed pile for insulation and odor control.	In-vessel composting contains an enclosed container vessel inside. The system can be divided into two major categories: plug flow and dynamic (agitated bed). In the plug flow system, the relationship between particles in the composting mass stays the same throughout the process, and system operates on first-in, first-out principle. In the dynamic system, the composting material is mixed mechanically during the processing.
Odors	Probably emits objectionable odors	Often releases offensive odors (accompanied by turning)	Controllable	Less than static pile and controllable
Degradation period	Three to five years	Three to four weeks (composting) Three to four months (curing)	Three to four weeks (composting) Three to four months (curing)	One to two weeks (composting) Four to twelve weeks (curing)
Required area	Very large	Large	Large	Small
Construction cost	Very cheap	Cheap	Intermediate	High
O & M cost	Very cheap	Cheap	Intermediate	High

Source : Integrated Solid Waste Management, McGraw-Hill

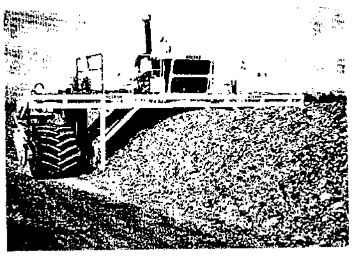
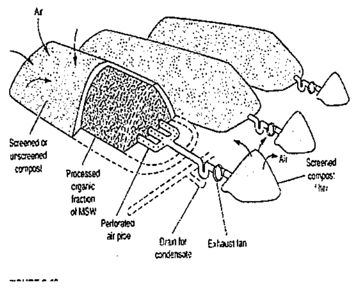
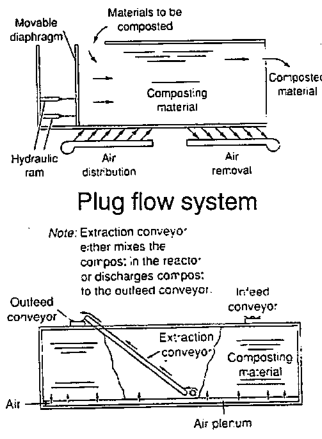
High-rate Windrow	Static Pile	In-vessel
		

Figure K-8: Major Composting System

d. Incineration

Incineration treatment can reduce the amount to 15% in weight, however its construction costs and O&M costs are enormous.

Generally speaking, incineration facilities of municipal SW requires the following that are considerably high:

- Construction investment costs that have a range of from U$100,000 to 150,000/ton[2] depending upon the plant capacity; and
- O&M cost ranges from U$25 to 38/ton.

Incineration plants further require substantial technical abilities of operators. Therefore, it is suggested that introduction of an incineration process for municipal waste in AMSS is still too early, in view of the absence of real necessity for incineration and economical capability that municipalities have at the present situation.

K.4.4 Final Disposal System

K.4.4.1 Landfill Structure

In view of groundwater and soil pollution prevention, it is required for final disposal sites to equip impermeable liner and/or to be localized at places whose ground is impermeable. In such cases, it becomes necessary to drain and treat leachate generated in the final disposal sites. Leachate treatment could be inside or outside of the landfill.

To equip impermeable liner and to treat leachate necessitates a considerable amount of financial resources and adequate technical assets for its operation and maintenance.

[2] daily treatment capacity (e.g., cost of 100ton/day capacity incinerator is U$15,000,000)

It generally turns out a crucial burden on municipal SWM in low and middle income countries and cities.

Accordingly, there are few cases in the past and to date in developing countries that municipal final disposal sites have impermeable liners. Majority of them allows leachate to infiltrate into the ground.

To infiltrate the leachate into the ground is undesirable from the viewpoints of groundwater and soil pollution prevention, however, in places where whose groundwater has no use due to it has already polluted long before or is saline, localizing a final disposal site without impermeable liner has little problems.

Anyhow, from the environmental viewpoints, it is desirable to equip an impermeable liner for final disposal sites. Meanwhile, as for the environmental legislation, the "Transitory Decree of Solid Waste" was issued on October 6th, 1999 and was turned into the "Special Regulation on Integral Solid Waste Management" on June 1st, 2000. The table below summarizes the technical requirements for the final disposal sites.

Table K-68: Outline of Technical Standard for MSW Landfill

			Transitory Decree (October/06/1999)	Special Regulation (June/01/2000)
Level from grand water table			More than 10 m	must ensure the conservation of the existing aquifers in the zone.
Distance from flood area			More than 500m	at a distance that prevents damages towards flooding zones, swamps, salt marshes, water bodies and natural drainage zones.
Distance from water source area			More than 1km	at a distance that ensures that the zones for recharging of aquifer or supply sources of drinkable water is free of pollution. Such distance will be set within national technical norms.
Soil characteristic and permeability			Loamy, 10^{-5} to 10^{-7} cm/sec	10^{-7} cm/sec
Land use			Without agricultural use	-
Distance from fault line			-	more than 60 meters away from faults with recent shifts.
Landfill area/ total site area			Less than 30 %	-
Location	Distance form urban area		More than 1km	More than 500 meter
	Prohibit area		natural protection area, airport influence area, pipelines area, gas-ducts, aqueducts, hydrocarbon storage area, winds area	natural protected areas or fragile ecosystems, buffer zones devoted for the passage of aquaducts, irrigation canals, sewerage and electricity wire lines.
Operation	daily disposal amount	less than 20ton/day	Manual filling	-ditto-
		20 to 40ton/day	combined filling (manual and heavy equipment)	-ditto-
		more than 40ton/day	heavy equipment filling	-ditto-

The present legislation (Special Regulation) requires soil characteristics of a maximum permeability coefficient of 10^{-7}cm/sec, and that the depth to groundwater level should guarantee the existing aquifer conservation.

Although the transitory decree stipulated the minimum depth to groundwater as 10 meter, the superceding legislation does not stipulate the depth to guarantee the existing aquifer conservation. Hence as an example calculation, where the leachate travel time to aquifer is calculated under the conditions of permeability 10^{-7}cm/sec and 10 meter thickness, the travel time becomes 320 years.

If it is assumed that the legislative requirements of "to guarantee aquifer conservation" refers a leachate travel time in the order of 320 years, it will be very difficult in El Salvador to find geological sites suitable for localizing a landfill without an artificial impermeable liner. Because, the geological requirements for such will be the impermeable soil layer thicker than 10 meter with the coefficient less than 10^{-7}cm/sec, sites intermittently wide enough with such soil characteristics and depth are hardly found in a volcanic geology.

Hence, in order to comply with this environmental requirement, it is necessary to artificially create the impermeability to satisfy these technical requirements. The following alternatives can be considered:

- To create impermeability by laying and compacting impermeable clay materials; or
- To create impermeability with synthetic liner (e.g., high density polyethylene sheet).

The former alternative has an important geological restriction that the landfill candidate site should be near to the abundant and high quality (impermeable) clay deposits. Meanwhile, since the latter does not depend on geological features, the landfill site can be selected from multiple choices without such geographical restrictions.

It is recommended in this M/P to select the latter alternative (synthetic liner) in final disposal system due to that accurate locations of final disposal candidate sites in the M/P are not determined and whose hydro-geological information are not sufficient.

When in the future an accurate location of final disposal site is determined along with the M/P implementation, detail investigation on hydro-geological conditions etc. should be carried out and specification of impermeable lining should be reviewed accordingly.

K.4.4.2 Leachate Treatment

Under such climatic conditions that the precipitation is about 500mm/year and the evapotranspiration is more than 3 times of the precipitation, leachate is scarcely generated or is little enough to handle and treat easily (e.g., temporal storage and circulation, etc.). However, under such climatic conditions near AMSS that the precipitation is more than 1,700mm/year, leachate needs to be treated properly.

There are various ways of treating leachate and whose engineering integrity, investment costs and O&M costs are diversely different.

In Japan, as quite high levels of leachate treatment are required, treatment costs (only O&M costs) range US$20 to 50 per 1m^3 leachate treated. As for investment cost for treatment plant installation, it ranges as high as U$300,000 to 500,000 per m^3/day of nominal capacity of the plant.

Permissible level of treated effluent quality is not defined in the current environmental legislation. Meanwhile, the existing MIDES Nejapa landfill is currently carrying out the leachate treatment. Hence, in planning a new final disposal site, it is considered necessary to set it forth as a premise that the same level of leachate treatment as that of MIDES Nejapa landfill is required.

Therefore, the Study recommends aerated lagoon type leachate treatment for a new landfill planning, which is same as the MIDES Nejapa landfill treatment.

K.4.4.3 Conceptual Cost Estimate

In order to compare alternatives in final disposal system, it is necessary to have conceptual cost estimate.

10 municipalities out of 14 municipalities in AMSS already perform Step III in the final disposal system (i.e., sanitary landfill). Meanwhile two municipalities are at Step I (open dumping) and other 2 municipalities are at Step II (i.e., controlled dumping).

Viewing the situation of the 4 municipalities, conceptual cost estimate on:

- Sanitary landfill costs
- Additional cost incurred with longer transport distance

are carried out herewith.

a. Sanitary Landfill Costs

The figure below shows correlation between "capacity" and "conceptual unit cost[3] (per ton)" of sanitary landfill.

[3] Source: adopted from "Teechnology, Prevalence and Economics of Landfill Disposal of Solid Waste", EPA, Washington D.C. 1980

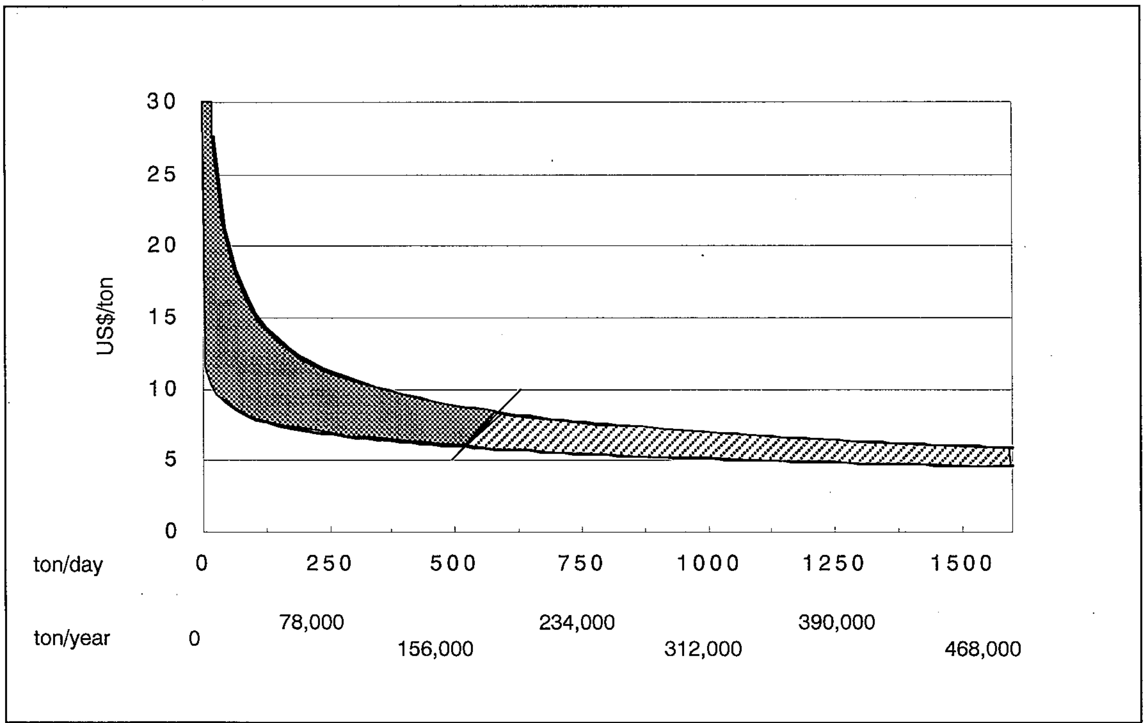


Figure K-9: Correlation of Capacity and Unit Cost of Sanitary Landfill

The figure above implies possible unit cost of sanitary landfill depending the capacity sizes that several alternatives imply. The table below summarizes range of possible unit cost for final disposal.

Table K-69: Correlation of Capacity and Unit Cost of Sanitary Landfill

Capacity (ton/day)	Range of possible unit cost	Mean value of possible unit cost	Remarks	Assumption (applicable alternatives)
30	US$23.5/ton to US$9.5/ton	US$ 16.5/ton		TN own use SMT own use
60	US$21.5/ton to US$8.5/ton	US$ 15/ton		TN and SMT together
100	US$ 20/ton to US$7.5/ton	US$ 13.7/ton	possible co-use of landfill by several municipalities (regional use landfill)	
150	US$ 18/ton to US$7.0/ton	US$ 12.5/ton		New ESPIGA size (assumption)
200	US$ 13/ton to US$6.4/ton	US$ 9.7/ton		
320	US$ 9.8/ton to US$5.6/ton	US$ 7.7/ton		
640	US$ 7.2/ton to US$5.0/ton	US$ 6.1/ton		
960	US$ 6.8/ton to US$ 4.6/ton	US$ 5.7/ton		
1280	US$ 6.5/ton to US$4.5/ton	US$ 5.5/ton		

b. Additional Cost Incurred with Longer Transport Distance

The figure below shows representative cost of collection and transport by collection vehicle (e.g., 18yd^3 compactor truck) with the parameter of transport distance (one-way distance). It calculates about **US$0.4/km/ton.**

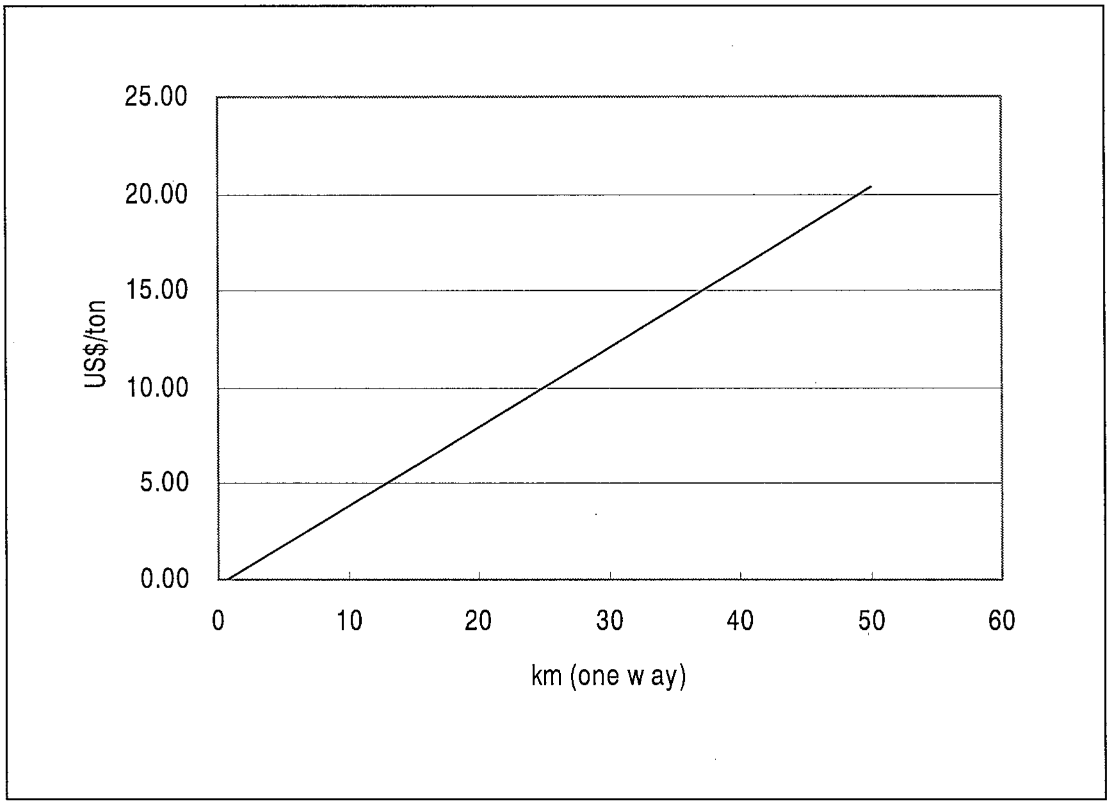


Figure K-10: Representative Cost of Collection and Transport (18yd^3 Compactor)

K.4.4.4 Cuscatancingo and Antiguo Cuscatlan (Step II to Step III)

a. Background

Cuscatancingo and Antiguo Cuscatlán municipalities used to dispose of their waste at Mariona site, and their transport distances were about 12.2km and 42.2km respectively.

Today they bring their waste to ESPIGA site. The transport distance to the site from respective municipalities is about 35km. The transport distance to ESPIGA site for Antiguo Cuscatlán municipality becomes about **7km shorter** than to the formerly used Mariona site. On the other hand, as for Cuscatancingo municipality, it becomes about **23km longer**.

Formerly the two municipalities did not bear the disposal cost at Mariona site, however, today they pay the disposal fee to the owner of the ESPIGA site.

b. Present Problems

As the current ESPIGA disposal site is a controlled dumping site, it should be improved to a level of a sanitary landfill.

Meanwhile, it seems impossible to improve the same site as “sanitary landfill”. The reasons are as follows:

- It is necessary to have impermeable liner to satisfy the current requirement[4], since the site seems to stand on a permeable ground.
- It is never practical to remove all wastes formerly buried and to place on a new S/L with impermeable liner.
- If the impermeable liner of a new S/L is placed above the formerly buried waste and the final soil cover on the former waste does not have a very sufficient thickness, the impermeable liner might possibly be broken by the waste buried that have sharp edges. Because the new S/L will add the weight burden on the impermeable liner by the waste buried above. Breakage of impermeable liner creates underground contamination by leachate. In other words, sufficient thickness of soil cover on former waste will induce relatively high cost.
- Furthermore, if the impermeable liner of a new S/L is placed above the formerly buried waste, biogas from formerly buried waste may accumulate and be pressurized below the impermeable liner. It consequently will create fatal hazard and accident.

Hence, it is recommended that a new S/L of ESPIGA be constructed at an off-set location of the current site.

c. Alternatives in Final Disposal System

It is awaited that a sanitary landfill be constructed and operated near the current ESPIGA site. Or, it is expected that the two municipalities of Cuscatancingo and Antiguo Cuscatlán participate to use MIDES Nejapa S/L or another regional S/L.

As it is aimed that until the target year 2010 both Cuscatancingo and Antiguo Cuscatlán municipalities should establish and implement the Step III (i.e., sanitary landfill) in their final disposal system, alternatives of sanitary landfill should be examined herewith.

The following should be the candidate alternatives for the examination.

- participate in MIDES Nejapa sanitary landfill
- participate in the new ESPIGA sanitary landfill
- participate in another regional sanitary landfill

Because, it is impossible for each municipality to locate candidate site of S/L within its jurisdiction area, where both are populated urbanized municipalities and sufficient land for S/L is hardly available.

c.1 Participate in MIDES Nejapa sanitary landfill

The conceptual cost estimate summarized in the table below gives additional cost in participating MIDES of about US$19.4/ton and US$7.6/ton respectively for Antiguo Cuscatlan and Cuscatancingo.

[4] The Transitory Decree on Solid Waste turned into the Special Regulation on Integral Management of Solid Waste, that appeared on the Official Gazzete on 1st June 2000.

Table K-70: Conceptual Cost Estimation for Participation in MIDES Nejapa Landfill

Item	Cost Increased		Remarks
	Antiguo Cuscatlan	Cuscatancingo	
grade up to sanitary landfill	US$13.0/ton	US$13.0/ton	MIDES landfill fee (US$18.0/ton) minus current ESPIGA fee (US$5.0/ton)
longer distance	US$6.4/ton	- US$5.4/ton	assumed US$0.4/km/ton, present 35km to 51km for AC, and present 35km to 22km for CT
Total	US$19.4/ton	US$7.6/ton	

As for Cuscatancingo, to participate MIDES has an advantage of reducing transport cost.

c.2 Participate in the new ESPIGA sanitary landfill

The conceptual cost estimate summarized in the table below gives additional cost in participating new ESPIGA of about US$7.5/ton for both Antiguo Cuscatlan and Cuscatancingo, since no transport cost increase is envisaged.

Table K-71: Conceptual Cost Estimation for Participation in New ESPIGA Landfill

Item	Cost Increased		Remarks
	Antiguo Cuscatlan	Cuscatancingo	
grade up to sanitary landfill	US$7.5/ton	US$7.5/ton	conceptual cost estimation (US$12.5/ton) minus current ESPIGA fee (US$5.0/ton)
longer distance	US$0.0/ton	US$0.0/ton	same distance to current ESPIGA site
Total	US$7.5/ton	US$7.5/ton	

c.3 Participate in Another Regional Sanitary Landfill

There is no information of another regional landfill at this moment.

d. Comparison of Alternatives for AC and CT

In view of the above examination on "conceptual cost estimate", the table below compares the alternatives.

d.1 Comparison of Alternatives for AC

Table K-72: Comparison of Alternatives for AC

Alternatives for Improvement	Cost Increased (US$/ton)			Remarks
	S/L level up	Longer distance	Total	
participate MIDES Nejapa	13.0	6.4	19.4	
participate new ESPIGA	7.5	0.0	7.5	
participate another regional S/L	-	-	-	no information

It could be suggested for Antiguo Cuscatlan to select the alternative of "new ESPIGA", with an assumption of that new ESPIGA tipping fee be about US$12.5/ton.

d.2 Comparison of Alternatives for CT

Table K-73: Comparison of Alternatives for CT

Alternatives for Improvement	Cost Increased (US$/ton)			Remarks
	S/L level up	Longer distance	Total	
participate MIDES Nejapa	13.0	-5.4	7.6	
participate new ESPIGA	7.5	0.0	7.5	
participate another regional S/L	-	-	-	no information

It could be suggested for Cuscatancingo to select either alternative of participating "MIDES" or "new ESPIGA", with an assumption of that new ESPIGA tipping fee be about US$12.5/ton.

If the MIDES tipping fee is discounted by several US$/ton, the alternative of "participating MIDES" become a competitive offer for the municipality of Cuscatancingo, which has shorter distance to the MIDES disposal site than to new ESPIGA site.

e. Recent Information on New ESPIGA Sanitary Landfill

A newspaper article regarding New ESPIGA S/L is published on 1st June 2000 (Diario de Hoy). A part of it is quoted below.

QUOTE
"The project will be executed through a public tender……...
The municipalities of Cuscatancingo, Antiguo Cuscatlan, Santiago Texacuangos, Panchimalco and Zaragoza wish to build a sanitary landfill, similar to that operating in Nejapa, in the land located at La Paz. ………
Nerio stated that a Canadian company is designing a sanitary landfill project, and it will then request a credit to an international bank or the Central Government ………
There are 20 blocks (manzanas) of land available for the construction of the landfill, which is the same space utilized by the dumping site. The costs and terms on which such landfill will be executed are not defined yet."
UNQUOTE

As this project will be subject to public tender, the project information is not available for the Study.

K.4.4.5 San Martin and Tonacatepeque (Step I to Step III)

a. Background

Since long time ago, Tonacatepeque municipality disposes their waste at the open dumping site in the same municipality. It is estimated that due to mainly financial restriction on municipal budget for SWM, the municipality is and was unable to transport their waste to a distant disposal site either to the former Mariona site or to the present MIDES Nejapa site or ESPIGA site.

Considerable years ago, San Martin municipality disposed of their waste at the open dumping site at the Tonacatepeque municipality. Since such disposal was rejected by the Tonacatepeque municipality, San Martin was forced to dispose their waste at some ravine in its municipality such as San Martin #1 open dumping site where soil cover on disposed waste is hardly difficult to carry out.

b. Present Problems

Today, San Martin and Tonacatepeque municipalities dispose of their waste respectively at their own dumping site. In so doing, transport distance becomes significantly short, however, there remains problems of environmental contamination by disposed waste.

c. Alternatives in Final Disposal System

As it is aimed that until the target year 2010 both San Martin and Tonacatepeque municipalities should establish and implement the Step III (i.e., sanitary landfill) in their final disposal system, alternatives of sanitary landfill should be examined herewith.

The following should be the candidate alternatives for the examination.

- proper sanitary landfill (its own use)
- co-use sanitary landfill (by the two municipalities, as they are neighboring municipalities)
- participate in MIDES Nejapa sanitary landfill
- participate in the new ESPIGA sanitary landfill
- participate in another regional sanitary landfill

c.1 Proper Sanitary Landfill

As San Martin and Tonacatepeque municipalities generate municipal waste 26.3ton/day and 22.9ton/day respectively in 1998 and 33.0ton/day and 28.7ton/day respectively in 2010, the capacity of its own sanitary landfill should be about **30**ton/day.

In view of possibility of localizing the new disposal site, transport distance to the new site could be estimated for example 4km longer than to the present disposal site.

Table K-74: Conceptual Cost Estimation for Proper Landfill in SMT and TN

Item	Cost Increased	Remarks
grade up to sanitary landfill	US$15.5/ton	$16.5/ton (conceptual cost for 30ton/day capacity) minus $1.0/ton (present disposal cost estimated)
longer transport distance	US$1.6/ton	assumed US$0.4/km/ton x 4km
Total	US$17.1/ton	

The conceptual cost estimate gives additional cost of about US$17.1/ton.