B.4.3 Results of the Survey

a. Electric Prospecting and Core Boring

Results of the electric prospecting and core boring survey are shown in Data Book.

The results of the survey indicated the following:

- In Etapa I, wastes are filled at the depth (from the surface of cover soil) down to approximately 2m to 12m.
- In Etapa II, wastes are filled at the depth (from the surface of cover soil) down to approximately 7m to 12m.
- In Etapa III, wastes are filled at the depth (from the surface of cover soil) down to approximately 8m to 14m.

The layer under the waste consisted of very soft clay soil in the surveyed depth. According to the previous reports, this very soft clay layer depth is approximately 60m. Table B-29 shows groundwater level.

Table B-29: Groundwater Level

	Bore Hole Number	Grand Water Level (m)
Etapa I	SM-5	0.85
	SM-6	0.64
Etapa II	SM-3	1.10
	SM-4	1.23
Etapa III	SM-1	0.89
	SM-2	0.46

b. In-situ Test

b.1 Permeability Test

b.1.1 Cover Soil

Table B-30 shows the results of the cover soil permeability in-situ test.

Table B-30: Result of Cover Soil Permeability Test

	Bore Hole Number	Soil Permeability (cm/sec)
Etapa I	SM-5	1.49E-04
	SM-6	1.37E-04
Etapa II	SM-3	1.05E-04
	SM-4	1.32E-04
Etapa III	SM-1	1.25E-04
	SM-2	2.68E-04

b.1.2 Under Layer

Table B-31 shows the results of the in-situ permeability test at boreholes.

Table B-31: Result of Bore Hole Permeability Test

	Bore Hole Number	Depth (m)	Permeability (cm/sec)
Etapa I	SM-5	14.00 to 17.10	4.45E-05
	SM-5	17.00 to 20.00	2.77E-05
	SM-6	14.00 to 17.00	4.44E-05
	SM-6	17.00 to 20.00	1.37E-05
Etapa II	SM-3	14.00 to 17.00	2.06E-05
	SM-3	17.00 to 20.00	9.85E-06
	SM-4	14.00 to 17.00	2.41E-05
	SM-4	17.00 to 20.10	2.62E-05
Etapa III	SM-1	13.85 to 17.20	3.71E-05
	SM-1	16.85 to 20.00	1.90E-05
	SM-2	14.00 to 17.00	3.19E-05
	SM-2	17.00 to 20.00	1.39E-05

c. Laboratory Test

Results of the survey is shown in Table B-32.

Table B-32: Results of the Laboratory Test

Location / Test item	Etapa III			Etapa II		Etapa I		
	SM-1 9.70-10.60 m	SM-1 12.40-13.30	SM-2 17.00-17.90	SM-3 8.80-9.70 m	SM-4 19.20-20.10 m	SM-5 17.00-18.00 m	SM-6 14.90-15.90 m	SM-6 15.90-16.90 m
SPECIFIC GRAVITY	2.501	2.38	2.632	2.488	2.617	2.88	2.48	2.5
UNIT WEIGHT (ton/m^3)	1.299	1.224	1.151	1.205	1.873 1.793	1.3	1.19	-
VOID RATIO	3.808	5.796	9.698	6.21	7.303	7.635	-	4.237
DEGREE OF SATURATION (%)	98.3	101.6	99.9	99.9	100	96.7	-	99.883
WATER CONTENT (%)	101.1	247.5	368.1	249.5	279	265.1	234.3	169.23
LIQUID LIMIT (%)	138.7	238	316.5	165	241.8	194.8	371	153
PLASTIC LIMIT (%)	40.7	125.4	65.1	54.7	54.9	31.3	69.6	77.5
PLASTICITY INDEX (%)	98	112.6	251.4	110.3	186.9	163.5	301.4	75.5
TRIAXIAL UNDRAINED C (ton/m^2)	0.5	0	*	0.8	*	1	**	**
PHI ANGLE (DEGREES)	0	0	*	0	*	3	**	**
SIMPLE COMPRESION q_u (ton/m^2)	0.8	0	7.3,2.1	1.5	2.4 4.2 2.9	1.5	**	**
GRAIN SIZE	100 F	100 F	100 F	100 F	100 F	100 F	100 F	100 F
CONSOLIDATION (COMPRESION INDEX)	1.158	1.883	4.734	2.602	3.313	5.481	N.A	1.55

* Due to the low consistency of the sample, Tri-axial test was not possible, and simple compression test were done instead.

** The soil samples recovered with the shelby tube were almost liquid and only the consolidation test and consistency limit were carried out.

B.4.4 Findings

a. Groundwater Level

In Etapa I, II and III where wastes were landfilled above the initial ground level, the groundwater level is high. It is about 2.0m from the surface according to the "Landfill Mining Survey" whereas groundwater tables in the bore holes in this survey range 0.8

to 1.2m from the surface. The groundwater level measured aside the landfills was also found at about 1.0m depth from the ground surface.

This phenomenon is backed by the two facts. First, there are no any leachate control mechanisms in landfills except part of Etapa III. Second, it is considered that substantial volume of rainwater seeps into the landfills from the facts that the permeability of cover soil is as high as an order of 10^{-4}(cm/sec) and that its layer depth is only 30cm.

Consequently, it can be concluded that groundwater level within the ex-landfills (Etapa I, II and III) has been raised to the level higher than the original ground surface by the rainwater seepage from the landfill surface and the groundwater intrusion from the landfill bottom by capillary force. This is illustrated in Figure B-9.

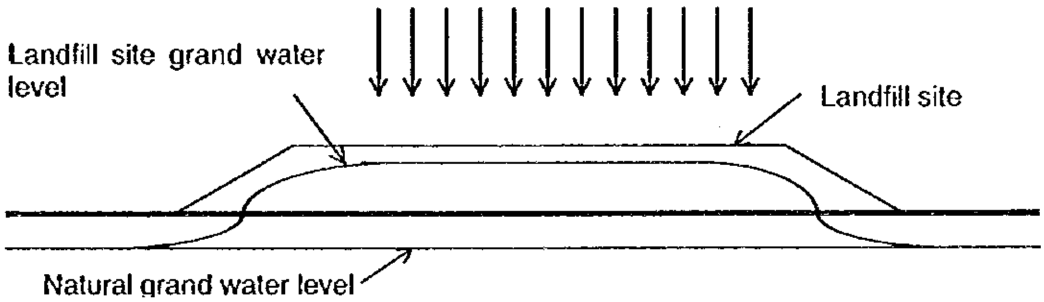

Figure B-9: Image of Landfill Site Grand Water Level

b. Permeability

b.1 Cover Soil

As stated above, the permeability of cover soil is relatively high (at the order of 10^{-4}(cm/sec)) and its layer thickness is small (30cm). Hence considerable volume of rainwater infiltrates to the landfilled waste, encouraging leachate generation.

b.2 Foundation Soil

As the foundation soil is clayey with permeability at the order of 10^{-5}(cm/sec), some form of impermeabilization is necessary to sufficiently operate a municipal solid waste final disposal site which complies with the existing environmental norms. For this reason, high-density-polyethylene (HDPE) impermeable liners are laid in the present landfill in Etapa IV.

b.3 Conclusion

In conclusion, bottom impermeable liners have to be employed if vertical expansion of Etapa I, II and/or III is to be implemented, in order to prevent groundwater contamination with leachate.

c. Soil Mechanics

As an indicator of ground stability, cohesion and internal friction angle at about 10m depth (i.e., about 2m below the original surface under the bottom of buried wastes) were studied and those results are shown in Table B-33.

Table B-33: Cohesion and Internal Friction Angle

	Etapa I	Etapa II	Etapa III	*Etapa IV
Operation period	1985 - 1988	1989 - 1991	1991 -1993	1993 -
Cohesion (ton/m^2)	1.0	0.8	0.5	0.8
Internal Friction Angle (deg.)	3.0	0	0	1.8

* Etapa IV : existing data

Comparing the figures above and the geological data in Etapa IV before landfilling, the following findings were drawn.

- Both cohesion and internal friction angle have been relatively improved in Etapa I, where nearly 10 years have passed after landfilling. This implies the improvement of ground stability due to land compression.
- On the other hand, data taken in Etapa II and III are similar to or rather smaller than those in Etapa IV, thus major improvement of ground stability due to land compression is not seen.

Consequently, it is envisaged that it will require substantial time to improve ground stability by land compression.

B.5 Recycle Market Survey

B.5.1 Objectives

The surveys investigated present markets and potential demands for recycled materials, particularly compost and plastic that would be generated by the technical alternatives to be proposed in the M/P.

The size of the markets and the prices of reusable articles are the main survey items since they could largely influence the selection of alternatives. Information on items such as bottles, cans, plastic, compost, and heat and electricity was investigated by using statistics available and by interviewing authorities concerned with heat and electric energy, recycling company and recycling union.

B.5.2 Methodology

a. Targets of Survey

The survey targets are following companies.

- glass recyclers.
- aluminum and steel cans recyclers.
- plastics recyclers.
- compost companies.
- electricity companies.
- heat energies supplying companies.
- INARE.
- unions dealing recycling materials.
- informal recyclers.

b. Number of Samples

The survey carried out for 22 companies. Table B-34 shows outline of surveyed companies.

Table B-34: Outline of Surveyed Companies

c	Name of Company or Institution	Major Dealing Item
1	Sr. Fernando Rosales	Glass, steel, aluminum, cardboard, newspaper, paper
2	Vidrería México S.A. DE C.V.	
3	Jose González	Cardboard and paper
4	Bodega Tacubaya S.A.	Cardboard and paper
5	La bodeguita	Scrap metal, paper, cardboard, aluminum cans
6	Maria Pérez Gárcia.	Paper
7	Antonio Hérnandez	Cardboard and paper
8	José Vidal.	Plastic
9	José Luis Pineda.	Aluminum cans, "*chacharas*" (toys, shoes, cloths, etc.)
10	Angel Básilio Hérnandez	Glass
11	Comercializadora de fibras secundarias S.A. de C.V.	Paper and distribution of used fiber
12	Todo de cartón S.A de C.V.	Corrugated board
13	Procesadora y recicladora El Ancla S.A. de C.V.	Steel and non-ferrous metal
14	Marco Antonio Rueda	Cardboard and paper
15	Vidriera Los Reyes	Glass
16	Sacarias Cepeda Guadarrama	Steel, copper, bronze, aluminum cans
17	José Silverio Escobar	Cardboard and cans
18	María de la Cruz Baéz Montes	Glass, tortilla, mattress
19	Comercial Carimex	Paper
20	Interamericana de Metales	Stainless alloyed steel, principally copper derivatives
21	Dirección General de Servicios Urbanos	Pruned branches, grass
22	Rubén Jiménez	Glass

c. **Survey Item**

The survey items are as follows.

- General information of company (number of employee, established year, working day, annual sales amount, etc.)
- Major activity (recycler, collector, sorting, brokerage, etc.)
- Profile of the major client (type of industry, sales price and amount, etc.)
- Profile of the major supplier (type of material, original cost, supply amount)
- Treatment and/or processing method
- Outline of treatment and/or processing equipment
- Major recycling item
- Transportation method
- Others

B.5.3 Results of the Survey

a. **Market Size of Recycled Material**

The future market size of recycled material in the DF in 2010 was determined by, firstly, estimating the production amount of paper, glass, plastic, aluminum and tin-plate in the DF from the existing data of previous studies[5], then secondly, applying the ratio of recycled material to the estimated production amount obtained from OECD's statistics and Japan's experience.

a.1 **Materials Production Amount**

Table B-35 shows the forecast of future production amount of paper, glass, plastic, aluminum and tin-plate in the DF.

Table B-35: Forecast of Future Production Amount in DF

unit : 1,000 ton/year

	Paper	Glass	Plastic	Aluminum	Tin-plate	Remarks
1988	2,149	4,496	382	75	619	* Existing data
1989	2,281	4,998	411	66	545	
1990	2,412	5,499	439	58	488	
1991	2,544	6,001	468	53	449	
1992	2,675	6,503	496	49	427	
1993	2,807	7,004	525	47	422	
1994	2,938	7,506	554	47	435	
1995	3,069	8,008	582	49	464	
1996	3,201	8,510	611	53	511	
1997	3,332	9,011	639	58	576	Forecast
1998	3,464	9,513	668	66	658	
1999	3,595	10,015	696	76	757	

[5] ESTUDIO INTEGRAL SOBRE ASPECTOS OPERACIONALES Y ECONOMICOS DE LA PLANTA DE SELECTION DE SUBPRODUCTOS DE BORDO PONIENTE, DDF, DGSU, 1992

	Paper	Glass	Plastic	Aluminum	Tin-plate	Remarks
2000	3,727	10,516	725	87	873	
2001	3,858	11,018	753	100	1,007	
2002	3,990	11,520	782	116	1,158	
2003	4,121	12,021	810	133	1,326	
2004	4,252	12,523	839	152	1,511	
2005	4,384	13,025	867	173	1,714	
2006	4,515	13,526	896	195	1,934	
2007	4,647	14,028	924	220	2,172	
2008	4,778	14,530	953	247	2,427	
2009	4,910	15,031	982	275	2,699	
2010	5,041	15,533	1,010	306	2,988	

* ESTUDIO INTEGRAL SOBRE ASPECTOS OPERACIONALES Y ECONOMICOS DE LA PLANTA DE SELECTION DE SUBPRODUCTOS DE BORDO PONIENTE, DDF, DGSU, 1992

In determining future data, the trend was assumed to be expressed by an ascending curve of linear, logarithmic, polynomial, power or exponential type. R^2 for each curve was compared and an equation with largest R^2 was adopted.

The regression curves for each material are expressed as follows.[6]

Paper : $y = 131.45x + 2{,}017.8$ $(R^2=0.9703)$

Glass : $y = 501.68x + 3{,}994.4$ $(R^2=0.9854)$

Plastic : $y = 28.533x + 353.78$ $(R^2=0.978)$

Aluminum : $y = 0.9502x^2 - 12.335x + 86.81$ $(R^2=0.7586)$

Tin-plate : $y = 8.6548x^2 - 100.03x + 710.64$ $(R^2=0.9571)$

a.2 Ratio of Recycled Material

Table B-36 shows the ratios of recycled material to total raw material. They are available only for the cases of paper and glass production.

Table B-36: Ratio of Recycled Material in OECD Countries

unit : %

	Paper				Glass			
year	1975	1980	1985	1990	1975	1980	1985	1990
Japan	39.6	48.1	49.6	-	-	35.3	47.2	*47.9
USA	19.1	21.8	21.3	28.6	3.0	5.3	7.6	19.9
France	31.7	37.0	41.3	45.7	-	20.0	26.0	28.5
Denmark	28.4	25.6	31.3	35.4	-	8.0	48.3	60.4
Portugal	40.7	38.0	38.4	39.1	-	-	10.0	30.0
Spain	-	38.1	56.7	51	-	-	13.1	27.0
Average	31.9	34.8	39.8	40	3.0	17.2	25.4	35.6

Source: OECD Environmental Data, 1993, *:Keyword of Recycling 3rd Edtion, 1997, Clean Japan Center

[6] X denotes the order of year by letting the year 1988 be x=1, 1989 be x=2, and so on. Y denotes the production amount.

Ratios of recycled material to the total raw material to produce paper, glass, plastic and aluminum in Japan are as seen in Table B-37.

Table B-37:Ratio of Recycled Material in Japan

Paper	Glass	Plastic	Aluminum
53.6 (%)	65 (%)	10.7 (%)	22 (%)

Source: Keyword of Recycling 3th Edtion, 1997, Clean Japan Center

These ratios vary with such factors as economic situation and policy of recycle market promotion of the countries. The figures are presented in Table B-36 and Table B-37 as example, and in general, they have an upward trend.

Since no statistical data of the DF equivalent to those above is available, it is not possible to estimate the future ratios based on the current data. Therefore, figures shown in Table B-38 were worked out referring to Table B-36 and Table B-37.

Table B-38: Recycling Rates of DF in 2010

Paper	Glass	Plastic	Aluminum
40 (%)	35 (%)	10 (%)	20 (%)

Using the values above, the market size of recycled material in 2010 in the DF was calculated and presented in Table B-39.

Table B-39: Future Recycled materials Market Size of DF in 2010

	Paper	Glass	Plastic	Aluminum
Production amount (1,000 ton/year)	5,041	15,533	1,010	306
Recycling rate (%)	40 (%)	35 (%)	10 (%)	20 (%)
Markets size (1,000 ton/year)	2,000	5,400	100	60

b. Compost

No explicit market for compost is found, but 10 to 20 tons of compost produced by the DGSU using pruned branches and grass is supplied monthly to be applied to the roadsides. Further, [7]a private sector has been producing compost from organic industrial waste such as residues of sugar refinery, brewery and mushroom production, but only in a small scale. However, demand for organic soil conditioner is large: it is reported that[8] an illegal collection of nutritious manure (or called *tierreros*) in mountains by those from the horticulture industry and individual gardeners who require soil conditioner has been causing serious soil erosion.

On the other hand, according to a report[9] prepared for the Bordo Poniente composting plant planned in 1993, demand for compost with purposes of covering waste disposed of at landfills, supplying soil conditioner to green areas in the delegations and reforesting was estimated at 1,750,000 ton/year approximately. Further, the Pre-F/S

[7] Estudio de Prefactibilidad para la Instalacion de una Planta Productora de COMPOSTA, DGSU
[8] Composting Organics in Mexico City, Christiam Gonzlez del Carpio, BioCycle
[9] Information requested in regard to compost for the global analysis of Bordo Poniente treatment plant, during the meeting held on April 22, 1993, Mr. Juan Rodriguez Jaquez

report for the Bordo Poniente composting plant conducted by the DGSU[3] gives the potential demand size for compost as shown in Table B-40.

Table B-40:Potential Compost Demand

unit : ton/year

	Farming	Reforestation	Green house	Final cove for landfill	Green area	Super markets	Total
Regional total	-	-	-	-	-	-	5,986,517
DF	186,235	731	72,000	560,960	35,655	387	855,969
State of Mexico	1,517,257	2,590	-	58,901	-	-	1,578,748
Hidalgo	1,327,710	-	-	9,910	-	-	1,337,620
Morelos	444,338	277,711	-	-	-	-	722,048
Puebla	1,231,749	649	-	-	-	-	1,232,398
Tlaxcala	248,607	2,298	-	8,829	-	-	259,734

These existing studies conclude that the amount of demand for compost will be in a range between 1,750,000 and 5,980,000 ton/year.

c. **Electricity**

The demand for electricity in 1988, 1994 and 1997 of the country is as shown in Table B-41 according to the CFE (Comisión Federal Electricidad). Based on these figures, the demand for electricity up to 2010 was estimated as in Table B-42.

Table B-41: Electricity Demand

	1988	1994	1997
Demand (GW/hr)	101,905	137,522	161,386

source : CFE y Secretaría de Energía

Table B-42: Forecast of Electricity Demand

Year	Electricity Demand (GW/hr)
1988	101,905
1994	137,522
1997	161,386
1998	166,000
1999	172,000
2000	179,000
2001	185,000
2002	192,000
2003	198,000
2004	205,000
2005	211,000
2006	218,000
2007	224,000
2008	231,000
2009	237,000
2010	244,000

The regression curve is derived as follows.[10]

$$y = (6.5129x - 12,847) \times 1,000 \ (R^2=0.9942)$$

d. Price

The market prices were mainly studied by interviewing the companies shown in Table B-34. The results are summarized in Table B-43.

Table B-43: Average Purchase and Sales Prices of Recycled Material

unit : pesos/kg

		Paper	Plastic	Aluminum can	Glass	Cardboard	Compost
Purchase	Informal collector	0.25	0.6	6.0	0.25	-	-
	Dealer	0.35		6.5	0.75	0.37	-
	Manufacturer	-	0.75	-	-	-	-
Sale	Informal collector	0.25	1.0	7.0	0.14	0.4	-
	Dealer	-	-	7.0	-	-	-
	Manufacturer	-	3.6	-	0.7	-	0.7

The average price of electricity in 1997[11] was 0.384 pesos/kWh, while power generation cost was 0.273 pesos/kWh.

B.5.4 Findings

a. Recycled Material

The figures of Table B-39 indicate the market size of individual materials. Furthermore, using the sales prices of Table B-43, the market size in the GDF is expressed in pesos as in Table B-44.

The market size for the recycled material is estimated to be as large as 5,000 million peso/year in 2010 (at 1998 price), assuming that there is no drop in sales prices of them. If the demand outside of the DF is considered in addition, the market size can be much larger.

Table B-44: Estimated Recycled Material Market Size of the GDF in 2010

	Paper	Glass	Plastic	Aluminum	Total
Unit rate (pesos/ton)	250	700	3,600	7,000	-
Market size (1,000 ton/year)	2,000	5,400	100	60	-
Market size (1,000 pesos/year)	500,000	3,780,000	360,000	420,000	5,060,000

However, as more recycled material is supplied to the market, the sales prices tend to be declined eventually down to below zero where there is no longer benefit but cost to supply it. In order to avoid such an event, the following policy management will be required beside recycling promotion.

[10] X denotes the year (1997, 1998, etc.) and Y denotes the electricity demand.
[11] Data from CFE and Secretaría de Energía

- Promotion of resource recovery industry.
- Encouragement of the use of recycled material.

b. Compost

As stated earlier in regard to compost, the major supplier is the GDF's compost plant, which produces only 10 to 20 tons in a month.

On the other hand, population are day by day settled near to the ex-landfill areas of Bordo Poniente I, II, and III (about 260 ha), where landscaping with a forested green area are awaited. However, the areas are in the ex-lake Texcoco area with high salinity in the soil, thus soil improvement will have to be needed in order to restore the green areas. Therefore, if soil conditioner of 30 cm thick is to be provided annually in these areas, compost demand of about 80,000 ton/year can be expected.

Furthermore, if composts are needed to be also applied in the other areas of ex-Lake Texcoco, its demand will become considerably large.

Besides, the existing studies showed the future demand size of about 1,750,000 to 5,980,000 ton/year, as mentioned before. This suggests that, if the quality of compost is satisfactory, large demand can be expected.

c. Electricity

On the other hand, the present electricity generation price is so low (0.273 pesos/kWh (1 U$= 9.1 pesos, 0.03U$/kWh)) that it can not be feasible to obtain electricity from incineration.

Therefore, material recycling is the promising area as a resource recovery method of municipal solid waste in the DF.

B.6 Bordo Poniente Landfill Mining Survey

B.6.1 Objective

The purpose of this work is to obtain physical and chemical characteristic data of buried waste in the Bordo Poniente disposal site (Etapa I, II and III), in view of examining possibility of landfill waste future reuse for such as: material recovery; compost or cover soil; and space obtainment for further landfilling.

B.6.2 Methodology

a. Site and Quantity of Survey

The closed landfill areas, Etapa I, II, and III at Bordo Poniente where landfilling have finished several years ago were investigated. The locations of the survey were selected where the waste depth is sufficiently thick, which was ascertained though electric prospecting and core boring of the Environmental Survey of the Bordo Poniente.

The survey was carried out in six pits in total, namely two pits in the Etapa I, two in the Etapa II, and two pits in the Etapa III of the Bordo Poniente Final Disposal Site. The pit (2.0 to 2.5m length, 2.0 to 2.5m width and 4.0m depth) was excavated and later backfilled in each location. Details of works are described below (b. to h.)

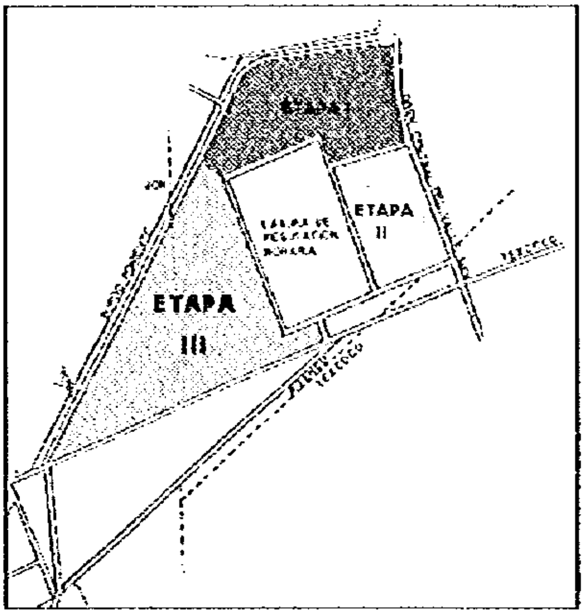

Figure B-10: Location Map

b. Temporary Slope Protection of Excavation Pits

Temporary slope protection of pits to be excavated such as listed below was carried out:

- temporary piling of posts for securing inner dimension of pits.
- placing struts and sheets where necessary for securing measurable inner dimension of pits.

c. Excavation of Top Covering Soil and Buried Waste

All works for excavating pits such as:

- excavation of top covering soil.
- excavation of buried waste in 3 stages by depth.
- bedding and shaping of excavated pits in respective depth stage for securing measurable inner dimension of pits.

were carried out.

Inner dimension of the pits to be excavated was planned to be approximately:

- 2.5 meter length and 2.5 meter width at ground surface.
- 4.0 meter depth.
- 2.0 meter length and 2.0 meter width at the pit bottom.

Actual dimension measured are presented in the following section.

B.6.2 Methodology

a. Site and Quantity of Survey

The closed landfill areas, Etapa I, II, and III at Bordo Poniente where landfilling have finished several years ago were investigated. The locations of the survey were selected where the waste depth is sufficiently thick, which was ascertained though electric prospecting and core boring of the Environmental Survey of the Bordo Poniente.

The survey was carried out in six pits in total, namely two pits in the Etapa I, two in the Etapa II, and two pits in the Etapa III of the Bordo Poniente Final Disposal Site. The pit (2.0 to 2.5m length, 2.0 to 2.5m width and 4.0m depth) was excavated and later backfilled in each location. Details of works are described below (b. to h.)

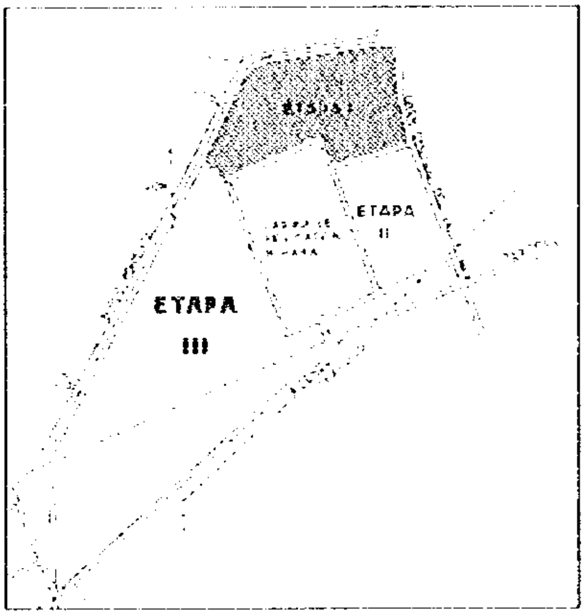

Figure B-10: Location Map

b. Temporary Slope Protection of Excavation Pits

Temporary slope protection of pits to be excavated such as listed below was carried out:

- temporary piling of posts for securing inner dimension of pits.
- placing struts and sheets where necessary for securing measurable inner dimension of pits.

c. Excavation of Top Covering Soil and Buried Waste

All works for excavating pits such as:

- excavation of top covering soil.
- excavation of buried waste in 3 stages by depth.
- bedding and shaping of excavated pits in respective depth stage for securing measurable inner dimension of pits.

were carried out.

Inner dimension of the pits to be excavated was planned to be approximately:

- 2.5 meter length and 2.5 meter width at ground surface.
- 4.0 meter depth.
- 2.0 meter length and 2.0 meter width at the pit bottom.

Actual dimension measured are presented in the following section.

d. Measurement of Excavated Volume and Weight in Stages

Volume and weight of total 4 stages (i.e., total 4 stages: 1 stage of top covering soil and 3 depth stages in buried waste) were measured.

- Volume of excavation was measured in each stage by inner dimension of excavation pit.
- Weight of excavated materials was measured in each stage by weighbridge. (i.e., Excavated materials were loaded on a dump truck for weighing at the weighbridge. The dump truck was weighed again after unloading the excavated materials in order to calculate the weight of excavated materials.)

e. Physical Composition Survey of Buried Waste Samples

Buried waste sample were taken at each depth stage of excavation. (i.e., 3 samples shall be taken from one excavation pit). Physical composition of sample were measured by dividing into:

- glass.
- aluminum.
- steel.
- combustible matters.
- and earth and sand matters.

Waste was measured respectively by portable weighing measures.

f. Laboratory Test for Chemical Analysis of Buried Waste Samples

Buried waste samples were taken at each depth stage of waste excavation. (i.e., 3 samples were taken from one excavation pit). Chemical analysis of sample were conducted at a laboratory. Chemical analysis were carried out for 14 items of:

- Carbon; Nitrogen; pH; Pb; Cd; Cr; Cu; Ni; Hg; Zn; As; Molybdenum; Selenium; and Polychlorinated-biphenyl (PCB)

referring to the US-EPA standard for agricultural use of sludge.

g. Backfilling of Excavated Pits

Backfilling of excavated pits were carried out as follows:

- firstly with excavated waste with sufficient compaction.
- secondly with excavated top covering soil with sufficient compaction.
- lastly with additional soil material (imported soil) with sufficient compaction.

Final shaping of the top of the backfilled pits was mounted with convex shape of about 40 cm higher in the middle than the surrounding existing ground level.

B.6.3 Results of the Survey

a. Sample Points

The summary on the identification of sample points is shown in the following table.

Table B-45: Identification of Sample Points

Stage No.	Pit No.	Stratum	Level
ETAPA I	3	stratum 3-1	shallow
		stratum 3-2	medium
		stratum 3-3	bottom
	4	stratum 4-1	shallow
		stratum 4-2	medium
		stratum 4-3	bottom
ETAPA II	5	stratum 5-1	shallow
		stratum 5-2	medium
		stratum 5-3	bottom
	6	stratum 6-1	shallow
		stratum 6-2	medium
		stratum 6-3	bottom
ETAPA III	1	stratum 1-1	shallow
		stratum 1-2	medium
		stratum 1-3	bottom
	2	stratum 2-1	shallow
		stratum 2-2	medium
		stratum 2-3	bottom

b. Physical Composition

The results of the physical composition from six sample points are shown in the following tables.

Table B-46: Composition of Wastes Extracted by Stratum, Pit No. 1 in Bordo Poniente Etapa III

BY-PRODUCT	STRATUM 1-1		STRATUM 1-2		STRATUM 1-3	
	kg	%	kg	%	kg	%
ALUMINUM	0.060	0.12	0.145	0.29	0.000	0.00
IRON	0.790	1.54	0.895	1.80	0.815	1.38
GLASS	0.970	1.89	1.715	3.45	1.730	2.93
PLASTIC	5.970	11.61	7.925	15.96	4.380	7.43
COMBUSTIBLE MATERIAL	20.410	39.70	3.745	7.54	18.330	31.09
SOIL AND MUD	23.215	45.15	35.230	70.95	33.705	57.17
Sample Total	51.415	100.00	49.655	100.00	58.960	100.00

Table B-47: Composition of Wastes Extracted by Stratum, Pit No. 2 in Bordo Poniente Etapa III

BY-PRODUCT	STRATUM 2-1		STRATUM 2-2		STRATUM 2-3	
	kg	%	kg	%	kg	%
ALUMINUM	0.000	0.00	0.000	0.00	0.000	0.00
IRON	0.855	1.60	1.290	2.53	2.765	5.18
GLASS	1.130	2.12	0.000	0.00	0.665	1.25
PLASTIC	9.500	17.82	16.785	32.90	8.845	16.56
COMBUSTIBLE MATERIAL	12.250	22.98	4.380	8.58	11.385	21.32
SOIL AND MUD	29.565	55.47	28.565	55.99	29.74	55.69
Sample Total	53.300	100.00	51.020	100.00	53.400	100.00

Table B-48: Composition of Wastes Extracted by Stratum, Pit No. 3 in Bordo Poniente Etapa I

BY-PRODUCT	STRATUM 3-1		STRATUM 3-2		STRATUM 3-3	
	kg	%	kg	%	kg	%
ALUMINUM	0.065	0.11	0.000	0.00	0.000	0.00
IRON	1.680	2.93	0.710	1.02	0.530	1.05
GLASS	1.770	3.09	2.105	3.03	0.000	0.00
PLASTIC	9.120	15.92	19.010	27.37	23.490	46.53
COMBUSTIBLE MATERIAL	11.265	19.66	13.170	18.96	6.230	12.34
SOIL AND MUD	33.400	58.29	34.460	49.61	20.235	40.08
Sample Total	57.300	100.00	69.455	100.00	50.485	100.00

Table B-49: Composition of Wastes Extracted by Stratum, Pit No. 4 in Bordo Poniente Etapa I

BY-PRODUCT	STRATUM 4-1		STRATUM 4-2		STRATUM 4-3	
	kg	%	kg	%	kg	%
ALUMINUM	0.000	0.00	0.000	0.00	0.000	0.00
IRON	0.000	0.00	2.410	4.82	0.000	0.00
GLASS	2.200	4.32	1.190	2.38	1.920	3.66
PLASTIC	8.155	16.02	17.030	34.08	19.845	37.80
COMBUSTIBLE MATERIAL	9.765	19.18	9.540	19.09	5.125	9.76
SOIL AND MUD	30.795	60.48	19.800	39.62	25.610	48.78
Sample Total	50.915	100.00	49.970	100.00	52.500	100.00

Table B-50: Composition of Wastes Extracted by Stratum, Pit No. 5 in Bordo Poniente Etapa II

BY-PRODUCT	STRATUM 5-1		STRATUM 5-2		STRATUM 5-3	
	kg	%	kg	%	kg	%
ALUMINUM	0.000	0.00	0.040	0.07	0.000	0.00
IRON	0.545	1.07	1.735	3.15	0.650	1.28
GLASS	2.170	4.27	1.980	3.59	0.940	1.84
PLASTIC	4.880	9.59	15.020	27.23	12.500	24.52
COMBUSTIBLE MATERIAL	23.320	45.84	11.855	21.50	2.290	4.49
SOIL AND MUD	19.955	39.23	24.520	44.46	34.600	67.87
Sample Total	50.870	100.00	55.150	100.00	50.980	100.00

Table B-51: Composition of Wastes Extracted by Stratum, Pit No. 6 in Bordo Poniente Etapa II

BY-PRODUCT	STRATUM 6-1		STRATUM 6-2		STRATUM 6-3	
	kg	%	kg	%	kg	%
ALUMINUM	0.000	0.00	0.000	0.00	0.000	0.00
IRON	1.310	2.53	0.695	1.36	0.155	0.28
GLASS	1.350	2.61	1.030	2.02	3.415	6.17
PLASTIC	16.000	30.94	9.265	18.19	8.715	15.75
COMBUSTIBLE MATERIAL	16.150	31.23	15.100	29.64	4.305	7.78
SOIL AND MUD	16.900	32.68	24.850	48.78	38.750	70.02
Sample Total	51.710	100.00	50.940	100.00	55.340	100.00

c. Bulk Density

The summary of the bulk density of the final cover is shown in the following table.

Table B-52: Density of the Final Cover of each Pit Explored

WELL No.	WIDTH (m)	LENGTH (m)	THICK (m)	VOLUME (m^3)	WEIGHT (ton)	DENSITY (ton/m^3)	AVERAGE (ton/m^3)
1	2.500	2.500	0.215	1.345	2.390	1.777	1.672
2	2.500	2.500	0.215	1.344	2.480	1.846	
3	2.450	2.500	0.222	1.362	2.480	1.821	
4	2.500	2.850	0.261	1.858	3.150	1.695	
5	2.500	2.950	0.371	2.734	3.860	1.412	
6	2.500	2.500	0.390	2.434	3.600	1.479	

c.1 Density of the Shallow Stratum

The following table shows the average density of shallow strata.

Table B-53: Density of the Wastes Extracted from Stratum 1 for each Pit Studied

Well-Stratum	WIDTH (m)	LENGTH (m)	THICK (m)	VOLUME (m^3)	WEIGHT (ton)	DENSITY (ton/m^3)	AVERAGE (ton/m^3)
1-1	2.500	2.600	1.352	8.790	8.250	0.939	1.122
2-1	2.400	2.550	0.984	6.025	6.710	1.114	
3-1	2.250	2.300	1.224	6.333	8.440	1.333	
4-1	2.550	2.850	1.232	8.950	13.830	1.545	
5-1	2.350	2.700	1.107	7.021	6.650	0.947	
6-1	2.130	2.800	1.261	7.522	6.430	0.855	

c.2 Density of the Medium Stratum

The following table shows the average density of medium strata.

Table B-54: Density of the Wastes Extracted from Stratum 2 for each Pit Studied

Well-Stratum	WIDTH (m)	LENGTH (m)	THICK (m)	VOLUME (m^3)	WEIGHT (ton)	DENSITY (ton/m^3)	AVERAGE (ton/m^3)
1-2	2.700	2.700	1.653	7.163	11.530	1.610	1.839
2-2	2.500	2.650	1.456	6.358	12.560	1.975	
3-2	2.150	2.100	1.075	4.407	9.590	2.176	
4-2	2.350	2.520	1.126	5.188	9.780	1.885	
5-2	2.350	2.650	1.096	5.255	9.970	1.897	
6-2	2.100	2.400	0.948	4.376	6.530	1.492	

c.3 Density of the Bottom Stratum

The following table shows the average density of bottom strata.

Table B-55: Density of the Wastes Extracted from Stratum 3 for each Pit Studied

Well-Stratum	WIDTH (m)	LENGTH (m)	THICK (m)	VOLUME (m^3)	WEIGHT (ton)	DENSITY (ton/m^3)	AVERAGE. (ton/m^3)
1-3	2.200	2.400	0.700	3.697	9.210	2.491	1.797
2-3	2.300	2.450	1.315	7.412	8.806	1.188	
3-3	2.300	2.400	1.090	6.016	13.050	2.169	
4-3	2.250	2.450	1.382	7.616	10.760	1.413	
5-3	2.200	2.400	1.296	6.844	9.890	1.445	
6-3	2.200	2.260	1.099	5.463	11.350	2.078	

d. Comparison of Physical Composition per Stratum

The following table shows the comparison of physical composition per strata.

Table B-56: Composition of Combustible Material, Soil and Mud, and Non-Combustible Material per Stratum-1, -2, and -3

Well No.	Shallow Stratum -1			Medium Stratum -2			Bottom Stratum -3		
	Comb. Material	Soil and Mud	Non-comb. material	Comb. Material	Soil and Mud	Non-comb. Material	Comb. Material	Soil and Mud	Non-comb. Material
(Unit)	%	%	%	%	%	%	%	%	%
1	39.70	45.15	15.15	7.54	70.95	21.51	31.09	57.17	11.74
2	22.98	55.47	21.55	8.58	55.99	35.43	21.32	55.69	22.99
3	19.66	58.29	22.05	18.96	49.61	31.43	12.34	40.08	47.58
4	19.18	60.48	20.34	19.09	39.62	41.29	9.76	48.78	41.46
5	45.84	39.23	14.93	21.50	44.46	34.04	4.49	67.87	27.64
6	31.23	32.68	36.09	29.64	48.78	21.58	7.78	70.02	22.20
Average	29.77	46.55	21.68	17.55	51.57	30.88	14.46	56.60	28.94

e. Comparison of Physical Composition per Stage

The following table shows the comparison of physical composition per Etapa I, II, and III.

Table B-57: Composition of Combustible Material, Soil and Mud and Non-Combustible Material per Etapa I, II, and III

		Combustible Material			Soil and Mud			Non-combustible Material		
	Well No.	Shallow stratum 1	Medium stratum 2	Bottom stratum 3	Shallow stratum 1	Medium stratum 2	Bottom stratum 3	Shallow stratum 1	Medium stratum 2	Bottom stratum 3
	(Unit)	%	%	%	%	%	%	%	%	%
Etapa III	1	39.70	7.54	31.09	45.15	70.95	57.17	15.15	21.51	11.74
	2	22.98	8.58	21.32	55.47	55.99	55.69	21.55	35.43	22.99
	Average	21.89			56.74			21.40		
Etapa I	3	19.66	18.96	12.34	58.29	49.61	40.08	22.05	31.43	47.58
	4	19.18	19.09	9.76	60.48	39.62	48.78	20.34	41.29	41.46
	Average	16.50			49.48			34.03		
Etapa II	5	45.84	21.50	4.49	39.23	44.46	67.87	14.93	34.04	27.64
	6	31.23	29.64	7.78	32.68	48.78	70.02	36.09	21.58	22.20
	Average	23.41			50.51			26.08		

Table B-58: Results of Chemical Analysis (Cd, Cr, Cu, Mo, Ni, Pb, Zn, pH and Water Content)

No. of Sample	Analyzed Elements (mg/kg dry base)							pH	H_2O
	Cd	Cr	Cu	Mo	Ni	Pb	Zn	-	(% weight)
1-1	5.1	44.5	97.5	<23	46.5	144	356.5	8.26	17.5
1-2	4.35	65	98.5	<23	20.5	146.5	498	8.235	44.9
1-3	3.95	73.5	58.5	<23	34.5	122.5	597.5	7.775	26.05
2-1	3.5	156.5	322	<23	64	128	394	8.075	26.05
2-2	4.2	129.5	214.5	<23	56.5	141.5	556	8.52	32.55
2-3	4.7	116	70	<23	44	124	325.5	9.04	35.15
3-1	4.7	76.5	65.5	<23	40.5	211.5	182	8.43	26.6
3-2	5.45	173	184.5	<23	146.5	182	540	8.62	41.9
3-3	3.8	46.5	81.5	<23	36	137	154.5	8.85	28.95
4-1	6.8	129.5	447.5	<23	62.5	210.5	645.5	8.47	34
4-2	7.6	336	443.5	<23	75	298	623	8.9	48.75
4-3	5.4	95	122.5	<23	42	170.5	256	9.06	34.75
5-1	4.4	159.5	91	<23	38.5	104	150.5	7.75	22.4
5-2	7.25	106.5	229.5	<23	213.5	164	464	8.575	43.75
5-3	5.2	77	63.5	<23	62	53	148	8.955	33.1
6-1	8.7	158	3,516.5	<23	104	236.5	3,388.5	8.165	44
6-2	4.8	321	78	195.5	44.5	156	644	7.95	30.85
6-3	4.95	75	87.5	<23	36	95.5	253.5	8.255	36.2
Average of 18 samples	5.27	129.9	348.4	-	64.8	156.9	565.4	8.44	33.75
US-EPA land application pollutant limits									
ceiling concentration limit (mg/kg)	85	3,000	4,300	75	420	840	7,500	-	-
"high quality" pollutant concentration limit (mg/kg)	39	1,200	1,500	18*	420	300	2,800	-	-
annual pollutant loading rate (kg/ha/day)	1.90	150.00	75.00	0.90	21.00	15.00	140.00	-	-

Note: The sample and the parameter whose concentration is over the permissible limit is shaded.
* In February 1994, EPA withdrew the molybdenum value of 18 mg/kg pending further reviews of scientific information supporting a high concentration.

Table B-59: Results of Chemical Analysis (As, Se, Hg, C, H, N, PCB)

No. of Sample	Analyzed Elements							
	As (mg/kg)	Se (mg/kg)	Hg (mg/kg)	C (% weight)	H (% weight)	N (% weight)	C/N ratio	PCB (mg/kg)
1-1	0.28	0.12	0.18	8	1.7	0.1	80	N.D.
1-2	0.26	0.03	0.41	13	2.2	0.1	13	N.D.
1-3	0.27	0.08	0.11	11	1.9	0.1	11	N.D.
2-1	0.20	0.07	0.41	13	2.2	0.06	217	N.D.
2-2	0.26	0.07	14	12	2.0	0.03	400	N.D.
2-3	0.12	0.13	5.8	9	1.6	0.12	75	N.D.
3-1	0.22	0.05	0.34	10	1.8	0.53	19	N.D.
3-2	0.17	0.05	1.0	10	1.7	0.28	37	N.D.
3-3	0.17	0.07	0.18	6	1.1	0.11	55	N.D.
4-1	0.18	0.03	0.32	12	2.2	0.15	80	N.D.
4-2	0.27	0.05	0.42	13	2.0	0.42	31	N.D.
4-3	0.34	0.07	0.58	6	1.5	0.07	86	N.D.

No. of Sample	Analyzed Elements							
	As (mg/kg)	Se (mg/kg)	Hg (mg/kg)	C (% weight)	H (% weight)	N (% weight)	C/N ratio	PCB (mg/kg)
5-1	0.12	0.04	0.12	10	1.9	0.10	100	N.D.
5-2	0.19	0.06	0.19	13	2.1	0.22	59	N.D.
5-3	0.15	0.08	0.54	4	0.9	0.12	33	N.D.
6-1	0.25	0.13	0.22	19	2.8	0.50	38	N.D.
6-2	0.18	0.03	68	12	2.1	0.03	400	N.D.
6-3	0.16	0.04	0.7	5	1.3	0.16	31	N.D.
Average of 18 samples	0.21	0.07	5.20	-	-	-	98	N.D.
US-EPA land application pollution limits								
ceiling concentration limit (mg/kg)	75	100	57	-	-	-	-	-
"high quality" pollutant concentration limit (mg/kg)	41	36	17	-	-	-	-	-
annual pollutant loading rate (kg/ha/day)	2.00	5.00	0.85	-	-	-	-	-

Note: N.D.: No detected
The sample and the parameter whose concentration is over the permissible limit is shaded.

B.6.4 Findings

B.6.4.1 Shallow/Medium/Bottom Layers

a. Bulk Density

Comparing the bulk density of shallow, medium and bottom layers, it is found that the shallow layer has an average bulk density of about **1.1 ton/m^3**, and the medium and bottom layers have an average bulk density of about **1.8 ton/m^3**. It reveals that since the shallow part has slow decomposition of buried waste, its bulk density is close to that of buried waste (which normally can be estimated at around **0.8 ton/m^3**).

Meanwhile it is estimated that since the medium and bottom layers are under the groundwater table, anaerobic decomposition takes place to raise its bulk density as high as **1.8 tom/m^3**.

b. Physical Composition

b.1 Combustible and Soil Matters

Comparing the proportion of combustible matters of shallow, medium and bottom layers, it is found that **combustible matters** in average account for about **29.8%, 17.6% and 14.5%** respectively in the shallow, medium and bottom layers. It reveals that since the shallow part has slow decomposition of buried waste, proportion of combustible matters in the shallow layer was found to be larger than those in the medium and bottom layers.

Meanwhile it is estimated that since the medium and bottom layers are under the groundwater table, anaerobic decomposition of combustible matters takes place to reduce its proportion and turned them into soil matters.

b.2 Soil Matters

Comparing the proportion of soil matters of the shallow, medium and bottom layers, it is found that **soil matters** in average account for about **48.6%, 51.6% and 56.6%** respectively in the shallow, medium and bottom layers. It reveals that since the shallow part has slow decomposition of buried waste, the proportion of soil matters in the shallow layer was smaller than those in medium and bottom layer.

Meanwhile it is estimated that since the medium and bottom layers are under the groundwater table, anaerobic decomposition of combustible matters takes place to reduce its proportion and turned them into soil matters.

b.3 Non-Decomposable Matters

Comparing the proportion of **non-decomposable matters (such as metals, glass, plastics)** of the shallow, medium and bottom layers, it is found that non-decomposable matters in average account for about **21.7%, 30.9% and 28.9%** respectively in shallow, medium and bottom layers. It reveals that proportion of non-decomposable matters in the shallow layer was smaller than those in the medium and bottom layer. It is estimated that since the medium and bottom layers are under the groundwater table, anaerobic decomposition of combustible matters takes place to turn them into water, gasses and soil matters, which consequently reduces the proportion of combustible matters and comparatively increases the proportion of non-decomposable matters in the medium and bottom layers.

B.6.4.2 Old/Medium/New (Etapa I, II, and III)

a. Physical Composition

a.1 Combustible Matters

Comparing the proportion of combustible matters of Etapa I, II, and III, it is found that **combustible matters** in average account for about **16.5%, 23.4% and 21.9%** respectively in Etapa I, II, and III. It reveals that since the Etapa I has longer time of decomposition of combustible matters, combustible matters in Etapa I were less than those in Etapa II and III, which have shorter time of decomposition than Etapa I.

b.1 Non-Decomposable Matters

Comparing the proportion of non-decomposable matters of Etapa I, II, and III, it is found that **non-decomposable matters** in average account for about **34.0%, 26.1% and 21.4%** respectively in Etapa I, II, and III. It reveals that the proportion of non-decomposable matters in the older cells (Etapa I) was higher than those in the medium old cells (Etapa II) and newer cells (Etapa III). It is estimated that the older cells are with longer time of decomposition of combustible matters. Decomposition takes place to turn the combustible matters into water (H_2O), landfill gases (CH_4 etc.) and soil matters, which consequently reduces proportion of combustible matters contents and comparatively increases the proportion of non-decomposable matters in the older cells.

B.6.4.3 Stabilization of Landfill

In view of the above results that the shallow layer or newly disposed part of landfills have slow decomposition, it will be suggested that **recirculation of leachate** will accelerate decomposition of buried waste and then to stabilize the landfill.

B.6.5 Conclusion

In general, landfill mining has two main objectives as follows:

- sub-products recovery.
- space recovery.

Meanwhile, the landfill mining will have a problem of

- **re-disposal of rejects** from landfill mining.

a. **Sub-Products Recovery**

Sub-products recovery can refer to:

- recovery of **valuable materials** (e.g., metals).

or

- recovery of **soil matters** (such as compost, soil for landfill cover materials).

a.1 **Recovery of Valuable Materials**

The survey revealed that the proportion of valuable materials in buried wastes is substantially small (e.g., aluminum and iron matters recovered in the survey account for only less than 2% to the total). Therefore it can be concluded that recovery of valuable materials (such as metals) from landfill mining is **not feasible** nor practicable, in comparing:

- costly works of landfill excavation, sieving such as aluminum and irons, re-disposal of rejects, etc. and
- recycling works of aluminum and iron which are currently practiced by citizen, collectors and workers in S/Ps in the DF.

a.2 **Recovery of Soil Matters**

The survey revealed that the proportion of soil matters in buried wastes is substantially large (e.g., soil and mud accounts for more than 50% to the total).

Laboratory analysis of the samples revealed as follows (see Table B-58 and Table B-59):

- Average of 18 samples are within the permissible level of concentration in every parameter for the agricultural land use application. As for 7 parameters (Cd, Cr, Ni, Pb, As, Se, PCB) out of 11 parameters, all 18 samples are within the permissible levels. As for the rest 4 parameters (Cu, Mo, Zn, Hg), only one sample out of 18 exceeds the permissible level. Therefore the pollution level of soil matters in landfills are within the permissible level for its agricultural use.

- As for pH, all the samples range from 7 to 9. Therefore the soil is applicable for agricultural use in view of acidity or alkalinity.

- As for C/N ratio, it ranges widely from 11 to 400, its average being about 100. Samples with high C/N ratio are judged that their carbon contents still can be decomposable with much time. Meanwhile, in order to adjust C/N ratio to an appropriate level, nitrogen application might become necessary.

It will be needed to discuss whether the soil matters recoverable from the landfills in DF are applicable for agricultural use or only for non-agricultural use.

a.3 Soil Matters for Agricultural Use or Non-Agricultural Use

The US-EPA regulation (Sewage Sludge Use and Disposal Regulations: Part 503 Standards) specifies that:

- If a sludge meets the "high quality" metal concentration limits, it can be land applied provided that the application rate does not exceed "annual pollutant loading rates".

Therefore, the "annual pollution loading rates (kg/ha/day)" might give a restriction on the quantity of agricultural application in view of the size of land that should receive the soil matters from landfill mining.

Furthermore, if excreta or manure is used for nitrogen application in order to adjust C/N ratio, it is necessary to take measures for controlling bacteriological level (i.e., fecal coliforms level). Otherwise soil matters with high bacteriological level (more than 1,000 fecal coliforms per gram) should also have restriction on agricultural application as follows (Sewage Sludge Use and Disposal Regulations: Part 503 Standards):

- food crops that receive the sludge application cannot be harvested for periods ranging from 14 to 38 months afterwards, depending upon the type of crop grown and the method of application.
- pasture lands that receive the sludge cannot be grazed for 30 days.
- turf lands are not allowed to be harvested within 12 months of application.
- public lands that receive the sludge application will have access restricted for 30 days in low-exposure areas and up to 1 year for high-exposure areas.

Consequently, in view of samples quality, the soil matters from "landfill mining" are usable for **agricultural** purposes **with conditions** such as "annual pollution loading rates (kg/ha/day)" and "bacteriological level". Meanwhile, **additional cost of laboratory analysis** of soil sample will become necessary in order to verify that can be safely used as agricultural purposes.

Meanwhile, in case of non-agricultural uses, "soil matters from landfill mining" can be utilized as:

- cover soil of landfill; or

- soil conditioner for no-orchard afforestation or no-grazing vegetation.

without the **cost of laboratory analysis.**

a.4 Odor Control of Soil Matters

One major disadvantage of soil matters from "landfill mining" is the offensive odor, which was experienced during the field investigation works. Since the decomposition of buried wastes in the landfill takes place at anaerobic conditions, soil matters re-excavated through "landfill mining" have offensive odor. Therefore, some measures (such as aeration) to reduce offensive odor is required for the soil matters recovered from the landfill mining, after separating the rejects (such as plastics) and before applying as compost or cover soil for landfill.

b. Space Recovery

As mentioned above, proportion of soil matters in buried wastes is substantially large (e.g., soil and mud accounts for more than 50% to the total). Therefore, if the soil matters are removed to be used in some purposes (such as landfill soil cover or soil conditioner for green areas), about 50% of space recovery could be achieved by that.

Hypothetically comparing economic values of space recovered from:

- Bordo Poniente Etapa I, II, III landfills **(old landfills without impermeable liner)**.
- Bordo Poniente Etapa IV and V **(new landfills with impermeable liner)**.

a unit space recovered in **landfills with impermeable liner** will have much higher values than that in **landfills without impermeable liner.**

because, if a space recovered in **Etapa I, II, III** are to be used for future landfill, a new impermeable bottom liner should be installed in the area (Etapa I, II, III) in order to comply the existing environmental norms. Meanwhile, if a space recovered in Etapa IV and V are to be used for future landfill, a space recovered therein has an economic advantage that the space is already exempted with the cost of impermeabilization, because a liner already exist below the space recovered.

c. Re-Disposal of Rejects

On the other hand, after soil matters are recovered, the rejects such as plastics should again be disposed of. It will be anticipated that additional costs of rejects re-disposal become costly.

B.6.6 Recommendation and Concluding Remarks

In view of conclusions listed above, "landfill mining" is not workable today. However, the "landfill mining" in the future (maybe after the study's target year 2010) might possibly become workable and feasible.

The possible scenarios in the future might be:

- If a windrow composting facility is introduced as the new intermediate treatment of the DF in the near future, as proposed as one of F/S projects, its facility can be co-used by the landfill mining operation in the process of soil matters aeration, in order to remove offensive odor. It will also be another future possibility that landfill mining will be an auxiliary function of windrow compost production.

- Preparation of separate disposal of only organic waste from today might be another possible scenario, in order to minimize the future cost of re-disposal of rejects in the landfill mining; and
- When and if in the future landfill becomes much more costly than today, it will in turn make the landfill mining technology feasible in view of space recovery merits.

Annex C

Current Situation of Solid Waste Management

Contents

List of Tables

List of Figures

C Current Situation of Solid Waste Management

C.1 History of Solid Waste Management

C.1.1 Collection and Haulage

By the end of 19th century in Mexico, police inspectors were in charge of the cleaning services with mules and cleaning carts. Around the middle of the same century, regulations were established to locate waste dumping sites.

The basis for the workers associations was found in the 1930s. In 1934, the Cleaning and Transportation Union was formed, which in the future would turn into Section 1 of the Only One Union of Workers for the DF, with 1,600 members.

The first Code of the Cleaning Service for the DF was promulgated in 1941, which was invalid until 1988. In the same year, the cleaning staff was 2,137 and 600-800 tons of waste were daily hauled to dumping sites.

The participation of public sectors was admitted in 1941 by a presidential decree, by which they were granted the concession to exploit and industrialize garbage and earned benefits to improve their services.

In 1946, the Cleaning Office started to take charge of sweeping and waste collection works.

It was 1972 when the cleaning service, including manual and mechanical sweeping and waste collection, were entrusted to the delegations, as seen today. Their activities were looked after by the Collection System and Garbage Treatment Office, which took over the Cleaning and Collection Office. The present collection routs and zoning were designed by this office.

In the next year, the construction of transfer stations started. The first one was installed in the delegation Miguel Hidalgo.

In 1976, the Collection System and Garbage Treatment Office was incorporated into new General Directorate of Urban Services (DGSU), which was regarded as a supportive institution for the cleaning and transportation offices of the delegations. During the next several years, however, the functions of the DGSU were gradually decentralized, and finally it was dismissed.

In 1984, the DGSU came back and the transfer system was strengthened through the acquisition of equipment and the construction of new facilities. The nighttime collection program for clandestine dumping sites was also implemented, along with other cleaning programs for main roads and specialized collection from hospitals and parks.

Since then, there were no major changes in the collection service, although waste to be collected has increased fivefold since 1950, when waste amount was about 2,000 ton/day from the population of about 3.96 million. In fact, some delegations have made diverse attempts to bring modifications to the collection routes, stopping points, and collection schedules, but all these efforts have not been successful. This is mainly because the truck drivers, who are virtually the decision makers to design their "optimum" collection system and distribute the pre-scavenged materials, do not cooperate.

C.1.2 Treatment and Final Disposal

The modern history of treatment and final disposal system in the DF is summarized in Figure C-1. As this figure suggests, the period since the 1980's can be divided into three.

The first period is until 1985, when there were no rational control of SWM and waste was simply disposed of at several open dumping sites and simultaneously scavenged by people. The excessive environmental stress given by such dumping sites let the authority take serious actions, one of which was a closure of the Santa Cruz Meyehualco.

The turning point came in 1985, when the DGSU carried out an assessment study of each existing dumping site. As a result, most dumping sites were found to be unacceptable for the environment and human health, and finally closed. Cleaning and forestation works were then provided to most of the closed sites in 1988. On the other hand, a new final disposal site was opened at Bordo Poniente, where a sanitary landfill operation was introduced. Thus, the years until the beginning of the 1990s can be regarded as a period when the sound SWM began to take shape.

The third term corresponds to the last several years to date. It is characterized by the activities of the DGSU which has been struggling to modernize and upgrade its SWM system and make it more environmentally friendly. For these purposes, they have been trying to introduce technical methodologies such as intermediate treatment and resource recovery in a systematic way. The necessity of such efforts can be, as a matter of fact, taken for granted since the waste generation amount is considerably huge, and Mexico City is so urbanized that there is a strong demand for advanced SWM.

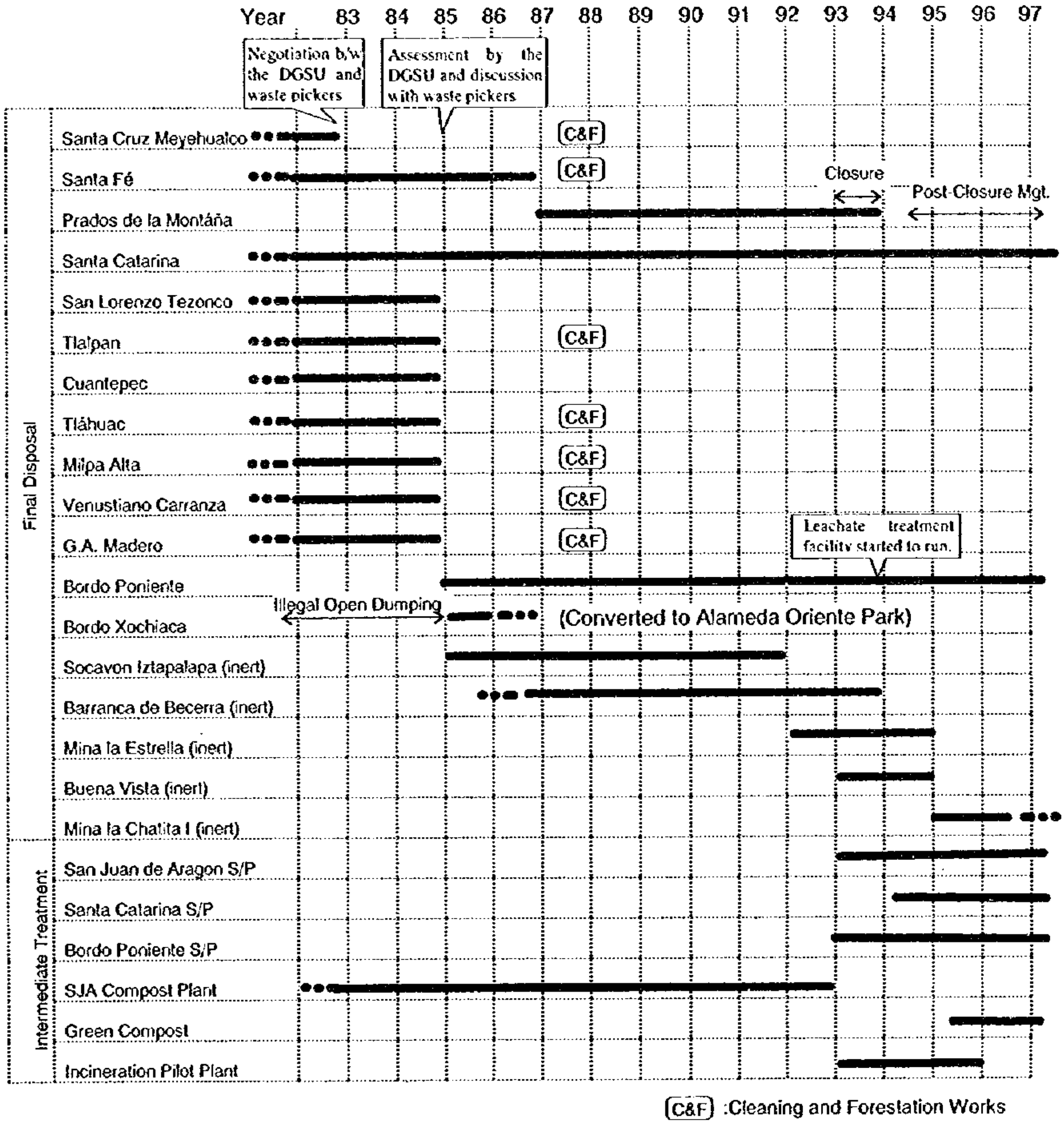

Figure C-1: Waste Treatment and Disposal in Last 15 Years

C.2 Waste Stream

C.2.1 Introduction

a. Outline of Waste Stream

There are found various features in the stream of municipal solid waste in the DF.

1. Wastes are collected at source and transported to the transfer stations, S/Ps or directly to the final disposal sites by the delegations, while waste transport from the transfer stations to the S/Ps or final disposal sites, and that from the S/Ps to the final disposal sites are carried out by the DGSU.

2. Wastes collected by private sectors or individuals are done through the same routs as the delegations.

3. At the S/Ps run by the DGSU, the recyclables with market values are recovered, and the residuals are further transported to the final disposal sites.

4. Wastes generated at hospitals in the DF are collected by private sectors. General wastes similar to domestic wastes are directly brought to the final disposal sites, while biological infectious wastes are first disinfected and transported to the final disposal sites and pathological wastes are incinerated.

5. Illegally dumped wastes in the DF are collected and transported to the final disposal sites by the DGSU. Illegal dumping is often found in places such as:

    - Roads.
    - Vacant lands.
    - Cliffs.
    - Valleys.

    It should be noted that because there are not many rivers or open drainage channels, wastes dumped to those are much fewer than in other developing countries.

6. Self disposal of wastes at households by burning, burying or composting is not common and the waste amount disposed of at households is considered negligible.

7. Recycling is practiced during the collection, and intermediate treatment processes. The mainly recovered materials include steel scrap and cans, aluminum scrap and cans, cardboard, paper and plastics. Material recovery is conducted by the following people.

    - Collection by crew.
    - Sweepers.
    - ex-pepenadores.

Taking these features into account, the waste stream is illustrated in Figure C-2.

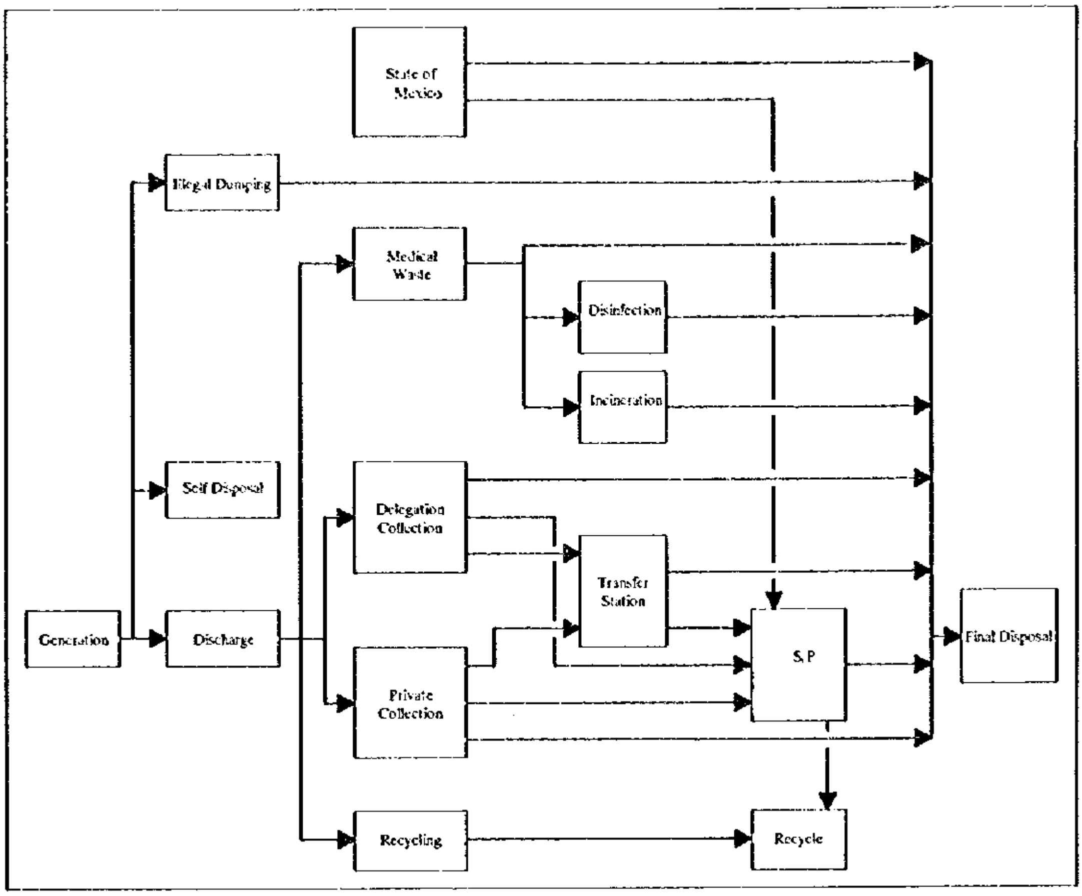

Figure C-2: Present Waste Stream

b. Definition of Terms for Waste Stream

Definition of specific terms used in Figure C-2 is given below.

- Generation

Waste amount of "generation" refers to the amount of waste generated in the whole DF.

- Illegal Dumping

Waste amount of "illegal dumping" refers to the amount of waste dumped where waste should not be thrown away.

- Self Disposal

Waste amount of "self disposal" refers to the amount of waste which is generated by households and disposed of by the waste generators themselves by such means as burning, burying or composting.

- Delegations Collection

Waste amount of "delegations collection" refers to the amount of waste collected by the delegations of the DF.

- Private Collection

Waste amount of "private collection" refers to the amount of waste collected not by the delegations but by private sectors or individuals.

- Recycling

Waste amount of "recycling" refers to the amount of waste which is recycled during the collection process or in the S/Ps.

- Transfer Station

"Transfer station" refers to a facility in which waste collected by the delegations, private sectors or individuals is transferred to a large trailer.

There are 13 transfer stations in the DF. Their styles of operation varies: six of them are operated directly by the DGSU, one by a corresponding delegation, and six by both parties.

- S/P

An "S/P" is a facility where recyclable materials are recovered from collected wastes.

- Final Disposal

The site of "final disposal" is a facility where collected waste and waste residues from the S/Ps are disposed of.

- The State of Mexico

Some or almost all of wastes generated in 11 municipalities of the State of Mexico are transported to the final disposal sites operated by the DGSU. Waste amount from "the State of Mexico" refers to the amount of waste from those municipalities, namely:

  - Atenco.
  - Chalco.
  - Chiautla.
  - Chiconcuac.
  - Cuatitlan Izcalli.
  - Ecatepec.
  - Ixtapaluca.
  - Nezahualcoyotl.
  - La Paz.
  - Texcoco.
  - Valle del Chalco.

C.2.2 Waste Composition and Generation Ratio

a. Waste Composition

The DGSU has been investigating municipal solid waste composition of wastes generated from five sectors with totally 19 sub-sectors in the DF, as shown in Figure C-3. Wastes are classified into 35 and the obtained data are utilized for SWM control.

Consequently, the present study is to follow the same waste classification as the DGSU.

Table C-1 is the result of the waste composition survey by the DGSU.

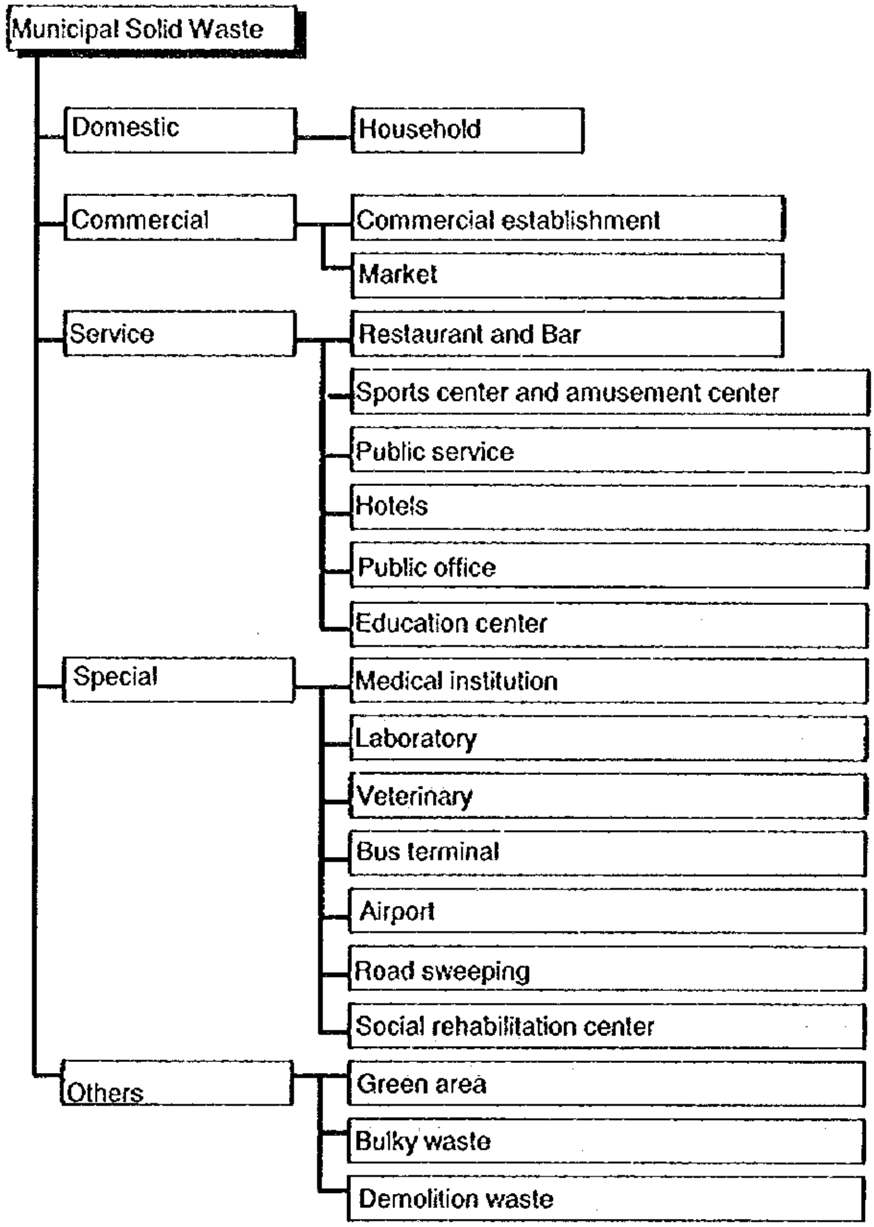

Figure C-3: Sectors and Sub-Sectors of Waste Sources

Table C-1: Waste Composition

(unit: %)

Composition	Domestic	Commercial		Service													Others			Total
	Household	Commercial	Market	Restaurant and Bar	Sports center and amusement	Public service	Hotels	Public office	Education center	Hospital	Laboratory	Veterinary	Bus terminal	Airport	Road	Social rehabilitation center	Green Area	Bulky waste	Demolition waste/Small repair	
1 Spatula										1.97										0.03
2 Cotton	2.15	0.07	0.83			0.38	0.03	2.99	0.17	1.97	10.38	5.57								1.30
3 Cardboard	5.36	11.51	5.29	5.97	11.04	23.18	3.77	11.20	8.98	8.30	8.01	2.56	4.34	5.31	3.66	5.06	4.00			6.68
4 Leather	0.11			0.02		3.69			0.04											0.11
5 Paper container	1.96	1.97	2.22	1.43	5.18	1.98	0.76		6.05	1.07		0.69	0.55		6.53	0.52	3.12			1.91
6 Vegetable fiber	0.06	1.79	2.63			1.13	0.08	0.01	0.78	0.20										0.69
7 Synthetic fiber	1.43	0.29	0.89	0.04			0.01	0.24		0.27	3.10				0.10					0.85
8 Gauze										3.77	5.74	5.94								0.05
9 Bone	0.08	0.44	1.11			0.21			0.67	0.07		0.38								0.27
10 Vinyl	0.20	1.07	0.16			0.36	0.18	0.83	1.33	2.07										0.37
11 Disposable syringe										2.80	1.31	1.38								0.04
12 Cans	1.58	0.31	1.47	0.25	1.23	3.10	0.52	0.28	4.89	1.73		2.31	4.53	3.17	4.77					1.24
13 Ceramics	0.37	0.12	0.09	0.45	0.29		0.18	0.08	2.01										2.09	0.30
14 Wood	0.10	1.20	1.17	0.67		6.72		0.01	3.92	0.43		4.82	0.29				5.12	20.00	1.53	1.24
15 Construction waste	0.63			0.52	0.09		2.89						1.24						95.27	2.14
16 Metal	1.39	2.59	0.07	0.92	5.65	0.71	1.79	0.15	0.40	1.90		0.69			0.41		2.86	50.00		2.56
17 Nonferrous metal	0.06	0.51				1.30		6.54		0.07	1.18	1.31					2.29			0.49
18 Paper	1.19	5.31	1.87	1.54	3.57	18.75	9.21	37.61	14.33	6.57	17.23	9.88	9.10	6.41	5.41	3.11	6.82		0.97	4.41
19 Newspaper	4.61	5.95	4.54	0.95	3.17	15.50	5.24	11.91	6.99	4.37	11.97	20.64	6.07	15.34	9.71	7.73	2.22			4.96
20 Toilet paper	8.78	1.94	4.27	3.40	9.59	4.20	8.16	1.99	10.72	11.00	9.62	7.38	15.20	8.92	9.52	4.65				5.89
21 Disposable diaper	3.37	0.14		0.08	0.09	0.32	0.89		0.30	1.43			1.94							1.62
22 X-ray film										0.30										0.00
23 Plastic film	6.24	5.38	1.50	3.08	7.13	2.14	3.58	0.16	1.95	3.27		0.44	5.34	3.91	5.38	2.00	9.29		0.14	4.53
24 Hard plastic	4.33	3.94	2.96	1.26	15.34	1.39	1.69	0.88	2.69	0.97	8.64	1.63	3.08	5.46	6.62	1.26	4.00			3.49
25 Polyurethane	0.16	0.11	0.08	0.03		2.70			0.67	0.76	2.17	2.56								0.16
26 Foamed polyurethane	0.78	0.12	0.46	0.35	0.72	1.85	0.16	0.11	0.46	1.70	2.27	1.06	1.10	1.18	1.22		1.23			0.58
27 Food waste	34.66	38.73	63.08	74.43	16.17	5.71	43.23	21.22	16.02	26.96	1.74	3.31	30.44	16.32	7.67	42.49				37.70
28 Garden waste	5.12	0.15	0.05	0.08	0.42	0.59	3.66	0.30	6.32	1.30	1.89	0.56		1.53	11.46	7.46	25.36			3.18
29 Sanitary napkin		0.17						0.04	0.63		1.61		0.01			2.00				0.04
30 Rags	0.64	0.20	0.30	0.12	1.14		1.72	0.31	1.02	0.50	1.84			4.88		3.00		30.00		1.22
31 Bandage										0.36					0.02					0.01
32 Color glass	4.00	1.77	0.30	1.53	4.67	2.81	3.09	0.26	2.44	6.70	4.86	2.00	3.45	8.07	8.64	0.42				2.62
33 Transparent glass	6.77	5.18	0.44	2.82	11.76	1.28	8.52	0.76	4.66	5.63	3.05	0.94	7.79	7.14	8.37	0.95	0.85			4.61
34 Fine fraction	1.21	0.07	3.97	0.03	2.75		0.26	0.01	0.73	0.43	0.03			3.61	4.02		26.30			1.71
35 Others	2.66	8.97	0.25	0.03			0.38	2.11	0.83	1.13	3.36	23.95	5.53	8.75	6.49	19.35	6.54			3.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.0	100.00	100.00	100.00	100.00	100.00	100.00	100.0	100.00	100.00	100.00	100.00	100.00

b. Generation Ratio

Generation ratio at each source surveyed by the DGSU is shown in Table C-2. The present study will adopt the same generation ratio.

Table C-2: Generation Ratio

Type of Source Generation	Classification	Generation Ratio	
Domestic	Household	0.616	kg/Person/Day
Commercial	Commercial Establishment		
	- Auto Service Shop	637.000	kg/Establishment/Day
	- Department Store	368.000	kg/Establishment/Day
	- Commercial Place	6.650	kg/Establishment/Day
	Market		
	- Meat Market	4.430	kg/Stall/Day
	- Vegetable Market	7.920	kg/Stall/Day
	- Grocery store	1.025	kg/Stall/Day
	- Food Preparation	14.960	kg/Stall/Day
	- Various	0.803	kg/Stall/Day
	- Shifting Market (Tianguis)	575.800	kg/Tianguis/Day
Service	Restaurant and Bar	25.442	kg/Establishment/Day
	Sports Center and Amusement Center		
	- Amusement Center	1.230	kg/Employee/Day
	- Sports Center	2.620	kg/Employee/Day
	- Cultural Center	0.330	kg/Employee/Day
	Public Service		
	- Services Office	3.460	kg/Establishment/Day
	- Repair and Maintenance Service	1.940	kg/Establishment/Day
	- Gas station	53.120	kg/Establishment/Day
	Hotel		
	- Five-star hotel	1,016.900	kg/Establishment/Day
	- Four-star hotel	218.500	kg/Establishment/Day
	- Three-star hotel	16.810	kg/Establishment/Day
	Education Center		
	- Kindergarten	0.040	kg/student/Day
	- Elementary School	0.055	kg/student/Day
	- Job Training Center	0.060	kg/student/Day
	- Junior High School	0.065	kg/student/Day
	- Technical School	0.060	kg/student/Day
	- Senior High School	0.060	kg/student/Day
	- University	0.070	kg/student/Day
	- Public Office	0.413	kg/Employee/Day
Special	Medical Institution		
	- 1st. Level	1.279	kg/Consultory Room/Day
	- 2nd. Level	4.730	kg/Bed/Day
	- 3rd. Level	5.390	kg/Bed/Day
	Laboratory	6.340	kg/Laboratory/Day
	Veterinary	1.700	kg/Employee/Day
	Bus Terminal	2,103.000	kg/Terminal/Day
	Airport	28,887.000	kg/Airport/Day
	Road Sweeping	125.530	kg/km/Day
	Social Rehabilitation Center	0.540	kg/Person/Day
Others	Green Area	0.00993	kg/m^2/Day
	Bulky Waste	28.850	kg/Ton-Solid Waste/Day
	Demolition Waste and Small Repair	20.850	kg/Ton-Solid waste/Day

C.2.3 Data Collection for Waste Stream Analysis

In order to obtain the amount of waste flow, data which were employed are as described below. It should be noted that when the waste amounts of transport and handling are to be calculated, the number of working days of each relevant facilities is used so that waste stream amount can be expressed by ton per day.

a. Generation Amount

The study[1] of generation amount by the DGSU in 1997 was based on the result of waste generation ratio survey, population, and the number of establishments by sector. The present study basically used the DGSU's study with minor corrections of some items.

b. Recycling at the S/Ps and Final Disposal Amount

Data regarding the S/Ps and the final disposal sites were extracted from the materials listed in the table below.

Table C-3: Data Sources

		Period	Company
Final Disposal	Bordo Poniente	January - April 1998	Ingenieria Sistemas y Tecnologia Ambiental S.A. de C:V:
	Santa Catarina	January - May 1998	Grupo Promotor De Ingenieria S.C.
S/P	Bordo Poniente	January - July 1998	Puntal S.A. de C.V.
	San Juan de Aragon	January - July 1998	Impulsora de Desarrollo Integral S.A.de C.V.
	Santa Catarina	January - July 1998	Planes y Analisis S.A. de C.V.

c. Waste Handled at Transfer Station

References in the above table also supplied data regarding the transfer stations.

d. Delegation and Private Collection Amounts

Data of waste collection by the delegations, private sectors and individuals were also found in references in Table C-3.

e. Illegal Dumping

Illegally dumped waste amount was available in references in Table C-3.

f. Medical Waste Amount

The DGSU's study on waste generation was used as a data source for medical waste amount.

g. Waste Amount of State of Mexico

References in Table C-3 and the DGSU's study on waste generation gave data for wastes amount from the State of Mexico.

[1] Ingreso Promedio Diario en Sitios de Disposicion Final y Plantas de Seleccion Durante 1997.

C.2.4 Waste Stream Analysis

Using the material mentioned above, the waste amount of each component for the waste stream was calculated and summarized in Figure C-4.

It was revealed that the waste generated in the DF in 1997 amounted to 11,422 ton/day and waste from the State of Mexico was 777 ton/day. 1,929 tons of waste were recycled daily and 10,276 ton/day were disposed of.

As for waste collection, the DGSU collected 8,867 ton/day of waste while the private sector and individuals collected 912 ton/day. Wastes of 8,558 ton/day of the total of these two went to the transfer stations prior to the final disposal sites.

The S/Ps received 4,913 tons of waste per day, 496 tons of which were recycled.

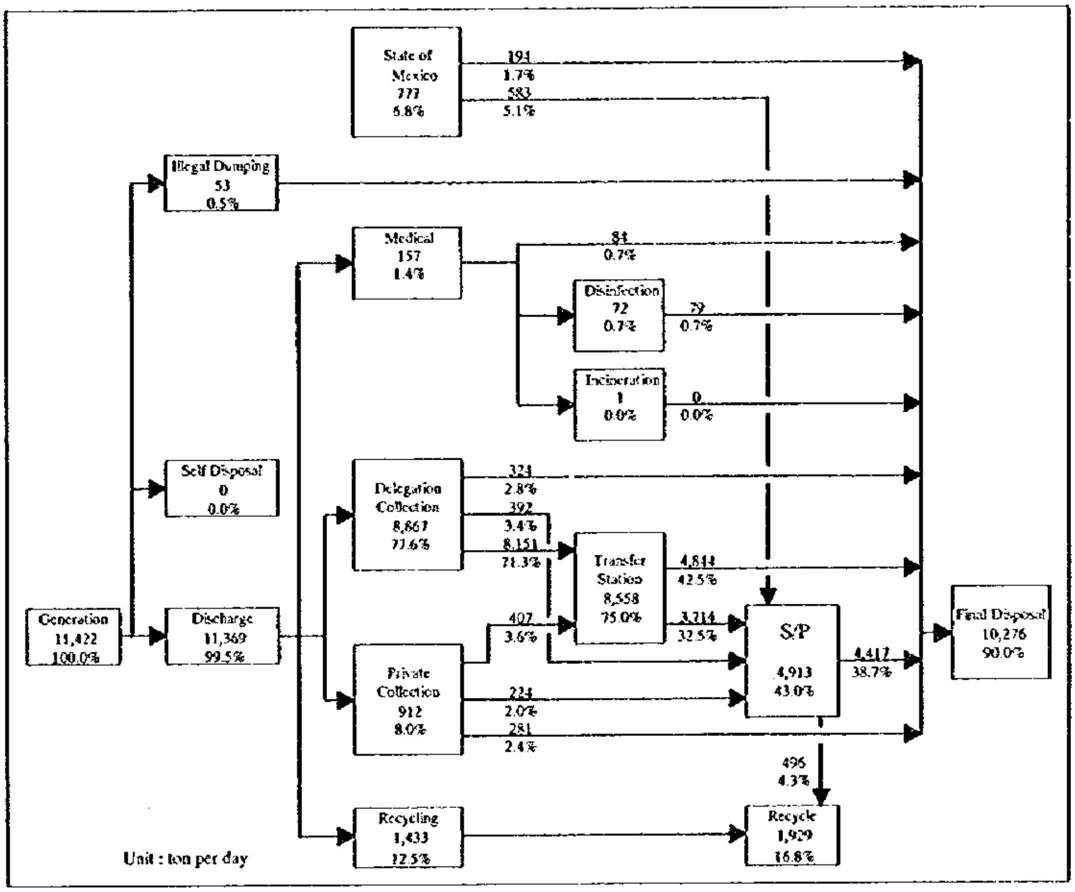

Figure C-4: Waste Stream in 1997

C.3 Technical System

C.3.1 Discharge and Storage System

The appropriate storage of wastes has to be in a manner, as a main purpose, to preserve the wastes sanitarily since the moment that are generated until they are collected with the appropriate equipment. The factors that affect the storage in Mexico City, are the following:

- Generation of wastes.
- Characteristics of the wastes (humidity, organic matter content, volumetric weight, etc.).
- Frequency and method of collection.
- Equipment and methods used for the receipt of the wastes.

a. Storage in Houses

A clear correlation exists among the type of domestic storage that is used and the user's socio-economic level.

It is difficult for waste storage containers, which are used for example in the "barrios" and "popular colonies", to fulfill the sanitary requirements such as: easy to handle, large enough, properly capped, light and easy to clean. In fact, it is commonly observed that they use sacks, baskets, wheelbarrows, boxes and all type of inappropriate containers for the storage of the garbage.

On the other hand, in residential areas with higher income level, more attentions are given to the containers used to store the wastes. Therefore in general terms, they use plastic containers with cover and appropriate capacity (manufactured exclusively for this function), normally plastic bags are located in their interior in order to contain the garbage in it with more comfort, and they normally empty them every two days. As a rule, these containers present the following characteristics:

- Easy to clean.
- With handles and an adjusted cover.
- Rapid discharge.
- Light and resistant.
- Difficult to be oxidized or deformed.
- With good appearance.

Placing of the wastes inside the storage containers is invariably made manually by the users themselves or by the employees, who are also responsible for handing wastes to the collection service, or to the sweepers who practically turn into complementary personnel of recollection.

Likewise, in order to easily hand the wastes to the collection teams in that moment, plastic bags of different types, sizes, characteristics and colors are used inside the containers. All these operations are made in manual form.

b. Storage in Other Source

In areas and installations of great waste generation, it is very common to employ metallic containers or any other material of big dimensions, either movable or stationary. Their volumes usually vary from 1 to 3 m^3, although there are other types of larger dimensions (up to 6 m^3). Their handling requires specialized vehicles and, on occasion, high sophistication. The loading system of these containers can be mechanical, hydraulic, or pneumatic. Hydraulic systems are prevalent.

The loading system can be in front, lateral or on the back. In fact, lateral loading systems are used with more frequency in Mexico City.

It is possible to mention, according to the experience in Mexico City, that the use of containers in appropriate places in establishments of great waste generation (such as markets, hotels, business, industries and residential units) can substantially lower the operational costs of collection, since the time for waste loading operation can be notably lowered and the vehicle can make more trips compared with a normal shift of manual loading works.

In some places of great generation, mainly in housing units, and corporate, commercial and departmental commercial centers, vertical ducts, compactors and occasionally garbage mills are used, although these are not common. (As a rule, they emphasize their service but offer very few benefits, since the process for users to adapt themselves to these equipment always encounters a natural rejection and a bigger attention on the part of the users who are not always ready to be served. Furthermore, these mechanisms demand maintenance that in turn are costly; which, as a rule, is not considered when the decision of its acquisition is made.)

C.3.2 Collection and Haulage System

Collection of municipal wastes generated is the responsibility of respective delegations and most of them are delivered by the Section 1 to the transfer stations managed by the DGSU (Exceptions are wastes that are brought directly to the final disposal sites or the S/Ps by some delegations due to their vicinity).

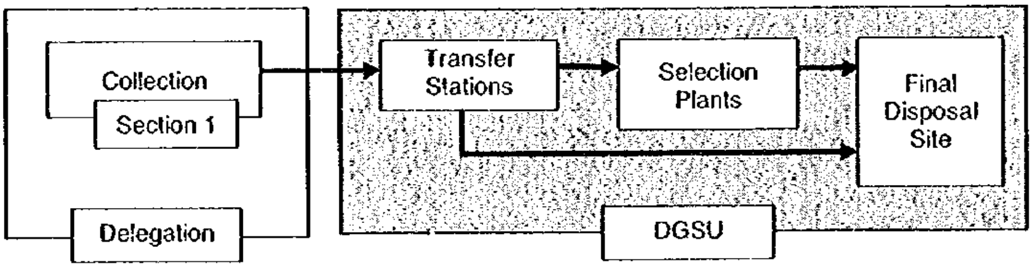

Figure C-5: Present Collection and Haulage System

However, in July 1998, the GDF and Section 1 signed an agreement that the Section 1 would withdraw its collection service from markets, primary schools, public residence units and parks from January 1999. It was decided in October 1998 that the delegations are to be in charge of employing private sectors through contracts for the wastes collection for those public institutions (or hereafter "Sub-System").

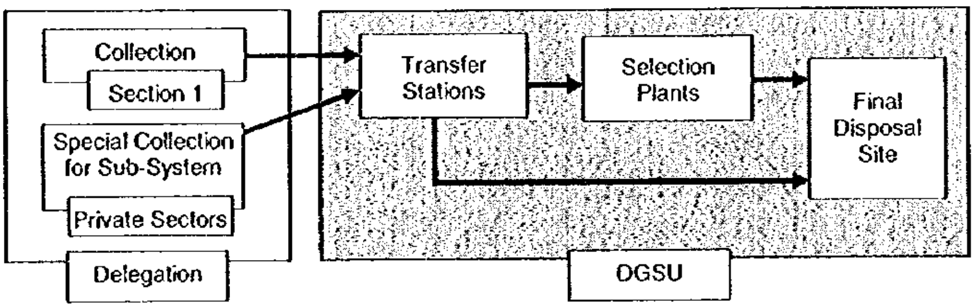

Figure C-6: New Collection and Haulage System

Wastes brought to the transfer stations are, after visual inspection, destined to one or the other below:

- S/Ps.
- final disposal sites.

Large-size trailers (70m^3) are employed for the transport from the transfer station to one of the two destinations.

C.3.2.1 Collection System

a. Collection Method

Regarding the collection methods, it can be said that the corner collection (with bell) is still popular, although there also exist door-to-door collection, curb collection and fixed stop collection, as described below.

In fact, the currently common collection methods emerge from deformation or degradation of the traditional collection methods, since they which are carried out by the sweeping personnel (sweepers) that completes certain functions of "additional collector" to the traditional collection service, which have become very popular in the last years. In addition, they allow and support the unofficial negotiation between the user and the operators to reconcile the amount of tips.

Sweepers begin their working day at 5 AM, yet their official schedule is from 7 AM to 3 PM. They sweep the street from 5 AM to 7 AM, and from that hour they pick the garbage of houses, segregate the most worthy waste in the market and then sell them.

There exist sweepers on the payroll(stably hired) and temporary sweepers(hired by periods) in this activity, who are paid by the GDF and adding up to almost 8,500 workers.

Besides, it is estimated that 3,000 or more voluntary sweepers carry out this activity; they rent the garbage carts and drums in order to work.

The collection service coverage rate is estimated to be almost 100%, whereas collection services (on-routes) are not provided to illegal squatters areas, since the provision of collection services for them will induce more illegal settlements. However, waste collection are realized in these area through a "station collection" system.

b. Collection Vehicle

By 1998, the waste collection vehicles were more than 2,000 units, as shown in Table C-4 where it is observed that the biggest percentage is accounted for by rectangular box collection vehicles. The rectangular box and tubular load types, both of which are equipped with compacting mechanisms of back loads, constitute more than 50%.

Table C-4: Number of Collection Vehicles

Delegation \ Type	Front loader	Back loads	Rectangular	Tube type	Dump truck	Mini collector	Total
Loading capacity	18m³,6.5 t	12m³5.0 t	12m³,4.5t* 16m³, 4.0t	12m³, 4.5t 16m³, 4.0t	8 m³, 2.5t 16m³, 4.0t	8m³,3.0 t	
Alvaro Obregon	4	34	31	17	52		138
Azcapotzalco	7	63	32	34	4		140
Benito Juarez	4	22	66	38	4		134
Coyoacan	5	52	34	32	5		128
Cuajimalpa		10	8	9	4	6	37
Cuauhtemoc	12	94	44	75	26		251
Gustavo A.Madero	7	56	96	76	46		281
Iztacalco	1	37	14	15	25		92
Iztapalapa	2	50	85	42	32		211
M.Contreras		12	6	3	11	29	61
Miguel Hidalgo	3	46	43	37	44		173
Milpa Alta		1			22	3	26
Tlahuac		19	8	4	16		47
Tlalpan		39	21	9	14		83
V.Carranza	8	17	73	19	38	5	160
Xochimilco	6	12	15	6	10		49
Total	59	564	576	416	353	43	2,011

Source: PARQUE VEHICULAR DE RECOLECCION ASIGNADO A LAS DELEGACIONES POLITICA, Enero, 1998, DGSU

Notes : 12m³,4.5t* is without compacting mechanism ,16m³,4.0t with compacting mechanism

It is also important to mention that, as shown in Table C-5, 1,078 out of the 2,011 units have been used for a period of obsolescence of more than 15 years, which are supposed to have been substituted already, not only due to the high maintenance cost that are recorded, but because they technologically imply a risk of inducing inefficiency and high administrative costs.

Table C-5: Purchase Years of Existing Collection Vehicles

	1965	1966	1967	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	Total
Alvaro Obregon			2	3	5	4		8		38	1		16					13	1			3	13	4	4	4	6	5	7	1	138
Azcapotzalco				10	3	2		8		11	3	11	28	1				7		5		6	9	2	14		14		6		140
Benito Juarez	1			6	7	6		18	1	23	1	9	20				13					3		18	5		9		3		143
Coyoacan			1	4	8	1		5		32	1		19				12		2	1		9	9	3	9		4	3	3		126
Cuajimalpa					1			1		5			5	2				4	1				2	1	1	4	15		3		45
Cuauhtemoc	3	1	1	19	18	5	1	26	1	26	2		31	3	22		34					8	12	18	2		19		3		255
Gustavo A.Madero		2	3	10	29	6	1	11	1	77	12		33		1	1	2	7	22	7		9		11	3	11	7	1	13		280
Iztacalco				4		1		5		4	3		16		5			2				4	15	10		2	11		3		85
Iztapalapa				13	4	7		12		23	1		19	7			9					5	30	65	2		7	13		8	225
M.Contreras				1		1		6		2	2		5					2				3	8	2	1		6		3		42
Miguel Hidalgo		1	1	8	20	4	1	10		37		1	17		5	1	19		8			7	4	20			1	3			168
Milpa Alta													1		3			1	1			1	6	3		6	7		3		32
Tlahuac						1	1	3	3				5			1	3	1	5			2	4	3	3	2	14		3		54
Tlalpan				1	3	2		6		9	1		17		4						2		13	6		2	2		4		72
V.Carranza				4	8	1		5		18	5	2	29	5					1			6	39	31			4		3		161
Xochimilco			1	2	1	1		2		7	1		13			1		2	2				7	2					3		45
Total	4	4	9	85	107	42	4	126	6	312	33	23	274	18	40	4	92	39	43	13	2	66	171	199	44	31	126	25	60	9	2,011
															1,087															924	2,011

Source: PARQUE VEHICULAR DE RECOLECCION ASIGNADO A LAS DELEGACIONES POLITICA, Enero, 1998, DGSU

c. **Number of Daily Trip**

Table C-6 shows the number of workable collection vehicles allocated to each delegation. Meanwhile, Table C-7 shows nominal loading capacity of each vehicle type and collection capacity of workable vehicles in total per one trip.

Table C-6: Number of Workable Vehicles by Delegation

	Front loader	Back load	Rectangular	Tube type	Dump truck	Mini collector	Total
Capacity (ton/trip)	6	5	4.5	4.5	2.5	2	
Alvaro Obregon	4	34	12	6	31		87
Azcapotzalco	7	63	15	24	3		112
Benito Juarez	4	22	46	32	3		107
Coyoacan	5	52	16	17	3		93
Cuajimalpa		10	5	3	2	6	26
Cuauhtemoc	10	90	20	23	11		154
Gustavo A.Madero	7	55	28	35	28		153
Iztacalco	1	36	11	11	19		78
Iztapalapa	2	50	65	23	19		159
M.Contreras		12	3	2	7	29	53
Miguel Hidalgo	3	46	33	23	20		125
Milpa Alta		1			21	3	25
Tlahuac		19	4	4	12		39
Tlalpan		38	11	6	10		65
V.Carranza	8	17	52	11	31	5	124
Xochimilco	6	12	5	2	9		34
Total	57	557	326	222	229	43	1,434

Source: PARQUE VEHICULAR DE RECOLECCION ASIGNADO A LAS DELEGACIONES POLITICA, Enero, 1998, DGSU

Table C-7: Collection Capacity (ton per trip) of Workable Vehicle Fleet

	Front loader	Back load	Rectangular	Tube type	Dump truck	Mini collector	Total (ton/day)
Loading capacity (ton/trip)	6	5	4.5	4.5	2.5	2	
Alvaro Obregon	24	170	54	27	78	0	353
Azcapotzalco	42	315	68	108	8	0	540
Benito Juarez	24	110	207	144	8	0	493
Coyoacan	30	260	72	77	8	0	446
Cuajimalpa	0	50	23	14	5	12	103
Cuauhtemoc	60	450	90	104	28	0	731
Gustavo A.Madero	42	275	126	158	70	0	671
Iztacalco	6	180	50	50	48	0	333
Iztapalapa	12	250	293	104	48	0	706
M.Contreras	0	60	14	9	18	58	158
Miguel Hidalgo	18	230	149	104	50	0	550
Milpa Alta	0	5	0	0	53	6	64
Tlahuac	0	95	18	18	30	0	161
Tlalpan	0	190	50	27	25	0	292
V.Carranza	48	85	234	50	78	10	504
Xochimilco	36	60	23	9	23	0	150
Total	342	2,785	1,467	999	573	86	6,252

Source: PARQUE VEHICULAR DE RECOLECCION ASIGNADO A LAS DELEGACIONES POLITICA, Enero, 1998, DGSU

Based on the data above, collection vehicles' average trips made per day in respective delegation are summarized in Table C-8. Average trips become about 1.7 trips/day for the GDF total, ranging from 0.9 trip/day in Azcapotzalco to 2.8 trips/day in Iztapalapa. 10 delegations make less trips than the GDF average.

Table C-8: Daily Average Trips

	Waste generation amount in 1997(ton/day)*	Collection vehicle capacity(ton/day)	Number of trip
Alvaro Obregon	570	353	1.6
Azcapotzalco	498	540	0.9
Benito Juarez	613	493	1.2
Coyoacan	782	446	1.8
Cuajimalpa	135	103	1.3
Cuauhtemoc	1,221	731	1.7
Gustavo A.Madero	1,551	671	2.3
Iztacalco	444	333	1.3
Iztapalapa	1,994	706	2.8
M.Contreras	218	158	1.4
Miguel Hidalgo	647	550	1.2
Milpa Alta	73	64	1.1
Tlahuac	261	161	1.6
Tlalpan	681	292	2.3
V.Carranza	840	504	1.7
Xochimilco	347	150	2.3
Total	10,875	6,252	(mean value)1.7

Notes: *excluding central market waste

C.3.2.2 Haulage System

a. Transfer Station

With respect to this situation and the necessity of strengthening and providing the efficient SWM service, it is indispensable to have suitable infrastructure that facilitates the improvement and the uniformity of such services in the whole Federal District in the short term. Transfer stations are a fundamental part of this infrastructure, and 13 transfer stations are presently located in Mexico City.

Table C-9: Outline of the Transfer Stations

unit: m^2

Name	Premise area*	Floor space*	Green area*	Operation body
Alvaro Obregon	8,000	7,900	3,284	DGSU
Azcapotzalco	8,900	6,607	355	Delegation / DGSU
Benito Juarez	8,804	7,380	1,877	Delegation
Coyoacan	12,187	6,798	2,067	Delegation / DGSU
Cuauhtemoc	6,974	4,420	485	Delegation / DGSU
Gustavo A. Madero	3,000	2,800	5,717	DGSU
Iztapalapa I	9,949	6,746	1,638	DGSU
Iztapalapa II	8,871	4,563	467	DGSU
Miguel Hidalgo	6,426	4,400	570	Delegation / DGSU
Milpa Alta	24,335	5,020	11,395	DGSU
Tlalpan	6,516	6,208	332	DGSU
Venustiano Carranza	8,867	7,507	1,106	Delegation / DGSU
Xochimilco	1,500	1,100	500	Delegation / DGSU

Source : *SOLID WASTE MANAGEMENT IN MEXICO CITY, DDF

They were designed and built considering environmental criterion for the control of noise, dusts and suspended particles, among others. For those reasons, the new ones and the already existing ones are in closed areas, with acoustic walls and hydro-pneumatic systems for the washing and watering, as well as environmental quality control equipment inside.

A transfer station located in delegation Magdalena Contraras was closed in February 1997, because:

- the transfer station was smaller than the other stations, and it was structured to transfer wastes to container type trailers.
- collection vehicles employed in the delegation became bigger year by year to the same capacity as the container trailers.
- location of the transfer station in hilly area lowered the transfer efficiency.

Delegation Iztapalapa has two transfer stations; one (Iztapalapa II) is handling wastes from the Central market (Central de Abasto) exclusively.

Those 13 transfer stations are managed by the DGSU or by a delegation, or co-managed by both. Practical operation of the stations are all contracted out to private sectors.

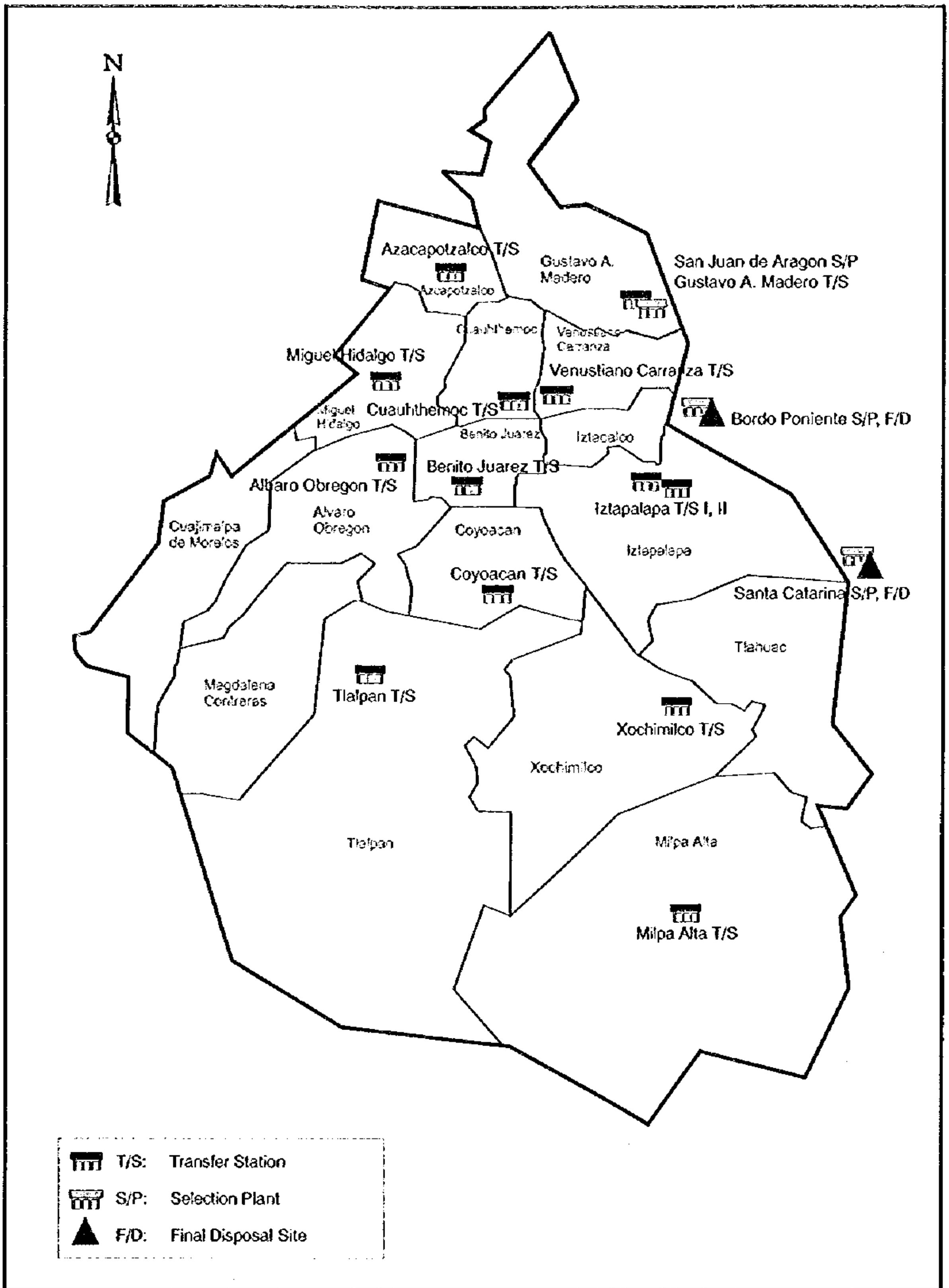

Figure C-7:
Location Map of Transfer Stations

State Limit
Delegation Limit
Scale (km)
0 3 6 9 12

KOKUSAI KOGYO Co., Ltd.

Table C-10 shows transfer amount at the respective transfer stations. However, non of them has a weighbridge, therefore the incoming and outgoing amounts are only forecast from the number of vehicles recorded and its nominal capacity (or from empirical surveys). Precisely measured transfer amounts (either incoming or outgoing amounts) do not exist to date.

Table C-10: Transfer Amount

Name	Transfer Record**(ton/day)
Alvaro Obregon	830
Azcapotzalco	728
Benito Juarez	no recorded
Coyoacan	1083
Cuauhtemoc	809
Gustavo A. Madero	416
Iztapalapa I	1000
Iztapalapa II	980
Miguel Hidalgo	584
Milpa Alta	49
Tlalpan	322
Venustiano Carranza	672
Xochimilco	408
Total	7,881

Sources : *SOLID WASTE MANAGEMENT IN MEXICO CITY, DDF
**S/P operation record (Jan. to July/1998), DGSU

b. Transportation

Municipal solid wastes collected by the delegations are mostly gathered in those 13 transfer stations and then transported by large-size trailers (70m^3) to the destinations (i.e., final disposal sites or S/Ps). An exception is direct transport by collection vehicles in view of the vicinity to the destination. Residues of the three S/Ps are loaded again to the trailers to be transported to the final disposal sites. These transport works are all contracted out to private sectors by the DGSU. The contract works are paid by a combined unit rate (peso/km/ton) on transport distance shown in Table C-11 and loaded weight. Apart from those 70m^3 trailers, there are transport fleets (capacity 17 m^3) exclusively employed for construction debris transport.

Table C-11: Origin to Destination Distance

Unit: km

Origin \ Destination		Landfill Site: Bordo Poniente	Landfill Site: Santa Catarina	S/P: Bordo Poniente	S/P: San Juan de Aragon	S/P: Santa Catarina
Transfer station	Alvaro Obregon	29.4	30.3	27.5	-	29.6
	Azcapotzalco	22.8	-	21.1	14.1	30.3
	Coyoacan	31.9	28.7	-	-	27.7
	Cuauhtemoc	19.5	23.4	17.8	-	22.5
	Gustavo A. Madero	13	-	-	-	-
	Iztapalapa I	16.3	17.8	14.7	-	16.7
	Iztapalapa II	16.1	17.6	14.5	-	16.5
	Miguel Hidalgo	32.5	-	-	23.6	-
	Milpa Alta	42.4	-	-	-	-
	Tlalpan	43.3	40.0	41.6	-	40
	Venustiano Carranza	16.6	0.0	14.9	-	0.0
	Xochimilco	35.6	17.3	34.0	-	16.6
S/P	Bordo Poniente	2.0	-	-	-	-
	San Juan de Aragon	13.0	-	-	-	-
	Santa Catarina	26.9	-	-	-	-

Transport trailers employed in the works have a variety in the ownership as follows:

- Tractor unit and trailer box unit are both owned by a private sector.
- Tractor unit is owned by a private sector, and trailer box by the DGSU.
- Tractor unit and trailer box unit are both owned by the DGSU.

Those trailer box units are 236 in total, all of which are moving-floor type. Each trailer box unit owned by the DGSU has its assigned transfer stations.

Meanwhile, a "global positioning system (GPS)" apparatus is installed on each tractor unit to monitor and control the total transportation system. This monitoring and controlling system is managed by an office of the DGSU in the Alvaro Obregon transfer station.

In order to optimize transportation, this office arranges any transport (tractor and trailer box) units to any transfer station when necessary, although each trailer box owned by the DGSU has the assigned transfer station.

Table C-12: Assignment of Trailers

		Private	DGSU T.C.A	DGSU T.C.P	Total
Private company		112	-	-	112
Transfer station	Alvaro Obregon	-	6	14	20
	Azcapotzalco	-	1	8	9
	Coyoacan	-	9	7	16
	Cuauhtemoc	-	-	12	12
	Gustavo A. Madero	-	-	5	5
	Iztapalapa I	-	-	11	11
	Iztapalapa II	-	5	6	11
	Miguel Hidalgo	-	5	9	14
	Milpa Alta	-	-	-	-
	Tlalpan	-	2	6	8
	Venustiano Carranza	-	1	6	7
	Xochimilco	-	1	6	7
S/P	Bordo Poniente	-	-	-	-
	San Juan de Aragon	-	1	3	4
	Santa Catarina	-	-	-	-
Total		112	31	93	236

Note:

T.C.A: Box-Chain Type

T.C.P: Sliding Platform Type

Table C-13 shows the record of transportation made from January to May in 1998. It reveals that wastes from Cuauhtemoc and Iztapalapa-I transfer stations are mostly transported to Santa Catarina S/P instead of Bordo Poniente S/P which is the nearest S/P from these two transfer stations.

Table C-13: Number of Trips (70m^3 Trailer, Jan./98 to May/98)

Origin	Destination	S/P BP	S/P SJA	S/P SC	S/P Total	Disposal site BP I	Disposal site BP IV	Disposal site SC	Disposal site Total	Total
Transfer station	Alvaro Obregon	4,309			4,309		2,351	1	2,352	6,661
	Azcapotzalco	1,002	586	763	2,351		2,808		2,808	5,159
	Benito Juarez		3	680	683				0	683
	Coyoacan	3		4,225	4,228		855	3,351	4,206	8,434
	Cuauhtemoc			2,918	2,918		197	3,081	3,278	6,196
	Gustavo A. Madero	44			44		3,598		3,598	3,642
	Iztapalapa I	173		718	891		6,444	653	7,097	7,988
	Iztapalapa II	2,275			2,275		4,312		4,312	6,587
	Miguel Hidalgo	175	2,352		2,527		3,074		3,074	5,601
	Milpa Alta	4			4		645	2	647	651
	Tlalpan	1,064		984	2,048		190	429	619	2,667
	Venustiano Carranza	1,459			1,459		3,368	9	3,377	4,836
	Xochimilco	4		742	746		285	2,074	2,359	3,105
S/P	Bordo Poniente				0		10,185		10,185	10,185
	San Juan de Aragon				0		10,261		10,261	10,261
	Santa Catarina	2			2		9,742		9,742	9,744
Total		10,514	2,941	11,030	24,485	0	58,315	9,600	67,915	92,400

Table C-13 shows total 92,400 trips by 70 m^3 trailers in this period. 103 working days in total during the period and the number of trailers (236) mean the average daily trips of about 3.8 trip/day. Dividing total transportation distance of 1,877,822 km by the working days and the numbers of trailers gives as the daily average transportation distance of about 77 km/day.

C.3.3 Processing, Treatment and Recycling System

As for processing, treatment and recycling facilities in Mexico City, a municipal SW incinerator and a composting facility which were used to be operated and maintained in the DGSU's premises of San Juan de Aragon are no more operated today. The facilities presently operated are the only three manual-sorting Selection Plants (S/Ps) in Bordo Poniente, San Juan de Aragon (SJA) and Santa Catarina.

a. Incinerator

Competitive tender for the construction of the municipal SW incinerator was held in 1979. On-site fabrication of the incinerator was commenced in 1984, once suspended in 1986 and completed in 1989.

Five stoker-type incineration units (unit nominal capacity: 50t/24h) were purchased. Two of them were installed in SJA, the third was dismantled soon after its installation in response to environmentalists objection.

In regard to the background mentioned above, the incinerator facility in SJA was being operated from February 1990 to June 1992 as a pilot facility with the objectives of data compilation on incineration technology. However, both two units have never been operated together, even when an expert dispatched from Switzerland expedited to control the operation.

The principal reason of the failure could be concluded as follows:

An incineration technology apt to drier wastes (common in Europe) was simply imported to Mexico. The size of "drying zone" of the incinerator turned out insufficient for more humid wastes in Mexico especially in rainy season. Incineration without additional fuel (gas) sometimes could be achieved in dry season, while wastes in rainy season almost always required combustion fuel. Consequently planned incineration treatment was not realized with these units.

Table C-14: Waste Composition of Incineration Test Runs

Item	RUN	Run-1, Municipal SW, 17/Jun/92	Run-2, Municipal SW, 17/Sept/92	Run-3, Municipal SW, 23/Sept/92	Run-5, Municipal SW, 12/Nov/92	Run-7, Municipal SW, 19/Nov/92	Run-12, Municipal SW, 07/Dec/92	Mean value
Combustible	(%)	26.63	13.75	32.40	42.06	40.60	34.30	31.62
Moisture	(%)	41.25	77.34	52.83	42.68	46.36	42.09	42.59
Ash	(%)	32.51	8.40	12.76	10.38	9.51	19.32	15.48
Bulk specific gravity	(g/cm^3)	0.47	0.22	0.26	0.14	0.22	0.24	0.26
Calorific value(1)	(cal/g)	3,849	2,706	3,435	3,400	3,398	3,258	3,341
Calorific value(2)	(cal/g)	3,686	2,618	3,223	3,110	3,126	3,019	3,130
Calorific value(3)	(cal/g)	1,253	1,594	1,199	1,553	1,410	1,521	1,422
Sulfur	(%)	0.37	0.15	0.16	0.05	0.14	0.26	0.19
Nitrogen	(%)	0.93	0.45	1.10	0.67	0.54	0.82	0.75
Carbon	(%)	15.45	7.99	18.70	24.30	23.50	19.83	18.30
Hydrogen	(%)	1.78	0.92	2.16	2.80	2.71	2.29	2.11
Chloride	(%)	0.15	0.19	-	0.56	0.28	0.30	0.30

Notes: Data collected from June to December 1992.
Calorific value(1) : logical calorific value of combustible matter
Calorific value(2) : measured calorific value of combustible matter
Calorific value(3) : calorific value of waste(combustible, ash and moisture)

Table C-14 presents waste composition of incineration runs. The first three columns are data during the rainy season. According to this table, the moisture content on average is not particularly high, but that in the rainy season varies. Calorific value of waste (calorific value (3)) also fluctuates and occasionally drops to about 1,200 cal/g, which corresponds to the range of minimum value for self-burning (wastes can be burn by itself without fuel).

The two incineration units in SJA are not dismantled to date, and their equipment is comparatively well preserved in view of time passage. However, if municipal waste incineration with this facility will have to be challenged, decent maintenance and considerable modification of mechanical and electric components will be necessary. In addition, in order to clear the new emission norms (drafts for which are presented in Table C-15 and Table C-16), all the incineration structures (from wastes intake to stack) should be replaced. Only civil and building structures can be utilized.

Table C-15: Comparison of Incineration Test and Draft Emission Limit

		Run-1, MSW, 17/Jun/92	Run-2, MSW, 17/Sept./92	Run-3, MSW, 23/Sept./92	Run-5, MSW, 12/Nov./92	Run-7, MSW, 19/Nov./92	Run-12, MSW, 07/Dec./92	Mean value	Emission limit
Particles	mg/m^3	400.46	123.56	95.13	190.09	13.49	100.14	153.81	30
SO_2	mg/m^3	288.53	n.d.	n.d.	368.84	36.40	135.95	207.43	80
CO	mg/m^3	85.82	191.68	887.53	n.d.	n.d.	n.d.	389.34	63
NO_x	mg/m^3	148.48	3.76	n.d.	n.d.	n.d.	n.d.	76.12	300
HF	mg/m^3	n.d.	n.d.	4.40	n.d.	n.d.	n.d.	4.40	5
HCl	mg/m^3	4.98	238.15	108.82	n.d.	n.d.	n.d.	117.32	15
PCDF	mg/m^3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d	0.00000015
PCDD	mg/m^3	n.d.	n.d.	n.d.	0.000035	0.000003	n.d.	0.0000190	0.00000015
Total HC	mg/m^3	58.92	420.80	5.67	5.74	12.44	12.21	85.96	-
Pb	mg/m^3	0.07284	0.40730	0.29135	0.43123	0.09860	1.26040	0.42695	0.7
Cu	mg/m^3	0.00525	0.01467	0.01102	0.03799	0.00680	0.12030	0.03267	0.7
Cr	mg/m^3	0.00063	1.26400	2.32854	0.01372	0.02930	0.01890	0.60918	0.7
Mg	mg/m^3	0.0007051	0.0388000	0.3198290	0.0093210	n.d.	0.0083460	0.07540	0.7
Ni	mg/m^3	0.0003234	2.5210000	1.9619400	0.0077383	0.0147900	0.0046900	0.75175	0.7
As	mg/m^3	0.0004400	0.0001000	0.0002116	0.0007035	0.0002250	0.0010400	0.00045	0.7
Cd	mg/m^3	0.0003205	0.0315980	0.0046200	0.0256770	0.0115700	0.0162000	0.01500	0.07
Hg	mg/m^3	n.d.	0.0022500	0.0014560	0.0043967	n.d.	n.d.	0.00270	0.07
Sn	mg/m^3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d	0.7
Ag	mg/m^3	0.0000799	0.0013000	0.0009734	0.0028139	n.d.	0.0039900	0.00183	-
Fe	mg/m^3	0.0423980	6.0800	10.9807	0.3381977	0.17727	0.3460	2.99409	-

n.d.: no detect

Table C-16: Draft Emission Limit for New Solid Waste Incinerator

Item	Unit	Concentration	Remarks
Particles	mg/m^3	30	hourly average value
CO	mg/m^3	63	daily average value
SO_2	mg/m^3	80	hourly average value
NO_x	mg/m^3	300	hourly average value
HCl	mg/m^3	15	daily average value
HF	mg/m^3	5	hourly average value
PCDD & PCDF	ng/m^3	0.15	6 hours average value
Cd	mg/m^3	0.07	hourly average value
Hg	mg/m^3	0.07	hourly average value
As, Co, Se, Ni, Mg, Sn	mg/m^3	0.7	hourly average value
Pb, total -Cr, Cu, Zn	mg/m^3	0.7	hourly average value

Possibility of converting this incinerator into a medical waste incinerator was once examined by the DGSU in beginning of the 1980's. The conversion was, however, judged to be unfeasible in view of limited modifiable functions and performance expected of the units.

b. Composting

Only one composting facility currently operated by the DGSU is a windrow compost plant with 18,000m^3/year processing capacity. It currently produces limited output of 2,300m^3/year compost exclusively from gardening wastes (e.g., pruned tree branches and grasses) brought from GDF's public park maintenance.

This facility carries out composting quality control based on the values recommended by the Compost Counseling in Texas, since norms or standards on compost are not established in Mexico today. Compost sample from this facility are monthly sent to the Compost Counseling in Texas for analyses.

Carbon/Nitrogen (C/N) ratio of the compost products ranges 20 to 30. Animal manure are proportioned to the garden wastes to adjust nitrogen contents (Table C-17). Experiments of animal carcass decomposition in garden wastes composting have achieved appreciable results.

Table C-17: Quality of Compost

Item	Unit	Concentration
Nitrogen	(%)	1.233
Phosphorus	(%)	0.38
Potassium	(%)	0.83
Calcium	(%)	1.96
Magnesium	(%)	1.56
Iron	(%)	0.127
Lead	(ppm)	126.58
Copper	(ppm)	18.7
Zinc	(ppm)	63.8

A municipal SW composting facility (nominal capacity 750 ton/day windrow system) was once operated in the SJA site adjacent to the incinerator, which was dismantled in 1993. The manual sorting lines on the facility intake were not dismantled but modified as a part of the material recovery lines of the currently operated S/P.

This composting facility, constructed by a Swiss company (Buheler Miag), employed the system of:

- mixed municipal wastes feeding.
- magnetic sorting (ferrous material removal).
- recyclable material manual sorting.
- composting the residues.

However, the compost products contained substantial amount of glass and plastics, and as a result, did not achieve quality required for marketable fertilizer. Consequently it only had an use of soil conditioner in the public parks and green areas.

An actual facility output was considerably lower than the nominal capacity due to: inappropriate operation and maintenance; lack of budget; imported spare parts deficiency; and ineffective administration. The production output was so lowered to 250 ton/day before the plant was ordered to suspend the operation.

On the other hand, having an objective of improving socio-economical situation of waste-pickers, the facility could not solely be administrated with focusing on production efficiency.

As described above, major causes of the failure were that:

- The project was oriented for mixed municipal wastes and produced low quality compost as a consequence.
- The facility with a social welfare development objective (i.e., waste-pickers) was out of management capability of the time.

c. **Selection Plants (S/Ps)**

Three S/Ps are currently operated for recovering recyclable materials from mixed municipal wastes. Outline of the S/Ps are shown in Table C-18. A weighbridge is installed at the Bordo Poniente S/P and the SJA S/P respectively. The Santa Catarina S/P is not equipped with a weighbridge, its waste flow amounts (at entrance and exit) are derived from recorded transport trips multiplied by estimated wastes load per transport.

Table C-18: Outline of S/P

	Bordo Poniente	San Juan de Aragon	Santa Catarina
Year of establishment	July/1994	July/1994	March/1996
Site area	9,500 m^2	8,000 m^2	5,600 m^2
Durability	15 years	15 years	15 years
Weighing system	Weighbridge	Weighbridge	Number of vehicles(not installed weighbridge)
Capacity	2,000 ton /day	2,000 ton/day	1,500 ton/day
Number of sorting line	4 lines	4 lines	3 lines
Capacity per line	500 ton/day	500 ton/day	500 ton/day
Working hour	24hours/3shifts, Monday to Friday	24hours/3shifts, Monday to Saturday	24hours/3shifts, Monday to Friday
Number of workers	400 persons (ex-waste picker from Prados de la Montana)	500 persons (ex-waste picker from Prados de la Montana)	400 persons
Labor organization	"Frente Unico de Pepenadores A.C."	"Asociacion de Selectores de Desechos Solidos de la Metropoli, A.C.	"Union de Pepenadores del DF Rafael Gutierrez Moreno, A.C."
Number of picking worker	42 persons/line	42 persons/line	62 persons/line
Recovered materials	Paper, Cardboard, Plastics, Glass, Steel sheet, aluminum, Copper, Iron, Tortilla, Junk, Mattress, Tire, Cloth	Paper, Cardboard, Plastics, Glass, Steel sheet, aluminum, Tortilla, Junk, Mattress, Tire, Cloth	Paper, Cardboard, Plastics, Glass, Steel sheet, aluminum, Copper, Iron, Tortilla, Junk, Mattress, Tire, Cloth

Initial objectives of installing these S/Ps were not only the promotion of recycling activities but also and mainly, the social welfare development (i.e., to improve working environment of waste-pickers by turning waste-pickers at open air dumping sites into recycling plant workers). The S/Ps today continue to hold the characteristics of social welfare installations.

Table C-19 shows recovery ratios of respective plants, which are as low as 4% to 6%. Meanwhile, waste composition surveys periodically carried out by the DGSU revealed that recyclable wastes account for about 37% on average at generation sources. Reasons of low recovery rate in the S/Ps could be as follows:

- About 14% recoverable materials are beforehand collected by sweepers and crews of collection vehicles.
- Only materials with higher market values are recovered in the S/Ps (materials with less or no market values are not recovered, although they are recyclable).
- Cleaner and purer materials (less contaminated and less deformed) are targeted in recovery, therefore recovery ratio goes lower (i.e., quantitative recovery is not targeted).
- As input wastes are mixed municipal wastes, wastes fed in conveyors can easily form an inter-mingled thick layer on the sorting lines, which consequently lowers the sorting efficiency.
- Velocity of sorting line conveyors is so fast as about 20 meter/min., thus impeding appropriate recovery of materials.

In addition, working spaces of sorting areas in all three S/Ps are insufficient. Especially in the Bordo Poniente S/P, which is firstly constructed among the three S/Ps, spaces are most limited than others. Furthermore, because bags are torn out manually on a feeding conveyor in Bordo Poniente, danger to workers safety is highly anticipated.

Table C-19: Annual Recovery Amount and Ratios in 1997

Unit: ton/year

	Bordo Poniente	San Juan de Aragon	Santa Catarina	Total
Annual input amount	609,973.77	700,470.05	455,438.30	1,765,882.12
Annual recovery amount	32,040.05	30,646.21	30,169.24	92,855.50
Recovery ratio(%)	5.3	4.4	6.6	5.3

Table C-20: Breakdown of Recovered Materials in 1997

Unit: ton/year

	Bordo Poniente	San Juan de Aragon	Santa Catarina	Total
Cardboard	3,305.98	5,303.34	933.55	9,542.87
Paper	3,249.87	4,856.80	3,742.31	11,848.98
Film			424.72	424.72
Hard Plastic			9,635.58	9,635.58
Glass	12,276.21	6,939.61	9,303.01	28,518.83
Steel Sheet	3,202.08	364.31	4,090.17	7,656.56
Aluminum			795.66	795.66
Aluminum Can		62.54		62.54
Iron	1,746.41		86.19	1,832.60
Steel Can		4816.15		4,816.15
Tortilla		268.13	655.91	924.04
Copper			30.54	30.54
Chacharas		300.87	130.86	431.73
Mattress			47.30	47.30
Tire	546.66		233.27	779.93
Battery			0.03	0.03
Cloth	470.36		16.02	486.38
Acrylic Resin(Fiber)			0.67	0.67
Paper pack			9.64	9.64
Wood (pine)	66.12		33.81	99.93
Plastic		6,990.92		6,990.92
Rag		41.90		41.90
Polyethylene		435.66		435.66
Christmas Tree		127.07		127.07
Mattress Frame		138.91		138.91
Pet Bottle	5,432.06			5,432.06
Plastic	789.5			789.50
Vinyl	704.56			704.56
Bone	250.24			250.24
Total	32,040.05	30,646.21	30,169.24	92,855.50

Operation and maintenance (O&M) costs of respective S/Ps in 1997 compiled by the DGSU is shown in Table C-21. It gives the unit cost of O&M (per S/P recycled waste tonnage) of 1,126 Pesos/ton on average.

Table C-21: Operation and Maintenance Cost in 1997

		Bordo Poniente	San Juan de Aragon	Santa Catarina	Average
Unit cost for recycling	pesos/ ton recovered	1,061	1,083	1,237	1,126
	pesos/ ton input	50.40	53.69	50.49	51.45

Sources : Costos de los Servicios Urbanos 1997, DGSU

Table C-22 summarizes O&M costs in 1996 estimated for the respective S/Ps.

Table C-22: Estimated Operation and Maintenance Cost in 1996

	Bordo Poniente	San Juan de Aragon	Santa Catarina	Total
Annual input amount	618,858	627,399	234,771	1,431,028
O&M cost (pesos)	22,020,077	25,232,160	6,145,062	53,407,299
Unit cost (pesos/ ton input)	35.60	40.22	26.17	(Ave.) 36.06

Sources : Dereccion Construccion y Mantenimiwnto Subdireccion de Mantenimento de Instalaciones y Equipo Plantas de Selection y Aprovechamento de Residous Solidos Costos de Operacion y Mantenimiento Ejercicio 1996 DGSU

C.3.4 Street Sweeping System

As for street sweeping in the DF, the DGSU is in charge of trunk roads sweeping, in which mechanical sweepers and manual sweeping are mainly employed. Each delegation is in charge of secondary roads, where manual sweeping is dominant.

Cleansing of public parks and green areas is mainly managed by the delegations and partly by the DGSU, where manual cleansing and sweeping are employed.

Street length in which the DGSU carries out sweeping is 1,237.4 km/day. An investigation by the DGSU reported that street waste generation ratio is 125.53 kg/km. It means that street waste generation is about 160 ton/day from trunk roads. On the other hand, street wastes swept in secondary streets where delegations are in charge are collected by the collection vehicles in respective delegations.

Table C-23: Street Sweeping Waste Generation Amount

Delegation	Daily sweeping length (km/day)	Street sweeping waste amount (kg/day)
Alvaro Obregon	88.95	11,166
Azcapotzalco	49.03	6,155
Benito Juarez	84.76	10,640
Coyoacan	75.30	9,452
Cuajimalpa	27.59	3,463
Cuauhtemoc	102.66	12,887
Gustavo A.Madero	245.85	30,862
Iztacalco	81.89	10,280
Iztapalapa	136.20	17,097
M.Contreras	27.30	3,427
Miguel Hidalgo	159.17	19,981
Milpa Alta	24.84	3,118
Tlahuac	51.72	6,492
Tlalpan	0.00	0
V.Carranza	69.30	8,699
Xochimilco	48.84	6,131
Total	1,273.40	159,850

Source: Estudio Preparatorio sobre el Manejo de los Residuos Sólidos para la Ciudad de México "Anexo J-1"

Public parks and green areas is totaled to about 2,128 ha. DGSU investigation reported its waste generation ratio being 0.00883 (kg/m^2/day). From this, it derives that waste generation from public parks and green area is about 211(ton/day).

Table C-24: Waste Generation Amount from Green Area

Delegation	Area (m^2)	Waste generation amount (kg/day)
Alvaro Obregon	792,000	7,865
Azcapotzalco	492,000	4,886
Benito Juarez	1,083,000	10,754
Coyoacan	868,000	8,619
Cuajimalpa	86,000	854
Cuauhtemoc	680,000	6,752
Gustavo A.Madero	4,155,000	41,259
Iztacalco	670,000	6,653
Iztapalapa	874,000	8,679
M.Contreras	115,000	1,142
Miguel Hidalgo	7,069,000	70,195
Milpa Alta	78,000	775
Tlahuac	148,000	1,470
Tlalpan	3,232,000	32,094
V.Carranza	766,000	7,606
Xochimilco	172,000	1,708
Total	21,280,000	211,310

Source: Estudio Preparatorio sobre el Manejo de los Residuos Sólidos para la Ciudad de México "Anexo J-1"