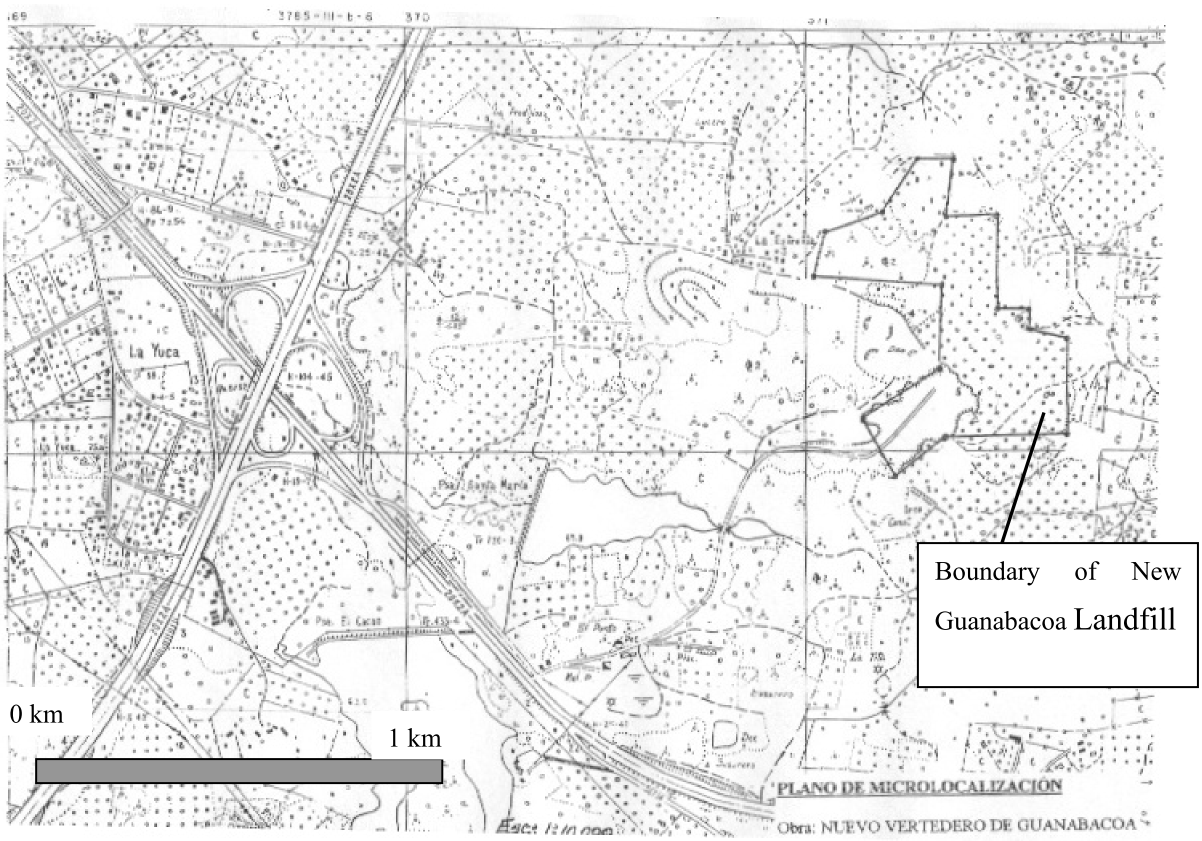
# C. Final Disposal:

## C3 Complement Information for Final Disposal Plan

# C3 COMPLEMENT INFORMATION FOR FINAL DISPOSAL PLAN

## 1. New Guanabacoa Landfill Design by C/P side




Note : Source by DPPF

**Figure 1.1 Location Map of Authorized area for New Guanabacoa Landfill**

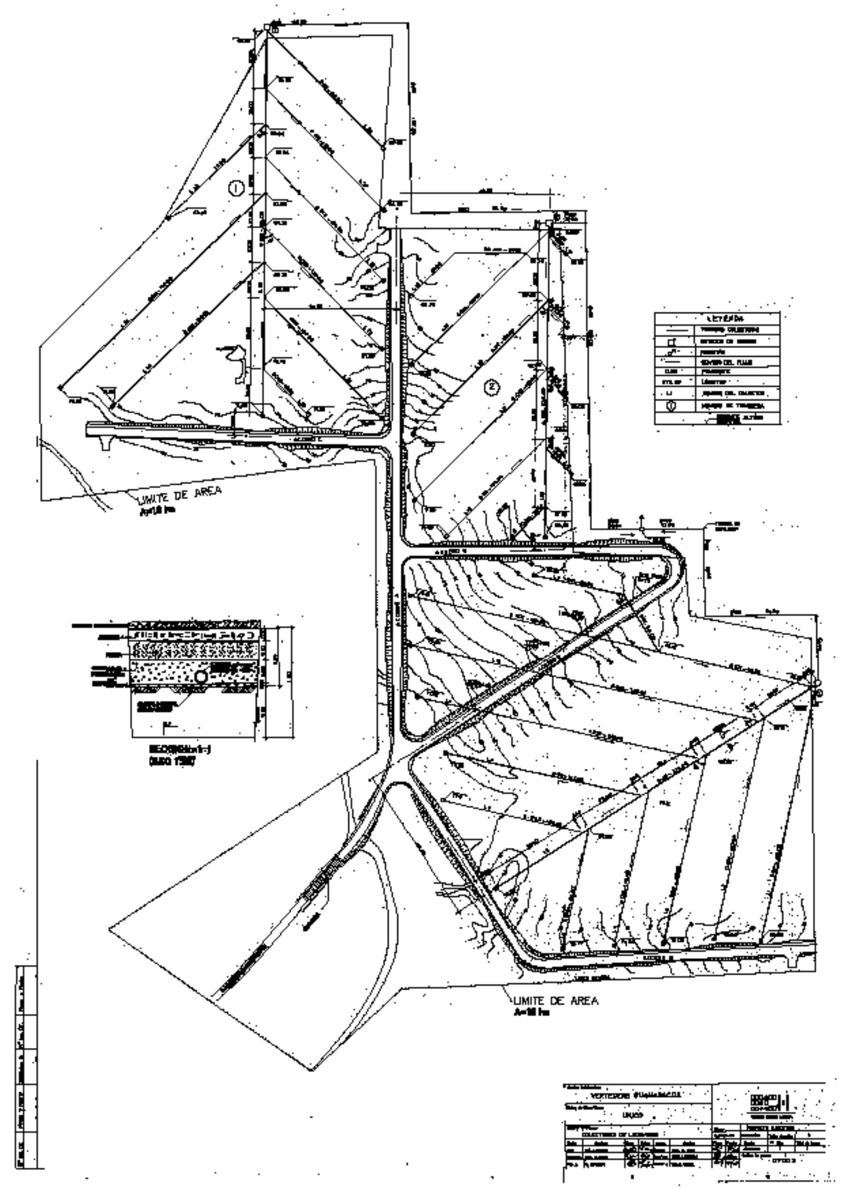



**Figure 1.2 General Plan of New Guanabacoa Landfill , designed by C/P side**

## 2. Estimated Volume of Covering Soil

**Table 2.1 Estimated Volume of Covering Soil at Calle 100 Landfill**

(Unit: 1000$m^3$)

| | Total | Clay | Top soil and sand | Soft rock and waste construction | Note |
|---|---|---|---|---|---|
| Rate of Volume | | 35% | 60% | 5% | |
| 1. Cutting Earth Volume in expansion Calle 100 Landfill | 2,050 | 720 | 1,230 | 100 | |
| 2. Using excavated soil | | | | | |
| 2.1 Use in site of expansion area | | | | | |
| Mounding | 195 | 80 | 195 | 10 | |
| Protection layer for Liner sheet | 0 | 0 | 71 | 0 | |
| Dairy Covering Soil | 692 | 0 | 692 | 0 | |
| Facility of landfill | | | | 50 | |
| Sub total | 887 | 80 | 958 | 60 | |
| 2.2 Use for Closure Landfill | | | | | |
| Special Period Landfill | 110 | 55 | 55 | 0 | * 10km on the average |
| GUANABACOA Landfill | 118 | 59 | 59 | 0 | * 17km |
| Existing area of Calle 100 Landfill | 400 | 200 | 200 | 0 | * Less than 1km |
| Expansion of Calle 100 Landfill | 120 | 52 | 52 | 0 | * Less than 1km |
| Sub total | 748 | 366 | 366 | 0 | |
| Total of 2.1 + 2.2 | 1,635 | 446 | 1,324 | 60 | |
| 1 – 2 Surplus Soil | 415 | 274 | -94 | 40 | |

Note: * Moving Distance from Calle 100 landfill

# 3. Breakdown of Quantities Estimation

## 3.1 New Site 1 Landfill

New Site 1 Landfill

A. Calculate of Earth Work

| | Waste volume with cover soil compaction | (A) Cover soil volume before compaction | | | (B) Compacted Volume (A)/0.9 | | (C) Portage Volume (B)x1.2 | |
|---|---|---|---|---|---|---|---|---|
| | (m3) | m3/day | m3/year | m3/year | m3 | Roundup (m3) | m3 | Roundup (m3) |
| Y2011 | 718,000 | 429 | 156,585 | 156,600 | 173,983 | 174,000 | 208,780 | 208,800 |
| Y2012 | 713,000 | 425 | 155,125 | 155,200 | 172,361 | 172,400 | 206,833 | 206,900 |
| Y2013 | 672,000 | 401 | 146,365 | 146,400 | 162,628 | 162,700 | 195,153 | 195,200 |
| Y2014 | 669,000 | 399 | 145,635 | 145,700 | 161,817 | 161,900 | 194,180 | 194,200 |
| Y2015 | 665,000 | 397 | 144,905 | 145,000 | 161,006 | 161,100 | 193,207 | 193,300 |
| Total | 3,437,000 | - | 748,615 | 748,900 | 831,794 | 832,100 | 998,153 | 998,200 |

Note : (B) and (C) are Volume of Natural ground condition

| | 1st Stage | 2nd Stage | Total | Situation |
|---|---|---|---|---|
| Require volume of waste and cover soil | 2,275,000 | 1,400,000 | 3,675,000 | Compaction |
| Necessary Volume | 2,388,750 | 1,470,000 | 3,858,750 | Compaction |
| Cover Soil Volume | 515,110 | 316,990 | 832,100 | Natural ground |

| | | | 1st Stage | 2nd Stage | Total |
|---|---|---|---|---|---|
| | | | m3 | m3 | |
| Earth Work | Excavated Volume | 1st Layer | 635,660 | 403,160 | 1,038,820 |
| | Mounding | 1st dike | 0 | 0 | 0 |
| | | 2nd dike | 76,100 | 68,600 | 144,700 |
| | | 3rd dike | 52,500 | 46,700 | 99,200 |
| | | 4th dike | 50,400 | 44,300 | 94,700 |
| | | 5th dike | 48,300 | 42,000 | 90,300 |
| | | sub-total | 227,300 | 201,600 | 428,900 |
| | Protective layer for Liner Seat | | 41,170 | 26,160 | 67,330 |
| | Road bed work | | 13,020 | 2,480 | 15,500 |
| | Total of filling and mounding work | | 281,490 | 230,240 | 511,730 |
| Cover Soil | use excavated soil on site | | 515,110 | 316,990 | 832,100 |
| | surplus soil | | 120,550 | 86,170 | 206,720 |
| Final Cover Soil Layer | | | | | |
| | | Gravel, t=30cm | 39,072 | 24,272 | 63,344 |
| | | Clay, t=60cm | 78,144 | 48,544 | 126,688 |
| | | Top Soil, t=30cm | 39,072 | 24,272 | 63,344 |
| | | Total | 156,288 | 97,088 | 253,376 |
| Liner Sheet | m2 | PE sheet + Geocomposite | 140,000 | 89,000 | 229,000 |
| Geo composite | m3 | use excavated on site | 41,170 | 26,160 | 67,330 |

| | | | | | |
|---|---|---|---|---|---|
| Leachate Treatment Pond | Excavate volume | Anaerobic pond | 7,410 | 5,170 | 12,580 |
| | | Aerobic Lagoon | 7,260 | 4,670 | 11,930 |
| | m3 | Maturation Pond | 16,620 | 10,740 | 27,360 |
| | | Total | 31,290 | 20,580 | 51,870 |
| | existing clay Compaction | Anaerobic pond | 3,530 | 2,440 | 5,970 |
| | | Aerobic Lagoon | 2,570 | 1,790 | 4,360 |
| | | Maturation Pond | 16,620 | 9,660 | 6,400 |
| | m2 | Total | 22,720 | 13,890 | 16,730 |
| | Sheet Anchorage ditc | Anaerobic pond | 296 | 264 | 560 |
| | m | Aerobic Lagoon | 252 | 214 | 466 |
| | | Maturation Pond | 342 | 272 | 614 |
| | | Total | 890 | 750 | 1,640 |

6. Leachate collection and gas removing facility

| | Main Pipe | Branch Pipe | Note |
|---|---|---|---|
| Dia. | 600mm | 200mm | |
| Stage1 | 500 | 5,000 | at interval of 30 m |
| Stage2 | 390 | 3,900 | |
| total | 890 | 8,900 | |

7. Gas removing facility, vertical type
PVC Diameter 300mm
9 unit/each ha

| | Area for 1st layer Area | Gas Vent | Height for 1 unit | Sum Height |
|---|---|---|---|---|
| | ha | unit | m | m |
| Stage1 | 12.0 | 108 | 14 | 1,512 |
| Stage2 | 7.8 | 70 | 14 | 980 |
| total | 19.8 | 178 | - | 2,492 |

8. Road — unit: m

| | Approach Road | | Onsite | Maintenance | |
|---|---|---|---|---|---|
| | Type A | Type B | Road | Road | note |
| Stage1 | 1,700 | 900 | 700 | 1,200 | |
| Stage2 | 0 | 850 | 560 | 1,000 | |
| total | 1,700 | 1,750 | 1,260 | 2,200 | |
| Height of Road bed | 1.0 | 0.5 | 0.0 | 0.0 | |
| width of road (m) | 8.0 | 8.0 | 7.0 | 5.0 | |
| Road Shoulder (m) | 0.5 | 0.5 | 0.5 | 0.3 | |
| Pavement | Asphalt Con. 10cm layer | Asphalt Con. 5cm layer | Gravel 50 cm | Gravel 30 cm | |
| Thickness of Road Earth Bed | 5.50 | 2.63 | - | - | (m3/m) |
| Thickness of Road Gravel Bed | 30 | 30 | 30 | 30 | cm |
| V= m3/m | 2.4 | 2.4 | 2.1 | 1.5 | (m3/m) |
| Thickness of Asphalt pavement | 10 | 5 | - | - | t cm |
| V m3/m | 0.80 | 0.40 | - | - | (m3/m) |
| Drainage of Surface exclusion | Slope 2% | | | | |
| Side Ditch | Brick and Mortar | | | | |

9.Anchorage ditch of liner sheet — unit: m

| | 1st layer top | 2nd layer top | total |
|---|---|---|---|
| Stage1 | 1,490 | 1,560 | 3,050 |
| Stage2 | 1,220 | 1,290 | 2,510 |

10. Rain Storm drainage system

| | | Type1 | Type2 | Type3 | Note |
|---|---|---|---|---|---|
| W x H | | 0.5mx0.5m with Riprap or Brick and mortar | 0.5mx1.0m with Riprap or Brick and mortar | 2.0mx1.0m with Riprap | |
| Landfill Area | | | | | |
| Stage1 | | | | | |
| | drainage ditch on emb | 6,000 | | | (425m + 325m) x 2 x 4layer |
| | Vertical | 210 | | | installation each of 100m |
| | Ground Level | 400 | 2,700 | 2,810 | Around Embankment in grand level |
| | Sub Total | 6,610 | 2,700 | 2,810 | |
| Stage2 | | | | | |
| | each embankment lay | 5,200 | | | (300m + 350m) x 2 x 4layer |
| | Vertical | 180 | | | installation each of 100m |
| | Ground Level | 400 | 370 | 600 | Around Embankment in grand level |
| | Sub Total | 5,780 | 370 | 600 | |
| TOTAL | | 11,560 | 740 | 1,200 | |

11. Turfing Work in embankment Slope

| | top Area | H | L | A | Layer | total |
|---|---|---|---|---|---|---|
| | m | m | m | m2/laer | unit | m2 |
| 1st Stage | 120,000 | 14.8 | 1,512 | 22,378 | 4 | 89,510 |
| 2nd Stage | 72,000 | 14.8 | 1,218 | 18,026 | 4 | 72,110 |
| total | 192,000 | | 2,730 | 40,404 | 8 | 161,620 |

Note) 3rd Layer is Average layer

**Administration Facility**

| | Items | | Qty | specification |
|---|---|---|---|---|
| 1. Measurement office | | | | |
| | Truck scale ,Pavement of concrete t=30 cm | | 1 Unit | |
| | Measurement office | | 15 m2 | 5m x 3m |
| 2. Security facility | | | | |
| | Light fixture on road | | 20 Unit | at interval of 50m |
| | Light fixture around building | | 5 Unit | per 300m2 |
| | Gate | galvanization pipe and Wire net | 1 unit | W=8m |
| | Boundary fence | barbed -wire fence | 4,000 m | |
| | Guards room | 3.5m x 3m | 10 m2 | 3.5m x 3m |
| 3. Work shop | | | | |
| | Resting Room | | 300 m2 | 10m x 30m |
| | Parking of Heavy equipment , Rc, Cocrete pavement | | 5,000 m2 | 100m x 50m |
| | Fuel tank | | 5000 L | |

| Stage Number | Required Condition(m3) | Volume | Dimension of Inside Bottom Area (Landfill Area) (ha) | | Embankment Slope (1:S)=(Vertical : Horizontal) | | | | | Distance from Tail end Blanket | Bottom Dimension of waste filling layer | | Top Surface dimension in Waste Filling Layer | | | Layer Dimension Landfill Area | | | Embankment Volume | | Soil Volume of Embankment | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Layer | | Inside Slope | Outside Slope | Height | Width top | Width Bottom | | Length bottom | Width bottom | L top | W top | Height | Each dimension | Sum Volume (*A) | Balance of volume demand | Section Area | Length | | Lbt | Wbt | Lbt | Wbt |
| | | (A*) | Number | | non. | non. | M | M | M | M | M | M | M | M | M | m3 | m3 | m3 | m3 | m | m3 | m | m | m | m |
| **New Site 1 Landfill** | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Stage 1** | Required Volumen(m3) | **2,275,000** | 1st Layer | Excavation | 2.0 | - | 5.0 | - | - | - | 400 | 300 | 420 | 320 | 5.0 | 635,660 | 635,660 | -1,753,090 | - | | - | | | | |
| | | | 2nd Layer | Mounding | 2.0 | 3.0 | 3.5 | 5.0 | 22.5 | 2.0 | 424 | 324 | 438 | 338 | 3.5 | 499,370 | 1,135,030 | -1,253,720 | 48.13 | 1,580 | 76,100 | 469 | 369 | 448 | 348 |
| | | | 3rd Layer | Mounding | 2.0 | 2.0 | 3.5 | 3.0 | 17.0 | 2.0 | 408 | 308 | 422 | 322 | 3.5 | 457,590 | 1,592,620 | -796,130 | 35.00 | 1,500 | 52,500 | 442 | 342 | 428 | 328 |
| | | | 4th Layer | Mounding | 2.0 | 2.0 | 3.5 | 3.0 | 17.0 | 2.0 | 392 | 292 | 406 | 306 | 3.5 | 417,610 | 2,010,230 | -378,520 | 35.00 | 1,440 | 50,400 | 426 | 326 | 412 | 312 |
| | | | 5th Layer | Mounding | 2.0 | 2.0 | 3.5 | 3.0 | 17.0 | 2.0 | 376 | 276 | 390 | 290 | 3.5 | 379,410 | 2,389,640 | 890 | 35.00 | 1,380 | 48,300 | 410 | 310 | 396 | 296 |
| | Necessary Volume | 2,388,750 | Sub Total | | | | 19.0 | | | | | | | | 19.0 | | - | | | | **227,300** | | | | |
| **Stage 2** | Required Volume (m3) | **1,400,000** | 1st Layer | Excavation | 2.0 | - | 5.0 | - | - | - | 250 | 300 | 270 | 320 | 5.0 | 403,160 | 403,160 | -1,066,840 | - | | - | | | | |
| | | | 2nd Layer | Mounding | 2.0 | 3.0 | 3.5 | 5.0 | 22.5 | 2.0 | 274 | 324 | 288 | 338 | 3.5 | 325,590 | 728,750 | -741,250 | 48.13 | 1,280 | 61,700 | 319 | 369 | 298 | 348 |
| | | | 3rd Layer | Mounding | 2.0 | 2.0 | 3.5 | 3.0 | 17.0 | 2.0 | 258 | 308 | 272 | 322 | 3.5 | 292,210 | 1,020,960 | -449,040 | 35.00 | 1,200 | 42,000 | 292 | 342 | 278 | 328 |
| | | | 4th Layer | Mounding | 2.0 | 2.0 | 3.5 | 3.0 | 17.0 | 2.0 | 242 | 292 | 256 | 306 | 3.5 | 260,630 | 1,281,590 | -188,410 | 35.00 | 1,140 | 39,900 | 276 | 326 | 262 | 312 |
| | | | 5th Layer | Mounding | 2.0 | 2.0 | 3.5 | 3.0 | 17.0 | 2.0 | 226 | 276 | 240 | 290 | 3.5 | 230,840 | 1,512,430 | 42,430 | 35.00 | 1,080 | 37,800 | 260 | 310 | 246 | 296 |
| | Necessary Volume | 1,470,000 | Sub Total | | | | 19.0 | | | | | | | | 19.0 | | | | | | **181,400** | | | | |
| **Total** | Required Volume (m3) | 3,675,000 | | | | | | | | | | | | | | | | | | | **408,700** | | | | |
| | Necessary Volume | 3,858,750 | | | | | | | | | | | | | | | | | | | | | | | |

**Table** **Calculation for Volume Landfill of New site 1 Landfill**

| Earth Work Volume | Dimension of Inside Bottom Area (ha) | Construction Method | Embankment Volume | Protective layer for Liner Sheet | Final Layer: Gravel | Final Layer: Rich Native Soil | Compacted condition | Natural ground condition |
|---|---|---|---|---|---|---|---|---|
| | | | | t=30cm | t= 30 cm | t= 30 cm | | |
| Stage Number | Layer No. | | m3 | | m3 | m3 | m3 | m3 |
| Stage 1 | 1st Layer | Excavation | | 41,170 | - | - | | |
| | 2nd Layer | Mounding | 76,100 | | - | - | | |
| | 3rd Layer | Mounding | 52,500 | | - | - | | |
| | 4thLayer | Mounding | 50,400 | | - | - | | |
| | 5th Layer | Mounding | 48,300 | | 35,165 | 35,165 | | |
| | Sub Total | | 227,300 | | 35,165 | 35,165 | 268,470 | 298,300 |
| Stage 2 | 1st Layer | Excavation | | 26,160 | - | - | | |
| | 2nd Layer | Mounding | 61,700 | | - | - | | |
| | 3rd Layer | Mounding | 42,000 | | - | - | | |
| | 4thLayer | Mounding | 39,900 | | - | - | | |
| | 5th Layer | Mounding | 37,800 | | 21,845 | 21,845 | | |
| | Sub Total | | 181,400 | | 21,845 | 21,845 | 207,560 | 230,700 |
| **Total** | | | **408,700** | **67,330** | **57,010** | **57,010** | **476,030** | **529,000** |

**Table** **Calculation of Earth Volume Landfill of New site 1 Landfill**
**In NEW SITE 1 Landfill**

| | Cutting Soil | m3 | Mounding Soil | | m3 |
|---|---|---|---|---|---|
| Landfill | 1st Stage | 635,660 | Embankment | 1st Stage | 298,300 |
| | 2nd Stage | 403,160 | | 2nd Stage | 230,700 |
| | | | Dairy cover soil | | 0 |
| | | | protective soil layer | 1st Stage | 51,900 |
| | | | protective soil layer | 2nd Stage | 34,400 |
| | sub-total | 1,038,820 | | sub total | 615,300 |
| Pond | 1st Stage | 31,290 | | | |
| | 2nd Stage | 20,580 | Road bed | (L=3000m) | 12,000 |
| | sub-total | 51,870 | | | |
| total | | 1,090,690 | TOTAL | | 615,300 |
| | | | *balance* | | *475,390* |

Note: Estimated Volume is condition of Natural ground

## Table Calculation of Pond Volume in New Site 1 Landfill

| | | Required volume (m3) | Slope 1:s | Bottom (m) | | High Water Level (m) | | | Allowance Level (HWL+0.5m) | | | Deposit Volume of Water Area | Excavation Volume | Compaction Cray Soil Area | Anchor ditch for liner sheet |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | part of Under H.W.L | | Lb | Wb | Iho | Who | H ho | La | Wa | Ha | V (m3) | (m3) | m2 | m |
| **(ALTERNATIVE 6)** | | | | | | | | | | | | | | | |
| | **Anaerobic Pond + Aerated Lagoon + Maturation Pond with recirculation** | | | | | | | | | | | | | | |
| | Anaerobic Pond (Embankment slope 1:3) | | | | | | | | | | | | | | |
| | Stage1 | 6,230 | 3.0 | 84 | 8 | 105 | 29 | 3.5 | 107 | 31 | 4.0 | 6,240 | 7,410 x 1 pond | 3,530 | 296 |
| | Stage2 | 4,270 | 3.0 | 72 | 4 | 93 | 25 | 3.5 | 95 | 27 | 4.0 | 4,310 | 5,170 x 1 pond | 2,440 | 264 |
| | Total | 10,500 | | | | | | | | | | 10,550 | 12,580 | 5,970 | 560 |
| | Aerated Lagoon (Embankment slope 1:1.5) | | | | | | | | | | | | | | |
| | Stage1 | 6,230 | 1.5 | 77 | 17 | 87 | 27 | 3.5 | 88 | 28 | 4.0 | 6,250 | 7,260 x 1 pond | 2,570 | 252 |
| | Stage2 | 3,990 | 1.5 | 63 | 12 | 73 | 22 | 3.5 | 74 | 23 | 4.0 | 4,000 | 4,670 x 1 pond | 1,790 | 214 |
| | Total | 10,220 | | | | | | | | | | 10,250 | 11,930 | 4,360 | 466 |
| | Maturation Pond (Embankment slope 1:3) | | | | | | | | | | | | | | |
| | Stage1 | 6,250 | 3.0 | 107 | 32 | 116 | 41 | 1.5 | 118 | 43 | 2.0 | 6,110 | 8,310 x 2 ponds | 9,660 | 342 |
| | Stage2 | 4,000 | 3.0 | 76 | 28 | 85 | 37 | 1.5 | 87 | 39 | 2.0 | 3,930 | 5,370 x 2 ponds | 6,400 | 272 |
| | Total | 10,250 | | | | | | | | | each pond | 10,040 | 27,360 | 16,060 | 614 |
| | TOTAL | | | | | | | | | | | | 51,870 | 26,390 | 1,640 |

# 3.2 New Guanabacoa Landfill

## Table 3.2.1 Breakdown of Quantities Estimation for New Guanabacoa Landfill

1. Require capacity of Landfill Area (unit m3)

| Propose by M/P | Necessary of Landfill Volume | filled waste Volume | Necessary Covering soil Volume (*1) | Necessary Covering soil Volume at Natural ground, before cutting |
|---|---|---|---|---|
| Dimension of Landfill Area | After compaction | After compaction | After compaction | (*1 ) / 0.9 |
| | (m3) | (m3) | (m3) | (m3) |
| 1st Stage East area 7.8 ha | 850,500 | 599,000 | 120,100 | 133,400 |
| 2nd Stage West area 5.5 ha | 550,000 | 458,800 | 91,600 | 101,800 |
| Total | 1,400,500 | 1,058,000 | 211,700 | 235,200 |

2. Earth Work ( calculated condition is natural ground condition ) (unit m3)

| | | 1st Stage | 2nd Stage | total | Note |
|---|---|---|---|---|---|
| Cutting Volume | | | | | |
| | Landfill Area | | | | |
| | 1st layer | 9,525 | 97,675 | 107,200 | |
| | 2nd layer | 55,325 | 116,650 | 171,975 | |
| | 3rd layer | 70,900 | 11,850 | 82,750 | |
| | 4th layer | 84,250 | 0 | 84,250 | |
| | 5th layer | 19,400 | 0 | 19,400 | |
| | Sub-Total | 239,400 | 226,175 | 465,575 | |
| | Compost Yard | 50,000 | 0 | 50,000 | |
| | Administration Area | 67,500 | 0 | 67,500 | |
| | Sub-Total | 117,500 | 0 | 117,500 | |
| | Total | 356,900 | 226,175 | 583,075 | 1) |
| Filling in site | | Stage 1 | Stage 2 | Ttotal | |
| | Filling | 99,722 | 72 | 99,794 | |
| | Enclosure Embankment | 100,123 | 110,474 | 210,597 | |
| | Administration area | 120,000 | 0 | 120,000 | |
| | Protection Soil for Liner sheet | 25,920 | 26,667 | 52,587 | |
| | Total | 345,766 | 137,213 | 482,978 | 2) |
| Surplus Soil | | 11,134 | 88,962 | 100,097 | 1)-2) |
| Necessary of Cover Soil m3 | | 133,400 | 101,800 | 235,200 | |
| by Onsite soil excavated m3 | | 11,134 | 88,962 | 100,097 | |
| Transport from out site m3 | | 122,266 | 12,838 | 135,103 | |

3. Pond Construction Work

| | | 1st Stage | 2nd Stage | total |
|---|---|---|---|---|
| Excavation Volume (m3) | Anaerobic Pond | 3,950 | 2,750 | 6,700 |
| | Aerobic Pond | 3,810 | 2,590 | 6,400 |
| | Maturation Pond | 9,480 | 7,100 | 16,580 |
| | Total | 17,240 | 12,440 | 29,680 |
| installation area of liner sheet (m2) | Anaerobic Pond | 2,102 | 2,039 | 4,141 |
| | Aerobic Pond | 1,544 | 1,184 | 2,728 |
| | Maturation Pond | 5,944 | 4,684 | 10,628 |
| | Total | 9,590 | 7,907 | 17,497 |
| Length of Anchorage ditch for liner sheet (m) | | 610 | 580 | 1,190 |

4. Dimension of Enclosure Embankment

| | 3.5m height type | 5.0m height type |
|---|---|---|
| Upper length of embankment | 3 m | 3 m |
| height of Embankment | 3.5 m | 5 m |
| Bottom length embankment | 17 m | 28 m |
| Out side Slope | 1: 2 | 1: 3 |
| Inside slope | 1: 2 | 1: 2 |
| Average Section are | 35.0 m2 | 77.5 m2 |

5. Volume of inside Area

| | | Enclosure Dike Embankment | | | capacity |
|---|---|---|---|---|---|
| | | L (m) | H (m) | Section Area(m3/m) | V(m3) |
| Stage1 | 1st Layer | - | 5 | - | 12,875 |
| | 2nd Layer | - | 3.5 | - | 109,775 |
| | 3rd Layer | - | 3.5 | - | 238,500 |
| | 4th Layer | - | 3.5 | - | 285,725 |
| | 5th Layer | - | 3.5 | - | 250,025 |
| | Total | - | - | - | 896,900 |
| Stage 2 | 1st Layer | - | 5 | - | 107,050 |
| | 2nd Layer | - | 3.5 | - | 172,275 |
| | 3rd Layer | - | 3.5 | - | 159,375 |
| | 4th Layer | - | 3.5 | - | 105,700 |
| | 5th Layer | - | 3.5 | - | 74,000 |
| | Total | | - | 0 | 618,400 |

5-1. Liner Sheet Installation Work

| | Bottom Area | Slope Area | total | anchorage Length | |
|---|---|---|---|---|---|
| | m2 | m2 | m2 | m | |
| Stage 1 | 70,000 | 26,000 | 96,000 | 1,300 | |
| Stage 2 | 50,000 | 30,000 | 80,000 | 1,500 | |

6. Leachate Collection Pipe

| | Area | Main Pipe 600mm | Branch Pipe 300mm |
|---|---|---|---|
| | ha | L (m) | L (m) |
| Stage1 | 8 | 700 | 2,340 |
| Stage2 | 6 | 300 | 1,650 |
| total | 13.3 | 1000 | 3,990 |

7. Leachate Collection Connection Pipe from Landfill to Pond

| | Connection Pipe | | |
|---|---|---|---|
| | From Landfill to pond | Connection for each pond | Total |
| | m | m | m |
| Syage1 | 50 | 70 | 120 |
| Stage 2 | 50 | 70 | 120 |
| Total | 100 | 140 | 240 |

8. Gas vent pipe , vertical type
Dia=300mm
9 unit per ha, installation of 30m pitch

| | Area of 1st layer | | Height per unit | Sum Height |
|---|---|---|---|---|
| | ha | unit | m | |
| Stage1 | 7.8 | 70.2 | 14 | 983 |
| Stage2 | 6.0 | 54.0 | 10.5 | 567 |
| total | | 124 | - | 1549.8 |

9. Road facility

| | unit | Approach Road Type A | Approach Road Type B | Maintenance Road | Onsite Road | amount | note |
|---|---|---|---|---|---|---|---|
| Stage1 | m | 700 | 900 | 600 | 700 | 2900 | |
| Stage2 | m | 0 | 500 | 900 | 700 | 2100 | |
| total | m | 700 | 1400 | 1500 | 1400 | 5000 | |
| Height of road bed | m | 1.0 | 0.5 | - | - | - | |
| Width of road | m | 8.0 | 8.0 | 5.0 | 7.0 | - | |
| Width of road shoulder | m | 0.5 | 0.5 | 0.3 | 0.3 | - | |
| Condition of pavement | | Asphalt Con. 5cm x2 layer | Asphalt Con. 5cm x 2 layer | Gravel 30 cm | Gravel 30 cm | | |
| Volume of Road Bed by soil | m3/m | 5.50 | 2.63 | - | - | - | |
| Thickness of Gravel paving laye | cm | 30 | 30 | 30 | 30 | - | |
| Volume of Section per meter leng | m3/m | 2.4 | 2.4 | 1.5 | 2.1 | - | |
| Thickness of Asphalt paving layer | t cm | 10 | 5 | - | - | - | |
| Volume of Section per meter leng | m3/m | 0.80 | 0.40 | - | - | - | |

10. Rain Storm drainage system

| | | Type1 | Type2 | Type3 | Type4 | Note |
|---|---|---|---|---|---|---|
| W x H | | 0.5mx 0.5m with Riprap or Brick and mortar | 0.5m x 1.0m with Riprap or Brick and mortar | 2.0m x 1.0m with Riprap | 2.0m x 2.0m with Riprap o Concrete | |
| Landfill and Embankment Area | | | | | | |
| Stage1 | Included administration area | | | | | |
| | each embankment la | 2,600 | 0 | 0 | | |
| | Vertical | 260 | 0 | 0 | | installation each length 100m of embankment distance |
| | Around Landfill | 650 | 200 | 100 | | Around Embankment in grand level |
| | Sub Total | 3,510 | 200 | 100 | | |
| | Pond area | 200 | 100 | 100 | | |
| | Total | 3,710 | 300 | 200 | | |
| Stage2 | | | | | | |
| | each embankment la | 2,250 | | | | |
| | Vertical | 225 | | | | installation each of 100m |
| | Around Landfill | 750 | 200 | 100 | | Around Embankment in grand level |
| | Sub Total | 3,225 | 200 | 100 | | |
| | Pond area | 200 | 100 | 100 | | |
| | Total | 3,425 | 300 | 200 | | |

11. Turfing Work for protective erosion in embankment Slope

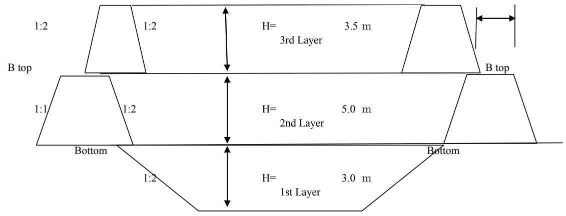
| | Height average | Wide bench | Embankment sl | Slop length | Length average | Turfing area |
|---|---|---|---|---|---|---|
| | m | m | m | m | m | m2 |
| Stage 1 | 14.0 | 8 | 2 | 39 | 1,300 | 51,096 |
| Stage 2 | 10.5 | 6 | 2 | 29 | 1,500 | 44,218 |
| total | - | - | - | - | - | 95,315 |

# Table3.2.2 Calculation of Pond Volume at New Guanabacoa Landfill

| | Area (ha) | | Dimension (m) | | | Required volume (m3) | Slope 1:s | Bottom (m) | | H.W.L (m) | | | Allowance Level (HWL+0.5m) | | | Deposit Volume of Water Area | Excavation Volume | | Liner Sheet Area | | Anchor length | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | L | W | H (MWL) | part of Under H.W. L | | Lb | Wb | Lh | Wh | Hh | La | Wa | Ha | V (m3) | m3 | | m2 | | m | |
| **Alternative 6** | | | | | | | | | | | | | | | | | | | | | | |
| **Anaerobic Pond + Aerated Lagoon + Maturation Pond** | | | | | | | | | | | | | | | | | | | | | | |
| Anaerobic Pond (Embankment slope 1:3) | | | | | | | | | | | | | | | | | | | | | | |
| Stage1 | 3,080 | | 44 | 20 | 3.5 | 3,080 | 3 | 46 | 5.0 | 67 | 26 | 3.5 | 69 | 28 | 4.0 | 3,190 | 3,950 | x 1 pond | 2,102 | x 1 pond | 204 | x 1 pond |
| Stage2 | 2,100 | | 40 | 15 | 3.5 | 2,100 | 3 | 46 | 5.0 | 67 | 21 | 3.5 | 69 | 23 | 4.0 | 2,200 | 2,750 | x 1 pond | 2,039 | x 1 pond | 194 | x 1 pond |
| Total | 5,180 | | - | - | - | 5,180 | | | | | | | | | | 5,390 | 6,700 | x 1 pond | 4,141 | x 1 pond | 398 | x 1 pond |
| Aerobic Lagoon (Embankment slope 1:1.5) | | | | | | | | | | | | | | | | | | | | | | |
| Stage1 | 3,080 | | 44 | 20 | 3.5 | 3,080 | 1.5 | 44.5 | 12.5 | 55 | 23 | 3.5 | 56 | 24 | 4.0 | 3,120 | 3,810 | x 1 pond | 1,544 | x 1 pond | 170 | x 1 pond |
| Stage2 | 2,100 | | 40 | 15 | 3.5 | 2,100 | 1.5 | 41.5 | 7.5 | 52 | 18 | 3.5 | 53 | 19 | 4.0 | 2,110 | 2,590 | x 1 pond | 1,184 | x 1 pond | 154 | x 1 pond |
| Total | 5,180 | | - | - | - | 5,180 | | | | | | | | | | 5,230 | 6,400 | x 1 pond | 2,728 | x 1 pond | 324 | x 1 pond |
| Maturation Pond (Embankment slope 1:3) | | | | | | | | | | | | | | | | | | | | | | |
| Stage1 | 3,150 | x 2 ponds | 70 | 30 | 1.5 | 3,150 | 3 | 69 | 24.0 | 78 | 33 | 1.5 | 80 | 35 | 2.0 | 3,150 | 4,740 | x 2 ponds | 2,972 | x 2 ponds | 240 | x 2 ponds |
| Stage2 | 2,250 | x 2 ponds | 60 | 25 | 1.5 | 2,250 | 3 | 62 | 19.0 | 71 | 28 | 1.5 | 73 | 30 | 2.0 | 2,350 | 3,550 | x 2 ponds | 2,342 | x 2 ponds | 216 | x 2 ponds |
| Total | 5,400 | x 2 ponds | - | - | - | 5,400 | | | | | | | | | | 5,500 | 8,290 | x 2 ponds | 5,314 | x 2 ponds | 456 | x 2 ponds |

## 3.3 Expansion of Calle 100

### Table 3.3.1 Breakdown of Quantities Estimation for Calle 100 Landfill




1. Landfill

1. 1Necessary Volume of Waste layer

| | (Average Volume with daily cove | Operation Period |
|---|---|---|
| 1st Stage | 1,764,000 m3 | 2007y-2008y Operation area<br>10000 m2 x 1.75 m x 10 layer |
| 2nd Stage | 1,400,000 m3 | 2008y-2010y<br>8000 m2 x 1.75m x 10 layer |
| 計 | 3,164,000 m3 | |

1.2. Standard section of Enclosure embankment

| | | 2nd Layer | upper 3rd layer |
|---|---|---|---|
| Dimension of Enclosure Embankment | Upper width of ba | 3.0 m | 3.0 m |
| | Height of bank | 5.0 m | 3.5 m |
| | Bottom width | 23.0 m | 15.3 m |
| | Outside slope | 1: 2 | 1: 2 |
| | Inside slope | 1: 2 | 1: 1.5 |
| | Average Dimensi | 65.0 m2 | 31.9 m2 |

1.3. Mounding volume

| | Bank layer | Section Area ( m2 ) | Length ( m ) | Volume ( m3 ) | Percent of Cutting Area | Volume ( m3 ) |
|---|---|---|---|---|---|---|
| 1st Stage | 1st layer | 65.0 | 1412 | 91,780 | 0 | 0 |
| | 2nd layer | 31.9 | 1488 | 47,467 | 70 | 33,227 |
| | 3rd layer | 31.9 | 1406 | 44,851 | 100 | 44,851 |
| | 4th layer | 31.9 | 1324 | 42,236 | 100 | 42,236 |
| | 5th layer | 31.9 | 1242 | 39,620 | 100 | 39,620 |
| | Total | | | 265,954 | | 159,934 |
| 2nd Stage | 1st layer | 65.0 | 1272 | 82,680 | 0 | 0 |
| | 2nd layer | 31.9 | 1332 | 42,491 | 70 | 29,744 |
| | 3rd layer | 31.9 | 1250 | 39,875 | 100 | 39,875 |
| | 4th layer | 31.9 | 1168 | 37,259 | 100 | 37,259 |
| | 5th layer | 31.9 | 1086 | 34,643 | 100 | 34,643 |
| | Total | | | 236,948 | | 141,521 |
| TOTAL | | | | 300,597 | | 194,577 |

1.4. Cutting volume

| | | L ( m ) | | W ( m ) | | | Layer Volume | | Cut Volume |
|---|---|---|---|---|---|---|---|---|---|
| | section layer | Bottom ( m ) | Top ( m ) | Bottom ( m ) | Top ( m ) | H ( m ) | Val ( m3 ) | % of Cutting a | Vic ( m3 ) |
| 1st Stage | 1st layer | 440 | 456 | 250 | 266 | 3.0 | 346,752 | 100 | 346,752 |
| | 2nd layer | 460 | 474 | 270 | 284 | 5.0 | 646,795 | 80 | 517,436 |
| | 3rd layer | 439.5 | 454 | 249.5 | 264 | 3.5 | 400,845 | 50 | 200,423 |
| | 4th layer | 419 | 433 | 229 | 243 | 3.5 | 351,876 | 5 | 17,594 |
| | 5th layer | 398.5 | 413 | 208.5 | 223 | 3.5 | 305,848 | 0 | 0 |
| | Total | | | | | 18.5 | 2,052,116 | | 1,082,205 |
| 2nd Stage | 1st layer | 370 | 386 | 250 | 266 | 3.0 | 292,572 | 100 | 292,572 |
| | 2nd layer | 386 | 400 | 266 | 280 | 5.0 | 536,445 | 90 | 482,801 |
| | 3rd layer | 365.5 | 380 | 245.5 | 260 | 3.5 | 329,197 | 50 | 164,599 |
| | 4th layer | 345 | 359 | 225 | 239 | 3.5 | 285,824 | 10 | 28,582 |
| | 5th layer | 324.5 | 339 | 204.5 | 219 | 3.5 | 245,393 | 0 | 0 |
| | Total | | | | | 18.5 | 1,689,431 | | 968,554 |
| TOTAL | | | | | | | 3,741,547 | | 2,050,759 |

1.5.Liner Sheet Installation Area

| | Waste Layer m2 |
|---|---|
| 1st Stage | 127,177 |
| 2nd Stage | 107,957 |
| total | 235,134 |

1.6.Liner sheet Anchor ditch

| | 1stLayer m | total m |
|---|---|---|
| 1st Stage | 1,484 | 1,484 |
| 2nd Stage | 1,344 | 1,344 |
| total | 2,828 | 2,828 |

1.7.Liner Sheet Protection Layer

| | sand layer (m3) t= 30 cm |
|---|---|
| 1st Stage | 38,153 |
| 2nd Stage | 32,387 |
| total | 70,540 |

1.8. Leachate Collection Pipe

| | Area ha | Main pipe 600mm | Branch Pipe 200mm |
|---|---|---|---|
| 1st Stage | 10 | 400 | 6,000 |
| 2nd Stage | 9 | 450 | 5,400 |
| total | 19 | 850 | 11,400 |

1.9.Gas removing Facility

Diameter 300mm PVC Perforated pipe
9 unit per ha ( at interval of 30m)

| | Unit | Height ( m ) 14.5m each |
|---|---|---|
| 1st Stage | 90 | 1,575 |
| 2nd Stage | 81 | 1,418 |
| total | 171 | 2,993 |

2.Pond Construction Work

21.Anaerobic Pond Construction

| | Excavation Volume m3 | Liner Sheet Area m2 | Anchor ditch m |
|---|---|---|---|
| 1st Stage | 2,490 | 1,738 | 234 |
| 2nd Stage | 2,090 | 1,842 | 234 |
| total | 4,580 | 3,580 | 468 |

22. Connection Leachate Pipe to Pond (connection Pipe Dia. 600mm)

| | Excavated Dimension | | | | Liner Sheet | filling |
|---|---|---|---|---|---|---|
| | Length m | Width m | Depth m | Volume m3 | A m2 | Volume m3 |
| 1st Stage | 50 | 1.5 | 4.5 | 337.5 | 675 | 323 |
| 2nd Stage | 50 | 1.5 | 4.5 | 337.5 | 675 | 323 |
| total | 100 | - | - | - | 1350 | 646 |

**Table -C-3-7** **Calculation for dimensionof expansion of calle100 landfill**

| Stage Number | Required Condition | Requirement capacity | Dimension of Inside Bottom Area (Landfill Area) (ha) | Method of earth work | Embankment Slope (1:S)=(Vertical : Horizontal) | | | | | Distance from Tail end Blanket | Landfill Area Layer Dimension (Bottom Surface) | | Layer Dimension with embankment (Top Surface) | | | Layer Dimension Area in Waste layer | | | Embankment Volume | | Soil Volume of Embankment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (m3) | Layer | | Inside Slope | Outside Slope | Height | Width top | Width Bottom | | L bottom | W bottom | L top | W top | Height | Each dimension | Sum Total Volume (*A) | Balance of volume demand | Section Area | Length | |
| | | (A*) | Number | | - | - | m | m | m | m | m | m | m | m | m | m3 | m3 | m3 | m3/m | m | m3 |
| **Expansion of Calle100 Landfill** | | | | | | | | | | | | | | | | | | | | | |
| **First Stage** | Required Volume (m3) | **1,764,000** | 1st Layer | Excavation | 2.0 | - | 4.0 | - | | - | 440 | 250 | 456 | 266 | 4.0 | 462,420 | 462,420 | -1,477,980 | - | | - |
| | Length (M) = | | 2nd Layer | Excavation | 2.0 | 2.0 | 3.5 | 3.0 | 17.0 | 2.0 | 460 | 270 | 474 | 284 | 3.5 | 452,810 | 915,230 | -1,025,170 | 35.00 | 1,530 | 53,600 |
| | Width (M) = | | 3rd Layer | mounding | 2.0 | 1.5 | 3.5 | 3.0 | 15.3 | 2.0 | 439.5 | 249.5 | 453.5 | 263.5 | 3.5 | 400,900 | 1,316,130 | -624,270 | 31.94 | 1,450 | 46,400 |
| | Average Height (M) = | | 4thLayer | mounding | 2.0 | 1.5 | 3.5 | 3.0 | 15.3 | 2.0 | 419 | 229 | 433 | 243 | 3.5 | 351,930 | 1,668,060 | -272,340 | 31.94 | 1,370 | 43,800 |
| | Volume (M3) | | 5th Layer | mounding | 2.0 | 1.5 | 3.5 | 3.0 | 15.3 | 2.0 | 398.5 | 208.5 | 412.5 | 222.5 | 3.5 | 305,900 | 1,973,960 | 33,560 | 31.94 | 1,290 | 41,300 |
| | *x 1.1 for preparative (m3)* | *1,940,400* | Sub Total | | | | 18.0 | | | | | | | | 18.0 | | - | | | | **185,100** |
| **Second Stage** | Required Volume (m3) | **1,400,000** | 1st Layer | Excavation | 2.0 | - | 4.0 | - | | - | 370 | 250 | 386 | 266 | 4.0 | 390,180 | 390,180 | -1,149,820 | - | | - |
| | Length (M) = | | 2nd Layer | mounding | 2.0 | 2.0 | 3.5 | 3.0 | 17.0 | 2.0 | 386 | 266 | 400 | 280 | 3.5 | 375,560 | 765,740 | -774,260 | 35.00 | 1,380 | 48,300 |
| | Width (M) = | | 3rd Layer | mounding | 2.0 | 1.5 | 3.5 | 3.0 | 15.3 | 2.0 | 365.5 | 245.5 | 379.5 | 259.5 | 3.5 | 329,250 | 1,094,990 | -445,010 | 31.94 | 1,290 | 41,300 |
| | Average Height (M) = | | 4thLayer | mounding | 2.0 | 1.5 | 3.5 | 3.0 | 15.3 | 2.0 | 345 | 225 | 359 | 239 | 3.5 | 285,880 | 1,380,870 | -159,130 | 31.94 | 1,210 | 38,700 |
| | | | 5th Layer | mounding | 2.0 | 1.5 | 3.5 | 3.0 | 15.3 | 2.0 | 324.5 | 204.5 | 338.5 | 218.5 | 3.5 | 245,450 | 1,626,320 | 86,320 | 31.94 | 1,130 | 36,100 |
| | *x 1.1 for preparative (m3)* | *1,540,000* | Sub Total | | | | 18.0 | | | | | | | | 18.0 | | | | | | **164,400** |
| Total | Required Volume (m3) | 3,164,000 | | | | | | | | | | | | | | | | | | | **349,500** |

| Earth Work Volume | Dimension of Inside Bottom Area (Landfill Area) (ha) | Blanket Soil Volume | | Liner Sheet installation Area | Gravel of final cover layer | Rich Native Soil for final cover layer |
|---|---|---|---|---|---|---|
| Stage Number | Layer | Compacted condition | Natural Condition | Area | t= 30 cm | t= 30 cm |
| | Number | m3 | | m2 | m3 | m3 |
| **Expansion of Calle 100 landfill** | | | | | | |
| Stage 1 | 1st Layer | - | | 127,177 | - | - |
| | 2nd Layer | 53,600 | | - | - | - |
| | 3rd Layer | 46,400 | | - | - | - |
| | 4thLayer | 43,800 | | - | - | - |
| | 5th Layer | 41,300 | | - | 27,534 | 27,534 |
| | Sub Total | 185,100 | 205,700 | 127,177 | 27,534 | 27,534 |
| Stage 2 | 1st Layer | - | | 107,957 | - | - |
| | 2nd Layer | 48,300 | | - | - | - |
| | 3rd Layer | 41,300 | | - | - | - |
| | 4thLayer | 38,700 | | - | - | - |
| | 5th Layer | 36,100 | | - | 22,189 | 22,189 |
| | Sub Total | 164,400 | 182,700 | 107,957 | 22,189 | 22,189 |
| Total | | **349,500** | **388,400** | **235,134** | **49,723** | **49,723** |

| | Cutting Volume (m3) | | Mounding Volume (m3) | | |
|---|---|---|---|---|---|
| Landfill | 1st Stage | 462,420 | Embankment | 1st Stage | 205,700 |
| | 2nd Stage | 390,180 | | 2nd Stage | 182,700 |
| | sub-total | 852,600 | daily coversoil | | 673,800 |
| | | | | sub total | 1,062,200 |
| Pond | | Pond | Road work | (L=3000m) | 30,000 |
| | 1st Stage | 36,670 | | | |
| | 2nd Stage | 24,230 | rprotective layer | 1st Stage | 44,300 |
| | sub-total | 60,900 | | 2nd Stage | 37,700 |
| | | | | sub total | 82,000 |
| total | | 913,500 | TOTAL | | 1,174,200 |
| *Balance* | | | | | *-260,700* |

note) the volume is in condition of natural ground

3. Road Construction Work

3.1 .Road

| | | Access Road Type A | Access Road Type B | Maintenance Road | Onsite Road | amount | note |
|---|---|---|---|---|---|---|---|
| 1st Stage | | 0 | 300 | 400 | 450 | 1150 | |
| 2nd Stage | | 0 | 0 | 300 | 300 | 600 | |
| total | | 0 | 300 | 700 | 750 | 1750 | |
| Height of road bed | m | 1.0 | 0.5 | 0.0 | 0.0 | | |
| Width of road | m | 8.0 | 8.0 | 5.0 | 7.0 | | |
| width of road | m | 0.5 | 0.5 | 0.3 | 0.3 | | |
| specification | | 5cm x2 layer | Asphalt Con. 5cm x 2 layer | Gravel 30 cm | Gravel 30 cm | | |
| Earth volume of road bed | m3/m | 5.50 | 2.63 | 0.00 | 0.00 | | Soil layer |
| Gravel Pavement | thickness (cm) | 30 | 30 | 30 | 30 | | Gravel |
| | Volume ( m3/m ) | 2.4 | 2.4 | 1.5 | 2.1 | | |
| Asphalt Pavement | thickness (cm) | 10 | 5 | - | - | | As |
| | Volume ( m3/m ) | 0.80 | 0.40 | - | - | | |

4. Rain Storm drainage system

41. Category of Ditch type

| | | Type1 | Type2 | Type3 |
|---|---|---|---|---|
| Width | m | 0.5 | 1 | 2 |
| Depth | m | 0.5 | 1 | 1 |
| | | with Riprap or Brick and mortar | | |

42. Landfill and Embankment Area

| | | | | | |
|---|---|---|---|---|---|
| 1st Stage | Landfill Area | | | | |
| | embankment 4 la | 2800 | | | |
| | on slope | 400 | | | installation each length 100m of embankment distance |
| | Around Dike | | 1600 | | |
| | Road side | | 300 | 600 | Around Embankment in grand level |
| | total | 3,200 | 1,900 | 600 | |
| 2nd Stage | Landfill Area | | | | |
| | embankment per | 2400 | | | |
| | on Slope | 100 | | | installation each of 100m |
| | Around Dike | | 1400 | | |
| | Road side | | 500 | 400 | Around Embankment in grand level |
| | total | 2,500 | 1,900 | 400 | |

43. Turfing Work in embankment Slope

| | Area m2/laer | total m2 |
|---|---|---|
| 1st Stage | 116,000 | 116000 |
| 2nd Stage | 90,000 | 90000 |
| total | 206,000 | 206,000 |

5. Final Covering Work in top layer

Final Cover Layer

| | L m | W m | A m2 | thickness cm | Volume m3 | thickness cm | Volume m3 |
|---|---|---|---|---|---|---|---|
| 1st Stage | 419 | 229 | 95,627 | 30 | 28,688 | 30 | 28,688 |
| 2nd Stage | 345 | 225 | 77,340 | 30 | 23,202 | 30 | 23,202 |
| total (Turfing area) | | | 172,968 | | 51,890 | | 51,890 |

## Table 3.3.2 Calculation of Pond Volume at Calle100 Landfill

(unit : 1000m3)

| Items | | First stage | | | | Second stage | | | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | Sandy Clay | Top soil and sand | soft rock and construction waste | Total | Sandy Clay | Top soil and sand | soft rock and construction waste | Total | Sandy Clay | Top soil and sand | soft rock and construction waste |
| Ratio of excavated Natural Soil Volume | | | 30% | 65% | 5% | | 30% | 65% | 5% | | 30% | 65% | 5% |
| 1. Cut Volume | | 374 | 112 | 243 | 19 | 239 | 72 | 155 | 12 | 612 | 184 | 398 | 31 |
| 2.1 Use soils in site | | | | | | | | | | | | | |
| | Mounding and filling | 320 | 100 | 110 | 10 | 111 | 50 | 55 | 6 | 430 | 150 | 165 | 16 |
| | Protection layer for Liner sheet | 26 | - | 26 | - | 27 | | 27 | | 53 | | 53 | |
| | Landfill facility of Landfill Site | | | | | | | 50 | 19 | | | 50 | 19 |
| | Sub Total | 346 | 100 | 136 | 10 | 137 | 50 | 132 | 25 | 483 | 150 | 268 | 35 |
| | Surplus Soil | 28 | 12 | 107 | 9 | 101 | 22 | 23 | -13 | 130 | 34 | 130 | -4 |
| 1 - 2 | Necessary Volume for Dairy Cove | 133 | | | | 92 | | | | 235 | | 212 | |
| | Obtain inside | 28 | | | | 101 | | | | 130 | | | |
| | From outside | 105 | | | | -10 | | | | 106 | | | |

## Table 3.3.3 Calculation of Soil Volume in the Expansion Area of Calle100 Landfill

| | Stage | Dimension (Average size) | | | Required volume (m3) | Slope 1:s *1 | Bottom (m) | | H.W.L (m) | | | Allowance Level (HWL+0.5m) | | | Deposit Volume of Water Area (m3)*2 | Impermeable Liner Zone (m) | | Excavation Volume |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | La | Wa | Ha | part of Under HOW. L | | Lb | Web | Lahr | Who | Hz | La | Way | Ha | V | Vertical Thickness | Horizontal Thickness | (m3) |
| (ALTERNATIVE 6) | Anaerobic Pond (Embankment slope 1:3) | | | | | | | | | | | | | | | | | |
| Level 3 | 1st Stage | 59 | 25 | 3.5 | 5,163 | 3.0 | 63 | 10 | 84 | 31 | 3.5 | 86 | 33 | 4.0 | 5,400 | 0.75 | 2.25 | 6,630 |
| | 2nd Stage | 60 | 20 | 3.5 | 4,200 | 3.0 | 70 | 5 | 91 | 26 | 3.5 | 93 | 28 | 4.0 | 4,490 | 0.75 | 2.25 | 5,530 |
| | Total | - | - | - | 9,363 | | | | | | | | | | 9,890 | | | 12,160 |

# 4. Unit Cost

**Table 4.1 Unit Cost of Materials**

| Items | Specification | Unit Cost | Unit | Specification |
|---|---|---|---|---|
| HDPE liner Sheet with Geo-composite | 1.5 mm double sided textured HDPE | 9.80 | US$ / m2 | Geomembran 60mil, t=1.5mm Pavco |
| | Double Sided geo-composite | 9.16 | US$ / m2 | geodren planar PAVCO |
| | Fitting cost for installation | 16,000 | US$ | Installation kit for installation HDPE liner Sheet |
| | | | | |
| PVC pipe for Under ground water drainage | Perforated type, Dia.600mm | 35.07 | US$ per meter | novafort PAVCO 515mm |
| Perforated type | Perforated type, Dia.400mm | 30.74 | US$ per meter | novafort PAVCO 400mm |
| | Perforated type, Dia.300mm | 15.04 | US$ per meter | novafor PAVCO 315mm |
| | Perforated type, Dia.200mm | 7.25 | US$ per meter | novafort PAVCO 200mm |

**Table 4.2 Unit Cost by Design and Cost estimation of Pilot Project in Campo Florido**

| Items | Specification | unit | Amount | Unit Price (CUP) | Note |
|---|---|---|---|---|---|
| Boundary Wire Fence | Barbed -wire Fence | m | 950 | 14,051.29 | |
| | | m | 1 | 14.79 | |
| littering prevention equipment, Fence type | Installation Fence | m | 200 | 3,505.87 | |
| | Unit Cost per meter | m | 1 | 17.53 | |
| Slope Protection Work | Turfing Work, each 10m x 10m | m2 | 100 | 2.58 | |
| Net fence Installation Work | | m | 360 | 31,237.66 | |
| | Unit Cost per meter | m | 1 | 86.78 | |
| Entrance Gate setting work | | unit | 1 | 500.00 | |
| Administration office | RC column and block wall | m2 | 70 | 27,126.38 | |
| | Unit Cost | m2 | 1 | 387.52 | |
| Parking Area with Roof | Steel beam with slate a roof , 12m x 18 m | m2 | 216 | 31930.18 | |
| | Unit Cost | m2 | 1 | 147.83 | |
| Fuel Tank | 1500Liters of Steel tank with RC column | Liter | 1500 | 3110.13 | |
| | Unit Cost | Liter | 1000 | 2073.5 | |
| Parking Area for visitors | Concrete pavement ,2.5m x 9m = 18.5m2 | m2 | 18.5 | 11837.06 | |
| | Unit Cost | m2 | 1 | 639.85 | |
| Asphalt pavement | thickness asphalt is 5cm, thickness of road bed is 18cm | m2 | 1542 | 11416.91 | |
| | Unit Cost | m2 | 1 | 7.41 | |

## 5. Existing Topographical Landfill Map

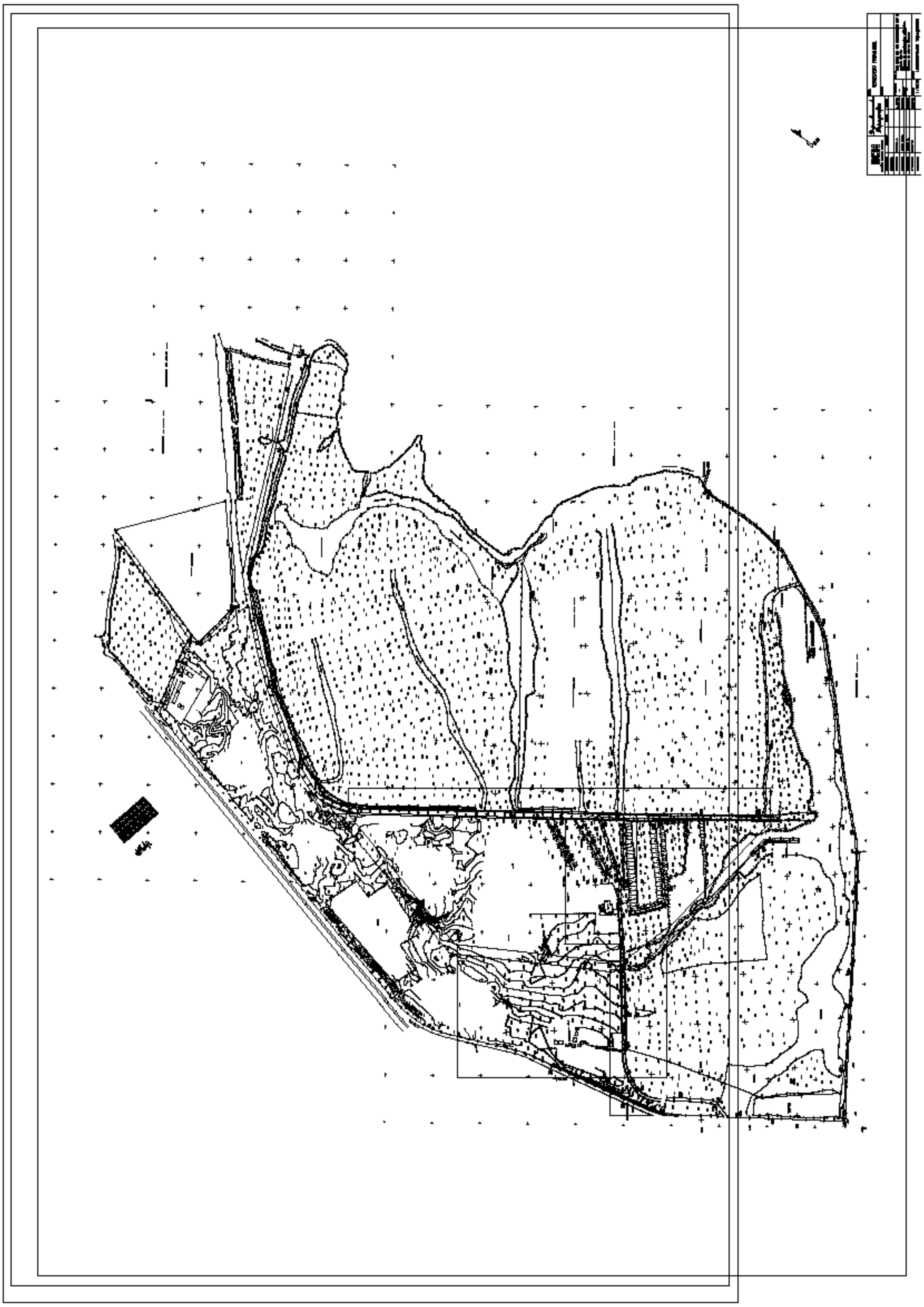


**Figure 5.1 Topographical Map of Calle 100 Landfill**

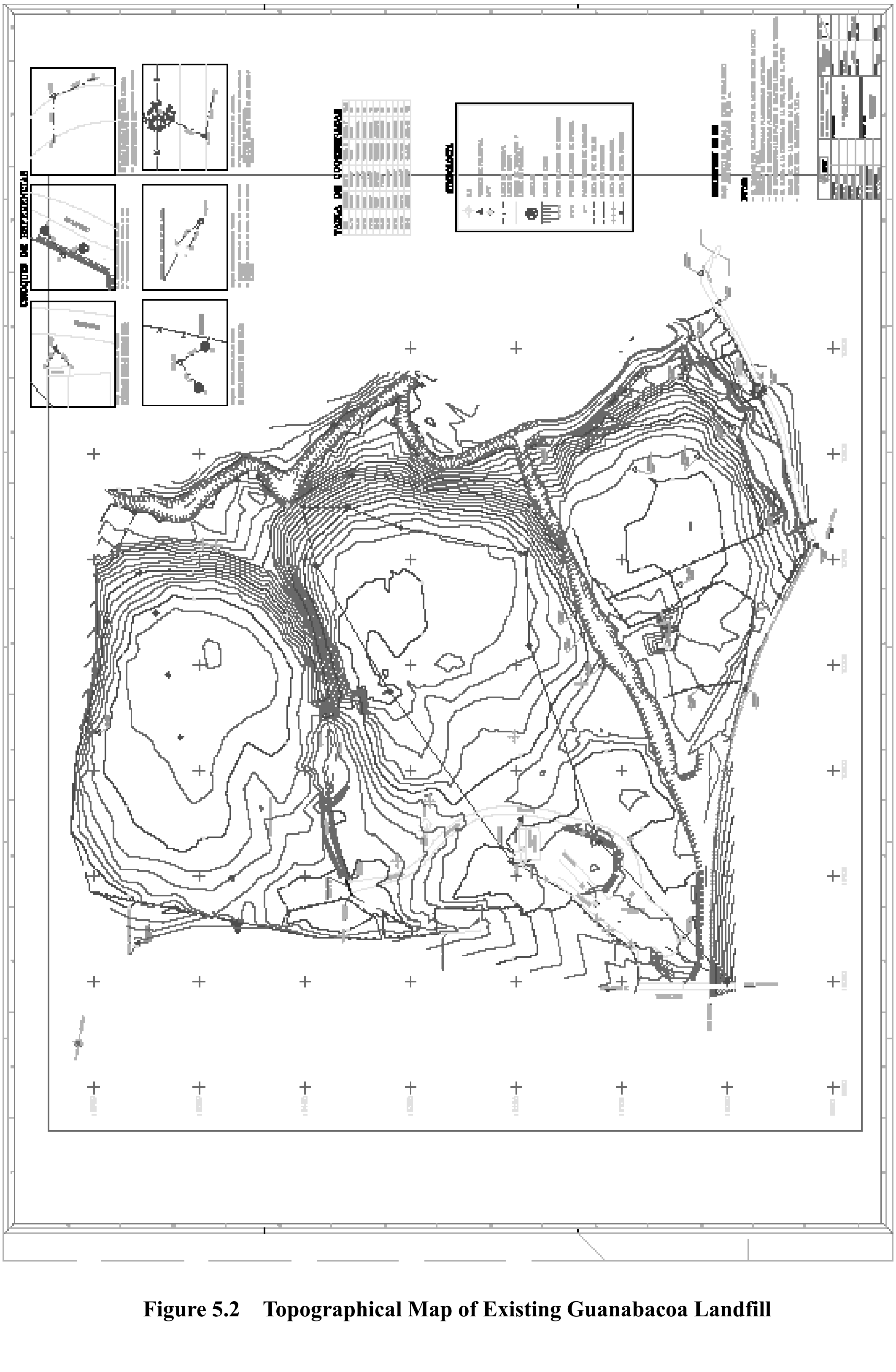


**Figure 5.2 Topographical Map of Existing Guanabacoa Landfill**

# 6. Method of Operation for Second Layer in Campo Florido PLP site

**# 1 ro** **Esta tapando de piso 1ro** Pagina #01

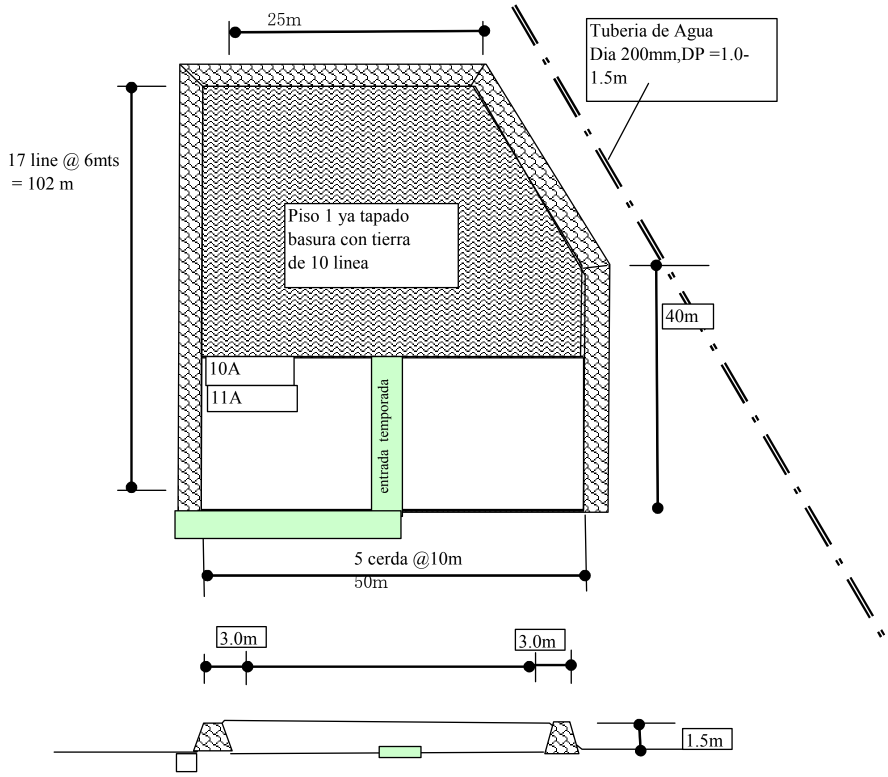
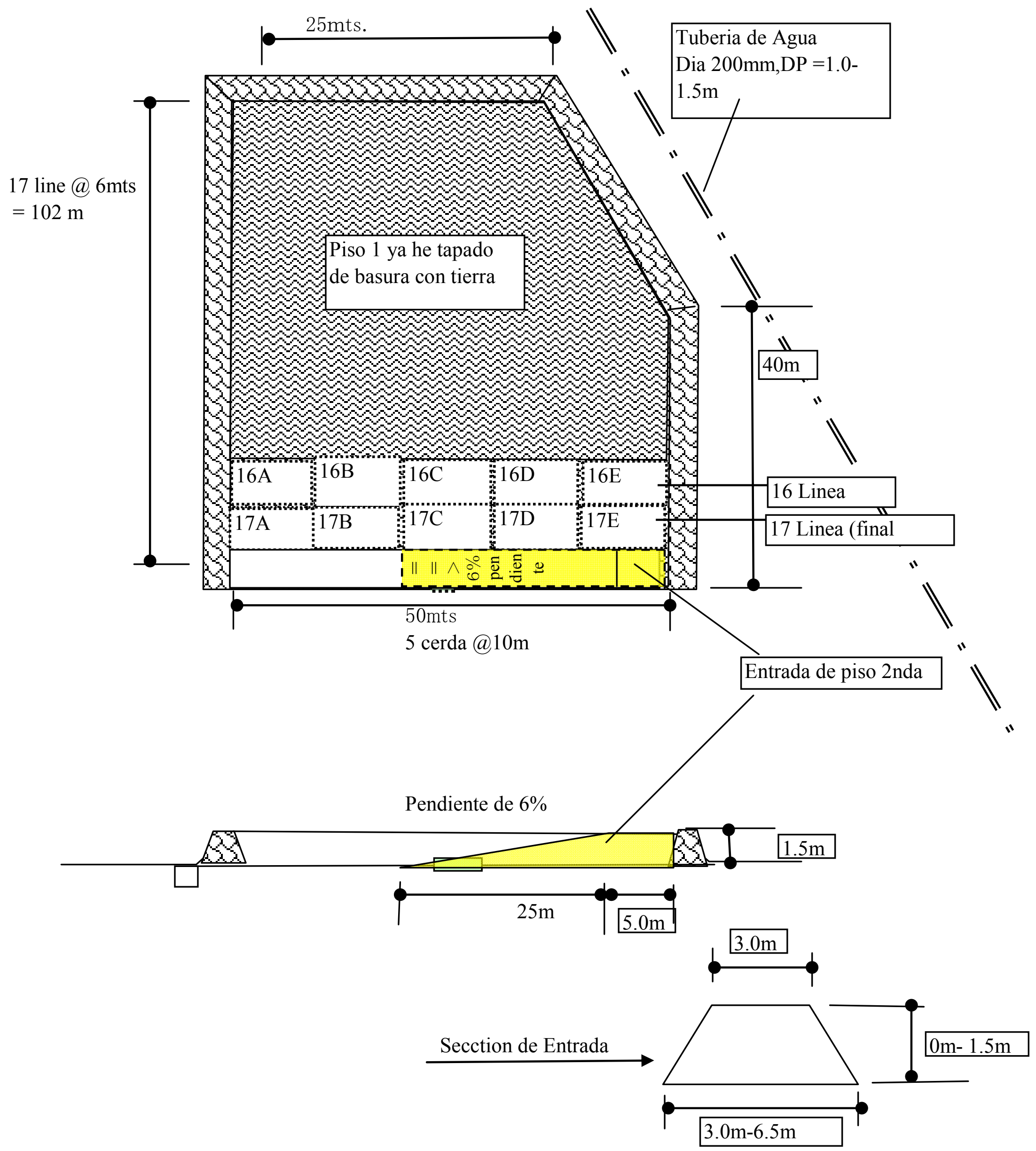



**Figure 6.1 Cover Soil Operation in Campo Frorido PLP Site (1)**

**#2 nd** **Prepara de Entrada para piso 2ndo** Pagina #02

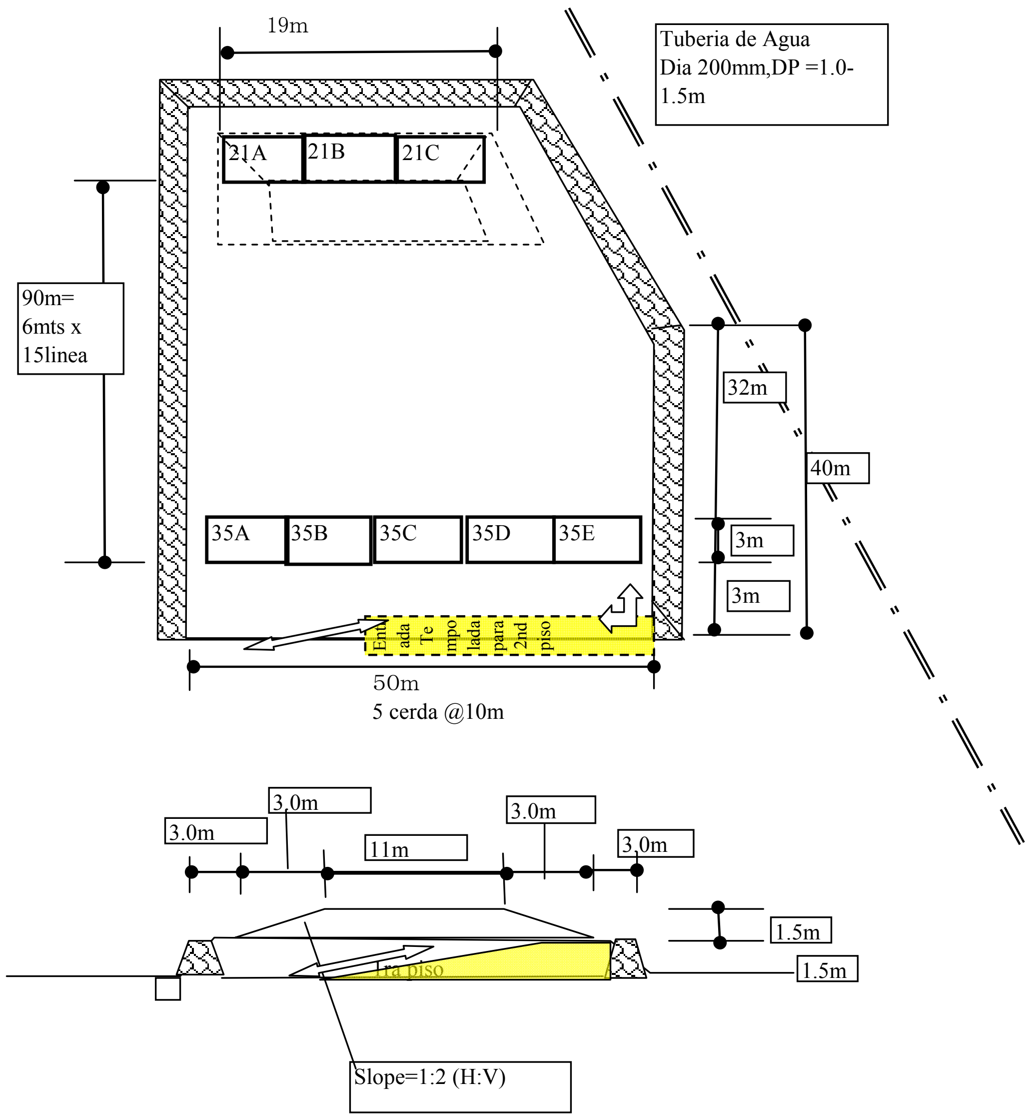



1.Cuand llena de Cerda 16-D, Construcir el entrada para 2nda Piso de tierra de cantera
2. La Entrada de Vehiclo tiene #A.0m de Ancho
3.En Linea 16 y 17(final) ,se Cambian turno de tapado,como sigeuente,
16E =>17E=>16D=>17D=>16C=>17C=>16B=>16A=>17B=>17A
4.La Enrtada Talud de Piso 2nda va empesar la costruction acabo de llenado de la Cerda de 17E.

**Figure 6.2 Cover Soil Operation in Campo Frorido PLP Site (2)**

**#3 ro** **Enpesar Cubierto piso segundo**

Pagina #03




1.Tamanyo de Carda son 6mts de Larga, 10mts de Ancho

**Figure 6.3 Cover Soil Operation in Campo Frorido PLP Site (3)**

**#4 to** **Llenado en el Piso 2ndo**

Pagina #04

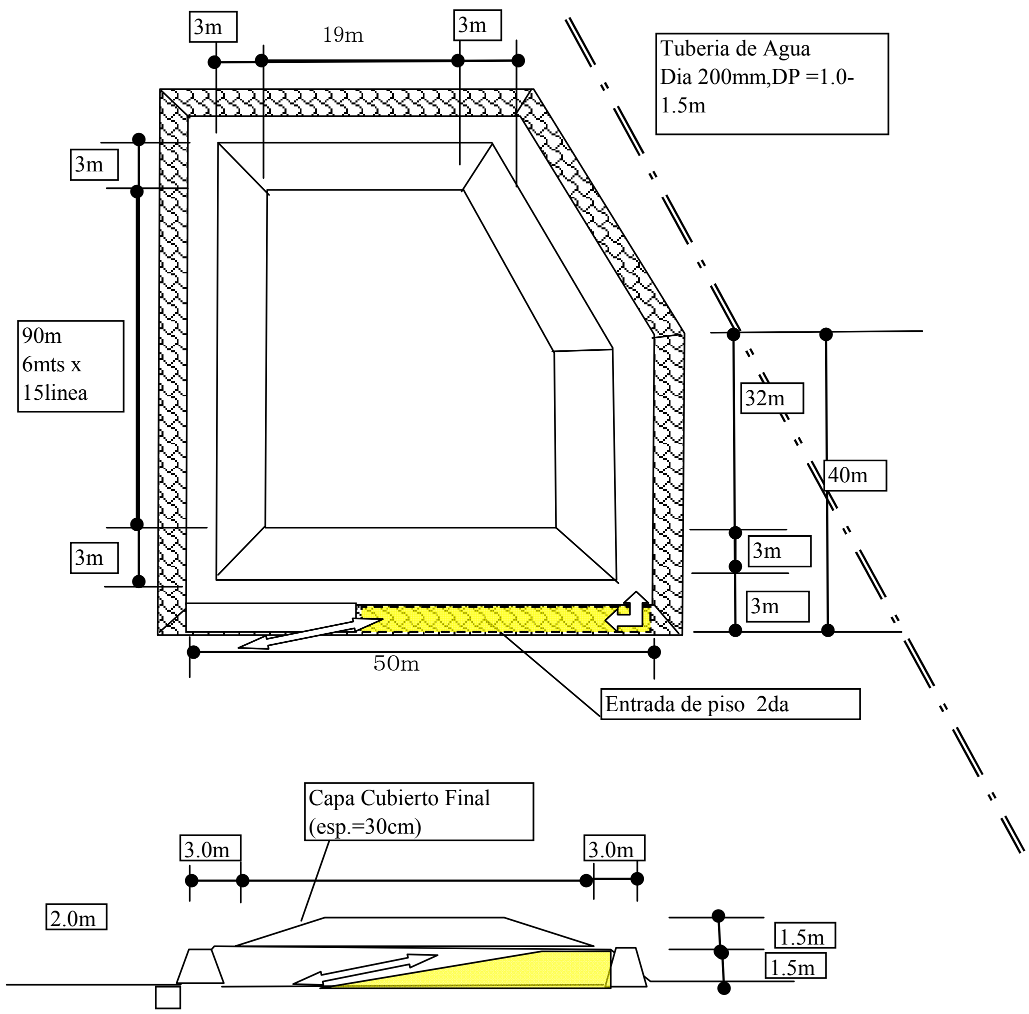



**Figure 6.4 Cover Soil Operation in Campo Frorido PLP Site (4)**

**#5 to Cubierto final de Piso 2nda**

Pagina #05

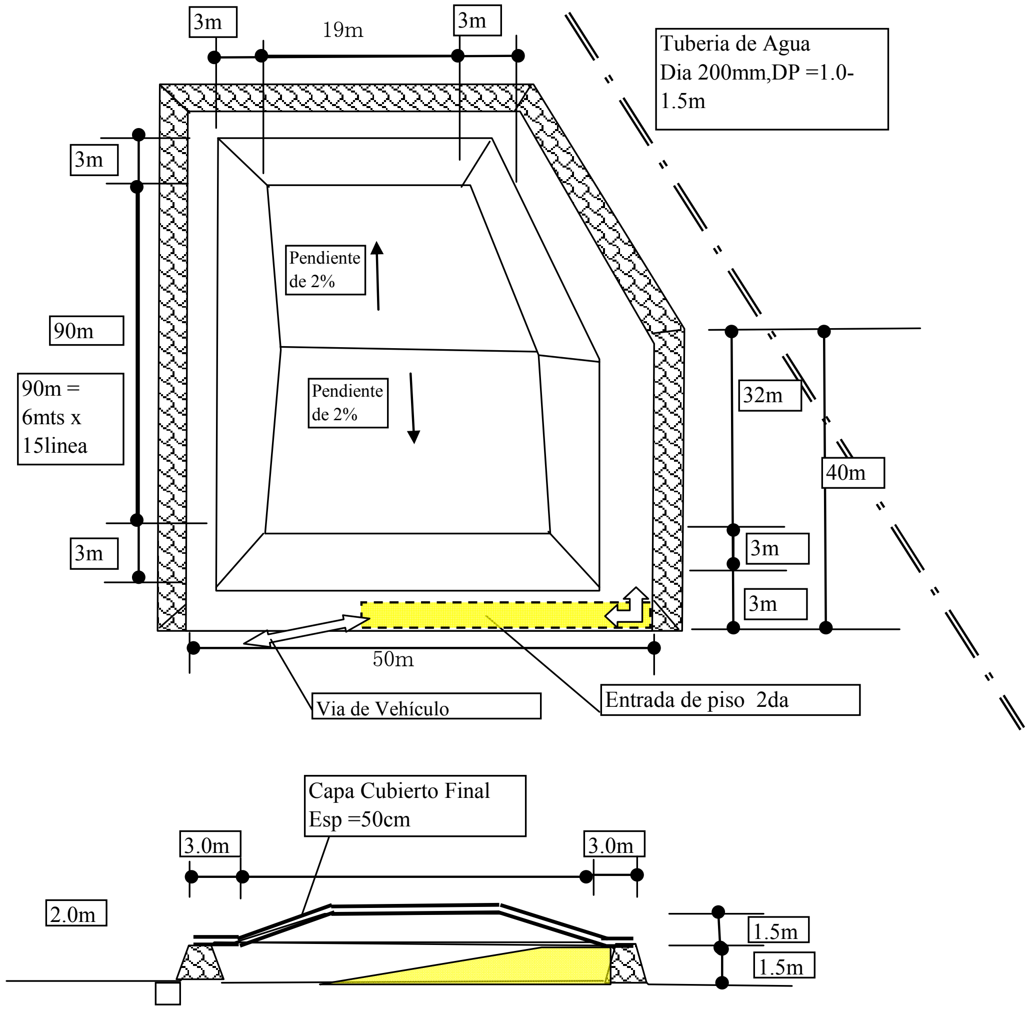



**Figure 6.5 Cover Soil Operation in Campo Frorido PLP Site (5)**

**#6 to** **Cubierto final de Piso 2nda**

Pagina #06

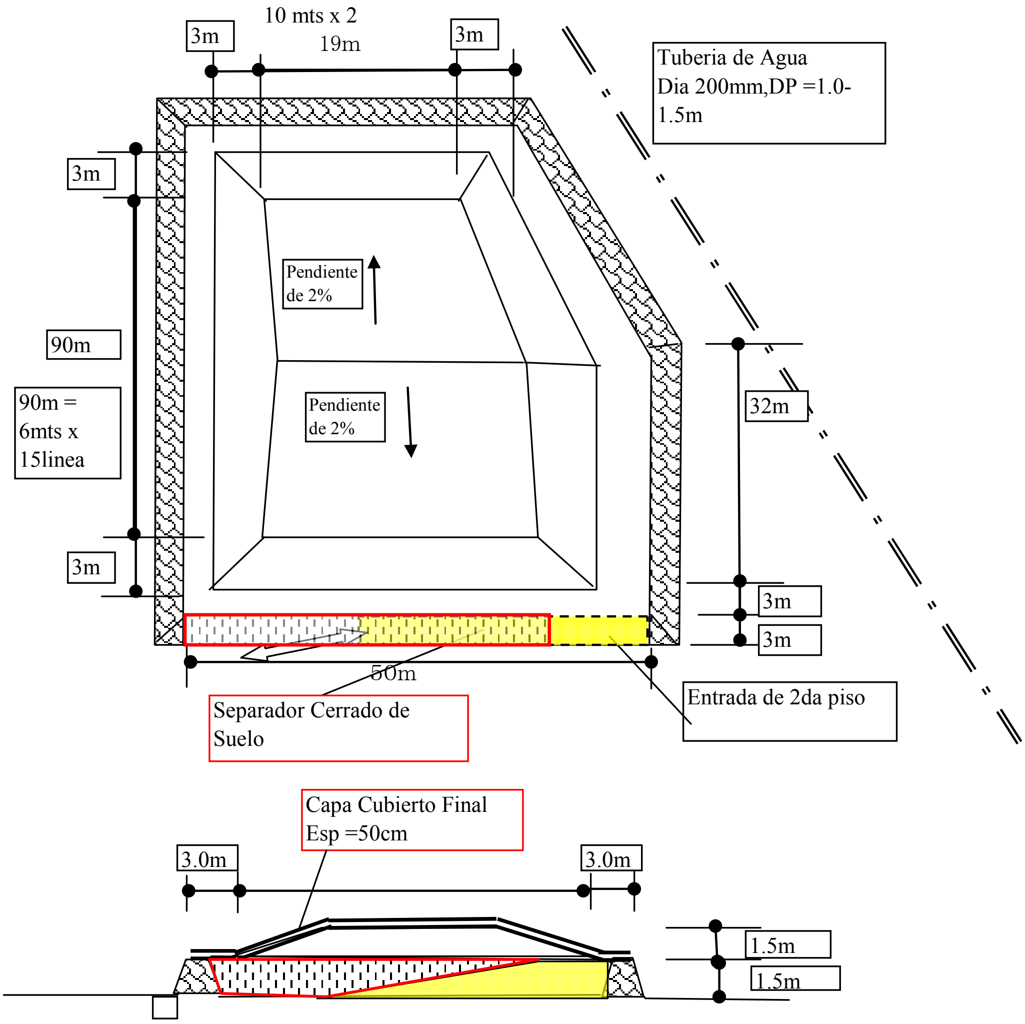
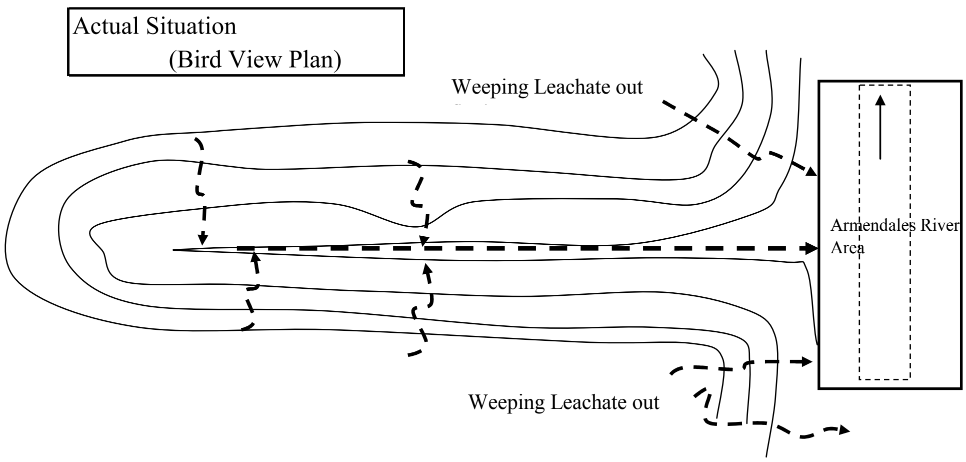



**Figure 6.6 Cover Soil Operation in Campo Frorido PLP Site (6)**

# 7. Improvement plan of Calle100 Landfill existing area at the Almendares riverside



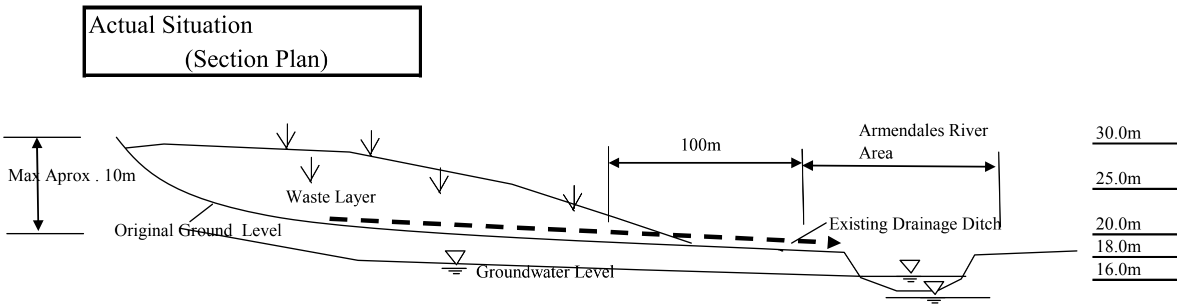




**Figure7.1 Actual Situation**

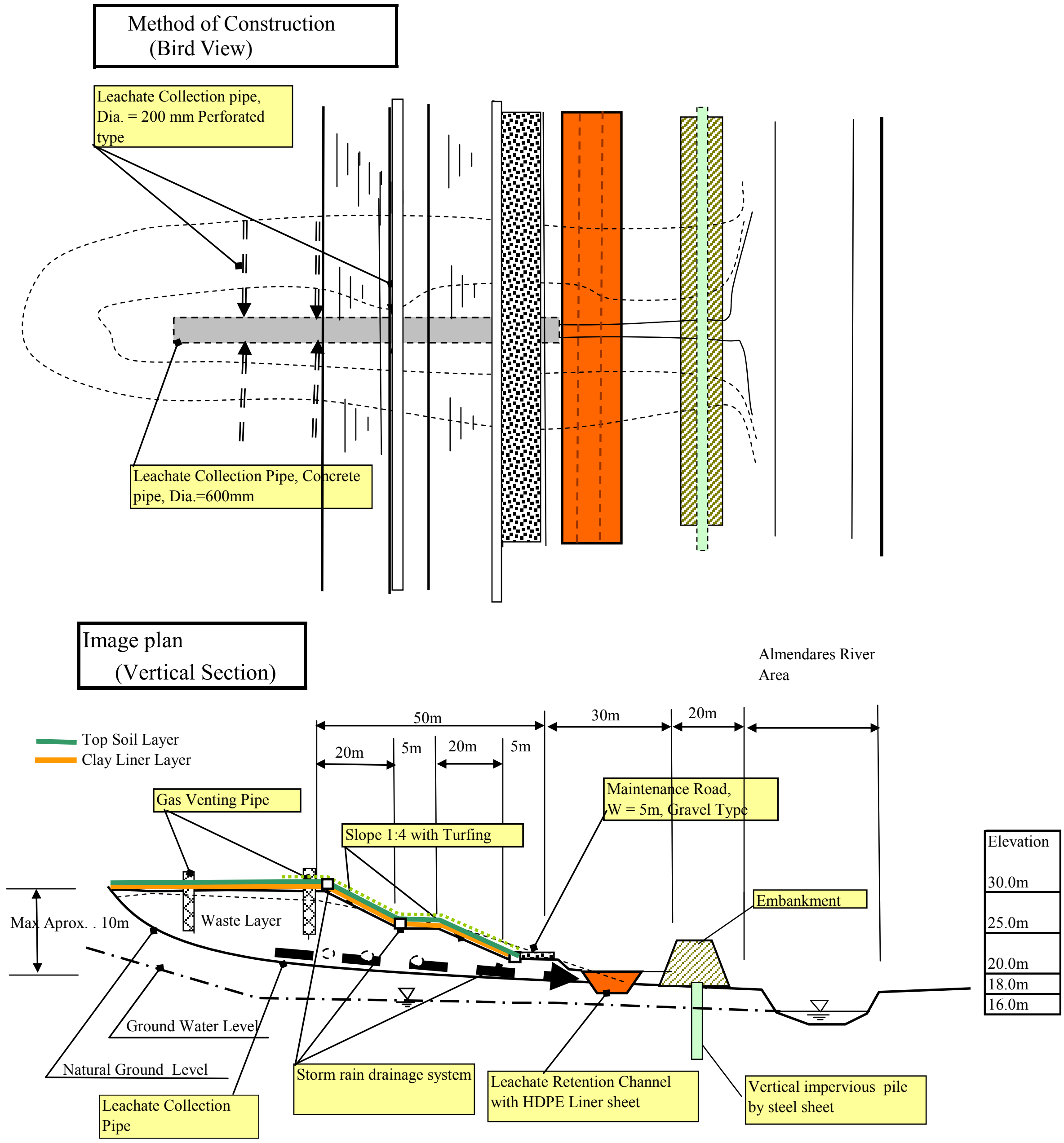



**Figure7.2 Proposed Implementation Plan**

# C. Final Disposal:

## C4 Cost of Leachate Treatment Alternatives

# C4 COST OF LEACHATE TREATMENT ALTERNATIVES

## Leachate Treatment alternatives for the Expansion of Calle 100

**Alternative 1: Aerated Lagoon + Maturation Pond with recirculation -calle100 Expansion**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is the same as the one which was adopted in the original pilot project in Campo Florido. However, an aerated lagoon alone cannot remove T-$BOD_5$ and SS. Therefore, a maturation pond after the aerated lagoon is proposed.

### 1. Assumptions

1.1 There are no discharge quality criteria for treated leachate. Therefore, the following temporary criteria were proposed.

**Table 1 Proposed Waste Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria will be established in the future, only T-$BOD_5$ and SS are removed by this system.

There are formulas for estimating leachate generation, including one that considers evaporation; however, in the case of using a pond system as the final treatment, the pond volume is designed ignoring evaporation.

1) Leachate generation

Landfill Area

| | | | |
|---|---|---|---|
| Stage1 | A1 | 10.1 ha | 10,800 $m^2$ |
| Stage2 | A2 | 8.4 ha | 8,400 $m^2$ |
| Stage3 | A3 | 0.0 ha | 0 $m^2$ |

Once the surface liner facility is constructed in the landfill site, it is assumed that no water flows into the landfill site

q =f*C*A*I/1000 ($m^3$/day)

Where
q: Daily effluent amount of leachate water ($m^3$/day)
c: Leachate coefficient of on-going landfill section 0.4
l: Annual maximum rainfall (mm/day)
Maximum rainfall during 2000 to 2002 38 mm in September, 2002
11.3 mm/day
A: Landfill area ($m^2$)
f: Safety factor 16
Q: Daily effluent amount of leachate with safety factor ($m^3$/day)

**Table 2 Proposed Leachate Volume**

| Q ($m^{3/}day$) | Stage1 | Stage2 | Stage3 |
|---|---|---|---|
| | 730 | 610 | 0 |

## 2. Leachate treatment

### 2.1 Aerated Lagoon Process Design

Design Base:

| | Symbol | Unit | |
|---|---|---|---|
| Influent flow | Q | $m^3/d$ | |
| Influent suspended solids | SS0 | mg/L | 540 |
| Influent soluble $BOD_5$ | S0 | mg/L | 920 |
| Effluent soluble $BOD_5$ | S-$BOD_5$ | mg/L | 30 |
| Effluent suspended solids after settling | SSe | mg/L | 70 |
| Kinetic coefficients: | | I/d | 0.65 |
| Y | | mg-$BOD_5$/L | 100 |
| Ks | | mg-$BOD_5$/L/d | 6.0 |
| Kmax | | I/d | 0.07 |
| Kd | k （20） | I/d | 2.5 |
| First order soluble BoD5 removal rate constants at 20 °C | Ti | °C | 21.0 |
| Waste water temperature | | | |
| in leachate | α | | 0.6 |
| in treated water | B | | 0.9 |
| Oxygen concentration to be maintained in liquid | | mg-$O_2$/L | 1.5 |
| Lagoon depth | H | m | 3.5 |
| Design mean cell - residence time | θc | d | 14 |

### 2.2 Surface area of the lagoon

θc = V/Q ∴θc*Q V: volume of the lagoon

A=V/H

Dimensions

**Table 3 Dimensions of Aerated Lagoon**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| V | $m^3$ | 10,220 | 8,540 | - |
| A | $m^2$ | 2,920 | 2,440 | - |
| L | m | 90 | 90 | - |
| W | m | 35 | 30 | - |
| H | m | 3.5 | 3.5 | - |
| A'(Connected A) | $m^3$ | 3,150 | 200 | - |
| V'(Connected V) | $m^2$ | 11,100 | 9,500 | - |

Number of lagoon:1

2.3 Soluble effluent $BOD_5$ at the lagoon outlet: S-$BOD_5$-out

S-$BOD_5$ out = {Ks (1+θc*kd)}/ { θc (Y*kmax-kd)-1}(mg/L)

| Ks | θc*kd | 1+θc*kd | Ks (1+θc*kd) | θc | Y*kmax | Y*kmax-kd | θc (Y*kmax-kd)-1 | S-$BOD_5$ out |
|---|---|---|---|---|---|---|---|---|
| 100 | 0.98 | 1.98 | 198 | 14 | 3.9 | 3.83 | 52.6 | 3.8 |

2.4 Effluent $BOD_5$

1) Correct the removal-rate for temperature effects

k(t)=k(20)*θT-20

| Ti | $k_{(20)}$ | T-20 | θ | $\theta^{(T-20)}$ | $k^{(20)\theta(T-20)}$ |
|---|---|---|---|---|---|
| 21.0 | 2.5 | 1 | 1.06 | 1.06 | 2.7 |

2) Determine the effluent $BOD_5$: St-out (mg/L)

| kt | V/Q | 1+kV/Q | 1/(1+kV/Q) | $S_0$ | St-out |
|---|---|---|---|---|---|
| 2.7 | 14 | 38.10 | 0.03 | 920 | 24 |

2.5 Concentration of biological solids produced: X(mg.L)

X=Y($S_0$-S-$BOD_5$-out)/(1+kdθc)(mg-VSS/L)

| Y | $S_0$-S-$BOD_{5\text{-out}}$ | kd | θc | Y($S_0$-S-$BOD_{5\text{-out}}$)/(1+kdθc) |
|---|---|---|---|---|
| 0.65 | 916.2 | 0.07 | 14 | 301 |

2.6 Suspended solids in the lagoon before settling

SSi=Influent suspended solids + X/0.7 (mg/L)

| SSo | X | SSi |
|---|---|---|
| 540 | 301 | 970 |

Ratio of volatile suspended solids 0.7

2.7 Oxygen requirements

$Q_2$(kg/d)=Q($S_0$-S-$BOD_{5\text{-out}}$)/f-1.42Px

f: conversion factor for $BOD_5$ to BODL 0.68

Px =Q*(concentration of biological solids produced)

**Table 4 Required $O_2$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| $S_0$-S-$BOD_{5\text{-out}}$ | mg/L | 916 | 916 | - |
| f | - | 0.68 | 0.68 | - |
| Px | kg/day | 220 | 183 | - |
| Required $O_2$ | kg/day | 672 | 561 | - |

2.8 Ratio of oxygen required to $BOD_5$ removed

$BOD_5$ removed (kg/d)

$O_2$/$BOD_5$ removed

**Table 5 Removed $BOD_5$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| $S_0$-S-$BOD_{5\text{-out}}$ | mg/L | 916 | 916 | - |
| $BOD_5$ removed | kg/day | 669 | 559 | - |
| $O_2$/$BOD_5$ | - | 1.0 | 1.0 | - |

2.9 Surface aerator power requirements

assumption: kg-$O_2$/kw/h kg-$O_2$/kw/h No 1.6

a) Correction factor for surface aerators for summer conditions f

f=No. /N

1) Oxygen saturation concentration at 21 °C Cs(21) mg/L 8.91

2) Cs(20) mg/L 9.08

3) Do concentration in Lagoon $C_L$ mg/L 1.5

f={B*CsT-CL}/Cs(20)*1.024T-20*α}

| Ti-20 | $1.024^{T-20}$ | α | B | f |
|---|---|---|---|---|
| 1 | 1.029 | 0.6 | 0.9 | 0.44 |

b) Field transfer rate: N

N=fNo kg-$O_2$/kw/h 0.71

Total amount of transfer $O_2$ kg-$O_2$/kw/d kg-$O_2$/kw/h 17.0

The total axis power required to meet the required oxygen

**Table 6 Required $O_2$ Supply**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Required $O_2$ | kg/day | 672 | 561 | - |
| Required power for $O_2$ supply | kw | 39.5 | 33.0 | - |

## 2.10 Energy requirements for mixing

**Table 7 Specifications of Aerator**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Power for Mixing | kW/m$^3$ | 0.005 | 0.005 | - |
| Lagoon volume | m$^3$ | 11,100 | 9,500 | - |
| Axis power for mixing | kW | 55.5 | 47.5 | - |
| Total efficiency | - | 0.75 | 0.75 | - |
| Required power | kW | 74 | 63 | - |
| Unit Power | kW/No. | 15 | 15 | - |
| No. of Aerators | Nos. | 6 | 5 | - |

# 3. Solid separation for aerated lagoon

## 3.1 Design Base:

1) Process: maturation pond

2) HRT (days): t

3) Depth (m) D

Necessary Area (m$^2$) A

A=Qt/d

Volume of the maturation pond (m$^3$) V

V=A*D0

The effluent SS may be expected to be at about 50-100 mg/L

Dimension Length L

width W

Height H

**Table 8 Dimensions of Maturation Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | m$^{3/}$day | 730 | 610 | - |
| t | days | 14 | 14 | - |
| V | m$^3$ | 10,220 | 8,540 | - |
| No.of Pounds | - | 2 | 2 | - |
| $D_0$ | m | 1.5 | 1.5 | - |
| A/pond | m$^2$ | 3,450 | 2,850 | - |
| D/pond | m | 100 | 90 | - |
| W/pond | m | 35 | 35 | - |
| A'(corrected A)/pond | m$^2$ | 3,500 | 3,150 | - |

# 4. Leachate recirculation pump

1) Recirculation rate r times/leachate

Recirculation pump flow Qr m$^3$/day

Qr = r*Q

| | | |
|---|---|---|
| Required Power | Ps | |
| ps=0.163*Qr(m³/min)*H(m)/ŋ | Hose power | |

Here

| | | |
|---|---|---|
| Total head of the pump | H | m |
| Total efficiency | ŋ | |
| Liquid density | ρs | 1.05 |

From the entrance of aerated lagoon to landfill

**Table 9 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 2,190 | 1,830 | - |
| | $m^3$/min | 1.52 | 1.27 | - |
| Head | m | 50 | 50 | - |
| ŋ | - | 0.56 | 0.56 | - |
| Ps | Horse power | 23.2 | 19.4 | - |
| | kW | 17.4 | 14.6 | - |
| Unit power | kW/No. | 19 | 19 | - |
| Nos.of pumps | Nos. | (1+1) | (1+1) | - |

## 5. Sludge accumulation

5.1 Mass of sludge accumulated in the basin each year without anaerobic decomposition

Mass=(SSi-SSe)(g/$m^3$)*$10^{-3}$(kg/g)*q($m^3$/day)*365(day/year)

SSi : SS from aerated lagoon

SSe : SS after solid separation

VSS: Volatile solids of the mass to be decomposition = 0.7*mass

Fixed solid = Mass-Volatile

**Table 10 Accumulated Sludge**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| SSi | mg/L | 970 | 970 | - |
| SSe | mg/L | 70 | 70 | - |
| Q | $m^3$/min | 730 | 610 | - |
| Mass | kg/year | 239,800 | 200,400 | - |
| Vss | kg/year | 168,000 | 141,000 | - |
| Fixed solid | kg/year | 71,800 | 59,400 | - |

5.2 Amount of sludge to be accumulated at the end of ty years

Assumption

1) Maximum volatile solids reduction 75 %

2) it will occur within 1 year

3) deposited volatile suspended solids undergo a liner decomposition

Mass of volatile suspended solids accumulated at the end of 2 year:

(VSS)t = {0.75+0.25(t-1)}*VSS kg

Total mass of solids accumulated at the end of ty1 year

SSt=Vsst + ty*Fixed solid kg

**Table 11 Accumulated Volatile Suspended Solids**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| VSS | kg/year | 168,000 | 141,000 | - |
| ty | year | 2 | 2 | - |
| (Vss)t | kg | 159,600 | 133,950 | - |
| SSt | kg | 303,200 | 252,750 | - |

5.3 Required liquid volume and the dimensions for the sedimentation basin

1) Volume of sedimentation basin:V $m^3$

$V=t*q(m^3/d)$

2) Surace area of the sedimentation basin A $m^2$

3) Effective depth of the solid -liquid separation m

**Table 12 Required Liquid Volume**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| V | $m^3$ | 10,220 | 8,540 | - |
| A' | $m^2$ | 7,000 | 6,300 | - |
| D1 | m | 1.0 | 1.0 | - |

5.4 Depth required for the storage of sludge

1) the mass of accumulated sludge per square meter $kg/m^2$

Accumulated mass of sludge: SSt kg

mass per unit area $kg/m^2$

**Table 13 Accumulated Sludge per Square Meter**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| SSt | kg | 303,200 | 252,750 | - |
| A' | $m^2$ | 7,000 | 6,300 | - |
| SSt/A | $kg/m^2$ | 43 | 40 | - |

2) Required depth

Vds: deposited solids accumulated %

ρs: density of the sludge: $ton/m^3$

The volume of sludge: Vsst ($m^3$)

0.15*Vsst ($m^3$)*1.06*103($kg/m^3$) =SSt(kg)

Hs: the height of the sludge zone (m)

Vsst=H*A Hs=Vsst/A m

**Table 14 Required Depth**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Vds | % | 15 | 15 | - |
| $\rho_s$ | $ton/m^3$ | 1.06 | 1.06 | - |
| SSt | kg | 303,200 | 252,750 | - |
| Vsst | $m^3$ | 1,907 | 1,590 | - |
| A | $m^2$ | 7,000 | 6,300 | - |
| Hs | m | 0.27 | 0.25 | - |

**Alternative 2: Aerated Lagoon + Sedimentation Tank + Wetland with recirculation-Calle 100 Expansion**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is the same as the one which was adopted in the original pilot project in Campo Florido. However an aerated lagoon alone cannot remove T-$BOD_5$ and SS. Therefore a sedimentation pond and wetland were proposed.

## 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 15 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of T-$BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1) Leachate generation

Landfill Area

| | | | |
|---|---|---|---|
| Stage1 | A1 | 10.1ha | 10,800 $m^2$ |
| Stage2 | A2 | 8.4 ha | 8,400 $m^2$ |
| Stage3 | A3 | 0.0 ha | 0 $m^2$ |

Once surface liner facility is constructed in landfill site, it is assumed that no water flows into the landfill site

q =f*C*A*I/1000($m^3$/day)

Where

q: Daily effluent amount of leachate water($m^3$/day)

c: Leachate coefficient of on-going landfill section 0.4

l: Annual maximum rainfall (mm/day)
Maximum rainfall during 2000 to 2002 38mm in September in 2002
11.3mm/day

A: Landfill area ($m^2$)

f: Safety factor 16

Q: Daily effluent amount of leachate with safety factor ($m^3$/day)

**Table 16 Proposed Leachate Volume**

| Q ($m^3$/day) | Stage1 | Stage2 | Stage3 |
|---|---|---|---|
| | 730 | 610 | 0 |

# 2. Leachate treatment

## 2.1 Aerated Lagoon Process Design

Design Base:

| | Symbol | Unit | |
|---|---|---|---|
| Influent flow | Q | $m^3/d$ | |
| Influent suspended solids | SS0 | mg/L | 540 |
| Influent soluble $BOD_5$ | S0 | mg/L | 920 |
| Effluent soluble $BOD_5$ | S-$BOD_5$ | mg/L | 30 |
| Effluent suspended solid after settling | SSe | mg/L | 70 |
| Kinetic coefficients: | | I/d | 0.65 |
| Y | | mg-$BOD_5$/L | 100 |
| Ks | | mg-$BOD_5$/L/d | 6.0 |
| Kmax | | I/d | 0.07 |
| Kd | k（20） | I/d | 2.5 |
| First order soluble $BOD_5$ removal rate constants at 20 °C | Ti | °C | 21.0 |
| Waste water temperature | | | |
| in leachate | α | | 0.6 |
| in treated water | B | | 0.9 |
| Oxygen concentration to be maintained in liquid | | mg-02/L | 1.5 |
| Lagoon depth | H | m | 3.5 |
| Design mean cell - residence time | θc | d | 14 |

## 2.2 Surface area of the lagoon

θc = V/Q ∴θc*Q V: volume of the lagoon

A=V/H

Dimension

**Table 17 Dimensions of Aerated Lagoon**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| V | $m^3$ | 10,220 | 8,540 | - |
| A | $m^2$ | 2,920 | 2,440 | - |
| L | m | 90 | 90 | - |
| W | m | 35 | 30 | - |
| H | m | 3.5 | 3.5 | - |
| A'(Connected A) | $m^3$ | 3,150 | 200 | - |
| V'(Connected V) | $m^2$ | 11,100 | 9,500 | - |

Number of lagoon:1

## 2.3 Soluble effluent $BOD_5$ at the lagoon outlet: S-$BOD_5$-out

S-$BOD_5$ out = {Ks (1+θc*kd)}/ { θc (Y*kmax-kd)-1}(mg/L)

| Ks | θc*kd | 1+θc*kd | Ks (1+θc*kd) | θc | Y*kmax | Y*kmax-kd | θc (Y*kmax-kd)-1 | S-$BOD_5$ out |
|---|---|---|---|---|---|---|---|---|
| 100 | 0.98 | 1.98 | 198 | 14 | 3.9 | 3.83 | 52.6 | 3.8 |

## 2.4 Effluent $BOD_5$

1) Correct the removal-rate for temperature effects

k(t)=k(20)*θT-20

| Ti | $k_{(20)}$ | T-20 | θ | $\theta^{(T-20)}$ | $k^{(20)\theta(T-20)}$ |
|---|---|---|---|---|---|
| 21.0 | 2.5 | 1 | 1.06 | 1.06 | 2.7 |

2) Determine the effluent $BOD_5$: St-out (mg/L)

| kt | V/Q | 1+kV/Q | 1/(1+kV/Q) | $S_0$ | St-out |
|---|---|---|---|---|---|
| 2.7 | 14 | 38.10 | 0.03 | 920 | 24 |

## 2.5 Concentration of biological solids produced: X (mg.L)

X=Y ($S_0$-S-$BOD_5$-out)/ (1+kdθc) (mg-VSS/L)

| Y | $S_0$-S-$BOD_{5\text{-out}}$ | kd | θc | Y($S_0$-S-$BOD_{5\text{-out}}$)/(1+kdθc) |
|---|---|---|---|---|
| 0.65 | 916.2 | 0.07 | 14 | 301 |

## 2.6 Suspended solids in the lagoon before settling

SSi =Influent suspended solids + X/0.7(mg/L)

| SSo | X | SSi |
|---|---|---|
| 540 | 301 | 970 |

Ratio of volatile suspended solid 0.7

## 2.7 Oxygen requirements

$Q_2$ (kg/d)=Q($S_0$-S-$BOD_{5\text{-out}}$)/f-1.42Px

f: conversion factor for $BOD_5$ to BODL 0.68

Px =Q*(concentration of biological solids produced)

**Table 18 Required $O_2$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| $S_0$-S-$BOD_{5\text{-out}}$ | mg/L | 916 | 916 | - |
| f | - | 0.68 | 0.68 | - |
| Px | kg/day | 220 | 183 | - |
| Required $O_2$ | kg/day | 672 | 561 | - |

2.8 Ratio of oxygen required to $BOD_5$ removed

$BOD_5$ removed (kg/d)

$O_2$/$BOD_5$ removed

**Table 19 Removed $BOD_5$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| $S_0$-S-$BOD_{5\text{-out}}$ | mg/L | 916 | 916 | - |
| $BOD_5$ removed | kg/day | 669 | 559 | - |
| $O_2$/$BOD_5$ | - | 1.0 | 1.0 | - |

2.9 Surface aerator power requirements

assumption: kg-$O_2$/kw/h kg-$O_2$/kw/h No 1.6

a) Correction factor for surface aerators for summer conditions f

f=No. /N

1) Oxygen saturation concentration at 21 °C Cs(21) mg/L 8.91

2) Cs(20) mg/L 9.08

3) Do concentration in Lagoon $C_L$ mg/L 1.5

f= {B*CsT-CL}/ Cs (20)*1.024T-20*α}

| Ti-20 | $1.024^{T-20}$ | α | B | f |
|---|---|---|---|---|
| 1 | 1.029 | 0.6 | 0.9 | 0.44 |

b) Field transfer rate : N

N=fNo kg-$O_2$/kw/h 0.71

Total amount of transfer $O_2$ kg-$O_2$/kw/d kg-$O_2$/kw/h 17.0

The total axis power required to meet the required oxygen

**Table 20 Required $O_2$ Supply**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Required $O_2$ | kg/day | 672 | 561 | - |
| Required power for $O_2$ supply | kw | 39.5 | 33.0 | - |

## 2.10 Energy requirements for mixing

**Table 21 Specifications of Aerator**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Power for Mixing | $kW/m^3$ | 0.005 | 0.005 | - |
| Lagoon volume | $m^3$ | 11,100 | 9,500 | - |
| Axis power for mixing | kW | 55.5 | 47.5 | - |
| Total efficiency | - | 0.75 | 0.75 | - |
| Required power | kW | 74 | 63 | - |
| Unit Power | kW/No. | 15 | 15 | - |
| No. of Aerator | Nos. | 6 | 5 | - |

# 3. Solid separation for aerated lagoon

## 3.1 Design Base:

1) Process: maturation pond

2) HRT (days): t

3) Depth (m) D

Necessary Area ($m^2$) A

A=Qt/d

Volume of the maturation pond ($m^3$) V

V=A*D0

The effluent SS may be expected to be at about 50-100 mg/L

Dimension Length L

width W

Height H

**Table 22 Dimension of Maturation Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^{3/}$day | 730 | 610 | - |
| t | days | 14 | 14 | - |
| V | $m^3$ | 10,220 | 8,540 | - |
| No.of Pounds | - | 2 | 2 | - |
| $D_0$ | m | 1.5 | 1.5 | - |
| A/pond | $m^2$ | 3,450 | 2,850 | - |
| D/pond | m | 100 | 90 | - |
| W/pond | m | 35 | 35 | - |
| A'(corrected A)/pond | $m^2$ | 3,500 | 3,150 | - |

# 4. Solid-liquid separation: sedimentation tank

Qi: Inflow $m^3$/day

Safety factor 3

R.t: Retention time at Qi*3 hr

OL: Overflow rate at Qi*3 $m^3/m^2/day$

Qi*Ci= Qo*Co+Qu*Cu

Ci: Inflow SS mg/L

Co: Outflow SS mg/L

Cu: Concentrated SS in the sedimentation tank mg/L

Qo: Outflow $m^3/day$

Qu: Underflow (Sludge flow) $m^3/day$

Qu=Qi-Qo $m^3/day$

Qo=Qi*(Cu-Ci) / (Cu-Co) $m^3/day$

As: surface area=Qo/OL $m^3$

Dimension Ls: Length of sedimentation tank m

Ws: Width of sedimentation tank m

Hs: Height of sludge zone =Vs/As m

Vs: Volume of sedimentation tank $m^3$

H2: Height allowance = Vs/As $m^2$

**Table 23 Dimension of sedimentation tank**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3/day$ | 730 | 610 | - |
| Qi | $m^3/day$ | 2,190 | 1,830 | - |
| RT | hr | 2 | 2 | - |
| OL | $m^3/m^2/day$ | 22 | 22 | - |
| Ci | mg/L | 970 | 970 | - |
| Co | mg/L | 70 | 70 | - |
| Cu | mg/L | 5,000 | 5,000 | - |
| Qo | $m^3/day$ | 1,800 | 1,500 | - |
| As | $m^2$ | 90 | 70 | - |
| Ls | m | 20 | 20 | - |
| Ws | m | 5 | 5 | - |
| Hs | m | 2.2 | 2.3 | - |
| Vs | $m^3$ | 190 | 160 | - |
| Qu | $m^3/day$ | 390 | 330 | - |
| H2 | m | 1.5 | 1.5 | - |
| H0 | m | 3.7 | 3.8 | - |

Total Height Ho=H2+Hs

Sludge is returned to land fill

Pump specification

Head

Liquid density

**5. To removal nutrients, use wetland.**

Only by aerated lagoon, only $BOD_5$ and SS are removed. For further treatment for nutrients another process is necessary.

Here, wetland was considered as an alternative for this purpose, considering cost efficiency.

Levels of nitrogen and phosphates are estimated as below based on the analysis of leachate during this Study.

| | | |
|---|---|---|
| Total-N: | 240 | mg/L |
| Total-P: | 64 | mg/L |

In biological treatment nitrogen and phosphate are necessary. The ratio of N and P towards $BOD_5$ is 3:0.3:100

Therefore N and P after biological treatment, their levels are expected as below.

| | | | |
|---|---|---|---|
| Inlet $BOD_5$ | | 920 | mg/L |
| Therefore N to be removed by biological treatment | | 27.6 | mg/L |
| After aerated lagoon remained N | N | 212 | mg/L |
| | P | 61 | mg/L |

| Criteria* | |
|---|---|
| 20 | mg/L. as KTN |
| 10 | mg/L. as P |

*:Discharge criteria of industrial waste water into general public water body

Inlet T-P level will be reduced by using cover soil.

Therefore, only removal of nitrogen would be considered.

Here, subsurface-flow (SSF) systems was considered.

In a SSF wetland, the basin is filled with gravel or some other coarse substrate, and the water level is maintained below-ground. Water flows horizontally, or sometimes vertically, through the gravel and the root mat of the wetland vegetation.

Arrow arum (Polyandry spp.) and Pickerel wee (Pontederia spp.) have been used in constructe wetlands.

Also common reed (Phragmitescommunis) is used

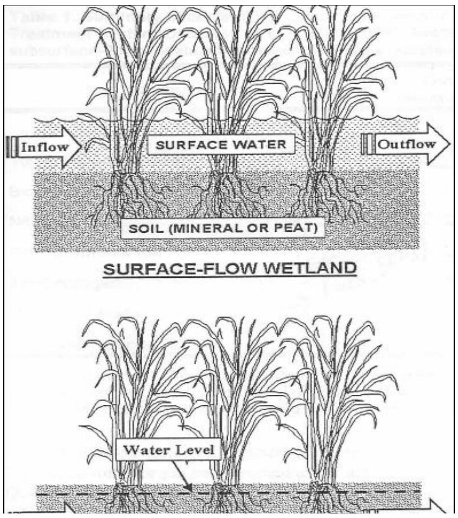



**Figure 1 Conceptual diagram of subsurface-flow wetlands**

**Example of determination of basin design for SFS wetlands system**

Nitrogen removal will proceed when $BOD_5$ level is less than 10 mg/L.

**1. Premises**

| | | |
|---|---|---|
| Influent $BOD_5$ | $C_0$ | 60 mg/L |
| Effluent $BOD_5$ | Q | $m^3$/day |
| | | $m^3$/day |
| Vegetation type | | cattails |
| Minimum water temperature | T | 21°C |
| Basin media | coarse sand with 2 mm of maximum effective size | |
| Basin slope | S | 0.01 |

**2. Solution**

| | | | |
|---|---|---|---|
| 1. | Basin depth for use wit cattail | d | 0.3m |
| 2. | Porosity | α | 0.39 |
| | Hydraulic conductivity | Ks | 480 $m^3/m^2$/day |
| | | $K_{20}$ | 1.35 |
| 3. | Temperature-dependent first order rate constant | | |
| | | $K_T$ at | 21°C |
| | | | 1.49 $d^{-1}$ |
| 4. | Pore-space detention time | $t^1$=-1nCe/C0/Kt | d |
| 5. | Cross-sectional area | AC=Q/Ks/S | $m^2$ |
| 6. | Basin width | W=Ac/d | m |
| 7. | Basin length | L=t'Q/W/d/α | m |
| 8. | Required surface area | As=L*W | $m^2$ |
| | | | ha |
| 9. | Check hydraulic-loading rate or specific area requirements | | |
| | | Lw = Q/L/W | 150 to 500 $m^3$/ha/day |
| | | | 0.015 to 0.005 $m^3/m^2$/day |
| | or | Asp= 1/Lw for advanced treatment 2.1 ha/$10^3m^3$ | |
| 10. | Check $BOD_5$ loading rate | Max.$BOD_{5L}$ | 60kg/ha/day |
| | $LBOD_5$ | | kg/day |
| | $BOD_{5L}$ | | kg/ha/day |
| 11. | Vegetation | | |
| | Reed can absprb | N | 18 to 21g/kg |
| | | P | 2.0 to 3.0 g/kg |
| | Inlet N | | 212.4 mg/L |
| | Vd: vegetation density | | 10 kg/$m^2$ |

**Table 24 Specification of Wetland**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| C0 | mg/L | 60 | 60 | - |
| Ce | mg/L | 8 | 8 | - |
| Q | $m^3$/day | 730 | 610 | - |
| T | °C | 21.0 | 21.0 | - |
| S | | 0.01 | 0.01 | - |
| d | m | 0.3 | 0.3 | - |
| α | | 0.39 | 0.39 | - |
| Ks | $m^3/m^2$/day | 480 | 480 | - |
| $K_{20}$ | | 1.35 | 1.35 | - |
| Kt | $d^{-1}$ | 1.49 | 1.49 | - |
| t' | day | 1.36 | 1.36 | - |
| Ac | $m^2$ | 1.52 | 1.27 | - |
| W | m | 510 | 430 | - |
| L | m | 17 | 16 | - |
| As | $m^2$ | 8,500 | 7,100 | - |
| Lw | $m^3/m^2$/day | 0.09 | 0.09 | - |
| Asp | ha/1000$m^3$ | 11.60 | 11.60 | - |
| L-$BOD_5$ | kg/day | 43.8 | 36.6 | - |
| $BOD_{5L}$ | kg/ha/day | 52 | 52 | - |
| V | $m^3$ | 2,550 | 2,130 | - |
| RT | day | 3.5 | 3.5 | - |
| Inlet N | mg/L | 212 | 212 | - |
| Total N in WL | g | 550,000 | 460,000 | - |
| N absorption | g/kg | 18 | 18 | - |
| Nos. of reed | kg | 30,556 | 2,556 | - |
| Vd | kg/$m^2$ | 10 | 10 | - |
| Max Reed | kg | 85,000 | 71,000 | - |

**Alternative 3: Natural Pond System (Anaerobic + Facultative + Maturation Pond) -Calle 100 Expansion**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is so called natural pond system to remove $BOD_5$, SS and nutrients such as N and P.

## 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 25 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of T-$BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1.2 Recirculation rate of leachate 3 times/day toward the leachate generated

## 2. Anaerobic pond

| | | | |
|---|---|---|---|
| RTa: Retention time of anaerobic pond | | | 7 days |
| $BOD_5$ Removal rate | | | 60% |
| $BOD_5$ out-a | | | 368 mg/L |
| Da: Depth of the anaerobic pond | | | 3.5 m |
| Aa: Surface area | | | $m^2$ |
| Va: Anaerobic pond volume | | | $m^3$ |
| Dimension | Length | La | m |
| | Width | Wa | m |

$BOD_{5La}$: $BOD_5$ load of anaerobic pond 100 to 350 g-$BOD_5$/$m^3$-pond/day

**Table 26 Dimension of Anaerobic Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| R.T | days | 7 | 7 | - |
| Va | $m^3$ | 5,110 | 4,270 | - |
| Da | m | 3.5 | 3.5 | - |
| Aa | $m^2$ | 1,460 | 1,220 | - |
| La | m | 60 | 60 | - |
| Wa | m | 25 | 22 | - |
| $BOD_5$ | g/day | 671,600 | 561,200 | - |
| $BOD_{5La}$ | g/$m^3$/day | 131 | 131 | - |

Number of ponds: 1

## 3. Facultative Pond

$ls_1$: BOD permissible loading — kg/ha/day

$ls_1 = 350 (1.107 - 0.002T)^{T-25}$ — 100 to 400 kg/ha/day

or

$ls_2 = 20T-120$ — kg/ha/day

Here, T: Minimum temperature — 21 °C

Ls: $BOD_5$ loading

$Ls = 10\ Li\ Q / Af$ — kg/ha/day

Here,

Li: Inflow $BOD_5$ — mg/L

Af: Facultative pond area — $m^2$

$Af = Q *(Li - Le)/18D/(1.05)^{T-20}$

Here,

Le: Outflow $BOD_5$ — mg/L

$L_r$: $BOD_5$ removal — kg/ha/day

$Lr = 0.725Ls \div 10.75$

Df: Depth of the facultative pond — m

| | | | |
|---|---|---|---|
| Dimensions of facultative pond | Length | Lf | m |
| | Width | Wf | m |

**Table 27 Dimension of Sedimentation Tank**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| T | °C | 21 | 21 | - |
| $ls_1$ | kg/ha/day | 272 | 272 | - |
| $ls_2$ | kg/ha/day | 300 | 300 | - |
| Ls | kg/ha/day | 269 | 270 | - |
| Li | mg/L | 368 | 368 | - |
| Df | m | 1.2 | 1.2 | - |
| Af | $m^2$ | 10,000 | 8,300 | - |
| Le | mg/L | 60 | 60 | - |
| Lr | kg/ha/day | 206 | 207 | - |
| $BOD_{5Rf}$ | % | 76.5 | 76.5 | - |
| $BOD_{5out-f}$ | mg/L | 87 | 87 | - |
| $R.T_f$ | days | 16 | 16 | - |

Remarks:

(a) There is a difference between $ls_1$ and $ls_2$. Adopt $ls_1$ for safety.

(b) There is a difference between Le and $BOD_{5out-f}$. This is because Equations for Ls and Af are the one to get 60 mg/L-$BOD_5$ in South America.

(c) On the contrary, the value of $BOD_{5out-f}$ is calculated by the equation for Lr. Lr shows the average of the data arranged by MacGarry and Pescord.

(d) The $BOD_5$ removal in primary facultative ponds is usually in the range 70-80 percent based on unfiltered samples (that is, including the BOD exerted by the algae).
Therefore, effluent $BOD_{5out-f}$ level from facultative pond will be considered 60-117 mg/L with algae.

(e) It is said $BOD_5$ quality of the effluent from a facultative ponds as most of the BOD contained (70 to 90%) will be "algal BOD. Therefore, the filtered (soluble) $BOD_5$ level will be at least 18-35 mg/L.

**Table 28 Dimensions of Facultative Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Af | $m^2$ | 10,000 | 8,300 | - |
| Nos. of ponds | - | 2 | 2 | - |
| Af/pond | $m^2$ | 5,000 | 4,150 | - |
| Lf/pond | m | 120 | 110 | - |
| Wf/pond | m | 45 | 40 | - |
| Df | m | 1.2 | 1.2 | - |
| Vf/pond | $m^3$ | 6,480 | 5,280 | - |
| Total Vf | $m^3$ | 12,960 | 10,560 | - |

Pond arrangement: Parallel

## 4. Maturation pond

Maturation ponds (low-cost polishing ponds, which succeed the primary or secondary facultative pond) are primarily designed for tertiary treatment, i.e., the removal of pathogens, nutrients and possibly algae.

With the combination of facultative pond and maturation pond,

(1) Total nitrogen removal in WSP systems can reach 80 percent or more, and ammonia removal can be as high as 95 percent.

(2) The best way of increasing phosphorus removal in WSP is to increase the number of

maturation ponds, so that progressively more and more phosphorus becomes immobilized in the sediments. From a well functioning 2 ponds system, 70% mass removal of total.

(3) The removal rate increases by adding maturation ponds.

Design criteria

$D_m$: Depth of maturation pond 4.5 m

$RT_m$: Retention time of maturation pond 14 days

$A_m$: Area od maturation pond

Dimensions of maturation pond

Length Lm m

Width Wm m

**Table 29 Dimensions of Maturation Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| $RT_m$ | days | 14 | 14 | - |
| Vm | $m^3$ | 10,220 | 8,540 | - |
| Nos. of Ponds | - | 2 | 2 | - |
| Vm/Pond | $m^3$ | 5,110 | 4,270 | - |
| Dm/Pond | m | 1.5 | 1.5 | - |
| Am/Pond | $m^2$ | 3,500 | 2,900 | - |
| Lm/Pond | m | 100 | 100 | - |
| Wm/Pond | m | 35 | 35 | - |

Pond arrangement: Series

## 5. Leachate Recirculation pump

Recirculation rate r times/leachate

Recirculation pump flow Qr $m^3$/day

Qr = r*Q

Required Power Ps

Ps = 0.163*Qr($m^3$/min)*H(m)/ή Horse power

Here

Total head of the pump H m

Total efficiency ή

Liquid density ρs 1.05

From the entrance of anaerobic lagoon to landfill

**Table 30 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 2,190 | 1,830 | - |
| | $m^3$/min | 1.52 | 1.27 | - |
| Head | m | 50 | 50 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 23.2 | 19.4 | - |
| | kW | 17.4 | 14.6 | - |
| Unit power | kW | 19 | 19 | - |
| Nos. of pumps | Nos. | (1+1) | (1+1) | - |

**Alternative 4: Natural Pond System (Anaerobic + Facultative + Wetland) -Calle 100 Expansion**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is an alternative to use wetland instead of Maturation Pond in Alternative 3 in order to remove nutrients such as N and P.

## 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 31 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of T-$BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1.2 Recirculation rate of leachate 3 times/day toward the leachate generated

## 2. Anaerobic pond

| | | | |
|---|---|---|---|
| RTa : Retention time of anaerobic pond | | | 7 days |
| $BOD_5$ Removal rate | | | 60% |
| $BOD_5$ out-a | | | 368 mg/L |
| Da: Depth of the anaerobic pond | | | 3.5 m |
| Aa: Surface area | | | $m^2$ |
| Va: Anaerobic pond volume | | | $m^3$ |
| Dimension | Length | La | m |
| | Width | Wa | m |
| $BOD_{5La}$: $BOD_5$ load of anaerobic pond | | 100 to 350 g-$BOD_5$/$m^3$-pond/day | |

**Table 32 Dimension of Anaerobic Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| R.T | days | 7 | 7 | - |
| Va | $m^3$ | 5,110 | 4,270 | - |
| Da | m | 3.5 | 3.5 | - |
| Aa | $m^2$ | 1,460 | 1,220 | - |
| La | m | 60 | 60 | - |
| Wa | m | 25 | 22 | - |
| $BOD_5$ | g/day | 671,600 | 561,200 | - |
| $BOD_{5La}$ | g/$m^3$/day | 131 | 131 | - |

Number of ponds: 1

## 3. Facultative Pond

$ls_1$: BOD permissible loading — kg/ha/day

$ls_1 = 350 (1.107 - 0.002T)^{T-25}$ — 100 to 400 kg/ha/day

or

$ls_2 = 20T-120$ — kg/ha/day

Here, T: Minimum temperature — 21 °C

Ls: $BOD_5$ loading

Ls = 10 Li Q / Af — kg/ha/day

Here,

Li: Inflow $BOD_5$ — mg/L

Af: Facultative pond area — $m^2$

$Af = Q *(Li - Le)/18D/(1.05)^{T-20}$

Here,

Le: Outflow $BOD_5$ — mg/L

$L_r$: $BOD_5$ removal — kg/ha/day

$Lr = 0.725Ls \div 10.75$

Df: Depth of the facultative pond — m

Dimensions of facultative pond — Length Lf — m

Width Wf — m

**Table 33 Dimension of Sedimentation Tank**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| T | °C | 21 | 21 | - |
| $ls_1$ | kg/ha/day | 272 | 272 | - |
| $ls_2$ | kg/ha/day | 300 | 300 | - |
| Ls | kg/ha/day | 269 | 270 | - |
| Li | mg/L | 368 | 368 | - |
| Df | m | 1.2 | 1.2 | - |
| Af | $m^2$ | 10,000 | 8,300 | - |
| Le | mg/L | 60 | 60 | - |
| Lr | kg/ha/day | 206 | 207 | - |
| $BOD_{5Rf}$ | % | 76.5 | 76.5 | - |
| $BOD_{5out\text{-}f}$ | mg/L | 87 | 87 | - |
| $R.T_f$ | days | 16 | 16 | - |

Remarks:

(a) There is a difference between $ls_1$ and $ls_2$. Adopt $ls_1$ for safety.

(b) There is a difference between Le and $BOD_{5out\text{-}f}$. This is because Equations for Ls and Af are the one to get 60 mg/L-$BOD_5$ in South America.

(c) On the contrary, the value of $BOD_{5out\text{-}f}$ is calculated by the equation for Lr. Lr shows the average of the data arranged by MacGarry and Pescord.

(d) The $BOD_5$ removal in primary facultative ponds is usually in the range 70-80 percent based on unfiltered samples (that is, including the BOD exerted by the algae).
Therefore, effluent $BOD_{5out\text{-}f}$ level from facultative pond will be considered 60-117 mg/L with algae.

(e) It is said $BOD_5$ quality of the effluent from a facultative ponds as most of the BOD contained (70 to 90%) will be "algal BOD. Therefore, the filtered (soluble) $BOD_5$ level will be at least 18-35 mg/L.

**Table 34 Dimensions of Facultative Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Af | $m^2$ | 10,000 | 8,300 | - |
| Nos. of ponds | - | 2 | 2 | - |
| Af/pond | $m^2$ | 5,000 | 4,150 | - |
| Lf/pond | m | 120 | 110 | - |
| Wf/pond | m | 45 | 40 | - |
| Df | m | 1.2 | 1.2 | - |
| Vf/pond | $m^3$ | 6,480 | 5,280 | - |
| Total Vf | $m^3$ | 12,960 | 10,560 | - |

Pond arrangement: Parallel

## 4. To removal nutrients, use wetland

Only by aerated lagoon, only $BOD_5$ and SS are removed. For further treatment for nutrients another process is necessary.

Here, wetland was considered as an alternative for this purpose, considering cost efficiency.

Levels of nitrogen and phosphates are estimated as below based on the analysis of leachate during this Study.

| | | | |
|---|---|---|---|
| Total-N: | | 240 | mg/L |
| Total-P: | | 64 | mg/L |

In biological treatment nitrogen and phosphate are necessary. The ratio of N and P towards $BOD_5$ is 3:0.3:100

Therefore N and P after biological treatment, their levels are expected as below.

| | | | |
|---|---|---|---|
| Inlet $BOD_5$ | | 920 | mg/L |
| Therefore N to be removed by biological treatment | | 27.6 | mg/L |
| Therefore P to be removed by biological treatment | | 2.76 | mg/L |
| After aerated lagoon remained N | N | 212 | mg/L |
| | P | 61 | mg/L |

| Criteria* | |
|---|---|
| 20 | mg/L. as KTN |
| 10 | mg/L. as P |

*:Discharge criteria of industrial waste water into general public water body

Inlet T-P level will be reduced by using cover soil. Therefore, only removal of nitrogen would be considered.

Here, subsurface-flow (SSF) systems was considered.

In a SSF wetland, the basin is filled with gravel or some other coarse substrate, and the water level is maintained below-ground. Water flows horizontally, or sometimes vertically, through the gravel and the root mat of the wetland vegetation.

Arrow arum (Polyandry spp.) and Pickerel weed (Pontederia spp.) have been used in constructed wetlands.

Also common reed (Phragmitescommunis) is used

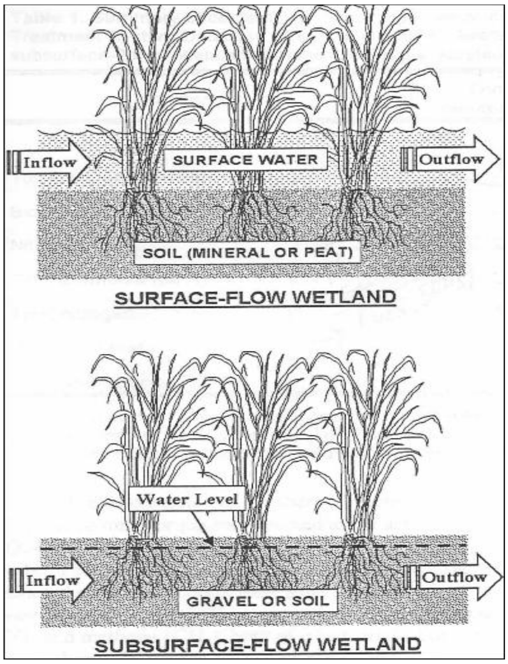



**Figure 2 Conceptual diagram of subsurface-flow wetlands**

**Example of determination of basin design for SFS wetlands system**

Nitrogen removal will proceed when $BOD_5$ level is less than 10 mg/L.

**1. Premises**

| | | |
|---|---|---|
| Influent $BOD_5$ | $C_0$ | 60 mg/L |
| Effluent $BOD_5$ | $C_e$ | 8 mg/L |
| Inflow | Q | $m^3$/day |
| | | $m^3$/day |
| Vegetation type | | cattails |
| Minimum water temperature | T | 21°C |
| Basin media | coarse sand with 2 mm of maximum effective size | |
| Basin slope | S | 0.01 |

**2. Solution**

| | | | |
|---|---|---|---|
| 1. | Basin depth for use wit cattail | d | 0.3 m |
| 2. | Porosity | α | 0.39 |
| | Hydraulic conductivity | Ks | 480 $m^3/m^2$/day |
| | | $K_{20}$ | 1.35 |
| 3. | Temperature-dependent first order rate constant | | |
| | | $K_T$ at | 21°C |
| | | | 1.49 $d^{-1}$ |
| 4. | Pore-space detention time | t' = -1nCe/C0/Kt | d |
| 5. | Cross-sectional area | Ac = Q/Ks/S | $m^2$ |
| 6. | Basin width | W = Ac/d | m |
| 7. | Basin length | L = t'Q/W/d/α | m |
| 8. | Required surface area | As = L*W | $m^2$ |
| | | | ha |
| 9. | Check hydraulic-loading rate or specific area requirements | | |
| | | Lw = Q/L/W | 150 to 500 $m^3$/ha/day |
| | | | 0.015 to 0.005 $m^3/m^2$/day |
| | or | Asp= 1/Lw for advanced treatment 2.1 ha/$10^3m^3$ | |
| 10. | Check $BOD_5$ loading rate | Max.$BOD_{5L}$ | 60kg/ha/day |
| | | $LBOD_5$ | kg/day |
| | | $BOD_{5L}$ | kg/ha/day |
| 11. | Vegetation | | |
| | Reed can absprb | N | 18 to 21g/kg |
| | | P | 2.0 to 3.0 g/kg |
| | Inlet N | | 240 mg/L |
| | Vd: vegetation density | | 10 kg/$m^2$ |

**Table 35 Specification of Wetland**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| $C_0$ | mg/L | 87 | 87 | - |
| Ce | mg/L | 8 | 8 | - |
| Q | $m^3$/day | 730 | 610 | - |
| T | °C | 21.0 | 21.0 | - |
| S | | 0.01 | 0.01 | - |
| d | m | 0.3 | 0.3 | - |
| α | | 0.39 | 0.39 | - |
| Ks | $m^3/m^2$/day | 480 | 480 | - |
| $K_{20}$ | | 1.35 | 1.35 | - |
| Kt | $d^{-1}$ | 1.49 | 1.49 | - |
| t' | day | 1.61 | 1.61 | - |
| Ac | $m^2$ | 152 | 127 | - |
| W | m | 510 | 430 | - |
| L | m | 20 | 20 | - |
| As | $m^2$ | 10,100 | 8,600 | - |
| Lw | $m^3/m^2$/day | 0.07 | 0.07 | - |
| Asp | ha/1000$m^3$ | 13.74 | 14.10 | - |
| L-$BOD_5$ | kg/day | 63.5 | 53.07 | - |
| $BOD_{5L}$ | kg/ha/day | 63 | 62 | - |
| V | $m^3$ | 3,030 | 2,580 | - |
| RT | day | 4.2 | 4.2 | - |
| Inlet N | mg/L | 240 | 240 | - |
| Total N in WL | g | 730,000 | 620,000 | - |
| N absorption | g/kg | 18 | 18 | - |
| Nos. of reed | kg | 40,556 | 34,444 | - |
| Vd | kg/$m^2$ | 10 | 10 | - |
| Max Reed | kg | 101,000 | 86,000 | - |

This system seems to be inferior in performance.

## 5. Leachate Recirculation pump

| | | |
|---|---|---|
| Recirculation rate | r | times/leachate |
| Recirculation pump flow | Qr | $m^3$/day |

Qr = r*Q

| | | |
|---|---|---|
| Required Power | Ps | |
| Ps = 0.163*Qr($m^3$/min)*H(m)/ή | | Horse power |

Here

| | | |
|---|---|---|
| Total head of the pump | H | m |
| Total efficiency | ή | |
| Liquid density | ρs | 1.05 |

From the entrance of anaerobic lagoon to landfill

**Table 36 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 2,190 | 1,830 | - |
| | $m^3$/min | 1.52 | 1.27 | - |
| Head | m | 50 | 50 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 23.2 | 19.4 | - |
| | kW | 17.4 | 14.6 | - |
| Unit power | kW | 19 | 19 | - |
| Nos. of pumps | Nos. | (1+1) | (1+1) | - |

**Alternative 5: Anaerobic Pond + Aerated Lagoon + Sedimentation Pond + Wetland with recirculation -Calle 100 Expansion**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is an alternative adding Anaerobic Pond to Alternative 2 in order to reduce area.

## 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 37 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of T-$BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1.2 Recirculation rate of leachate 3 times/day toward the leachate generated

## 2. Anaerobic pond

| | | | |
|---|---|---|---|
| RTa : Retention time of anaerobic pond | | | 7 days |
| $BOD_5$ Removal rate | | | 60% |
| $BOD_5$ out-a | | | 368 mg/L |
| Da: Depth of the anaerobic pond | | | 3.5 m |
| Aa: Surface area | | | $m^2$ |
| Va: Anaerobic pond volume | | | $m^3$ |
| Dimension | Length | La | m |
| | Width | Wa | m |

$BOD_{5La}$: $BOD_5$ load of anaerobic pond 100 to 350 g-$BOD_5$/$m^3$-pond/day

**Table 38 Dimension of Anaerobic Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| R.T | days | 7 | 7 | - |
| Va | $m^3$ | 5,110 | 4,270 | - |
| Da | m | 3.5 | 3.5 | - |
| Aa | $m^2$ | 1,460 | 1,220 | - |
| La | m | 60 | 60 | - |
| Wa | m | 25 | 22 | - |
| $BOD_5$ | g/day | 671,600 | 561,200 | - |
| $BOD_{5La}$ | g/$m^3$/day | 131 | 131 | - |

Number of ponds: 1

## 3. Aerated Lagoon

### 3.1 Aerated Lagoon Process

Design Base:

| | Symbol | Unit | |
|---|---|---|---|
| Influent flow | Q | $m^3$/d | |
| Influent suspended solids | $SS_0$ | mg/L | 378 |
| Influent soluble $BOD_5$ | $S_0$ | mg/L | 368 |
| Effluent soluble $BOD_5$ | S-$BOD_{5\text{-out}}$ | mg/L | 30 |
| Effluent suspended solid after setting | SSe | mg/L | 70 |
| Kinetic coefficients: | | | |
| Y | | l/d | 0.65 |
| Ks | | mg-$BOD_5$/L | 100 |
| Kmax | | mg-$BOD_5$/L/d | 6.0 |
| Kd | | l/d | 0.07 |
| First order soluble $BOD_5$ removal rate constants at 20 °C | | | |
| | $k_{(20)}$ | l/d | 2.5 |
| Waste water temperature | Ti | °C | 21.0 |
| Aeration constants in leachate | | | |
| in leachate | α | | 0.6 |
| in treated water | β | | 0.9 |
| Oxygen concentration to be maintained in liquid | | mg - $O_2$/L | 1.5 |
| Lagoon depth | H | m | 3.5 |
| Design mean cell - residence time | θc | d | 7 |

3.2 Surface area of the lagoon A $m^2$

$\theta c = V/Q \quad \therefore V = \theta c * Q$ V: volume of the lagoon

A = V/H

Dimension

**Table 39 Dimension of Aerated Lagoon**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| V | $m^3$ | 5,110 | 4,270 | - |
| A | $m^2$ | 1,460 | 1,220 | - |
| L | m | 60 | 60 | - |
| W | m | 25 | 22 | - |
| H | m | 3.5 | 3.5 | - |
| A' (corrected A) | $m^2$ | 1,500 | 1,320 | - |
| V' (Corrected V) | $m^3$ | 5,300 | 4,700 | - |

3.3 Soluble effluent $BOD_5$ at the lagoon outlet: S-$BOD_5$-out

S-$BOD_5$out = { Ks (1 + 0c*kd) } / {θc (Y*kmax - kd) - I } (mg/L)

| Ks | θc*kd | 1+θc*kd | Ks (1+θc*kd) | θc | Y*kmax | Y*kmax-kd | θc (Y*kmax-kd)-1 | S-$BOD_5$ out |
|---|---|---|---|---|---|---|---|---|
| 100 | 0.49 | 1.49 | 149 | 7 | 3.9 | 3.83 | 25.8 | 5.8 |

3.4 Effluent $BOD_5$

(1) Correct the removal-rate for temperature effects

$k(t) = k(20)*\theta^{T-20}$ (l/d)

| Ti | $k_{(20)}$ | T-20 | θ | $\theta^{(T-20)}$ | $k_{(20)}\theta^{(T-20)}$ |
|---|---|---|---|---|---|
| 21.0 | 2.5 | 1 | 1.06 | 1.06 | 2.7 |

(2) Determine the effluent $BOD_5$: St-$_{out}$ (mg/L)

$St\text{-}out/S_0 = 1/(1+k\theta_H) = S/S_0 = 1/(1+kV/Q)$

| kt | V/Q | 1+kV/Q | 1/(1+kV/Q) | $S_0$ | St-out |
|---|---|---|---|---|---|
| 2.7 | 14 | 19.55 | 0.05 | 368 | 19 |

3.5 Concentration of biological solids produced: X (mg/L)

$X = Y (S_0\text{-}S\text{-}BOD_5\text{-}out)/ (1+k_d\theta_c)$ (mg-VSS/L)

| Y | $S_0$-S-$BOD_{5\text{-}out}$ | $k_d$ | θc | $Y(S_0\text{-}S\text{-}BOD_{5\text{-}out})/(1+k_d\theta_c)$ |
|---|---|---|---|---|
| 0.65 | 362.2 | 0.07 | 7 | 158 |

3.6 Suspended solids in the lagoon before settling

SSi = Influent suspended solids + X/0.7(mg/L)

Ratio of volatile suspended solid 0.7

| SSo | X | SSi |
|---|---|---|
| 378 | 158 | 604 |

3.7 Oxygen requirements

$Q_2$ (kg/d) = Q ($S_0$-S-$BOD_{5\text{-out}}$)/f-1.42Px

f: conversion factor for $BOD_5$ to $BOD_L$ 0.68

Px = Q*(concentration of biological solids produced)

**Table 40 Required $O_2$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| $S_0$-s-$BOD_{5\text{-out}}$ | mg/L | 362 | 362 | - |
| f | - | 0.68 | 0.68 | - |
| Px | kg/day | 115 | 96 | - |
| Required $O_2$ | kg/day | 225 | 188 | - |

3.8 Ratio of oxygen required to $BOD_5$ removed

$BOD_5$ removed (kg/d)

$O_2$/$BOD_5$ removed

**Table 41 Removed $BOD_5$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| So-S-$BOD_{5\text{-out}}$ | mg/L | 362.2 | 362.2 | - |
| $BOD_5$ removed | kg/day | 264 | 221 | - |
| $O_2$/$BOD_5$ | - | 0.9 | 0.9 | - |

3.9 Surface aerator power requirements

assumption: kg-$O_2$/kw/h kg-$O_2$/kw/h No 1.6

a) Correction factor for surface aerators for summer conditions f

f = No/N

1) Oxygen saturation concentration at 21 °C Cs(21) mg/L 8.91

2) Cs(20) mg/L 9.08

3) DO concentration in Lagoon CL mg/L 1.5

f = {B*CsT-CL}/ Cs (20)*1.024T-20*α}

| Ti-20 | $1.024^{T-20}$ | α | B | f |
|---|---|---|---|---|
| 1 | 1.029 | 0.6 | 0.9 | 0.44 |

b) Field transfer rate : N

$N = fN_0$ kg-$O_2$/kw/h 0.71

Total amount of transfer $O_2$ kg-$O_2$/kw/d kg-$O_2$/kw/h 17.0

The total axis power required to meet the required oxygen

**Table 42 Required $O_2$ Supply**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Required $O_2$ | kg/day | 225 | 188 | - |
| Required power for $O_2$ supply | kW | 13.2 | 11.1 | - |

3.10 Energy requirements for mixing

**Table 43 Specifications of Aerator**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Power for Mixing | kW/$m^3$ | 0.005 | 0.005 | - |
| Lagoon volume | $m^3$ | 5,300 | 4,700 | - |
| Axis power for mixing | kW | 26.5 | 23.5 | - |
| Total efficiency | - | 0.75 | 0.75 | - |
| Required power | kW | 35 | 31 | - |
| Required power per unit | kW/No. | 11 | 7.5 | - |
| Power for Mixing | Nos. | 4 | 5 | - |

## 4. Leachate recirculation pump

Recirculation rate r times/leachate

Recirculation pump flow Qr $m^3$/day

$Qr = r*Q$

Required Power Ps

$Ps = 0.163*Qr(m^3/min)*H(m)/ή$ Horse power

Here

Total head of the pump H m

Total efficiency ή

Liquid density ρs 1.05

From the entrance of anaerobic lagoon to landfill

**Table 44 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 2,190 | 1,830 | - |
| | $m^3$/min | 1.52 | 1.27 | - |
| Head | m | 50 | 50 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 23.2 | 19.4 | - |
| | kW | 17.4 | 14.6 | - |
| Unit power | kW/Nos. | 19 | 19 | - |
| Nos. of pumps | Nos. | (1+1) | (1+1) | - |

## 5. Solid-liquid separation: sedimentation tank

| | | |
|---|---|---|
| Qi: Inflow | | $m^3$/day |
| Safety factor | | 3 |
| R.t: Retention time at Qi*3 | | hr |
| OL: Overflow rate at Qi*3 | | $m^3/m^2$/day |
| Qi*Ci = Qo*Co+Qu*Cu | | |
| Ci: Inflow SS | | mg/L |
| Co: Outflow SS | | mg/L |
| Cu: Concentrated SS in the sedimentation tank | | mg/L |
| Qo: Outflow | | $m^3$/day |
| Qu: Underflow (Sludge flow) | | $m^3$/day |
| Qu = Qi-Qo | | $m^3$/day |
| Qo = Qi*(Cu-Ci) / (Cu-Co) | | $m^3$/day |
| As: surface area=Qo/OL | | $m^3$ |
| Dimension | Ls: Length of sedimentation tank | m |
| | Ws: Width of sedimentation tank | m |
| Hs: Height of sludge zone =Vs/As | | m |
| Vs: Volume of sedimentation tank | | $m^3$ |
| $H_2$: Height allowance = Vs/As | | $m^2$ |

**Table 45 Dimension of Sedimentation Tank**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| Qi | $m^3$/day | 2,190 | 1,830 | - |
| R.T | hr | 2 | 2 | - |
| $O_L$ | $m^3/m^2$/day | 22 | 22 | - |
| Ci | mg/L | 604 | 604 | - |
| Co | mg/L | 70 | 70 | - |
| Cu | mg/L | 5,000 | 5,000 | - |
| Qo | $m^3$/day | 2,000 | 1,600 | - |
| As | $m^2$ | 100 | 80 | - |
| Ls | m | 20 | 20 | - |
| Ws | m | 5 | 5 | - |
| Hs | m | 1.9 | 2.0 | - |
| Vs | $m^3$ | 190 | 160 | - |
| Qu | $m^3$/day | 190 | 230 | - |
| $H_2$ | m | 1.5 | 1.5 | - |
| H0 | m | 3.4 | 3.5 | - |

## 6. To removal nutrients, use wetland.

Only by aerated lagoon, only $BOD_5$ and SS are removed. For further treatment for nutrients another process is necessary.

Here, wetland was considered as an alternative for this purpose, considering cost efficiency.

Levels of nitrogen and phosphates are estimated as below based on the analysis of leachate during this Study.

| | | | |
|---|---|---|---|
| Total-N: | | 240 | mg/L |
| Total-P: | | 64 | mg/L |

In biological treatment nitrogen and phosphate are necessary. The ratio of N and P towards $BOD_5$ is 3:0.3:100

Therefore N and P after biological treatment, their levels are expected as below.

| | | | |
|---|---|---|---|
| Inlet $BOD_5$ | | 920 | mg/L |
| Therefore N to be removed by biological treatment | | 27.6 | mg/L |
| Therefore P to be removed by biological treatment | | 2.76 | mg/L |
| After aerated lagoon remained N | N | 212 | mg/L |
| | P | 61 | mg/L |

| Criteria* | |
|---|---|
| 20 | mg/L. as KTN |
| 10 | mg/L. as P |

*:Discharge criteria of industrial waste water into general public water body

Inlet T-P level will be reduced by using cover soil.

Therefore, only removal of nitrogen would be considered.

Here, subsurface-flow (SSF) systems was considered.

In a SSF wetland, the basin is filled with gravel or some other coarse substrate, and the water level is maintained below-ground. Water flows horizontally, or sometimes vertically, through the gravel and the root mat of the wetland vegetation.

Arrow arum (Polyandry spp.) and Pickerel weed (Pontederia spp.) have been used in constructed wetlands.

Also common reed (Phragmitescommunis) is used

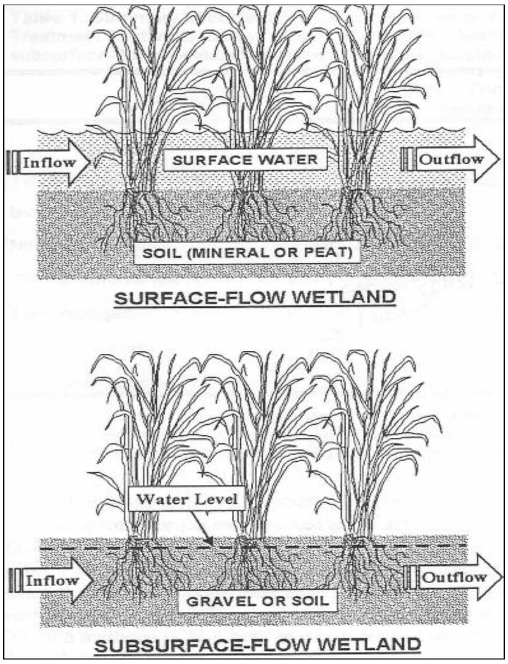



**Figure 3 Conceptual diagram of subsurface-flow wetlands**

**Example of determination of basin design for SFS wetlands system**

Nitrogen removal will proceed when $BOD_5$ level is less than 10 mg/L.

**1. Premises**

| | | |
|---|---|---|
| Influent $BOD_5$ | $C_0$ | 60 mg/L |
| Effluent $BOD_5$ | Ce | 8 mg/L |
| Inflow | Q | $m^3$/day |
| | | $m^3$/day |
| Vegetation type | | cattails |
| Minimum water temperature | T | 21°C |
| Basin media | coarse sand with 2 mm of maximum effective size | |
| Basin slope | S | 0.01 |

**2. Solution**

| | | | |
|---|---|---|---|
| 1. | Basin depth for use wit cattail | d | 0.3 m |
| 2. | Porosity | α | 0.39 |
| | Hydraulic conductivity | Ks | 480 $m^3/m^2$/day |
| | | $K_{20}$ | 1.35 |
| 3. | Temperature-dependent first order rate constant | | |
| | | $K_T$ at | 21°C |
| | | | 1.49 $d^{-1}$ |
| 4. | Pore-space detention time | t' = -1nCe/C0/Kt | d |
| 5. | Cross-sectional area | $A_C$ = Q/Ks/S | $m^2$ |
| 6. | Basin width | W = Ac/d | m |
| 7. | Basin length | L = t'Q/W/d/α | m |
| 8. | Required surface area | As = L*W | $m^2$ |
| | | | ha |
| 9. | Check hydraulic-loading rate or specific area requirements | | |
| | | Lw = Q/L/W | 150 to 500 $m^3$/ha/day |
| | | | 0.015 to 0.005 $m^3/m^2$/day |
| | or | Asp= 1/Lw for advanced treatment 2.1 ha/$10^3m^3$ | |
| 10. | Check $BOD_5$ loading rate | Max.$BOD_{5L}$ | 60 kg/ha/day |
| | $LBOD_5$ | | kg/day |
| | $BOD_{5L}$ | | kg/ha/day |
| 11. | Vegetation | | |
| | Reed can absorb | N | 18 to 21 g/kg |
| | | P | 2.0 to 3.0 g/kg |
| | Inlet N | | 212.4 mg/L |
| | Vd: vegetation density | | 10 kg/$m^2$ |

**Table 46 Specification of Wetland**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| $C_0$ | mg/L | 60 | 60 | - |
| Ce | mg/L | 8 | 8 | - |
| Q | $m^3$/day | 730 | 610 | - |
| T | °C | 21.0 | 21.0 | - |
| S | | 0.01 | 0.01 | - |
| d | m | 0.3 | 0.3 | - |
| α | | 0.39 | 0.39 | - |
| Ks | $m^3/m^2$/day | 480 | 480 | - |
| $K_{20}$ | | 1.35 | 1.35 | - |
| Kt | $d^{-1}$ | 1.49 | 1.49 | - |
| t' | day | 1.36 | 1.36 | - |
| Ac | $m^2$ | 152 | 127 | - |
| W | m | 510 | 430 | - |
| L | m | 17 | 16 | - |
| As | $m^2$ | 8,500 | 7,100 | - |
| Lw | $m^3/m^2$/day | 0.09 | 0.09 | - |
| Asp | ha/1000$m^3$ | 11.60 | 11.60 | - |
| L-$BOD_5$ | kg/day | 43.8 | 36.6 | - |
| $BOD_{5L}$ | kg/ha/day | 52 | 52 | - |
| V | $m^3$ | 2,550 | 2,130 | - |
| R.T | day | 3.5 | 3.5 | - |
| Inlet N | mg/L | 212 | 212 | - |
| Total N in WL | g | 550,000 | 460,000 | - |
| N absorption | g/kg | 18 | 18 | - |
| Nos. of reed | kg | 30,556 | 25,556 | - |
| Vd | kg/$m^2$ | 10 | 10 | - |
| Max Reed | kg | 85,000 | 71,000 | - |

**Alternative 6: Anaerobic Pond + Aerated Lagoon + Maturation Pond with recirculation -Calle 100 Expansion**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is an alternative adding Anaerobic Pond to Alternative 1 to reduce area.

## 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 47 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of T-$BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1.2 Recirculation rate of leachate 3 times/day toward the leachate generated

## 2. Anaerobic pond

| | | | |
|---|---|---|---|
| RTa: Retention time of anaerobic pond | | | 7 days |
| $BOD_5$ Removal rate | | | 60% |
| $BOD_5$ out-a | | | 368 mg/L |
| Da: Depth of the anaerobic pond | | | 3.5 m |
| Aa: Surface area | | | $m^2$ |
| Va: Anaerobic pond volume | | | $m^3$ |
| Dimension | Length | La | m |
| | Width | Wa | m |
| $BOD_{5La}$: $BOD_5$ load of anaerobic pond | | 100 to 350 g-$BOD_5$/$m^3$-pond/day | |

**Table 48 Dimension of Anaerobic Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| R.T | days | 7 | 7 | - |
| Va | $m^3$ | 5,110 | 4,270 | - |
| Da | m | 3.5 | 3.5 | - |
| Aa | $m^2$ | 1,460 | 1,220 | - |
| La | m | 60 | 60 | - |
| Wa | m | 25 | 22 | - |
| $BOD_5$ | g/day | 671,600 | 561,200 | - |
| $BOD_{5La}$ | g/$m^3$/day | 131 | 131 | - |

Number of ponds: 1

## 3. Aerated Lagoon

### 3.1 Aerated Lagoon Process

Design Base:

| | Symbol | Unit | |
|---|---|---|---|
| Influent flow | Q | $m^3$/d | |
| Influent suspended solids | $SS_0$ | mg/L | 378 |
| Influent soluble $BOD_5$ | $S_0$ | mg/L | 368 |
| Effluent soluble $BOD_5$ | $S\text{-}BOD_{5\text{-}out}$ | mg/L | 30 |
| Effluent suspended solid after setting | SSe | mg/L | 70 |
| Kinetic coefficients: | | | |
| Y | | l/d | 0.65 |
| Ks | | mg-$BOD_5$/L | 100 |
| Kmax | | mg-$BOD_5$/L/d | 6.0 |
| Kd | | l/d | 0.07 |
| First order soluble $BOD_5$ removal rate constants at 20 °C | | | |
| | $k_{(20)}$ | l/d | 2.5 |
| Waste water temperature | Ti | °C | 21.0 |
| Aeration constants in leachate | | | |
| in leachate | α | | 0.6 |
| in treated water | β | | 0.9 |
| Oxygen concentration to be maintained in liquid | | mg - $O_2$/L | 1.5 |
| Lagoon depth | H | m | 3.5 |
| Design mean cell - residence time | θc | d | 7 |

3.2 Surface area of the lagoon A $m^2$

$\theta c = V/Q \quad \therefore V = \theta c * Q$ V: volume of the lagoon

$A = V/H$

Dimension

**Table 49 Dimension of Aerated Lagoon**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| V | $m^3$ | 5,110 | 4,270 | - |
| A | $m^2$ | 1,460 | 1,220 | - |
| L | m | 60 | 60 | - |
| W | m | 25 | 22 | - |
| H | m | 3.5 | 3.5 | - |
| A' (corrected A) | $m^2$ | 1,500 | 1,320 | - |
| V' (Corrected V) | $m^3$ | 5,300 | 4,700 | - |

3.3 Soluble effluent $BOD_5$ at the lagoon outlet: S-$BOD_5$-out

S-$BOD_5$out = { Ks (1 + 0c*kd) } / {θc (Y*kmax - kd) - I } (mg/L)

| Ks | θc*kd | 1+θc*kd | Ks (1+θc*kd) | θc | Y*kmax | Y*kmax-kd | θc (Y*kmax-kd)-1 | S-$BOD_5$ out |
|---|---|---|---|---|---|---|---|---|
| 100 | 0.49 | 1.49 | 149 | 7 | 3.9 | 3.83 | 25.8 | 5.8 |

3.4 Effluent $BOD_5$

(1) Correct the removal-rate for temperature effects

$k(t) = k(20)*\theta^{T-20}$ (l/d)

| Ti | $k_{(20)}$ | T-20 | θ | $\theta^{(T-20)}$ | $k_{(20)}\theta^{(T-20)}$ |
|---|---|---|---|---|---|
| 21.0 | 2.5 | 1 | 1.06 | 1.06 | 2.7 |

(2) Determine the effluent $BOD_5$: St-$_{out}$ (mg/L)

$St\text{-}out/S_0 = 1/(1+k\theta_H) = S/S_0 = 1/(1+kV/Q)$

| kt | V/Q | 1+kV/Q | 1/(1+kV/Q) | $S_0$ | St-out |
|---|---|---|---|---|---|
| 2.7 | 14 | 19.55 | 0.05 | 368 | 19 |

3.5 Concentration of biological solids produced: X (mg/L)

$X = Y (S_0\text{-S-BOD}_5\text{-out})/ (1+k_d\theta_c)$ (mg-VSS/L)

| Y | $S_0$-S-$BOD_{5\text{-out}}$ | $k_d$ | θc | $Y(S_0\text{-S-BOD}_{5\text{-out}})/(1+k_d\theta_c)$ |
|---|---|---|---|---|
| 0.65 | 362.2 | 0.07 | 7 | 158 |

3.6 Suspended solids in the lagoon before settling

SSi = Influent suspended solids + X/0.7(mg/L)

Ratio of volatile suspended solid 0.7

| SSo | X | SSi |
|---|---|---|
| 378 | 158 | 604 |

3.7 Oxygen requirements

$Q_2$ (kg/d) = Q ($S_0$-S-$BOD_{5\text{-out}}$)/f-1.42Px

f: conversion factor for $BOD_5$ to $BOD_L$ 0.68

Px = Q*(concentration of biological solids produced)

**Table 50 Required $O_2$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| $S_0$-s-$BOD_{5\text{-out}}$ | mg/L | 362 | 362 | - |
| f | - | 0.68 | 0.68 | - |
| Px | kg/day | 115 | 96 | - |
| Required $O_2$ | kg/day | 225 | 188 | - |

3.8 Ratio of oxygen required to $BOD_5$ removed

$BOD_5$ removed (kg/d)

$O_2$/$BOD_5$ removed

**Table 51 Removed $BOD_5$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| So-S-$BOD_{5\text{-out}}$ | mg/L | 362.2 | 362.2 | - |
| $BOD_5$ removed | kg/day | 264 | 221 | - |
| $O_2$/$BOD_5$ | - | 0.9 | 0.9 | - |

3.9 Surface aerator power requirements

assumption: kg-$O_2$/kw/h kg-$O_2$/kw/h No 1.6

a) Correction factor for surface aerators for summer conditions f

f = No/N

1) Oxygen saturation concentration at 21 °C Cs(21) mg/L 8.91

2) Cs(20) mg/L 9.08

3) DO concentration in Lagoon CL mg/L 1.5

f = {B*CsT-CL}/ Cs (20)*1.024T-20*α}

| Ti-20 | $1.024^{T-20}$ | α | B | f |
|---|---|---|---|---|
| 1 | 1.029 | 0.6 | 0.9 | 0.44 |

b) Field transfer rate: N

$N = fN_0$ kg-$O_2$/kw/h 0.71

Total amount of transfer $O_2$ kg-$O_2$/kw/d kg-$O_2$/kw/h 17.0

The total axis power required to meet the required oxygen

**Table 52 Required $O_2$ Supply**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Required $O_2$ | kg/day | 225 | 188 | - |
| Required power for $O_2$ supply | kW | 13.2 | 11.1 | - |

3.10 Energy requirements for mixing

**Table 53 Specifications of Aerator**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Power for Mixing | kW/m$^3$ | 0.005 | 0.005 | - |
| Lagoon volume | m$^3$ | 5,300 | 4,700 | - |
| Axis power for mixing | kW | 26.5 | 23.5 | - |
| Total efficiency | - | 0.75 | 0.75 | - |
| Required power | kW | 35 | 31 | - |
| Unit power | kW/No. | 11 | 7.5 | - |
| No. of Aerator | Nos. | (4+1) | (5+1) | - |

## 4. Leachate recirculation pump

Recirculation rate r times/leachate

Recirculation pump flow Qr m$^3$/day

$Qr = r*Q$

Required Power Ps

$Ps = 0.163*Qr(m^3/min)*H(m)/ή$ Horse power

Here

Total head of the pump H m

Total efficiency ή

Liquid density ρs 1.05

From the entrance of anaerobic lagoon to landfill

**Table 54 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 2,190 | 1,830 | - |
| | $m^3$/min | 1.52 | 1.27 | - |
| Head | m | 50 | 50 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 23.2 | 19.4 | - |
| | kW | 17.4 | 14.6 | - |
| Unit power | kW | 19 | 19 | - |
| Nos. of pumps | Nos. | (1+1) | (1+1) | - |

## 5. Maturation Pond

<u>Design criteria</u>

$D_m$: Depth of maturation pond 1.5 m

$RT_m$: Retention time of maturation pond 14 days

$A_m$: Area od maturation pond

Dimensions of maturation pond

Length Lm m

Width Wm m

**Table 55 Dimensions of Maturation Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 730 | 610 | - |
| $RT_m$ | days | 14 | 14 | - |
| Vm | $m^3$ | 10,220 | 8,540 | - |
| Nos. of Ponds | - | 2 | 2 | - |
| Vm/Pond | $m^3$ | 5,110 | 4,270 | - |
| Dm/Pond | m | 1.5 | 1.5 | - |
| Am/Pond | $m^2$ | 3,500 | 2,900 | - |
| Lm/Pond | m | 100 | 100 | - |
| Wm/Pond | m | 35 | 35 | - |

Pond arrangement: Series

## Leachate Treatment Alternatives of New Site-1

**Alternative 1: Aerated Lagoon + Maturation Pond with recirculation -New Site 1**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is the same as the one which was adopted in the original pilot project in Campo Florido. However only aerated lagoon can not remove T-$BOD_5$ and SS. Therefore maturation pond after aerated lagoon was proposed.

### 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 56 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of T-$BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1) Leachate generation

| | | | |
|---|---|---|---|
| Stage1 | $A_1$ | 13.41 ha | 134,000 $m^2$ |
| Stage2 | $A_2$ | 8.4 ha | 84,000 $m^2$ |
| Stage3 | $A_3$ | 0.0 ha | 0 $m^2$ |

Once surface liner facility is constructed in landfill site, it is assumed that no water flows into the landfill site

$q = f*C*A*I/1000$ ($m^3$/day)

Where
q: Daily effluent amount of leachate water($m^3$/day)
C: Leachate coefficient of on-going landfill section 0.4
I: Annual maximum rainfall (mm/day)
Maximum rainfall during 2000 to 2002 338 mm in September in 2002
11.3 mm/day
A: Landfill area ($m^2$)
f: Safety factor 1.6
Q: Daily effluent amount of leachate with safety factor ($m^3$/day)

**Table 57 Proposed Leachate Volume**

| Q ($m^3$/day) | Stage1 | Stage2 | Stage3 |
|---|---|---|---|
| | 730 | 610 | 0 |

## 2. Leachate treatment

### 2.1 Aerated Lagoon Process Design

Design Base:

| | Symbol | Unit | |
|---|---|---|---|
| Influent flow | Q | $m^3/d$ | |
| Influent suspended solids | $SS_0$ | mg/L | 540 |
| Influent soluble $BOD_5$ | $S_0$ | mg/L | 920 |
| Effluent soluble $BOD_5$ | $S\text{-}BOD_{5\text{-out}}$ | mg/L | 30 |
| Effluent suspended solid after settling | SSe | mg/L | 70 |
| Kinetic coefficients: | | l/d | 0.65 |
| Y | | mg-$BOD_5$/L | 100 |
| Ks | | mg-$BOD_5$/L/d | 6.0 |
| Kmax | | l/d | 0.07 |
| Kd | $k_{(20)}$ | l/d | 2.5 |
| First order soluble $BOD_5$ removal rate constants at 20 °C | Ti | °C | 21.0 |
| Waste water temperature | | | |
| in leachate | α | | 0.6 |
| in treated water | β | | 0.9 |
| Oxygen concentration to be maintained in liquid | | mg-$O_2$/L | 1.5 |
| Lagoon depth | H | m | 3.5 |
| Design mean cell - residence time | θc | d | 14 |

### 2.2 Surface area of the lagoon

$\theta c = V/Q \quad \therefore V = \theta c * Q$ V: volume of the lagoon

$A = V/H$

Dimension

**Table 58 Dimensions of Aerated Lagoon**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| V | $m^3$ | 13,580 | 8,540 | - |
| A | $m^2$ | 3,880 | 2,440 | - |
| L | m | 100 | 90 | - |
| W | m | 40 | 30 | - |
| H | m | - | - | - |
| A' (Connected A) | $m^2$ | 4,000 | 2,700 | - |
| V' (Connected V) | $m^3$ | 14,000 | 9,500 | - |

Number of lagoon: 1

### 2.3 Soluble effluent $BOD_5$ at the lagoon outlet: S-$BOD_5$-out

S-$BOD_5$ out = $\{Ks\,(1+\theta c * kd)\} / \{\theta c\,(Y*kmax-kd)-1\}$(mg/L)

| Ks | θc*kd | 1+θc*kd | Ks (1+θc*kd) | θc | Y*kmax | Y*kmax-kd | θc (Y*kmax-kd)-1 | S-$BOD_5$ out |
|---|---|---|---|---|---|---|---|---|
| 100 | 0.98 | 1.98 | 198 | 14 | 3.9 | 3.83 | 52.6 | 3.8 |

## 2.4 Effluent $BOD_5$

1) Correct the removal-rate for temperature effects

k(t) = k(20)*θT-20

| Ti | $k_{(20)}$ | T-20 | θ | $\theta^{(T-20)}$ | $k_{(20)}\theta^{(T-20)}$ |
|---|---|---|---|---|---|
| 21.0 | 2.5 | 1 | 1.06 | 1.06 | 2.7 |

2) Determine the effluent $BOD_5$: St-out (mg/L)

| kt | V/Q | 1+kV/Q | 1/(1+kV/Q) | $S_0$ | St-out |
|---|---|---|---|---|---|
| 2.7 | 14 | 38.10 | 0.30 | 920 | 24 |

## 2.5 Concentration of biological solids produced : X(mg.L)

X = Y(S0-S-$BOD_5$-out)/(1+kdθc)(mg-VSS/L)

| Y | $S_0$-S-$BOD_{5\text{-out}}$ | kd | θc | Y($S_0$-S-$BOD_{5\text{-out}}$)/(1+kdθc) |
|---|---|---|---|---|
| 0.65 | 916.2 | 0.07 | 14 | 301 |

## 2.6 Suspended solids in the lagoon before settling

SSi = Influent suspended solids + X/0.7(mg/L)

| SSo | X | SSi |
|---|---|---|
| 540 | 301 | 970 |

Ratio of volatile suspended solid 0.7

## 2.7 Oxygen requirements

$Q_2$(kg/d) = Q($S_0$-S-$BOD_{5\text{-out}}$)/f - 1.42Px

f: conversion factor for $BOD_5$ to BODL 0.68

Px =Q*(concentration of biological solids produced)

**Table 59 Required $O_2$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| $S_0$-s-$BOD_{5\text{-out}}$ | mg/L | - | - | - |
| f | - | - | - | - |
| Px | kg/day | 292 | 183 | - |
| Required $O_2$ | kg/day | 893 | 561 | - |

## 2.8 Ratio of oxygen required to $BOD_5$ removed

$BOD_5$ removed (kg/d)

$O_2$/$BOD_5$ removed

**Table 60 Removed $BOD_5$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| $S_0$-S-$BOD_{5\text{-out}}$ | mg/L | - | - | - |
| $BOD_5$ removed | kg/day | 889 | 559 | - |
| $O_2$/$BOD_5$ | - | - | - | - |

## 2.9 Surface aerator power requirements

assumption: kg-$O_2$/kw/h kg-$O_2$/kw/h No 1.6

a) Correction factor for surface aerators for summer conditions f

f=No. /N

1) Oxygen saturation concentration at 21 °C Cs(21) mg/L 8.91
2) Cs(20) mg/L 9.08
3) Do concentration in Lagoon $C_L$ mg/L 1.5

f = {B*CsT-CL}/Cs(20)*1.024T-20*α}

| Ti-20 | $1.024^{T-20}$ | α | B | f |
|---|---|---|---|---|
| 1 | 1.029 | 0.6 | 0.9 | 0.44 |

b) Field transfer rate : N

N=fNo kg-$O_2$/kw/h 0.71

Total amount of transfer $O_2$ kg-$O_2$/kw/d kg-$O_2$/kw/h 17.0

The total axis power required to meet the required oxygen

**Table 61 Required $O_2$ Supply**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Required $O_2$ | kg/day | 893 | 561 | - |
| Required power for $O_2$ supply | kw | 52.5 | 33 | - |

2.10 Energy requirements for mixing

**Table 62 Specifications of Aerator**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Power for Mixing | $kW/m^3$ | 0.005 | 0.005 | - |
| Lagoon volume | $m^3$ | 14,000 | 9,500 | - |
| Axis power for mixing | kW | 70 | 47.5 | - |
| Total efficiency | - | 0.75 | 0.75 | - |
| Required power | kW | 93 | 63 | - |
| Unit Power | kW/No. | 15 | 15 | - |
| No. of Aerator | Nos. | 7 | 5 | - |

## 3. Solid separation for aerated lagoon

3.1 Design Base:

1) Process: maturation pond

2) HRT (days): t

3) Depth (m) D

Necessary Area ($m^2$) A

A = Qt/d

Volume of the maturation pond ($m^3$) V

V = A*D0

The effluent SS may be expected to be at about 50-100 mg/L

Dimension Length L

Width W

Height H

**Table 63 Dimension of Maturation Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| t | days | 14 | 14 | - |
| V | $m^3$ | 13,580 | 8,540 | - |
| No. of Ponds | - | 2 | 2 | - |
| $D_0$ | m | 1.5 | 1.5 | - |
| A/pond | $m^2$ | 4,550 | 2,850 | - |
| D/pond | m | 120 | 90 | - |
| W/pond | m | 40 | 35 | - |
| A' (corrected A)/pond | $m^2$ | 4,800 | 3,150 | - |

## 4. Leachate recirculation pump

1) Recirculation rate r times/leachate

Recirculation pump flow Qr $m^3$/day

Qr = r*Q

Required Power Ps

Ps = 0.163*Qr($m^3$/min)*H(m)/ή Hose power

Here

Total head of the pump H m

Total efficiency ή

Liquid density ρs 1.05

From the entrance of aerated lagoon to landfill

**Table 64 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 2,910 | 1,830 | - |
| | $m^3$/min | 2.02 | 1.27 | - |
| Head | m | 50 | 50 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 15.4 | 19.4 | - |
| | kW | 19.6 | 14.6 | - |
| Unit power | kW/No. | 15 | 19 | - |
| Nos. of pumps | Nos. | (2+1) | (1+1) | - |

## 5. Sludge accumulation

5.1 Mass of sludge accumulated in the basin each year without anaerobic decomposition

Mass = (SSi - SSe) (g/$m^3$) * $10^{-3}$(kg/g) * q($m^3$/day) * 365(day/year)

SSi: SS from aerated lagoon

SSe: SS after solid separation

VSS: Volatile solids of the mass to be decomposition = 0.7 * mass

Fixed solid = Mass - Volatile

**Table 65 Accumulated Sludge**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| SSi | mg/L | 970 | 970 | - |
| SSe | mg/L | 70 | 70 | - |
| Q | $m^3$/min | 970 | 610 | - |
| Mass | kg/year | 318,600 | 200,400 | - |
| Vss | kg/year | 224,000 | 141,000 | - |
| Fixed solid | kg/year | 94,600 | 59,400 | - |

5.2 Amount of sludge to be accumulated at the end of ty years

Assumption

1) Maximum volatile solids reduction 75 %

2) it will occur within 1 year

3) deposited volatile suspended solids undergo a liner decomposition

Mass of volatile suspended solids accumulated at the end of 2 year:

(VSS)t = {0.75+0.25(t-1)}*VSS kg

Total mass of solids accumulated at the end of ty-1 year

SSt = Vsst + ty*Fixed solid kg

**Table 66 Accumulated Volatile Suspended Solids**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| VSS | kg/year | 224,000 | 141,000 | - |
| ty | year | 2 | 2 | - |
| (Vss)t | kg | 212,800 | 133,950 | - |
| SSt | kg | 402,000 | 252,750 | - |

5.3 Required liquid volume and the dimensions for the sedimentation basin

1) Volume of sedimentation basin:V $m^3$

$V = t*q(m^3/d)$

2) Surface area of the sedimentation basin A $m^2$

3) Effective depth of the solid -liquid separation m

**Table 67 Required Liquid Volume**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| V | $m^3$ | 13,580 | 8,540 | - |
| A' | $m^2$ | 9,600 | 6,300 | - |
| D1 | m | 1.0 | 1.0 | - |

5.4 Depth required for the storage of sludge

1) the mass of accumulated sludge per square meter $kg/m^2$

Accumulated mass of sludge: SSt kg

mass per unit area $kg/m^2$

**Table 68 Accumulated Sludge per Square Meter**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| SSt | kg | 402,000 | 252,750 | - |
| A' | $m^2$ | 9,600 | 6,300 | - |
| SSt/A | $kg/m^2$ | 42 | 40 | - |

2) Required depth

Vds: deposited solids accumulated to the extend of %

ρs: density of the sludge: $ton/m^3$

The volume of sludge: Vsst ($m^3$)

$0.15 * Vsst (m^3) * 1.06*103 (kg/m^3) = SSt (kg)$

Hs: the height of the sludge zone (m)

Vsst = H*A Hs = Vsst/A m

**Table 69 Required Depth**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Vds | % | 15 | 15 | - |
| $\rho_s$ | $ton/m^3$ | 1.06 | 1.06 | - |
| SSt | kg | 402,000 | 252,750 | - |
| Vsst | $m^3$ | 2,528 | 1,590 | - |
| A | $m^2$ | 9,600 | 6,300 | - |
| Hs | m | 0.26 | 0.25 | - |

**Alternative 2: Aerated Lagoon + Sedimentation Pond + Wetland with recirculation -New Site 1**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is the same as the one which was adopted in the original pilot project in Campo Florido. However only aerated lagoon can not remove T-$BOD_5$ and SS. Therefore sedimentation pond and wetland were proposed.

## 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 70 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of T-$BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1) Leachate generation

Landfill Area

| | | | |
|---|---|---|---|
| Stage1 | $A_1$ | 13.41 ha | 134,000 $m^2$ |
| Stage2 | $A_2$ | 8.4 ha | 84,000 $m^2$ |
| Stage3 | $A_3$ | 0.0 ha | 0 $m^2$ |

Once surface liner facility is constructed in landfill site, it is assumed that no water flows into the landfill site

$q = f*C*A*I/1000$ ($m^3$/day)

Where

q: Daily effluent amount of leachate water($m^3$/day)

C: Leachate coefficient of on-going landfill section 0.4

l: Annual maximum rainfall (mm/day)
Maximum rainfall during 2000 to 2002 38 mm in September in 2002
11.3 mm/day

A: Landfill area ($m^2$)

f: Safety factor 16

Q: Daily effluent amount of leachate with safety factor ($m^3$/day)

**Table 71 Proposed Leachate Volume**

| Q ($m^3$/day) | Stage1 | Stage2 | Stage3 |
|---|---|---|---|
| | 730 | 610 | 0 |

## 2. Leachate treatment

### 2.1 Aerated Lagoon Process Design

Design Base:

| | Symbol | Unit | |
|---|---|---|---|
| Influent flow | Q | $m^3$/d | |
| Influent suspended solids | $SS_0$ | mg/L | 540 |
| Influent soluble $BOD_5$ | $S_0$ | mg/L | 920 |
| Effluent soluble $BOD_5$ | $S\text{-}BOD_{5\text{-}out}$ | mg/L | 30 |
| Effluent suspended solid after settling | SSe | mg/L | 70 |
| Kinetic coefficients: | | l/d | 0.65 |
| Y | | mg-$BOD_5$/L | 100 |
| Ks | | mg-$BOD_5$/L/d | 6.0 |
| Kmax | | l/d | 0.07 |
| Kd | $k_{(20)}$ | l/d | 2.5 |
| First order soluble BoD5 removal rate constants at 20 °C | Ti | °C | 21.0 |
| Waste water temperature | | | |
| in leachate | α | | 0.6 |
| in treated water | β | | 0.9 |
| Oxygen concentration to be maintained in liquid | | mg-$O_2$/L | 1.5 |
| Lagoon depth | H | m | 3.5 |
| Design mean cell - residence time | θc | d | 14 |

### 2.2 Surface area of the lagoon

$\theta c = V/Q \quad \therefore V = \theta c * Q$ V: volume of the lagoon

$A = V/H$

Dimension

**Table 72 Dimensions of Aerated Lagoon**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| V | $m^3$ | 13,580 | 8,540 | - |
| A | $m^2$ | 3,880 | 2,440 | - |
| L | m | 100 | 90 | - |
| W | m | 40 | 30 | - |
| H | m | 3.5 | 3.5 | - |
| A' (Connected A) | $m^2$ | 4,000 | 2,700 | - |
| V' (Connected V) | $m^3$ | 14,000 | 9,500 | - |

Number of lagoon: 1

2.3 Soluble effluent $BOD_5$ at the lagoon outlet: S-$BOD_5$-out

S-$BOD_5$-out = {Ks (1+θc*kd)}/ { θc (Y*kmax-kd)-1}(mg/L)

| Ks | θc*kd | 1+θc*kd | Ks (1+θc*kd) | θc | Y*kmax | Y*kmax-kd | θc (Y*kmax-kd)-1 | S-$BOD_5$-out |
|---|---|---|---|---|---|---|---|---|
| 100 | 0.98 | 1.98 | 198 | 14 | 3.9 | 3.83 | 52.6 | 3.8 |

2.4 Effluent BOD5

1) Correct the removal-rate for temperature effects

k(t) = k(20)*θT-20

| Ti | $k_{(20)}$ | T-20 | θ | $\theta^{(T-20)}$ | $k_{(20)}\theta^{(T-20)}$ |
|---|---|---|---|---|---|
| 21.0 | 2.5 | 1 | 1.06 | 1.06 | 2.7 |

2) Determine the effluent $BOD_5$: St-out (mg/L)

| kt | V/Q | 1+kV/Q | 1/(1+kV/Q) | $S_0$ | St-out |
|---|---|---|---|---|---|
| 2.7 | 14 | 38.10 | 0.03 | 920 | 24 |

2.5 Concentration of biological solids produced: X (mg/L)

X = Y (S0-S-$BOD_{5\text{-out}}$) / (1+kdθc) (mg-VSS/L)

| Y | $S_0$-S-$BOD_{5\text{-out}}$ | kd | θc | $Y(S_0\text{-S-}BOD_{5\text{-out}})/(1+k_d\theta_c)$ |
|---|---|---|---|---|
| 0.65 | 916.2 | 0.07 | 14 | 301 |

2.6 Suspended solids in the lagoon before settling

SSi = Influent suspended solids + X/0.7(mg/L)

| SSo | X | SSi |
|---|---|---|
| 540 | 301 | 970 |

Ratio of volatile suspended solid 0.7

2.7 Oxygen requirements

$Q_2$ (kg/d) = Q($S_0$-S-$BOD_{5\text{-out}}$)/f-1.42Px

f: conversion factor for $BOD_5$ to BODL 0.68

Px = Q*(concentration of biological solids produced)

**Table 73 Required $O_2$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| $S_0$-S-$BOD_{5\text{-out}}$ | mg/L | 916 | 916 | - |
| f | - | 0.68 | 0.68 | - |
| Px | kg/day | 292 | 183 | - |
| Required $O_2$ | kg/day | 893 | 561 | - |

## 2.8 Ratio of oxygen required to $BOD_5$ removed

$BOD_5$ removed (kg/d)

$O_2$/$BOD_5$ removed

**Table 74 Removed $BOD_5$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| $S_0$-S-$BOD_{5\text{-out}}$ | mg/L | 916 | 916 | - |
| $BOD_5$ removed | kg/day | 889 | 559 | - |
| $O_2$/$BOD_5$ | - | 1.0 | 1.0 | - |

## 2.9 Surface aerator power requirements

assumption: kg-$O_2$/kw/h kg-$O_2$/kw/h No 1.6

a) Correction factor for surface aerators for summer conditions f

f = No. /N

1) Oxygen saturation concentration at 21 °C Cs(21) mg/L 8.91

2) Cs(20) mg/L 9.08

3) Do concentration in Lagoon $C_L$ mg/L 1.5

f= {B*CsT-CL}/ Cs (20)*1.024T-20*α}

| Ti-20 | $1.024^{T-20}$ | α | B | f |
|---|---|---|---|---|
| 1 | 1.029 | 0.6 | 0.9 | 0.44 |

b) Field transfer rate: N

N = fNo kg-$O_2$/kw/h 0.71

Total amount of transfer $O_2$ kg-$O_2$/kw/d kg-$O_2$/kw/h 17.0

The total axis power required to meet the required oxygen

**Table 75 Required $O_2$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Required $O_2$ | kg/day | 893 | 561 | - |
| Required power for $O_2$ supply | kw | 52.5 | 33.0 | - |

## 2.10 Energy requirements for mixing

**Table 76 Specifications of Aerator**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Power for Mixing | kW/m$^3$ | 0.005 | 0.005 | - |
| Lagoon volume | m$^3$ | 14,000 | 9,500 | - |
| Axis power for mixing | kW | 70 | 47.5 | - |
| Total efficiency | - | 0.75 | 0.75 | - |
| Required power | kW | 93 | 63 | - |
| Unit Power | kW/No. | 15 | 15 | - |
| No. of Aerator | Nos. | 7 | 5 | - |

# 3. Leachate recirculation pump

1) Recirculation rate r times/leachate

Recirculation pump flow Qr m$^3$/day

Qr = r*Q

Required Power Ps

Ps = 0.163*Qr(m$^3$/min)*H(m)/ή Hose power

Here

Total head of the pump H m

Total efficiency ή

Liquid density ρs 1.05

From the entrance of aerated lagoon to landfill

**Table 77 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | m$^3$/day | 970 | 610 | - |
| r | - | 3 | 3 | - |
| Qr | m$^3$/day | 2,910 | 1,830 | - |
| | m$^3$/min | 2.02 | 1.27 | - |
| Head | m | 50 | 50 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 15.4 | 19.4 | - |
| | kW | 19.6 | 14.6 | - |
| Unit power | kW/No. | 15 | 19 | - |
| Nos. of pumps | Nos. | (2+1) | (1+1) | - |

# 4. Solid-liquid separation: sedimentation tank

Qi: Inflow m$^3$/day

Safety factor 3

R.T: Retention time at Qi*3 hr

OL: Overflow rate at Qi*3 m$^3$/m$^2$/day

Qi*Ci = Qo*Co+Qu*Cu

| | | |
|---|---|---|
| Ci: Inflow SS | | mg/L |
| Co: Outflow SS | | mg/L |
| Cu: Concentrated SS in the sedimentation tank | | mg/L |
| Qo: Outflow | | $m^3$/day |
| Qu: Underflow (Sludge flow) | | $m^3$/day |
| Qu = Qi-Qo | | $m^3$/day |
| Qo=Qi*(Cu-Ci) / (Cu-Co) | | $m^3$/day |
| As: Surface area = Qo/OL | | $m^2$ |
| Dimension | Ls: Length of sedimentation tank | m |
| | Ws: Width of sedimentation tank | m |
| Hs: Height of sludge zone = Vs/As | | m |
| Vs: Volume of sedimentation tank | | $m^3$ |
| H2: Height allowance = Vs/As | | $m^2$ |

**Table 78 Dimension of sedimentation tank**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| Qi | $m^3$/day | 2,910 | 1,830 | - |
| RT | hr | 2 | 2 | - |
| OL | $m^3/m^2$/day | 22 | 22 | - |
| Ci | mg/L | 970 | 970 | - |
| Co | mg/L | 70 | 70 | - |
| Cu | mg/L | 5,000 | 5,000 | - |
| Qo | $m^3$/day | 2,400 | 1,500 | - |
| As | $m^2$ | 110 | 70 | - |
| Ls | m | 30 | 20 | - |
| Ws | m | 5 | 5 | - |
| Hs | m | 2.3 | 2.3 | - |
| Vs | $m^3$ | 250 | 160 | - |
| Qu | $m^3$/day | 510 | 330 | - |
| H2 | m | 1.5 | 1.5 | - |
| H0 | m | 3.8 | 3.8 | - |

Total Height Ho=H2+Hs

## 5. To removal nutrients, use wetland.

Only by aerated lagoon, only $BOD_5$ and SS are removed. For further treatment for nutrients another process is necessary.

Here, wetland was considered as an alternative for this purpose, considering cost efficiency.

Levels of nitrogen and phosphates are estimated as below based on the analysis of leachate during this Study.

| | | | |
|---|---|---|---|
| Total-N: | | 240 | mg/L |
| Total-P: | | 64 | mg/L |

In biological treatment nitrogen and phosphate are necessary. The ratio of N and P towards $BOD_5$ is 3:0.3:100

Therefore N and P after biological treatment, their levels are expected as below.

| | | | |
|---|---|---|---|
| Inlet $BOD_5$ | | 920 | mg/L |
| Therefore N to be removed by biological treatment | | 27.6 | mg/L |
| Therefore P to be removed by biological treatment | | 2.76 | mg/L |
| After aerated lagoon remained N | N | 212 | mg/L |
| | P | 61 | mg/L |

| Criteria* | |
|---|---|
| 20 | mg/L. as KTN |
| 10 | mg/L. as P |

*:Discharge criteria of industrial waste water into general public water body

Inlet T-P level will be reduced by using cover soil.

Therefore, only removal of nitrogen would be considered.

Here, subsurface-flow (SSF) systems was considered.

In a SSF wetland, the basin is filled with gravel or some other coarse substrate, and the water level is maintained below-ground. Water flows horizontally, or sometimes vertically, through the gravel and the root mat of the wetland vegetation.

Arrow arum (Polyandry spp.) and Pickerel weed (Pontederia spp.) have been used in constructed wetlands.

Also common reed (Phragmitescommunis) is used

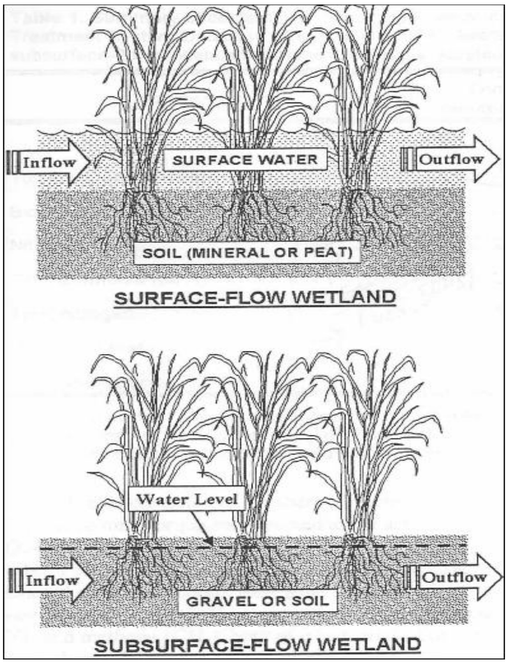



**Figure 4 Conceptual diagram of subsurface-flow wetlands**

**Example of determination of basin design for SFS wetlands system**

Nitrogen removal will proceed when $BOD_5$ level is less than 10 mg/L.

**1. Premises**

| | | |
|---|---|---|
| Influent $BOD_5$ | $C_0$ | 60 mg/L |
| Effluent $BOD_5$ | Ce | 8 mg/L |
| Inflow | Q | $m^3$/day |
| | | $m^3$/day |
| Vegetation type | | cattails |
| Minimum water temperature | T | 21°C |
| Basin media | coarse sand with 2 mm of maximum effective size | |
| Basin slope | S | 0.01 |

**2. Solution**

| | | | |
|---|---|---|---|
| 1. | Basin depth for use wit cattail | d | 0.3 m |
| 2. | Porosity | α | 0.39 |
| | Hydraulic conductivity | Ks | 480 $m^3/m^2$/day |
| | | $K_{20}$ | 1.35 |
| 3. | Temperature-dependent first order rate constant | | |
| | | $K_T$ at | 21°C |
| | | | 1.49 $d^{-1}$ |
| 4. | Pore-space detention time | t' = -1nCe/C0/Kt | d |
| 5. | Cross-sectional area | Ac = Q/Ks/S | $m^2$ |
| 6. | Basin width | W = Ac/d | m |
| 7. | Basin length | L = t'Q/W/d/α | m |
| 8. | Required surface area | As = L*W | $m^2$ |
| | | | ha |
| 9. | Check hydraulic-loading rate or specific area requirements | | |
| | | Lw = Q/L/W | 150 to 500 $m^3$/ha/day |
| | | | 0.015 to 0.005 $m^3/m^2$/day |
| | or | Asp= 1/Lw for advanced treatment 2.1 ha/$10^3m^3$ | |
| 10. | Check $BOD_5$ loading rate | Max.$BOD_{5L}$ | 60 kg/ha/day |
| | $LBOD_5$ | | kg/day |
| | $BOD_{5L}$ | | kg/ha/day |
| 11. | Vegetation | | |
| | Reed can absprb | N | 18 to 21g/kg |
| | | P | 2.0 to 3.0 g/kg |
| | Inlet N | | 212.4 mg/L |
| | Vd: vegetation density | | 10kg/$m^2$ |

**Table 79 Specification of Wetland**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| $C_0$ | mg/L | 60 | 60 | - |
| Ce | mg/L | 8 | 8 | - |
| Q | $m^3$/day | 970 | 610 | - |
| T | °C | 21 | 21 | - |
| S | | 0.01 | 0.01 | - |
| d | m | 0.3 | 0.3 | - |
| α | | 0.39 | 0.39 | - |
| Ks | $m^3/m^2$/day | 480 | 480 | - |
| $K_{20}$ | | 1.35 | 1.35 | - |
| Kt | $d^{-1}$ | 1.49 | 1.49 | - |
| t' | day | 1.36 | 1.36 | - |
| Ac | $m^2$ | 202 | 127 | - |
| W | m | 680 | 430 | - |
| L | m | 17 | 16 | - |
| As | $m^2$ | 11,300 | 7,100 | - |
| Lw | $m^3/m^2$/day | 0.09 | 0.09 | - |
| Asp | ha/1000$m^3$ | 11.60 | 11.60 | - |
| L-$BOD_5$ | kg/day | 58.2 | 36.6 | - |
| $BOD_{5L}$ | kg/ha/day | 52 | 52 | - |
| V | $m^3$ | 3,390 | 2,130 | - |
| R.T | day | 3.5 | 3.5 | - |
| Inlet N | mg/L | 212 | 212 | - |
| Total N in WL | g | 739,000 | 460,000 | - |
| N absorption | g/kg | 18 | 18 | - |
| Nos. of reed | kg | 40,556 | 25,556 | - |
| Vd | kg/$m^2$ | 10 | 10 | - |
| Max Reed | kg | 113,000 | 71,000 | - |

**Alternative 3: Natural Pond System (Anaerobic + Facultative + Maturation Pond) -New Site 1**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is so called natural pond system to remove $BOD_5$, SS and nutrients such as N and P.

## 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 80 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of T-$BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1.2 Recirculation rate of leachate 3 times/day toward the leachate generated

## 2. Anaerobic pond

| | | | |
|---|---|---|---|
| RTa: Retention time of anaerobic pond | | | 7 days |
| $BOD_5$ Removal rate | | | 60% |
| $BOD_5$ out-a | | | 368 mg/L |
| Da: Depth of the anaerobic pond | | | 3.5 m |
| Aa: Surface area | | | $m^2$ |
| Va: Anaerobic pond volume | | | $m^3$ |
| Dimension | Length | La | m |
| | Width | Wa | m |

$BOD_{5La}$: $BOD_5$ load of anaerobic pond 100 to 350 g-$BOD_5$/$m^3$-pond/day

**Table 81 Dimension of Anaerobic Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| R.T | days | 7 | 7 | - |
| Va | $m^3$ | 6,790 | 4,270 | - |
| Da | m | 3.5 | 3.5 | - |
| Aa | $m^2$ | 1,940 | 1,220 | - |
| La | m | 70 | 60 | - |
| Wa | m | 30 | 22 | - |
| $BOD_5$ | g/day | 892,410 | 561,200 | - |
| $BOD_{5La}$ | g/$m^3$/day | 131 | 131 | - |

Number of ponds: 1

## 3. Facultative Pond

$ls_1$: BOD permissible loading — kg/ha/day

$ls_1 = 350\ (1.107 - 0.002T)^{T-25}$ — 100 to 400 kg/ha/day

or

$ls_2 = 20T-120$ — kg/ha/day

Here, T: Minimum temperature — 21 °C

Ls: $BOD_5$ loading

Ls = 10 Li Q / Af — kg/ha/day

Here,

Li: Inflow $BOD_5$ — mg/L

Af: Facultative pond area — $m^2$

$Af = Q *(Li - Le)/18D/(1.05)^{T-20}$

Here,

Le: Outflow $BOD_5$ — mg/L

$L_r$: $BOD_5$ removal — kg/ha/day

$Lr = 0.725Ls \div 10.75$

Df: Depth of the facultative pond — m

| | | | |
|---|---|---|---|
| Dimensions of facultative pond | Length | Lf | m |
| | Width | Wf | m |

**Table 82 Dimension of Sedimentation Tank**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| T | °C | 21 | 21 | - |
| $ls_1$ | kg/ha/day | 272 | 272 | - |
| $ls_2$ | kg/ha/day | 300 | 300 | - |
| Ls | kg/ha/day | 270 | 270 | - |
| Li | mg/L | 368 | 368 | - |
| Df | m | 1.2 | 1.2 | - |
| Af | $m^2$ | 13,200 | 8,300 | - |
| Le | mg/L | 60 | 60 | - |
| Lr | kg/ha/day | 207 | 207 | - |
| $BOD_{5Rf}$ | % | 76.5 | 76.5 | - |
| $BOD_{5out-f}$ | mg/L | 87 | 87 | - |
| $R.T_f$ | days | 16 | 16 | - |

Remarks:

(a) There is a difference between $ls_1$ and $ls_2$. Adopt $ls_1$ for safety.

(b) There is a difference between Le and $BOD_{5out-f}$. This is because Equations for Ls and Af are the one to get 60 mg/L-$BOD_5$ in South America.

(c) On the contrary, the value of $BOD_{5out-f}$ is calculated by the equation for Lr. Lr shows the average of the data arranged by MacGarry and Pescord.

(d) The $BOD_5$ removal in primary facultative ponds is usually in the range 70-80 percent based on unfiltered samples (that is, including the BOD exerted by the algae).
Therefore, effluent $BOD_{5out-f}$ level from facultative pond will be considered 60-117 mg/L with algae.

(e) It is said $BOD_5$ quality of the effluent from a facultative ponds as most of the BOD contained (70 to 90%) will be "algal BOD. Therefore, the filtered (soluble) $BOD_5$ level will be at least 18-35 mg/L.

**Table 83 Dimensions of Facultative Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Af | $m^2$ | 13,200 | 8,300 | - |
| Nos. of ponds | - | 2 | 2 | - |
| Af/pond | $m^2$ | 6,600 | 4,150 | - |
| Lf/pond | m | 140 | 110 | - |
| Wf/pond | m | 50 | 40 | - |
| Df | m | 1.2 | 1.2 | - |
| Vf/pond | $m^3$ | 8,400 | 5,280 | - |
| Total Vf | $m^3$ | 16,800 | 10,560 | - |

Pond arrangement: Parallel

## 4. Maturation pond

Maturation ponds (low-cost polishing ponds, which succeed the primary or secondary facultative pond) are primarily designed for tertiary treatment, i.e., the removal of pathogens, nutrients and possibly algae.

With the combination of facultative pond and maturation pond,

(1) Total nitrogen removal in WSP systems can reach 80 percent or more, and ammonia removal can be as high as 95 percent.

(2) The best way of increasing phosphorus removal in WSP is to increase the number of

maturation ponds, so that progressively more and more phosphorus becomes immobilized in the sediments. From a well functioning 2 ponds system, 70% mass removal of total.

(3) The removal rate increases by adding maturation ponds.

Design criteria

$D_m$: Depth of maturation pond 1.5 m

$RT_m$: Retention time of maturation pond 14 days

$A_m$: Area od maturation pond

Dimensions of maturation pond

Length Lm m

Width Wm m

**Table 84 Dimensions of Maturation Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| $RT_m$ | days | 14 | 14 | - |
| Vm | $m^3$ | 13,580 | 8,540 | - |
| Nos. of Ponds | - | 2 | 2 | - |
| Vm/Pond | $m^3$ | 6,790 | 4,270 | - |
| Dm/Pond | m | 1.5 | 1.5 | - |
| Am/Pond | $m^2$ | 4,600 | 2,900 | - |
| Lm/Pond | m | 120 | 90 | - |
| Wm/Pond | m | 40 | 35 | - |

Pond arrangement: Series

## 5. Leachate Recirculation pump

Recirculation rate r times/leachate

Recirculation pump flow Qr $m^3$/day

Qr = r*Q

Required Power Ps

Ps = 0.163*Qr($m^3$/min)*H(m)/ή Horse power

Here

Total head of the pump H m

Total efficiency ή

Liquid density ρs 1.05

From the entrance of anaerobic lagoon to landfill

**Table 85 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 2,910 | 1,830 | - |
| | $m^3$/min | 2.02 | 1.27 | - |
| Head | m | 50 | 50 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 15.4 | 19.4 | - |
| | kW | 19.6 | 14.6 | - |
| Unit power | kW/No. | 15 | 19 | - |
| Nos. of pumps | Nos. | (2+1) | (1+1) | - |

**Alternative 4: Natural Pond System (Anaerobic + Facultative + Wetland) -New Site 1**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is an alternative to use wetland instead of Maturation Pond in Alternative 3 in order to remove nutrients such as N and P.

## 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 86 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | $T\text{-}BOD_5$ | SS | $S\text{-}BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of $T\text{-}BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1.2 Recirculation rate of leachate 3 times/day toward the leachate generated

## 2. Anaerobic pond

| | | | |
|---|---|---|---|
| RTa : Retention time of anaerobic pond | | | 7 days |
| $BOD_5$ Removal rate | | | 60% |
| $BOD_5$ out-a | | | 368 mg/L |
| Da: Depth of the anaerobic pond | | | 3.5 m |
| Aa: Surface area | | | $m^2$ |
| Va: Anaerobic pond volume | | | $m^3$ |
| Dimension | Length | La | m |
| | Width | Wa | m |
| $BOD_{5La}$: $BOD_5$ load of anaerobic pond | | 100 to 350 $g\text{-}BOD_5/m^3$-pond/day | |

**Table 87 Dimension of Anaerobic Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| R.T | days | 7 | 7 | - |
| Va | $m^3$ | 6,790 | 4,270 | - |
| Da | m | 3.5 | 3.5 | - |
| Aa | $m^2$ | 1,940 | 1,220 | - |
| La | m | 70 | 60 | - |
| Wa | m | 30 | 70 | - |
| $BOD_5$ | g/day | 892,400 | 20 | - |
| $BOD_{5La}$ | g/$m^3$/day | 131 | 131 | - |

Number of ponds: 1

## 3. Facultative Pond

$ls_1$: BOD permissible loading — kg/ha/day

$ls_1 = 350 (1.107 - 0.002T)^{T-25}$ — 100 to 400 kg/ha/day

or

$ls_2 = 20T-120$ — kg/ha/day

Here, T: Minimum temperature — 21 °C

Ls: $BOD_5$ loading

Ls = 10 Li Q / Af — kg/ha/day

Here,

Li: Inflow $BOD_5$ — mg/L

Af: Facultative pond area — $m^2$

$Af = Q *(Li - Le)/18D/(1.05)^{T-20}$

Here,

Le: Outflow $BOD_5$ — mg/L

$L_r$: $BOD_5$ removal — kg/ha/day

$Lr = 0.725Ls \div 10.75$

Df: Depth of the facultative pond — m

| | | | |
|---|---|---|---|
| Dimensions of facultative pond | Length | Lf | m |
| | Width | Wf | m |

**Table 88 Dimension of Sedimentation Tank**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| T | °C | 21 | 21 | - |
| $ls_1$ | kg/ha/day | 272 | 272 | - |
| $ls_2$ | kg/ha/day | 300 | 300 | - |
| Ls | kg/ha/day | 270 | 270 | - |
| Li | mg/L | 368 | 368 | - |
| Df | m | 1.2 | 1.2 | - |
| Af | $m^2$ | 13,200 | 8,900 | - |
| Le | mg/L | 60 | 60 | - |
| Lr | kg/ha/day | 207 | 207 | - |
| $BOD_{5Rf}$ | % | 76.5 | 76.5 | - |
| $BOD_{5out-f}$ | mg/L | 87 | 87 | - |
| $R.T_f$ | days | 16 | 16 | - |

Remarks:

(a) There is a difference between $ls_1$ and $ls_2$. Adopt $ls_1$ for safety.

(b) There is a difference between Le and $BOD_{5out-f}$. This is because Equations for Ls and Af are the one to get 60 mg/L-$BOD_5$ in South America.

(c) On the contrary, the value of $BOD_{5out-f}$ is calculated by the equation for Lr. Lr shows the average of the data arranged by MacGarry and Pescord.

(d) The $BOD_5$ removal in primary facultative ponds is usually in the range 70-80 percent based on unfiltered samples (that is, including the BOD exerted by the algae).
Therefore, effluent $BOD_{5out-f}$ level from facultative pond will be considered 60-117 mg/L with algae.

(e) It is said $BOD_5$ quality of the effluent from a facultative ponds as most of the BOD contained (70 to 90%) will be "algal BOD. Therefore, the filtered (soluble) $BOD_5$ level will be at least 18-35 mg/L.

**Table 89 Dimensions of Facultative Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Af | $m^2$ | 13,200 | 8,300 | - |
| Nos. of ponds | - | 2 | 2 | - |
| Af/pond | $m^2$ | 6,600 | 6,600 | - |
| Lf/pond | m | 140 | 140 | - |
| Wf/pond | m | 50 | 50 | - |
| Df | m | 1.2 | 1.2 | - |
| Vf/pond | $m^3$ | 8,400 | 8,400 | - |
| Total Vf | $m^3$ | 16,800 | 16,800 | - |

Pond arrangement: Parallel

## 4. To removal nutrients, use wetland

Only by aerated lagoon, only $BOD_5$ and SS are removed. For further treatment for nutrients another process is necessary.

Here, wetland was considered as an alternative for this purpose, considering cost efficiency.

Levels of nitrogen and phosphates are estimated as below based on the analysis of leachate during this Study.

| | | | |
|---|---|---|---|
| Total-N: | | 240 | mg/L |
| Total-P: | | 64 | mg/L |

In biological treatment nitrogen and phosphate are necessary. The ratio of N and P towards $BOD_5$ is 3:0.3:100

Therefore N and P after biological treatment, their levels are expected as below.

| | | | |
|---|---|---|---|
| Inlet $BOD_5$ | | 920 | mg/L |
| Therefore N to be removed by biological treatment | | 27.6 | mg/L |
| Therefore P to be removed by biological treatment | | 2.76 | mg/L |
| After aerated lagoon remained N | N | 212 | mg/L |
| | P | 61 | mg/L |

| Criteria* | |
|---|---|
| 20 | mg/L. as KTN |
| 10 | mg/L. as P |

*:Discharge criteria of industrial waste water into general public water body

Inlet T-P level will be reduced by using cover soil. Therefore, only removal of nitrogen would be considered.

Here, subsurface-flow (SSF) systems was considered.

In a SSF wetland, the basin is filled with gravel or some other coarse substrate, and the water level is maintained below-ground. Water flows horizontally, or sometimes vertically, through the gravel and the root mat of the wetland vegetation.

Arrow arum (Polyandry spp.) and Pickerel weed (Pontederia spp.) have been used in constructed wetlands.

Also common reed (Phragmitescommunis) is used

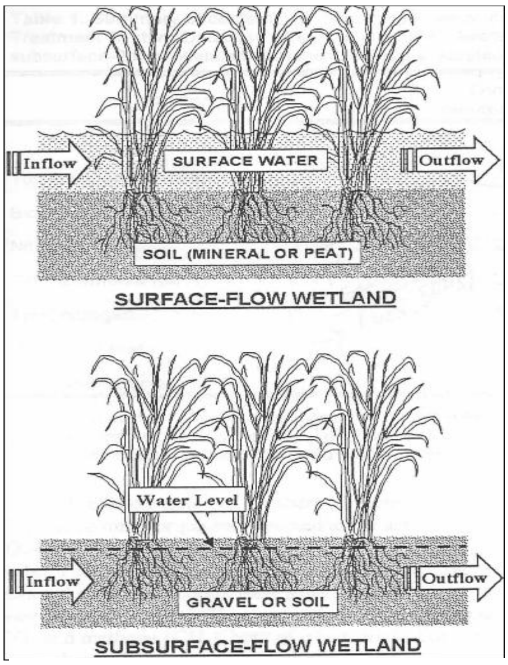



**Figure 5 Conceptual diagram of subsurface-flow wetlands**

**Example of determination of basin design for SFS wetlands system**

Nitrogen removal will proceed when $BOD_5$ level is less than 10 mg/L.

**1. Premises**

| | | |
|---|---|---|
| Influent $BOD_5$ | $C_0$ | 87 mg/L |
| Effluent $BOD_5$ | $C_e$ | 8 mg/L |
| Inflow | Q | $m^3$/day |
| | | $m^3$/day |
| Vegetation type | | cattails |
| Minimum water temperature | T | 21°C |
| Basin media | coarse sand with 2 mm of maximum effective size | |
| Basin slope | S | 0.01 |

**2. Solution**

| | | | |
|---|---|---|---|
| 1. | Basin depth for use wit cattail | d | 0.3 m |
| 2. | Porosity | α | 0.39 |
| | Hydraulic conductivity | Ks | 480 $m^3/m^2$/day |
| | | $K_{20}$ | 1.35 |
| 3. | Temperature-dependent first order rate constant | | |
| | | $K_T$ at | 21 °C |
| | | | 1.49 $d^{-1}$ |
| 4. | Pore-space detention time | t' = -1nCe/C0/Kt | d |
| 5. | Cross-sectional area | Ac = Q/Ks/S | $m^2$ |
| 6. | Basin width | W = Ac/d | m |
| 7. | Basin length | L = t'Q/W/d/α | m |
| 8. | Required surface area | As = L*W | $m^2$ |
| | | | ha |
| 9. | Check hydraulic-loading rate or specific area requirements | | |
| | | Lw = Q/L/W | 150 to 500 $m^3$/ha/day |
| | | | 0.015 to 0.005 $m^3/m^2$/day |
| | or | Asp= 1/Lw for advanced treatment 2.1 ha/$10^3 m^3$ | |
| 10. | Check $BOD_5$ loading rate | Max.$BOD_{5L}$ | 60kg/ha/day |
| | | $LBOD_5$ | kg/day |
| | | $BOD_{5L}$ | kg/ha/day |
| 11. | Vegetation | | |
| | Reed can absprb | N | 18 to 21g/kg |
| | | P | 2.0 to 3.0 g/kg |
| | Inlet N | | 240 mg/L |
| | Vd: vegetation density | | 10 $kg/m^2$ |

**Table 90 Specification of Wetland**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| $C_0$ | mg/L | 87 | 87 | - |
| Ce | mg/L | 8 | 8 | - |
| Q | $m^3$/day | 970 | 610 | - |
| T | °C | 21.0 | 21.0 | - |
| S | | 0.01 | 0.01 | - |
| d | m | 0.3 | 0.3 | - |
| α | | 0.39 | 0.39 | - |
| Ks | $m^3/m^2$/day | 480 | 480 | - |
| $K_{20}$ | | 1.35 | 1.35 | - |
| Kt | $d^{-1}$ | 1.49 | 1.49 | - |
| t' | day | 1.61 | 1.61 | - |
| Ac | $m^2$ | 202 | 127 | - |
| W | m | 680 | 430 | - |
| L | m | 20 | 19 | - |
| As | $m^2$ | 13,400 | 8,400 | - |
| Lw | $m^3/m^2$/day | 0.07 | 0.07 | - |
| Asp | ha/1000$m^3$ | 13.74 | 13.74 | - |
| L-$BOD_5$ | kg/day | 84.4 | 53.07 | - |
| $BOD_{5L}$ | kg/ha/day | 63 | 63 | - |
| V | $m^3$ | 4,020 | 2,520 | - |
| RT | day | 4.1 | 4.1 | - |
| Inlet N | mg/L | 240 | 240 | - |
| Total N in WL | g | 970,000 | 610,000 | - |
| N absorption | g/kg | 18 | 18 | - |
| Nos. of reed | kg | 53,889 | 33,889 | - |
| Vd | kg/$m^2$ | 10 | 10 | - |
| Max Reed | kg | 134,000 | 84,000 | - |

This system seems to be inferior in performance.

## 5. Leachate Recirculation pump

| | | |
|---|---|---|
| Recirculation rate | r | times/leachate |
| Recirculation pump flow | Qr | $m^3$/day |

Qr = r*Q

| | | |
|---|---|---|
| Required Power | Ps | |
| Ps = 0.163*Qr($m^3$/min)*H(m)/ή | | Horse power |

Here

| | | |
|---|---|---|
| Total head of the pump | H | m |
| Total efficiency | ή | |
| Liquid density | ρs | 1.05 |

From the entrance of anaerobic lagoon to landfill

**Table 91 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 2,910 | 1,830 | - |
| | $m^3$/min | 2.02 | 1.27 | - |
| Head | m | 50 | 50 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 15.4 | 19.4 | - |
| | kW | 19.6 | 14.6 | - |
| Unit power | kW/No. | 15 | 19 | - |
| Nos. of pumps | Nos. | (2+1) | (1+1) | - |

**Alternative 5: Anaerobic Pond + Aerated Lagoon + Sedimentation Pond + Wetland with recirculation -New Site 1**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is an alternative adding Anaerobic Pond to Alternative 2 in order to reduce area.

## 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 92 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of T-$BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1.2 Recirculation rate of leachate 3 times/day toward the leachate generated

## 2. Anaerobic pond

| | | | |
|---|---|---|---|
| RTa : Retention time of anaerobic pond | | | 7 days |
| $BOD_5$ Removal rate | | | 60% |
| $BOD_5$ out-a | | | 368 mg/L |
| Da: Depth of the anaerobic pond | | | 3.5 m |
| Aa: Surface area | | | $m^2$ |
| Va: Anaerobic pond volume | | | $m^3$ |
| Dimension | Length | La | m |
| | Width | Wa | m |

$BOD_{5La}$: $BOD_5$ load of anaerobic pond 100 to 350 g-$BOD_5$/$m^3$-pond/day

**Table 93 Dimension of Anaerobic Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| R.T | days | 7 | 7 | - |
| Va | $m^3$ | 6,790 | 4,270 | - |
| Da | m | 3.5 | 3.5 | - |
| Aa | $m^2$ | 1,940 | 1,220 | - |
| La | m | 70 | 66 | - |
| Wa | m | 30 | 22 | - |
| $BOD_5$ | g/day | 892,400 | 561,200 | - |
| $BOD_{5La}$ | g/$m^3$/day | 131 | 131 | - |

Number of ponds: 1

# 3. Aerated Lagoon

## 3.1 Aerated Lagoon Process

Design Base:

| | Symbol | Unit | |
|---|---|---|---|
| Influent flow | Q | $m^3$/d | |
| Influent suspended solids | $SS_0$ | mg/L | 378 |
| Influent soluble $BOD_5$ | $S_0$ | mg/L | 368 |
| Effluent soluble $BOD_5$ | $S\text{-}BOD_{5\text{-}out}$ | mg/L | 30 |
| Effluent suspended solid after setting | SSe | mg/L | 70 |
| Kinetic coefficients: | | | |
| Y | | l/d | 0.65 |
| Ks | | mg-$BOD_5$/L | 100 |
| Kmax | | mg-$BOD_5$/L/d | 6.0 |
| Kd | | l/d | 0.07 |
| First order soluble $BOD_5$ removal rate constants at 20 °C | | | |
| | $k_{(20)}$ | l/d | 2.5 |
| Waste water temperature | Ti | °C | 21.0 |
| Aeration constants in leachate | | | |
| in leachate | α | | 0.6 |
| in treated water | β | | 0.9 |
| Oxygen concentration to be maintained in liquid | | mg - $O_2$/L | 1.5 |
| Lagoon depth | H | m | 3.5 |
| Design mean cell - residence time | θc | d | 7 |

3.2 Surface area of the lagoon A $m^2$

θc = V/Q ∴ V = θc*Q V: volume of the lagoon

A = V/H

Dimension

**Table 94 Dimension of Aerated Lagoon**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| V | $m^3$ | 6,790 | 4,270 | - |
| A | $m^2$ | 1,940 | 1,220 | - |
| L | m | 70 | 60 | - |
| W | m | 30 | 22 | - |
| H | m | 3.5 | 3.5 | - |
| A' (corrected A) | $m^2$ | 2,100 | 1,320 | - |
| V' (Corrected V) | $m^3$ | 7,400 | 4,700 | - |

3.3 Soluble effluent $BOD_5$ at the lagoon outlet: S-$BOD_5$-out

S-$BOD_5$out = { Ks (1 + 0c*kd) } / {θc (Y*kmax - kd) - I } (mg/L)

| Ks | θc*kd | 1+θc*kd | Ks (1+θc*kd) | θc | Y*kmax | Y*kmax-kd | θc (Y*kmax-kd)-1 | S-$BOD_5$ out |
|---|---|---|---|---|---|---|---|---|
| 100 | 0.49 | 1.49 | 149 | 7 | 3.9 | 3.83 | 25.8 | 5.8 |

3.4 Effluent $BOD_5$

(1) Correct the removal-rate for temperature effects

$k(t) = k(20)*\theta^{T-20}$ (l/d)

| Ti | $k_{(20)}$ | T-20 | θ | $\theta^{(T-20)}$ | $k_{(20)}\theta^{(T-20)}$ |
|---|---|---|---|---|---|
| 21.0 | 2.5 | 1 | 1.06 | 1.06 | 2.7 |

(2) Determine the effluent $BOD_5$: St-$_{out}$ (mg/L)

$St\text{-}out/S_0 = 1/(1+k\theta_H) = S/S_0 = 1/(1+kV/Q)$

| kt | V/Q | 1+kV/Q | 1/(1+kV/Q) | $S_0$ | St-out |
|---|---|---|---|---|---|
| 2.7 | 14 | 19.55 | 0.05 | 368 | 19 |

3.5 Concentration of biological solids produced: X (mg/L)

$X = Y (S_0\text{-S-}BOD_5\text{-out})/ (1+k_d\theta_c)$ (mg-VSS/L)

| Y | $S_0$-S-$BOD_{5\text{-out}}$ | $k_d$ | θc | $Y(S_0\text{-S-}BOD_{5\text{-out}})/(1+k_d\theta_c)$ |
|---|---|---|---|---|
| 0.65 | 362.2 | 0.07 | 7 | 158 |

3.6 Suspended solids in the lagoon before settling

SSi = Influent suspended solids + X/0.7(mg/L)

Ratio of volatile suspended solid 0.7

| SSo | X | SSi |
|---|---|---|
| 378 | 158 | 604 |

3.7 Oxygen requirements

$Q_2$ (kg/d) = Q ($S_0$-S-$BOD_{5\text{-out}}$)/f-1.42Px

f: conversion factor for $BOD_5$ to $BOD_L$ 0.68

Px = Q*(concentration of biological solids produced)

**Table 95 Required $O_2$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| $S_0$-s-$BOD_{5\text{-out}}$ | mg/L | 362 | 362 | - |
| f | - | 0.68 | 0.68 | - |
| Px | kg/day | 153 | 96 | - |
| Required $O_2$ | kg/day | 299 | 188 | - |

3.8 Ratio of oxygen required to $BOD_5$ removed

$BOD_5$ removed (kg/d)

$O_2$/$BOD_5$ removed

**Table 96 Removed $BOD_5$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| So-S-$BOD_{5\text{-out}}$ | mg/L | 362 | 362.2 | - |
| $BOD_5$ removed | kg/day | 351 | 221 | - |
| $O_2$/$BOD_5$ | - | 0.9 | 0.9 | - |

3.9 Surface aerator power requirements

assumption: kg-$O_2$/kw/h  kg-$O_2$/kw/h  No  1.6

a) Correction factor for surface aerators for summer conditions f

f=No/N

1) Oxygen saturation concentration at 21 °C  Cs(21)  mg/L  8.91

2) Cs(20)  mg/L  9.08

3) DO concentration in Lagoon  CL  mg/L  1.5

f= {B*CsT-CL}/ Cs (20)*1.024T-20*α}

| Ti-20 | $1.024^{T-20}$ | α | B | f |
|---|---|---|---|---|
| 1 | 1.029 | 0.6 | 0.9 | 0.44 |

b) Field transfer rate : N

$N = fN_0$ $kg\text{-}O_2/kw/h$ 0.71

Total amount of transfer $O_2$ $kg\text{-}O_2/kw/d$ $kg\text{-}O_2/kw/h$ 17.0

The total axis power required to meet the required oxygen

**Table 97 Required $O_2$ Supply**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Required $O_2$ | kg/day | 299 | 188 | - |
| Required power for $O_2$ supply | kW | 17.6 | 11.1 | - |

3.10 Energy requirements for mixing

**Table 98 Specifications of Aerator**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Power for Mixing | $kW/m^3$ | 0.005 | 0.005 | - |
| Lagoon volume | $m^3$ | 7,400 | 7,400 | - |
| Axis power for mixing | kW | 37 | 23.5 | - |
| Total efficiency | - | 0.75 | 0.75 | - |
| Required power | kW | 49.3 | 31 | - |
| Required power per unit | kW/No. | 11 | 7.5 | - |
| Power for Mixing | Nos. | 5 | 5 | - |

## 4. Leachate recirculation pump

Recirculation rate r times/leachate

Recirculation pump flow Qr $m^3/day$

$Qr = r*Q$

Required Power Ps

$Ps = 0.163*Qr(m^3/min)*H(m)/ή$ Horse power

Here

Total head of the pump H m

Total efficiency ή

Liquid density ρs 1.05

From the entrance of anaerobic lagoon to landfill

**Table 99 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 2,910 | 1,830 | - |
| | $m^3$/min | 2.02 | 1.27 | - |
| Head | m | 50 | 50 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 15.4 | 19.4 | - |
| | kW | 19.6 | 14.6 | - |
| Unit power | kW | 15 | 19 | - |
| Nos. of pumps | Nos. | (2+1) | (1+1) | - |

## 5. Solid-liquid separation: sedimentation tank

| | | |
|---|---|---|
| Qi: Inflow | | $m^3$/day |
| Safety factor | | 3 |
| R.t: Retention time at Qi*3 | | hr |
| OL: Overflow rate at Qi*3 | | $m^3/m^2$/day |
| Qi*Ci = Qo*Co+Qu*Cu | | |
| Ci: Inflow SS | | mg/L |
| Co: Outflow SS | | mg/L |
| Cu: Concentrated SS in the sedimentation tank | | mg/L |
| Qo: Outflow | | $m^3$/day |
| Qu: Underflow (Sludge flow) | | $m^3$/day |
| Qu = Qi-Qo | | $m^3$/day |
| Qo = Qi*(Cu-Ci) / (Cu-Co) | | $m^3$/day |
| As: surface area=Qo/OL | | $m^3$ |
| Dimension | Ls: Length of sedimentation tank | m |
| | Ws: Width of sedimentation tank | m |
| Hs: Height of sludge zone =Vs/As | | m |
| Vs: Volume of sedimentation tank | | $m^3$ |
| $H_2$: Height allowance = Vs/As | | $m^2$ |

**Table 100 Dimension of Sedimentation Tank**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| Qi | $m^3$/day | 2,910 | 1,830 | - |
| R.T | hr | 2 | 2 | - |
| $O_L$ | $m^3/m^2$/day | 22 | 22 | - |
| Ci | mg/L | 604 | 604 | - |
| Co | mg/L | 70 | 70 | - |
| Cu | mg/L | 5,000 | 5,000 | - |
| Qo | $m^3$/day | 2,600 | 1,600 | - |
| As | $m^2$ | 120 | 80 | - |
| Ls | m | 30 | 20 | - |
| Ws | m | 5 | 5 | - |
| Hs | m | 2.1 | 2.0 | - |
| Vs | $m^3$ | 250 | 160 | - |
| Qu | $m^3$/day | 310 | 230 | - |
| $H_2$ | m | 1.5 | 1.5 | - |
| H0 | m | 3.6 | 3.5 | - |

## 6. To removal nutrients, use wetland.

Only by aerated lagoon, only $BOD_5$ and SS are removed. For further treatment for nutrients another process is necessary.

Here, wetland was considered as an alternative for this purpose, considering cost efficiency.

Levels of nitrogen and phosphates are estimated as below based on the analysis of leachate during this Study.

| | | | |
|---|---|---|---|
| Total-N: | | 240 | mg/L |
| Total-P: | | 64 | mg/L |

In biological treatment nitrogen and phosphate are necessary. The ratio of N and P towards $BOD_5$ is 3:0.3:100

Therefore N and P after biological treatment, their levels are expected as below.

| | | | |
|---|---|---|---|
| Inlet $BOD_5$ | | 920 | mg/L |
| Therefore N to be removed by biological treatment | | 27.6 | mg/L |
| Therefore P to be removed by biological treatment | | 2.76 | mg/L |
| After aerated lagoon remained N | N | 212 | mg/L |
| | P | 61 | mg/L |

| Criteria* | |
|---|---|
| 20 | mg/L. as KTN |
| 10 | mg/L. as P |

*:Discharge criteria of industrial waste water into general public water body

Inlet T-P level will be reduced by using cover soil.

Therefore, only removal of nitrogen would be considered.

Here, subsurface-flow (SSF) systems was considered.

In a SSF wetland, the basin is filled with gravel or some other coarse substrate, and the water level is maintained below-ground. Water flows horizontally, or sometimes vertically, through the gravel and the root mat of the wetland vegetation.

Arrow arum (Polyandry spp.) and Pickerel weed (Pontederia spp.) have been used in constructed wetlands.

Also common reed (Phragmitescommunis) is used

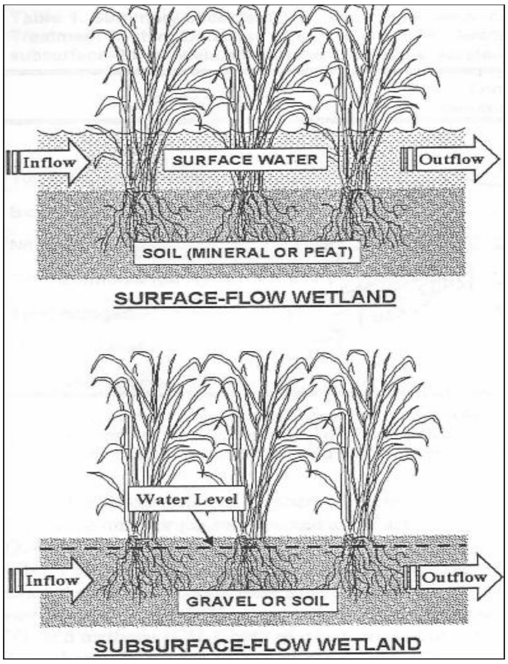



**Figure 6 Conceptual diagram of subsurface-flow wetlands**

**Example of determination of basin design for SFS wetlands system**

Nitrogen removal will proceed when $BOD_5$ level is less than 10 mg/L.

**1. Premises**

| | | |
|---|---|---|
| Influent $BOD_5$ | $C_0$ | 60 mg/L |
| Effluent $BOD_5$ | Ce | 8 mg/L |
| Inflow | Q | $m^3$/day |
| | | $m^3$/day |
| Vegetation type | | cattails |
| Minimum water temperature | T | 21°C |
| Basin media | coarse sand with 2 mm of maximum effective size | |
| Basin slope | S | 0.01 |

**2. Solution**

| | | | |
|---|---|---|---|
| 1. | Basin depth for use wit cattail | d | 0.3 m |
| 2. | Porosity | α | 0.39 |
| | Hydraulic conductivity | Ks | 480 $m^3/m^2$/day |
| | | $K_{20}$ | 1.35 |
| 3. | Temperature-dependent first order rate constant | | |
| | | $K_T$ at | 21°C |
| | | | 1.49 $d^{-1}$ |
| 4. | Pore-space detention time | t' = -1nCe/C0/Kt | d |
| 5. | Cross-sectional area | $A_C$ = Q/Ks/S | $m^2$ |
| 6. | Basin width | W = Ac/d | m |
| 7. | Basin length | L = t'Q/W/d/α | m |
| 8. | Required surface area | As = L*W | $m^2$ |
| | | | ha |
| 9. | Check hydraulic-loading rate or specific area requirements | | |
| | | Lw = Q/L/W | 150 to 500 $m^3$/ha/day |
| | | | 0.015 to 0.005 $m^3/m^2$/day |
| | or | Asp= 1/Lw for advanced treatment 2.1 ha/$10^3m^3$ | |
| 10. | Check $BOD_5$ loading rate | Max.$BOD_{5L}$ | 60 kg/ha/day |
| | $LBOD_5$ | | kg/day |
| | $BOD_{5L}$ | | kg/ha/day |
| 11. | Vegetation | | |
| | Reed can absorb | N | 18 to 21 g/kg |
| | | P | 2.0 to 3.0 g/kg |
| | Inlet N | | 212.4 mg/L |
| | Vd: vegetation density | | 10 kg/$m^2$ |

**Table 101 Specification of Wetland**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| $C_0$ | mg/L | 60 | 60 | - |
| Ce | mg/L | 8 | 8 | - |
| Q | $m^3$/day | 970 | 610 | - |
| T | °C | 21.0 | 21.0 | - |
| S | | 0.01 | 0.01 | - |
| d | m | 0.3 | 0.3 | - |
| α | | 0.39 | 0.39 | - |
| Ks | $m^3/m^2$/day | 480 | 480 | - |
| $K_{20}$ | | 1.35 | 1.35 | - |
| Kt | $d^{-1}$ | 1.49 | 1.49 | - |
| t' | day | 1.36 | 1.36 | - |
| Ac | $m^2$ | 202 | 127 | - |
| W | m | 680 | 430 | - |
| L | m | 17 | 16 | - |
| As | $m^2$ | 11,300 | 7,100 | - |
| Lw | $m^3/m^2$/day | 0.09 | 0.09 | - |
| Asp | ha/1000$m^3$ | 11.60 | 11.60 | - |
| L-$BOD_5$ | kg/day | 58.2 | 36.6 | - |
| $BOD_{5L}$ | kg/ha/day | 52 | 52 | - |
| V | $m^3$ | 3,390 | 2,130 | - |
| R.T | day | 3.5 | 3.5 | - |
| Inlet N | mg/L | 212 | 212 | - |
| Total N in WL | g | 730,000 | 460,000 | - |
| N absorption | g/kg | 18 | 18 | - |
| Nos. of reed | kg | 40,556 | 25,556 | - |
| Vd | kg/$m^2$ | 10 | 10 | - |
| Max Reed | kg | 113,000 | 71,000 | - |

**Alternative 6: Anaerobic Pond + Aerated Lagoon + Maturation Pond with recirculation -New Site 1**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is an alternative adding Anaerobic Pond to Alternative 1 to reduce area.

## 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 102 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | $T\text{-}BOD_5$ | SS | $S\text{-}BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of $T\text{-}BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1.2 Recirculation rate of leachate 3 times/day toward the leachate generated

## 2. Anaerobic pond

| | | | |
|---|---|---|---|
| RTa: Retention time of anaerobic pond | | | 7 days |
| $BOD_5$ Removal rate | | | 60% |
| $BOD_5$ out-a | | | 368 mg/L |
| Da: Depth of the anaerobic pond | | | 3.5 m |
| Aa: Surface area | | | $m^2$ |
| Va: Anaerobic pond volume | | | $m^3$ |
| Dimension | Length | La | m |
| | Width | Wa | m |

$BOD_{5La}$: $BOD_5$ load of anaerobic pond 100 to 350 g-$BOD_5$/$m^3$-pond/day

**Table 103 Dimension of Anaerobic Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| R.T | days | 7 | 7 | - |
| Va | $m^3$ | 6,790 | 4,270 | - |
| Da | m | 3.5 | 3.5 | - |
| Aa | $m^2$ | 1,940 | 1,220 | - |
| La | m | 70 | 60 | - |
| Wa | m | 30 | 22 | - |
| $BOD_5$ | g/day | 892,400 | 561,200 | - |
| $BOD_{5La}$ | g/$m^3$/day | 131 | 131 | - |

Number of ponds: 1

## 3. Aerated Lagoon

### 3.1 Aerated Lagoon Process

Design Base:

| | Symbol | Unit | |
|---|---|---|---|
| Influent flow | Q | $m^3$/d | |
| Influent suspended solids | $SS_0$ | mg/L | 378 |
| Influent soluble $BOD_5$ | $S_0$ | mg/L | 368 |
| Effluent soluble $BOD_5$ | $S\text{-}BOD_{5\text{-}out}$ | mg/L | 30 |
| Effluent suspended solid after setting | SSe | mg/L | 70 |
| Kinetic coefficients: | | | |
| Y | | l/d | 0.65 |
| Ks | | mg-$BOD_5$/L | 100 |
| Kmax | | mg-$BOD_5$/L/d | 6.0 |
| Kd | | l/d | 0.07 |
| First order soluble $BOD_5$ removal rate constants at 20 °C | | | |
| | $k_{(20)}$ | l/d | 2.5 |
| Waste water temperature | Ti | °C | 21.0 |
| Aeration constants in leachate | | | |
| in leachate | α | | 0.6 |
| in treated water | β | | 0.9 |
| Oxygen concentration to be maintained in liquid | | mg - $O_2$/L | 1.5 |
| Lagoon depth | H | m | 3.5 |
| Design mean cell - residence time | θc | d | 7 |

3.2 Surface area of the lagoon A $m^2$

θc = V/Q ∴ V = θc*Q V: volume of the lagoon

A = V/H

Dimension

**Table 104 Dimension of Aerated Lagoon**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| V | $m^3$ | 6,790 | 4,270 | - |
| A | $m^2$ | 1,940 | 1,220 | - |
| L | m | 70 | 60 | - |
| W | m | 30 | 22 | - |
| H | m | 3.5 | 3.5 | - |
| A' (corrected A) | $m^2$ | 2,100 | 1,320 | - |
| V' (Corrected V) | $m^3$ | 7,400 | 4,700 | - |

3.3 Soluble effluent $BOD_5$ at the lagoon outlet: S-$BOD_5$-out

S-$BOD_5$out = { Ks (1 + 0c*kd) } / {θc (Y*kmax - kd) - I } (mg/L)

| Ks | θc*kd | 1+θc*kd | Ks (1+θc*kd) | θc | Y*kmax | Y*kmax-kd | θc (Y*kmax-kd)-1 | S-$BOD_5$ out |
|---|---|---|---|---|---|---|---|---|
| 100 | 0.49 | 1.49 | 149 | 7 | 3.9 | 3.83 | 25.8 | 5.8 |

3.4 Effluent $BOD_5$

(1) Correct the removal-rate for temperature effects

$k(t) = k(20)*\theta^{T-20}$ (l/d)

| Ti | $k_{(20)}$ | T-20 | θ | $\theta^{(T-20)}$ | $k_{(20)}\theta^{(T-20)}$ |
|---|---|---|---|---|---|
| 21.0 | 2.5 | 1 | 1.06 | 1.06 | 2.7 |

(2) Determine the effluent $BOD_5$: St-$_{out}$ (mg/L)

$St\text{-}out/S_0 = 1/(1+k\theta_H) = S/S_0 = 1/(1+kV/Q)$

| kt | V/Q | 1+kV/Q | 1/(1+kV/Q) | $S_0$ | St-out |
|---|---|---|---|---|---|
| 2.7 | 14 | 19.55 | 0.05 | 368 | 19 |

3.5 Concentration of biological solids produced: X (mg/L)

$X = Y (S_0\text{-S-}BOD_5\text{-out})/ (1+k_d\theta_c)$ (mg-VSS/L)

| Y | $S_0$-S-$BOD_{5\text{-out}}$ | $k_d$ | θc | $Y(S_0\text{-S-}BOD_{5\text{-out}})/(1+k_d\theta_c)$ |
|---|---|---|---|---|
| 0.65 | 362.2 | 0.07 | 7 | 158 |

3.6 Suspended solids in the lagoon before settling

SSi = Influent suspended solids + X/0.7(mg/L)

Ratio of volatile suspended solid 0.7

| SSo | X | SSi |
|---|---|---|
| 378 | 158 | 604 |

3.7 Oxygen requirements

$Q_2$ (kg/d) = Q ($S_0$-S-$BOD_{5\text{-out}}$)/f-1.42Px

f: conversion factor for $BOD_5$ to $BOD_L$ 0.68

Px = Q*(concentration of biological solids produced)

**Table 105 Required $O_2$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| $S_0$-s-$BOD_{5\text{-out}}$ | mg/L | 362 | 362 | - |
| f | - | 0.68 | 0.68 | - |
| Px | kg/day | 153 | 96 | - |
| Required $O_2$ | kg/day | 299 | 188 | - |

3.8 Ratio of oxygen required to $BOD_5$ removed

$BOD_5$ removed (kg/d)

$O_2$/$BOD_5$ removed

**Table 106 Removed $BOD_5$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| So-S-$BOD_{5\text{-out}}$ | mg/L | 362 | 362.2 | - |
| $BOD_5$ removed | kg/day | 351 | 22.1 | - |
| $O_2$/$BOD_5$ | - | 0.9 | 0.9 | - |

3.9 Surface aerator power requirements

assumption: kg-$O_2$/kw/h kg-$O_2$/kw/h No 1.6

a) Correction factor for surface aerators for summer conditions f

f=No/N

1) Oxygen saturation concentration at 21 °C Cs(21) mg/L 8.91

2) Cs(20) mg/L 9.08

3) DO concentration in Lagoon CL mg/L 1.5

f= {B*CsT-CL}/ Cs (20)*1.024T-20*α}

| Ti-20 | $1.024^{T-20}$ | α | B | f |
|---|---|---|---|---|
| 1 | 1.029 | 0.6 | 0.9 | 0.44 |

b) Field transfer rate: N

$N = fN_0$ kg-$O_2$/kw/h 0.71

Total amount of transfer $O_2$ kg-$O_2$/kw/d kg-$O_2$/kw/h 17.0

The total axis power required to meet the required oxygen

**Table 107 Required $O_2$ Supply**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Required $O_2$ | kg/day | 299 | 188 | - |
| Required power for $O_2$ supply | kW | 17.6 | 11.1 | - |

3.10 Energy requirements for mixing

**Table 108 Specifications of Aerator**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Power for Mixing | $kW/m^3$ | 0.005 | 0.005 | - |
| Lagoon volume | $m^3$ | 7,400 | 4,700 | - |
| Axis power for mixing | kW | 37 | 23.5 | - |
| Total efficiency | - | 0.75 | 0.75 | - |
| Required power | kW | 49 | 31 | - |
| Unit power | kW/No. | 11 | 11 | - |
| No. of Aerator | Nos. | 5 | 3 | - |

## 4. Leachate recirculation pump

Recirculation rate r times/leachate

Recirculation pump flow Qr $m^3$/day

Qr = r*Q

Required Power Ps

Ps = 0.163*Qr($m^3$/min)*H(m)/ή Horse power

Here

Total head of the pump H m

Total efficiency ή

Liquid density ρs 1.05

From the entrance of anaerobic lagoon to landfill

**Table 109 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 2,910 | 1,830 | - |
| | $m^3$/min | 2.02 | 1.27 | - |
| Head | m | 50 | 50 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 15.4 | 19.4 | - |
| | kW | 11.6 | 14.6 | - |
| Unit power | kW/No. | 15 | 19 | - |
| Nos. of pumps | Nos. | (2+1) | (1+1) | - |

## 5. Maturation Pond

Design criteria

$D_m$: Depth of maturation pond 1.5 m

$RT_m$: Retention time of maturation pond 14 days

$A_m$: Area od maturation pond

Dimensions of maturation pond

Length Lm m

Width Wm m

**Table 110 Dimensions of Maturation Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| $RT_m$ | days | 14 | 14 | - |
| Vm | $m^3$ | 13,580 | 8,540 | - |
| Nos. of Ponds | - | 2 | 2 | - |
| Vm/Pond | $m^3$ | 6,790 | 4,270 | - |
| Dm/Pond | m | 1.5 | 1.5 | - |
| Am/Pond | $m^2$ | 4,600 | 2,900 | - |
| Lm/Pond | m | 120 | 90 | - |
| Wm/Pond | m | 40 | 35 | - |

Pond arrangement: Series

## Leachate Treatment Alternatives of New Guanabacoa

**Alternative 1: Aerated Lagoon + Maturation Pond with recirculation -New Guanabacoa**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is the same as the one which was adopted in the original pilot project in Campo Florido. However only aerated lagoon can not remove T-$BOD_5$ and SS. Therefore maturation pond after aerated lagoon was proposed.

### 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 111 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of T-$BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1) Leachate generation

| | | | |
|---|---|---|---|
| Stage1 | $A_1$ | 6.0 ha | 60,000 $m^2$ |
| Stage2 | $A_2$ | 4.0 ha | 40,000 $m^2$ |
| Stage3 | $A_3$ | 0.0 ha | 0 $m^2$ |

Once surface liner facility is constructed in landfill site, it is assumed that no water flows into the landfill site

$q = f*C*A*I/1000$ ($m^3$/day)

Where

q: Daily effluent amount of leachate water($m^3$/day)

C: Leachate coefficient of on-going landfill section 0.4

I: Annual maximum rainfall (mm/day)
Maximum rainfall during 2000 to 2002 338 mm in September in 2002
11.3 mm/day

A: Landfill area ($m^2$)

f: Safety factor 1.6

Q: Daily effluent amount of leachate with safety factor ($m^3$/day)

**Table 112 Proposed Leachate Volume**

| Q ($m^3$/day) | Stage1 | Stage2 | Stage3 |
|---|---|---|---|
| | 730 | 610 | 0 |

## 2. Leachate treatment

### 2.1 Aerated Lagoon Process Design

Design Base:

| | Symbol | Unit | |
|---|---|---|---|
| Influent flow | Q | $m^3/d$ | |
| Influent suspended solids | $SS_0$ | mg/L | 540 |
| Influent soluble $BOD_5$ | $S_0$ | mg/L | 920 |
| Effluent soluble $BOD_5$ | $S\text{-}BOD_{5\text{-}out}$ | mg/L | 30 |
| Effluent suspended solid after settling | SSe | mg/L | 70 |
| Kinetic coefficients: | | l/d | 0.65 |
| Y | | mg-$BOD_5$/L | 100 |
| Ks | | mg-$BOD_5$/L/d | 6.0 |
| Kmax | | l/d | 0.07 |
| Kd | $k_{(20)}$ | l/d | 2.5 |
| First order soluble $BOD_5$ removal rate constants at 20 °C | Ti | °C | 21.0 |
| Waste water temperature | | | |
| in leachate | α | | 0.6 |
| in treated water | β | | 0.9 |
| Oxygen concentration to be maintained in liquid | | mg-$O_2$/L | 1.5 |
| Lagoon depth | H | m | 3.5 |
| Design mean cell - residence time | θc | d | 14 |

### 2.2 Surface area of the lagoon

$\theta c = V/Q \quad \therefore\ V = \theta c * Q$ V: volume of the lagoon

$A = V/H$

Dimension

**Table 113 Dimensions of Aerated Lagoon**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| V | $m^3$ | 6,160 | 4,060 | - |
| A | $m^2$ | 1,760 | 1,160 | - |
| L | m | 60 | 60 | - |
| W | m | 30 | 20 | - |
| H | m | 3.5 | 3.5 | - |
| A' (Connected A) | $m^2$ | 1,800 | 1,200 | - |
| V' (Connected V) | $m^3$ | 6,300 | 4,200 | - |

Number of lagoon: 1

### 2.3 Soluble effluent $BOD_5$ at the lagoon outlet: S-$BOD_5$-out

$S\text{-}BOD_5\ out = \{Ks\ (1+\theta c*kd)\}/ \{ \theta c\ (Y*kmax-kd)-1\}(mg/L)$

| Ks | θc*kd | 1+θc*kd | Ks (1+θc*kd) | θc | Y*kmax | Y*kmax-kd | θc (Y*kmax-kd)-1 | S-$BOD_5$ out |
|---|---|---|---|---|---|---|---|---|
| 100 | 0.98 | 1.98 | 198 | 14 | 3.9 | 3.83 | 52.6 | 3.8 |

2.4 Effluent $BOD_5$

1) Correct the removal-rate for temperature effects

k(t) = k(20)*θT-20

| Ti | $k_{(20)}$ | T-20 | θ | $\theta^{(T-20)}$ | $k_{(20)}\theta^{(T-20)}$ |
|---|---|---|---|---|---|
| 21.0 | 2.5 | 1 | 1.06 | 1.06 | 2.7 |

2) Determine the effluent $BOD_5$: St-out (mg/L)

| kt | V/Q | 1+kV/Q | 1/(1+kV/Q) | $S_0$ | St-out |
|---|---|---|---|---|---|
| 2.7 | 14 | 38.10 | 0.03 | 920 | 24 |

2.5 Concentration of biological solids produced : X(mg/L)

X = Y(S0-S-$BOD_5$-out)/(1+kdθc)(mg-VSS/L)

| Y | $S_0$-S-$BOD_{5\text{-out}}$ | kd | θc | Y($S_0$-S-$BOD_{5\text{-out}}$)/(1+kdθc) |
|---|---|---|---|---|
| 0.65 | 916.2 | 0.07 | 14 | 301 |

2.6 Suspended solids in the lagoon before settling

SSi = Influent suspended solids + X/0.7(mg/L)

| SSo | X | SSi |
|---|---|---|
| 540 | 301 | 970 |

Ratio of volatile suspended solid 0.7

2.7 Oxygen requirements

$Q_2$(kg/d) = Q($S_0$-S-$BOD_{5\text{-out}}$)/f - 1.42Px

f: conversion factor for $BOD_5$ to BODL 0.68

Px =Q*(concentration of biological solids produced)

**Table 114 Required $O_2$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| $S_0$-s-$BOD_{5-out}$ | mg/L | 916 | 916 | - |
| f | - | 0.68 | 0.68 | - |
| Px | kg/day | 132 | 87 | - |
| Required $O_2$ | kg/day | 405 | 267 | - |

## 2.8 Ratio of oxygen required to $BOD_5$ removed

$BOD_5$ removed (kg/d)

$O_2/BOD_5$ removed

**Table 115 Removed $BOD_5$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| $S_0$-S-$BOD_{5-out}$ | mg/L | 916 | 916 | - |
| $BOD_5$ removed | kg/day | 403 | 266 | - |
| $O_2/BOD_5$ | - | 1.0 | 1.0 | - |

## 2.9 Surface aerator power requirements

assumption: kg-$O_2$/kw/h    kg-$O_2$/kw/h    No    1.6

a) Correction factor for surface aerators for summer conditions f

f=No. /N

1) Oxygen saturation concentration at 21 °C    Cs(21)    mg/L    8.91

2) Cs(20)    mg/L    9.08

3) Do concentration in Lagoon    $C_L$    mg/L    1.5

f = {B*CsT-CL}/Cs(20)*1.024T-20*α}

| Ti-20 | $1.024^{T-20}$ | α | B | f |
|---|---|---|---|---|
| 1 | 1.029 | 0.6 | 0.9 | 0.44 |

b) Field transfer rate : N

N=fNo    kg-$O_2$/kw/h    0.71

Total amount of transfer $O_2$    kg-$O_2$/kw/d    kg-$O_2$/kw/h    17.0

The total axis power required to meet the required oxygen

**Table 116 Required $O_2$ Supply**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Required $O_2$ | kg/day | 405 | 267 | - |
| Required power for $O_2$ supply | kw | 23.8 | 15.7 | - |

2.10 Energy requirements for mixing

**Table 117 Specifications of Aerator**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Power for Mixing | $kW/m^3$ | 0.005 | 0.005 | - |
| Lagoon volume | $m^3$ | 6,300 | 4,200 | - |
| Axis power for mixing | kW | 31.5 | 21 | - |
| Total efficiency | - | 0.75 | 0.75 | - |
| Required power | kW | 42 | 28 | - |
| Unit Power | kW/No. | 11 | 11 | - |
| No. of Aerator | Nos. | 5 | 4 | - |

## 3. Solid separation for aerated lagoon

3.1 Design Base:

1) Process: maturation pond

2) HRT (days): t

3) Depth (m) D

Necessary Area ($m^2$) A

A = Qt/d

Volume of the maturation pond ($m^3$) V

V = A*D0

The effluent SS may be expected to be at about 50-100 mg/L

Dimension Length L

Width W

Height H

**Table 118 Dimension of Maturation Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^{3/}$day | 440 | 290 | - |
| t | days | 14 | 14 | - |
| V | $m^3$ | 6,160 | 4,060 | - |
| No. of Ponds | - | 2 | 2 | - |
| $D_0$ | m | 1.5 | 1.5 | - |
| A/pond | $m^2$ | 2,100 | 1,400 | - |
| D/pond | m | 70 | 60 | - |
| W/pond | m | 30 | 25 | - |
| A' (corrected A)/pond | $m^2$ | 2,100 | 1,500 | - |

## 4. Leachate recirculation pump

1) Recirculation rate r times/leachate

Recirculation pump flow Qr $m^3$/day

Qr = r*Q

| | | |
|---|---|---|
| Required Power | Ps | |
| Ps = 0.163*Qr($m^3$/min)*H(m)/ή | Hose power | |

Here

| | | |
|---|---|---|
| Total head of the pump | H | m |
| Total efficiency | ή | |
| Liquid density | ρs | 1.05 |

From the entrance of aerated lagoon to landfill

**Table 119 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 2,9910 | 1,830 | - |
| | $m^3$/min | 2.02 | 1.27 | - |
| Head | m | 50 | 50 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 15.4 | 19.4 | - |
| | kW | 11.6 | 14.6 | - |
| Unit power | kW/No. | 15 | 19 | - |
| Nos. of pumps | Nos. | (2+1) | (1+1) | - |

**Alternative 2: Aerated Lagoon + Sedimentation Pond + Wetland with recirculation -New Guanabacoa**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is the same as the one which was adopted in the original pilot project in Campo Florido. However only aerated lagoon can not remove T-$BOD_5$ and SS. Therefore sedimentation pond and wetland were proposed.

## 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 120 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of T-$BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1) Leachate generation

Landfill Area

| | | | |
|---|---|---|---|
| Stage1 | $A_1$ | 6.0 ha | 60,000 $m^2$ |
| Stage2 | $A_2$ | 4.0 ha | 40,000 $m^2$ |
| Stage3 | $A_3$ | 0.0 ha | 0 $m^2$ |

Once surface liner facility is constructed in landfill site, it is assumed that no water flows into the landfill site

$q = f*C*A*I/1000$ ($m^3$/day)

Where

q: Daily effluent amount of leachate water($m^3$/day)
C: Leachate coefficient of on-going landfill section 0.4
l: Annual maximum rainfall (mm/day)
Maximum rainfall during 2000 to 2002 338 mm in September in 2002
11.3 mm/day
A: Landfill area ($m^2$)
f: Safety factor 16
Q: Daily effluent amount of leachate with safety factor ($m^3$/day)

**Table 121 Proposed Leachate Volume**

| Q ($m^3$/day) | Stage1 | Stage2 | Stage3 |
|---|---|---|---|
| | 440 | 290 | 0 |

## 2. Leachate treatment

### 2.1 Aerated Lagoon Process Design

Design Base:

| | Symbol | Unit | |
|---|---|---|---|
| Influent flow | Q | $m^3$/d | |
| Influent suspended solids | $SS_0$ | mg/L | 540 |
| Influent soluble $BOD_5$ | $S_0$ | mg/L | 920 |
| Effluent soluble $BOD_5$ | $S\text{-}BOD_{5\text{-}out}$ | mg/L | 30 |
| Effluent suspended solid after settling | SSe | mg/L | 70 |
| Kinetic coefficients: | | l/d | 0.65 |
| Y | | mg-$BOD_5$/L | 100 |
| Ks | | mg-$BOD_5$/L/d | 6.0 |
| Kmax | | l/d | 0.07 |
| Kd | $k_{(20)}$ | l/d | 2.5 |
| First order soluble BoD5 removal rate constants at 20 °C | Ti | °C | 21.0 |
| Waste water temperature | | | |
| in leachate | α | | 0.6 |
| in treated water | β | | 0.9 |
| Oxygen concentration to be maintained in liquid | | mg-$O_2$/L | 1.5 |
| Lagoon depth | H | m | 3.5 |
| Design mean cell - residence time | θc | d | 14 |

### 2.2 Surface area of the lagoon

$\theta c = V/Q \quad \therefore V = \theta c * Q$ V: volume of the lagoon

$A = V/H$

Dimension

**Table 122 Dimensions of Aerated Lagoon**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| V | $m^3$ | 6,160 | 4,060 | - |
| A | $m^2$ | 1,760 | 1,160 | - |
| L | m | 60 | 60 | - |
| W | m | 30 | 20 | - |
| H | m | 3.5 | 3.5 | - |
| A' (Connected A) | $m^2$ | 1,800 | 1,200 | - |
| V' (Connected V) | $m^3$ | 6,300 | 4,200 | - |

Number of lagoon: 1

2.3 Soluble effluent $BOD_5$ at the lagoon outlet: S-$BOD_5$-out

S-$BOD_5$-out = {Ks (1+θc*kd)}/ { θc (Y*kmax-kd)-1}(mg/L)

| Ks | θc*kd | 1+θc*kd | Ks (1+θc*kd) | θc | Y*kmax | Y*kmax-kd | θc (Y*kmax-kd)-1 | S-$BOD_5$-out |
|---|---|---|---|---|---|---|---|---|
| 100 | 0.98 | 1.98 | 198 | 14 | 3.9 | 3.83 | 52.6 | 3.8 |

2.4 Effluent BOD5

1) Correct the removal-rate for temperature effects

k(t) = k(20)*θT-20

| Ti | $k_{(20)}$ | T-20 | θ | $\theta^{(T-20)}$ | $k_{(20)}\theta^{(T-20)}$ |
|---|---|---|---|---|---|
| 21.0 | 2.5 | 1 | 1.06 | 1.06 | 2.7 |

2) Determine the effluent BOD5: St-out (mg/L)

| kt | V/Q | 1+kV/Q | 1/(1+kV/Q) | $S_0$ | St-out |
|---|---|---|---|---|---|
| 2.7 | 14 | 38.10 | 0.03 | 920 | 24 |

2.5 Concentration of biological solids produced: X (mg/L)

X = Y (S0-S-$BOD_{5\text{-out}}$) / (1+kdθc) (mg-VSS/L)

| Y | $S_0$-S-$BOD_{5\text{-out}}$ | kd | θc | $Y(S_0\text{-S-}BOD_{5\text{-out}})/(1+k_d\theta_c)$ |
|---|---|---|---|---|
| 0.65 | 916.2 | 0.07 | 14 | 301 |

2.6 Suspended solids in the lagoon before settling

SSi = Influent suspended solids + X/0.7(mg/L)

| SSo | X | SSi |
|---|---|---|
| 540 | 301 | 970 |

Ratio of volatile suspended solid 0.7

2.7 Oxygen requirements

$Q_2$ (kg/d) = Q($S_0$-S-$BOD_{5\text{-out}}$)/f-1.42Px

f: conversion factor for $BOD_5$ to BODL 0.68

Px = Q*(concentration of biological solids produced)

**Table 123 Required $O_2$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| $S_0$-S-$BOD_{5\text{-out}}$ | mg/L | 916 | 916 | - |
| f | - | 0.68 | 0.68 | - |
| Px | kg/day | 132 | 87 | - |
| Required $O_2$ | kg/day | 405 | 267 | - |

2.8 Ratio of oxygen required to $BOD_5$ removed

$BOD_5$ removed (kg/d)

$O_2$/$BOD_5$ removed

**Table 124 Removed $BOD_5$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| $S_0$-S-$BOD_{5\text{-out}}$ | mg/L | 916 | 916 | - |
| $BOD_5$ removed | kg/day | 403 | 266 | - |
| $O_2$/$BOD_5$ | - | 1.0 | 1.0 | - |

2.9 Surface aerator power requirements

assumption: kg-$O_2$/kw/h kg-$O_2$/kw/h No 1.6

a) Correction factor for surface aerators for summer conditions f

f = No. /N

1) Oxygen saturation concentration at 21 °C Cs(21) mg/L 8.91

2) Cs(20) mg/L 9.08

3) Do concentration in Lagoon $C_L$ mg/L 1.5

f= {B*CsT-CL}/ Cs (20)*1.024T-20*α}

| Ti-20 | $1.024^{T-20}$ | α | B | f |
|---|---|---|---|---|
| 1 | 1.029 | 0.6 | 0.9 | 0.44 |

b) Field transfer rate: N

N = fNo kg-$O_2$/kw/h 0.71

Total amount of transfer $O_2$ kg-$O_2$/kw/d kg-$O_2$/kw/h 17.0

The total axis power required to meet the required oxygen

**Table 125 Required $O_2$ Supply**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Required $O_2$ | kg/day | 405 | 267 | - |
| Required power for $O_2$ supply | kw | 23.8 | 15.7 | - |

2.10 Energy requirements for mixing

**Table 126 Specifications of Aerator**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Power for Mixing | $kW/m^3$ | 0.005 | 0.005 | - |
| Lagoon volume | $m^3$ | 6,300 | 4,200 | - |
| Axis power for mixing | kW | 31.5 | 21 | - |
| Total efficiency | - | 0.75 | 0.75 | - |
| Required power | kW | 42 | 28 | - |
| Unit Power | kW/No. | 11 | 11 | - |
| No. of Aerator | Nos. | 5 | 4 | - |

## 3. Leachate recirculation pump

1) Recirculation rate r times/leachate

Recirculation pump flow Qr $m^3$/day

Qr = r*Q

Required Power Ps

Ps = 0.163*Qr($m^3$/min)*H(m)/ή Hose power

Here

Total head of the pump H m

Total efficiency ή

Liquid density ρs 1.05

From the entrance of aerated lagoon to landfill

**Table 127 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 970 | 610 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 2,910 | 1,830 | - |
| | $m^3$/min | 2.02 | 1.27 | - |
| Head | m | 50 | 50 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 15.4 | 19.4 | - |
| | kW | 11.6 | 14.6 | - |
| Unit power | kW/No. | 15 | 19 | - |
| Nos. of pumps | Nos. | (2+1) | (1+1) | - |

## 4. Solid-liquid separation: sedimentation tank

Qi: Inflow $m^3$/day

Safety factor 3

R.T: Retention time at Qi*3 hr

OL: Overflow rate at Qi*3 $m^3/m^2$/day

Qi*Ci = Qo*Co+Qu*Cu

| | |
|---|---|
| Ci: Inflow SS | mg/L |
| Co: Outflow SS | mg/L |
| Cu: Concentrated SS in the sedimentation tank | mg/L |
| Qo: Outflow | $m^3$/day |
| Qu: Underflow (Sludge flow) | $m^3$/day |

Qu = Qi-Qo $m^3$/day

Qo=Qi*(Cu-Ci) / (Cu-Co) $m^3$/day

As: Surface area = Qo/OL $m^2$

Dimension Ls: Length of sedimentation tank m

Ws: Width of sedimentation tank m

Hs: Height of sludge zone = Vs/As m

Vs: Volume of sedimentation tank $m^3$

H2: Height allowance = Vs/As $m^2$

**Table 128 Dimension of sedimentation tank**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| Qi | $m^3$/day | 1,320 | 870 | - |
| RT | hr | 2 | 2 | - |
| OL | $m^3/m^2$/day | 22 | 22 | - |
| Ci | mg/L | 970 | 970 | - |
| Co | mg/L | 70 | 70 | - |
| Cu | mg/L | 5,000 | 5,000 | - |
| Qo | $m^3$/day | 1,100 | 700 | - |
| As | $m^2$ | 50 | 40 | - |
| Ls | m | 20 | 10 | - |
| Ws | m | 4 | 4 | - |
| Hs | m | 2.2 | 2.0 | - |
| Vs | $m^3$ | 110 | 80 | - |
| Qu | $m^3$/day | 220 | 170 | - |
| H2 | m | 1.5 | 1.5 | - |
| H0 | m | 3.7 | 3.8 | - |

Total Height Ho=H2+Hs

## 5. To removal nutrients, use wetland.

Only by aerated lagoon, only $BOD_5$ and SS are removed. For further treatment for nutrients another process is necessary.

Here, wetland was considered as an alternative for this purpose, considering cost efficiency.

Levels of nitrogen and phosphates are estimated as below based on the analysis of leachate during this Study.

| | | | |
|---|---|---|---|
| Total-N: | | 240 | mg/L |
| Total-P: | | 64 | mg/L |

In biological treatment nitrogen and phosphate are necessary. The ratio of N and P towards $BOD_5$ is 3:0.3:100

Therefore N and P after biological treatment, their levels are expected as below.

| | | | |
|---|---|---|---|
| Inlet $BOD_5$ | | 920 | mg/L |
| Therefore N to be removed by biological treatment | | 27.6 | mg/L |
| Therefore P to be removed by biological treatment | | 2.76 | mg/L |
| After aerated lagoon remained N | N | 212 | mg/L |
| | P | 61 | mg/L |

| Criteria* | |
|---|---|
| 20 | mg/L. as KTN |
| 10 | mg/L. as P |

*:Discharge criteria of industrial waste water into general public water body

Inlet T-P level will be reduced by using cover soil.

Therefore, only removal of nitrogen would be considered.

Here, subsurface-flow (SSF) systems was considered.

In a SSF wetland, the basin is filled with gravel or some other coarse substrate, and the water level is maintained below-ground. Water flows horizontally, or sometimes vertically, through the gravel and the root mat of the wetland vegetation.

Arrow arum (Polyandry spp.) and Pickerel weed (Pontederia spp.) have been used in constructed wetlands.

Also common reed (Phragmitescommunis) is used

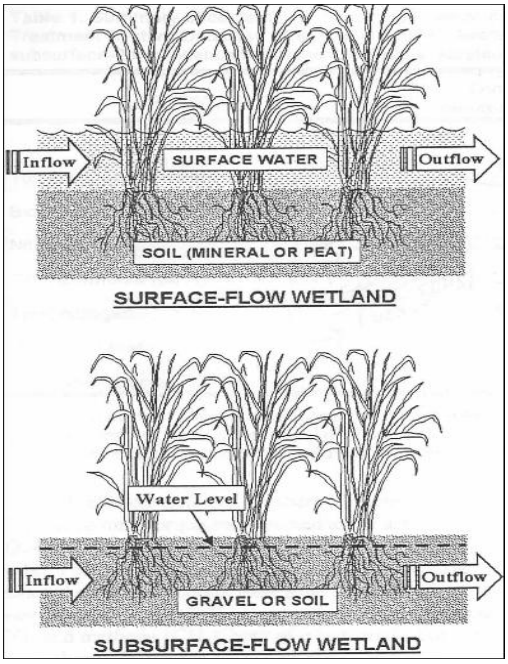



**Figure 7 Conceptual diagram of subsurface-flow wetlands**

**Example of determination of basin design for SFS wetlands system**

Nitrogen removal will proceed when $BOD_5$ level is less than 10 mg/L.

**1. Premises**

| | | |
|---|---|---|
| Influent $BOD_5$ | $C_0$ | 60 mg/L |
| Effluent $BOD_5$ | Ce | 8 mg/L |
| Inflow | Q | $m^3$/day |
| | | $m^3$/day |
| Vegetation type | | cattails |
| Minimum water temperature | T | 21°C |
| Basin media | coarse sand with 2 mm of maximum effective size | |
| Basin slope | S | 0.01 |

**2. Solution**

| | | | |
|---|---|---|---|
| 1. | Basin depth for use wit cattail | d | 0.3 m |
| 2. | Porosity | α | 0.39 |
| | Hydraulic conductivity | Ks | 480 $m^3/m^2$/day |
| | | $K_{20}$ | 1.35 |
| 3. | Temperature-dependent first order rate constant | | |
| | | $K_T$ at | 21 °C |
| | | | 1.49 $d^{-1}$ |
| 4. | Pore-space detention time | t' = -1nCe/C0/Kt | d |
| 5. | Cross-sectional area | Ac = Q/Ks/S | $m^2$ |
| 6. | Basin width | W = Ac/d | m |
| 7. | Basin length | L = t'Q/W/d/α | m |
| 8. | Required surface area | As = L*W | $m^2$ |
| | | | ha |
| 9. | Check hydraulic-loading rate or specific area requirements | | |
| | | Lw = Q/L/W | 150 to 500 $m^3$/ha/day |
| | | | 0.015 to 0.005 $m^3/m^2$/day |
| | or | Asp= 1/Lw for advanced treatment 2.1 ha/$10^3 m^3$ | |
| 10. | Check $BOD_5$ loading rate | Max.$BOD_{5L}$ | 60 kg/ha/day |
| | $LBOD_5$ | | kg/day |
| | $BOD_{5L}$ | | kg/ha/day |
| 11. | Vegetation | | |
| | Reed can absprb | N | 18 to 21g/kg |
| | | P | 2.0 to 3.0 g/kg |
| | Inlet N | | 212.4 mg/L |
| | Vd: vegetation density | | 10 $kg/m^2$ |

**Table 129 Specification of Wetland**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| $C_0$ | mg/L | 60 | 60 | - |
| Ce | mg/L | 8 | 8 | - |
| Q | $m^3$/day | 440 | 290 | - |
| T | °C | 21 | 21 | - |
| S | | 0.01 | 0.01 | - |
| d | m | 0.3 | 0.3 | - |
| α | | 0.39 | 0.39 | - |
| Ks | $m^3/m^2$/day | 480 | 480 | - |
| $K_{20}$ | | 1.35 | 1.35 | - |
| Kt | $d^{-1}$ | 1.49 | 1.49 | - |
| t' | day | 1.36 | 1.36 | - |
| Ac | $m^2$ | 92 | 60 | - |
| W | m | 310 | 210 | - |
| L | m | 16 | 16 | - |
| As | $m^2$ | 5,200 | 3,400 | - |
| Lw | $m^3/m^2$/day | 0.09 | 0.09 | - |
| Asp | ha/1000$m^3$ | 11.60 | 11.60 | - |
| L-$BOD_5$ | kg/day | 26.4 | 17.4 | - |
| $BOD_{5L}$ | kg/ha/day | 51 | 51 | - |
| V | $m^3$ | 1,560 | 1,020 | - |
| R.T | day | 3.5 | 3.5 | - |
| Inlet N | mg/L | 212 | 212 | - |
| Total N in WL | g | 340,000 | 220,000 | - |
| N absorption | g/kg | 18 | 18 | - |
| Nos. of reed | kg | 18,889 | 12,222 | - |
| Vd | kg/$m^2$ | 10 | 10 | - |
| Max Reed | kg | 52,000 | 34,000 | - |

**Alternative 3: Natural Pond System (Anaerobic + Facultative + Maturation Pond) -New Guanabacoa**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is so called natural pond system to remove $BOD_5$, SS and nutrients such as N and P.

## 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 130 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of T-$BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1.2 Recirculation rate of leachate 3 times/day toward the leachate generated

## 2. Anaerobic pond

| | | | |
|---|---|---|---|
| RTa: Retention time of anaerobic pond | | | 7 days |
| $BOD_5$ Removal rate | | | 60% |
| $BOD_5$ out-a | | | 368 mg/L |
| Da: Depth of the anaerobic pond | | | 3.5 m |
| Aa: Surface area | | | $m^2$ |
| Va: Anaerobic pond volume | | | $m^3$ |
| Dimension | Length | La | m |
| | Width | Wa | m |
| $BOD_{5La}$: $BOD_5$ load of anaerobic pond | | 100 to 350 g-$BOD_5$/$m^3$-pond/day | |

**Table 131 Dimension of Anaerobic Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 940 | 290 | - |
| R.T | days | 7 | 7 | - |
| Va | $m^3$ | 3,080 | 2,080 | - |
| Da | m | 3.5 | 3.5 | - |
| Aa | $m^2$ | 880 | 580 | - |
| La | m | 50 | 40 | - |
| Wa | m | 20 | 15 | - |
| $BOD_5$ | g/day | 404,800 | 266,800 | - |
| $BOD_{5La}$ | g/$m^3$/day | 131 | 131 | - |

Number of ponds: 1

## 3. Facultative Pond

$ls_1$: BOD permissible loading — kg/ha/day

$ls_1 = 350\ (1.107 - 0.002T)^{T-25}$ — 100 to 400 kg/ha/day

or

$ls_2 = 20T-120$ — kg/ha/day

Here, T: Minimum temperature — 21 °C

Ls: $BOD_5$ loading

Ls = 10 Li Q / Af — kg/ha/day

Here,

Li: Inflow $BOD_5$ — mg/L

Af: Facultative pond area — $m^2$

$Af = Q *(Li - Le)/18D/(1.05)^{T-20}$

Here,

Le: Outflow $BOD_5$ — mg/L

$L_r$: $BOD_5$ removal — kg/ha/day

$Lr = 0.725Ls \div 10.75$

Df: Depth of the facultative pond — m

Dimensions of facultative pond — Length — Lf — m

Width — Wf — m

**Table 132 Dimension of Sedimentation Tank**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| T | °C | 21 | 21 | - |
| $ls_1$ | kg/ha/day | 272 | 272 | - |
| $ls_2$ | kg/ha/day | 300 | 300 | - |
| Ls | kg/ha/day | 270 | 267 | - |
| Li | mg/L | 368 | 368 | - |
| Df | m | 1.2 | 1.2 | - |
| Af | $m^2$ | 6,000 | 4,000 | - |
| Le | mg/L | 60 | 60 | - |
| Lr | kg/ha/day | 206 | 204 | - |
| $BOD_{5Rf}$ | % | 76.5 | 76.5 | - |
| $BOD_{5out\text{-}f}$ | mg/L | 87 | 87 | - |
| $R.T_f$ | days | 16 | 17 | - |

Remarks:

(a) There is a difference between $ls_1$ and $ls_2$. Adopt $ls_1$ for safety.

(b) There is a difference between Le and $BOD_{5out\text{-}f}$. This is because Equations for Ls and Af are the one to get 60 mg/L-$BOD_5$ in South America.

(c) On the contrary, the value of $BOD_{5out\text{-}f}$ is calculated by the equation for Lr. Lr shows the average of the data arranged by MacGarry and Pescord.

(d) The $BOD_5$ removal in primary facultative ponds is usually in the range 70-80 percent based on unfiltered samples (that is, including the BOD exerted by the algae).
Therefore, effluent $BOD_{5out\text{-}f}$ level from facultative pond will be considered 60-117 mg/L with algae.

(e) It is said $BOD_5$ quality of the effluent from a facultative ponds as most of the BOD contained (70 to 90%) will be "algal BOD. Therefore, the filtered (soluble) $BOD_5$ level will be at least 18-35 mg/L.

**Table 133 Dimensions of Facultative Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Af | $m^2$ | 6,000 | 4,000 | - |
| Nos. of ponds | - | 2 | 2 | - |
| Af/pond | $m^2$ | 3,000 | 2,000 | - |
| Lf/pond | m | 90 | 70 | - |
| Wf/pond | m | 35 | 30 | - |
| Df | m | 1.2 | 1.2 | - |
| Vf/pond | $m^3$ | 3,780 | 2,520 | - |
| Total Vf | $m^3$ | 7,560 | 5,040 | - |

Pond arrangement: Parallel

## 4. Maturation pond

Maturation ponds (low-cost polishing ponds, which succeed the primary or secondary facultative pond) are primarily designed for tertiary treatment, i.e., the removal of pathogens, nutrients and possibly algae.

With the combination of facultative pond and maturation pond,

(1) Total nitrogen removal in WSP systems can reach 80 percent or more, and ammonia removal can be as high as 95 percent.

(2) The best way of increasing phosphorus removal in WSP is to increase the number of

maturation ponds, so that progressively more and more phosphorus becomes immobilized in the sediments. From a well functioning 2 ponds system, 70% mass removal of total.

(3) The removal rate increases by adding maturation ponds.

Design criteria

$D_m$: Depth of maturation pond 1.5 m

$RT_m$: Retention time of maturation pond 14 days

$A_m$: Area od maturation pond

Dimensions of maturation pond

Length Lm m

Width Wm m

**Table 134 Dimensions of Maturation Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| $RT_m$ | days | 14 | 14 | - |
| Vm | $m^3$ | 6,160 | 4,060 | - |
| Nos. of Ponds | - | 2 | 2 | - |
| Vm/Pond | $m^3$ | 3,080 | 2,030 | - |
| Dm/Pond | m | 1.5 | 1.5 | - |
| Am/Pond | $m^2$ | 2,100 | 1,400 | - |
| Lm/Pond | m | 70 | 60 | - |
| Wm/Pond | m | 30 | 25 | - |

Pond arrangement: Series

## 5. Leachate Recirculation pump

Recirculation rate r times/leachate

Recirculation pump flow Qr $m^3$/day

Qr = r*Q

Required Power Ps

$Ps = 0.163 * Qr(m^3/min) * H(m)/ή$ Horse power

Here

Total head of the pump H m

Total efficiency ή

Liquid density ρs 1.05

From the entrance of anaerobic lagoon to landfill

**Table 135 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 1,320 | 870 | - |
| | $m^3$/min | 0.92 | 0.60 | - |
| Head | m | 40 | 40 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 11.2 | 7.4 | - |
| | kW | 8.4 | 5.5 | - |
| Unit power | kW/No. | 11 | 7.5 | - |
| Nos. of pumps | Nos. | (1+1) | (1+1) | - |

**Alternative 4: Natural Pond System (Anaerobic + Facultative + Wetland) -New Guanabacoa**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is an alternative to use wetland instead of Maturation Pond in Alternative 3 in order to remove nutrients such as N and P.

## 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 136 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | $T\text{-}BOD_5$ | SS | $S\text{-}BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of $T\text{-}BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1.2 Recirculation rate of leachate 3 times/day toward the leachate generated

## 2. Anaerobic pond

| | | | |
|---|---|---|---|
| RTa : Retention time of anaerobic pond | | | 7 days |
| $BOD_5$ Removal rate | | | 60% |
| $BOD_5$ out-a | | | 368 mg/L |
| Da: Depth of the anaerobic pond | | | 3.5 m |
| Aa: Surface area | | | $m^2$ |
| Va: Anaerobic pond volume | | | $m^3$ |
| Dimension | Length | La | m |
| | Width | Wa | m |
| $BOD_{5La}$: $BOD_5$ load of anaerobic pond | | 100 to 350 $g\text{-}BOD_5/m^3$-pond/day | |

**Table 137 Dimension of Anaerobic Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| R.T | days | 7 | 7 | - |
| Va | $m^3$ | 3,080 | 2,030 | - |
| Da | m | 3.5 | 3.5 | - |
| Aa | $m^2$ | 880 | 580 | - |
| La | m | 50 | 40 | - |
| Wa | m | 20 | 15 | - |
| $BOD_5$ | g/day | 404,800 | 266,800 | - |
| $BOD_{5La}$ | g/$m^3$/day | 131 | 131 | - |

Number of ponds: 1

## 3. Facultative Pond

$ls_1$: BOD permissible loading — kg/ha/day

$ls_1 = 350\ (1.107 - 0.002T)^{T-25}$ — 100 to 400 kg/ha/day

or

$ls_2 = 20T-120$ — kg/ha/day

Here, T: Minimum temperature — 21 °C

Ls: $BOD_5$ loading

Ls = 10 Li Q / Af — kg/ha/day

Here,

Li: Inflow $BOD_5$ — mg/L

Af: Facultative pond area — $m^2$

$Af = Q *(Li - Le)/18D/(1.05)^{T-20}$

Here,

Le: Outflow $BOD_5$ — mg/L

$L_r$: $BOD_5$ removal — kg/ha/day

$Lr = 0.725Ls \div 10.75$

Df: Depth of the facultative pond — m

Dimensions of facultative pond — Length Lf — m

Width Wf — m

**Table 138 Dimension of Sedimentation Tank**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| T | °C | 21 | 21 | - |
| $ls_1$ | kg/ha/day | 272 | 272 | - |
| $ls_2$ | kg/ha/day | 300 | 300 | - |
| Ls | kg/ha/day | 270 | 267 | - |
| Li | mg/L | 368 | 368 | - |
| Df | m | 1.2 | 1.2 | - |
| Af | $m^2$ | 6,000 | 4,000 | - |
| Le | mg/L | 60 | 60 | - |
| Lr | kg/ha/day | 206 | 204 | - |
| $BOD_{5Rf}$ | % | 76.5 | 76.5 | - |
| $BOD_{5out\text{-}f}$ | mg/L | 87 | 87 | - |
| $R.T_f$ | days | 16 | 17 | - |

Remarks:
(a) There is a difference between $ls_1$ and $ls_2$. Adopt $ls_1$ for safety.
(b) There is a difference between Le and $BOD_{5out\text{-}f}$. This is because Equations for Ls and Af are the one to get 60 mg/L-$BOD_5$ in South America.
(c) On the contrary, the value of $BOD_{5out\text{-}f}$ is calculated by the equation for Lr. Lr shows the average of the data arranged by MacGarry and Pescord.
(d) The $BOD_5$ removal in primary facultative ponds is usually in the range 70-80 percent based on unfiltered samples (that is, including the BOD exerted by the algae).
Therefore, effluent $BOD_{5out\text{-}f}$ level from facultative pond will be considered 60-117 mg/L with algae.
(e) It is said $BOD_5$ quality of the effluent from a facultative ponds as most of the BOD contained (70 to 90%) will be "algal BOD. Therefore, the filtered (soluble) $BOD_5$ level will be at least 18-35 mg/L.

**Table 139 Dimensions of Facultative Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Af | $m^2$ | 6,000 | 4,000 | - |
| Nos. of ponds | - | 2 | 2 | - |
| Af/pond | $m^2$ | 3,000 | 2,000 | - |
| Lf/pond | m | 90 | 70 | - |
| Wf/pond | m | 35 | 30 | - |
| Df | m | 1.2 | 1.2 | - |
| Vf/pond | $m^3$ | 3,780 | 2,520 | - |
| Total Vf | $m^3$ | 7,560 | 5,040 | - |

Pond arrangement: Parallel

## 4. To removal nutrients, use wetland

Only by aerated lagoon, only $BOD_5$ and SS are removed. For further treatment for nutrients another process is necessary.

Here, wetland was considered as an alternative for this purpose, considering cost efficiency.

Levels of nitrogen and phosphates are estimated as below based on the analysis of leachate during this Study.

| | | | |
|---|---|---|---|
| Total-N: | | 240 | mg/L |
| Total-P: | | 64 | mg/L |

In biological treatment nitrogen and phosphate are necessary. The ratio of N and P towards $BOD_5$ is 3:0.3:100

Therefore N and P after biological treatment, their levels are expected as below.

| | | | |
|---|---|---|---|
| Inlet $BOD_5$ | | 920 | mg/L |
| Therefore N to be removed by biological treatment | | 27.6 | mg/L |
| Therefore P to be removed by biological treatment | | 2.76 | mg/L |
| After aerated lagoon remained N | N | 212 | mg/L |
| | P | 61 | mg/L |

| Criteria* | |
|---|---|
| 20 | mg/L. as KTN |
| 10 | mg/L. as P |

*:Discharge criteria of industrial waste water into general public water body

Inlet T-P level will be reduced by using cover soil. Therefore, only removal of nitrogen would be considered.

Here, subsurface-flow (SSF) systems was considered.

In a SSF wetland, the basin is filled with gravel or some other coarse substrate, and the water level is maintained below-ground. Water flows horizontally, or sometimes vertically, through the gravel and the root mat of the wetland vegetation.

Arrow arum (Polyandry spp.) and Pickerel weed (Pontederia spp.) have been used in constructed wetlands.

Also common reed (Phragmitescommunis) is used

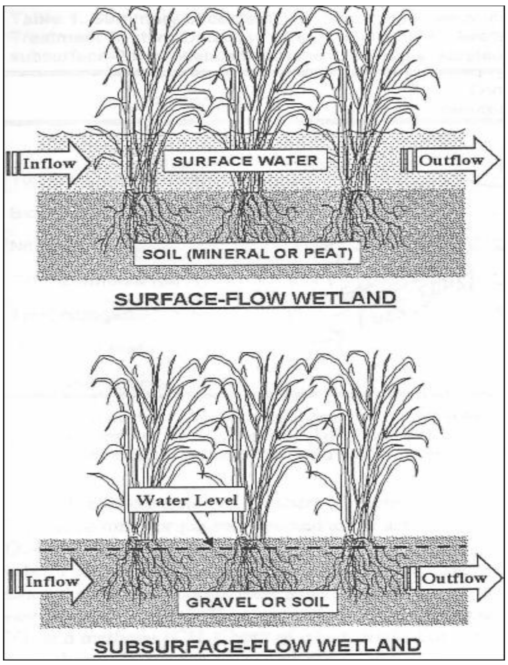



**Figure 8 Conceptual diagram of subsurface-flow wetlands**

**Example of determination of basin design for SFS wetlands system**

Nitrogen removal will proceed when $BOD_5$ level is less than 10 mg/L.

**1. Premises**

| | | |
|---|---|---|
| Influent $BOD_5$ | $C_0$ | 87 mg/L |
| Effluent $BOD_5$ | $C_e$ | 8 mg/L |
| Inflow | Q | $m^3$/day |
| | | $m^3$/day |
| Vegetation type | | cattails |
| Minimum water temperature | T | 21°C |
| Basin media | coarse sand with 2 mm of maximum effective size | |
| Basin slope | S | 0.01 |

**2. Solution**

| | | | |
|---|---|---|---|
| 1. | Basin depth for use wit cattail | d | 0.3 m |
| 2. | Porosity | α | 0.39 |
| | Hydraulic conductivity | Ks | 480 $m^3/m^2$/day |
| | | $K_{20}$ | 1.35 |
| 3. | Temperature-dependent first order rate constant | | |
| | | $K_T$ at | 21 °C |
| | | | 1.49 $d^{-1}$ |
| 4. | Pore-space detention time | t' = -1nCe/C0/Kt | d |
| 5. | Cross-sectional area | Ac = Q/Ks/S | $m^2$ |
| 6. | Basin width | W = Ac/d | m |
| 7. | Basin length | L = t'Q/W/d/α | m |
| 8. | Required surface area | As = L*W | $m^2$ |
| | | | ha |
| 9. | Check hydraulic-loading rate or specific area requirements | | |
| | | Lw = Q/L/W | 150 to 500 $m^3$/ha/day |
| | | | 0.015 to 0.005 $m^3/m^2$/day |
| | or | Asp= 1/Lw for advanced treatment 2.1 ha/$10^3m^3$ | |
| 10. | Check $BOD_5$ loading rate | Max.$BOD_{5L}$ | 60kg/ha/day |
| | | $LBOD_5$ | kg/day |
| | | $BOD_{5L}$ | kg/ha/day |
| 11. | Vegetation | | |
| | Reed can absprb | N | 18 to 21g/kg |
| | | P | 2.0 to 3.0 g/kg |
| | Inlet N | | 240 mg/L |
| | Vd: vegetation density | | 10 kg/$m^2$ |

**Table 140 Specification of Wetland**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| $C_0$ | mg/L | 87 | 87 | - |
| Ce | mg/L | 8 | 8 | - |
| Q | $m^3$/day | 440 | 290 | - |
| T | °C | 21 | 21 | - |
| S | | 0.01 | 0.01 | - |
| d | m | 0.3 | 0.3 | - |
| α | | 0.39 | 0.39 | - |
| Ks | $m^3/m^2$/day | 480 | 480 | - |
| $K_{20}$ | | 1.35 | 1.35 | - |
| Kt | $d^{-1}$ | 1.49 | 1.49 | - |
| t' | day | 1.61 | 1.61 | - |
| Ac | $m^2$ | 92 | 60 | - |
| W | m | 310 | 210 | - |
| L | m | 19 | 19 | - |
| As | $m^2$ | 6,100 | 4,000 | - |
| Lw | $m^3/m^2$/day | 0.07 | 0.07 | - |
| Asp | ha/1000$m^3$ | 13.74 | 13.74 | - |
| L-$BOD_5$ | kg/day | 38.3 | 25.23 | - |
| $BOD_{5L}$ | kg/ha/day | 63 | 63 | - |
| V | $m^3$ | 1,830 | 1,200 | - |
| RT | day | 4.2 | 4.1 | - |
| Inlet N | mg/L | 240 | 240 | - |
| Total N in WL | g | 440,000 | 290,000 | - |
| N absorption | g/kg | 18 | 18 | - |
| Nos. of reed | kg | 24,444 | 290,000 | - |
| Vd | kg/$m^2$ | 10 | 10 | - |
| Max Reed | kg | 61,000 | 40,000 | - |

This system seems to be inferior in performance.

## 5. Leachate Recirculation pump

| | | |
|---|---|---|
| Recirculation rate | r | times/leachate |
| Recirculation pump flow | Qr | $m^3$/day |

Qr = r*Q

Required Power Ps

$Ps = 0.163 * Qr(m^3/min) * H(m)/ή$ Horse power

Here

| | | |
|---|---|---|
| Total head of the pump | H | m |
| Total efficiency | ή | |
| Liquid density | ρs | 1.05 |

From the entrance of anaerobic lagoon to landfill

**Table 141 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 1,320 | 870 | - |
| | $m^3$/min | 0.92 | 0.60 | - |
| Head | m | 40 | 40 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 11.2 | 7.4 | - |
| | kW | 8.4 | 5.5 | - |
| Unit power | kW/No. | 11 | 7.5 | - |
| Nos. of pumps | Nos. | (1+1) | (1+1) | - |

**Alternative 5: Anaerobic Pond + Aerated Lagoon + Sedimentation Pond + Wetland with recirculation -New Guanabacoa**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is an alternative adding Anaerobic Pond to Alternative 2 in order to reduce area.

## 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 142 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of T-$BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1.2 Recirculation rate of leachate 3 times/day toward the leachate generated

## 2. Anaerobic pond

| | | | |
|---|---|---|---|
| RTa : Retention time of anaerobic pond | | | 7 days |
| $BOD_5$ Removal rate | | | 60% |
| $BOD_5$ out-a | | | 368 mg/L |
| Da: Depth of the anaerobic pond | | | 3.5 m |
| Aa: Surface area | | | $m^2$ |
| Va: Anaerobic pond volume | | | $m^3$ |
| Dimension | Length | La | m |
| | Width | Wa | m |

$BOD_{5La}$: $BOD_5$ load of anaerobic pond 100 to 350 g-$BOD_5$/$m^3$-pond/day

**Table 143 Dimension of Anaerobic Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| R.T | days | 7 | 7 | - |
| Va | $m^3$ | 3,080 | 2,030 | - |
| Da | m | 3.5 | 3.5 | - |
| Aa | $m^2$ | 880 | 580 | - |
| La | m | 50 | 40 | - |
| Wa | m | 20 | 15 | - |
| $BOD_5$ | g/day | 404,800 | 266,800 | - |
| $BOD_{5La}$ | g/$m^3$/day | 131 | 131 | - |

Number of ponds: 1

## 3. Aerated Lagoon

### 3.1 Aerated Lagoon Process

Design Base:

| | Symbol | Unit | |
|---|---|---|---|
| Influent flow | Q | $m^3$/d | |
| Influent suspended solids | $SS_0$ | mg/L | 378 |
| Influent soluble $BOD_5$ | $S_0$ | mg/L | 368 |
| Effluent soluble $BOD_5$ | $S\text{-}BOD_{5\text{-}out}$ | mg/L | 30 |
| Effluent suspended solid after setting | SSe | mg/L | 70 |
| Kinetic coefficients: | | | |
| Y | | l/d | 0.65 |
| Ks | | mg-$BOD_5$/L | 100 |
| Kmax | | mg-$BOD_5$/L/d | 6.0 |
| Kd | | l/d | 0.07 |
| First order soluble $BOD_5$ removal rate constants at 20 °C | | | |
| | $k_{(20)}$ | l/d | 2.5 |
| Waste water temperature | Ti | °C | 21.0 |
| Aeration constants in leachate | | | |
| in leachate | α | | 0.6 |
| in treated water | β | | 0.9 |
| Oxygen concentration to be maintained in liquid | | mg - $O_2$/L | 1.5 |
| Lagoon depth | H | m | 3.5 |
| Design mean cell - residence time | θc | d | 7 |

3.2 Surface area of the lagoon A $m^2$

θc = V/Q ∴ V = θc*Q V: volume of the lagoon

A = V/H

Dimension

**Table 144 Dimension of Aerated Lagoon**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| V | $m^3$ | 3,080 | 2,030 | - |
| A | $m^2$ | 880 | 580 | - |
| L | m | 50 | 40 | - |
| W | m | 20 | 15 | - |
| H | m | 3.5 | 3.5 | - |
| A' (corrected A) | $m^2$ | 1,000 | 600 | - |
| V' (Corrected V) | $m^3$ | 3,500 | 2,100 | - |

3.3 Soluble effluent $BOD_5$ at the lagoon outlet: S-$BOD_5$-out

S-$BOD_5$out = { Ks (1 + 0c*kd) } / {θc (Y*kmax - kd) - I } (mg/L)

| Ks | θc*kd | 1+θc*kd | Ks (1+θc*kd) | θc | Y*kmax | Y*kmax-kd | θc (Y*kmax-kd)-1 | S-$BOD_5$ out |
|---|---|---|---|---|---|---|---|---|
| 100 | 0.49 | 1.49 | 149 | 7 | 3.9 | 3.83 | 25.8 | 5.8 |

3.4 Effluent $BOD_5$

(1) Correct the removal-rate for temperature effects

$k(t) = k(20)*\theta^{T-20}$ (l/d)

| Ti | $k_{(20)}$ | T-20 | θ | $\theta^{(T-20)}$ | $k_{(20)}\theta^{(T-20)}$ |
|---|---|---|---|---|---|
| 21.0 | 2.5 | 1 | 1.06 | 1.06 | 2.7 |

(2) Determine the effluent $BOD_5$: St-$_{out}$ (mg/L)

$St\text{-}out/S_0 = 1/(1+k\theta_H) = S/S_0 = 1/(1+kV/Q)$

| kt | V/Q | 1+kV/Q | 1/(1+kV/Q) | $S_0$ | St-out |
|---|---|---|---|---|---|
| 2.7 | 7 | 19.55 | 0.05 | 368 | 19 |

3.5 Concentration of biological solids produced: X (mg/L)

$X = Y (S_0\text{-S-}BOD_5\text{-out})/ (1+k_d\theta_c)$ (mg-VSS/L)

| Y | $S_0$-S-$BOD_{5\text{-out}}$ | $k_d$ | θc | $Y(S_0\text{-S-}BOD_{5\text{-out}})/(1+k_d\theta_c)$ |
|---|---|---|---|---|
| 0.65 | 362.2 | 0.07 | 7 | 158 |

3.6 Suspended solids in the lagoon before settling

SSi = Influent suspended solids + X/0.7(mg/L)

Ratio of volatile suspended solid 0.7

| SSo | X | SSi |
|---|---|---|
| 378 | 158 | 604 |

3.7 Oxygen requirements

$Q_2$ (kg/d) = Q ($S_0$-S-$BOD_{5\text{-out}}$)/f-1.42Px

f: conversion factor for $BOD_5$ to $BOD_L$ 0.68

Px = Q*(concentration of biological solids produced)

**Table 145 Required $O_2$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| $S_0$-s-$BOD_{5\text{-out}}$ | mg/L | 362 | 362 | - |
| f | - | 0.68 | 0.68 | - |
| Px | kg/day | 70 | 46 | - |
| Required $O_2$ | kg/day | 136 | 89 | - |

3.8 Ratio of oxygen required to $BOD_5$ removed

$BOD_5$ removed (kg/d)

$O_2$/$BOD_5$ removed

**Table 146 Removed $BOD_5$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| So-S-$BOD_{5\text{-out}}$ | mg/L | 362 | 362 | - |
| $BOD_5$ removed | kg/day | 159 | 105 | - |
| $O_2$/$BOD_5$ | - | 0.9 | 0.9 | - |

3.9 Surface aerator power requirements

assumption: kg-$O_2$/kw/h kg-$O_2$/kw/h No 1.6

a) Correction factor for surface aerators for summer conditions f

f=No/N

1) Oxygen saturation concentration at 21 °C Cs(21) mg/L 8.91

2) Cs(20) mg/L 9.08

3) DO concentration in Lagoon CL mg/L 1.5

f= {B*CsT-CL}/ Cs (20)*1.024T-20*α}

| Ti-20 | $1.024^{T-20}$ | α | B | f |
|---|---|---|---|---|
| 1 | 1.029 | 0.6 | 0.9 | 0.44 |

b) Field transfer rate : N

$N = fN_0$ kg-$O_2$/kw/h 0.71

Total amount of transfer $O_2$ kg-$O_2$/kw/d kg-$O_2$/kw/h 17.0

The total axis power required to meet the required oxygen

**Table 147 Required $O_2$ Supply**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Required $O_2$ | kg/day | 136 | 89 | - |
| Required power for $O_2$ supply | kW | 8.0 | 5.3 | - |

3.10 Energy requirements for mixing

**Table 148 Specifications of Aerator**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Power for Mixing | $kW/m^3$ | 0.005 | 0.005 | - |
| Lagoon volume | $m^3$ | 3,500 | 2,100 | - |
| Axis power for mixing | kW | 17.5 | 10.5 | - |
| Total efficiency | - | 0.75 | 0.75 | - |
| Required power | kW | 23 | 14 | - |
| Required power per unit | kW/No. | 11 | 11 | - |
| Power for Mixing | Nos. | 3 | 2 | - |

## 4. Leachate recirculation pump

Recirculation rate r times/leachate

Recirculation pump flow Qr $m^3$/day

$Qr = r*Q$

Required Power Ps

$Ps = 0.163*Qr(m^3/min)*H(m)/ή$ Horse power

Here

Total head of the pump H m

Total efficiency ή

Liquid density ρs 1.05

From the entrance of anaerobic lagoon to landfill

**Table 149 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 1,320 | 870 | - |
| | $m^3$/min | 0.92 | 0.60 | - |
| Head | m | 40 | 40 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 11.2 | 7.4 | - |
| | kW | 8.4 | 5.5 | - |
| Unit power | kW/No. | 11 | 7.5 | - |
| Nos. of pumps | Nos. | (1+1) | (1+1) | - |

## 5. Solid-liquid separation: sedimentation tank

| | | |
|---|---|---|
| Qi: Inflow | | $m^3$/day |
| Safety factor | | 3 |
| R.t: Retention time at Qi*3 | | hr |
| OL: Overflow rate at Qi*3 | | $m^3/m^2$/day |
| Qi*Ci = Qo*Co+Qu*Cu | | |
| Ci: Inflow SS | | mg/L |
| Co: Outflow SS | | mg/L |
| Cu: Concentrated SS in the sedimentation tank | | mg/L |
| Qo: Outflow | | $m^3$/day |
| Qu: Underflow (Sludge flow) | | $m^3$/day |
| Qu = Qi-Qo | | $m^3$/day |
| Qo = Qi*(Cu-Ci) / (Cu-Co) | | $m^3$/day |
| As: surface area=Qo/OL | | $m^3$ |
| Dimension | Ls: Length of sedimentation tank | m |
| | Ws: Width of sedimentation tank | m |
| Hs: Height of sludge zone =Vs/As | | m |
| Vs: Volume of sedimentation tank | | $m^3$ |
| $H_2$: Height allowance = Vs/As | | $m^2$ |

**Table 150 Dimension of Sedimentation Tank**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| Qi | $m^3$/day | 1,320 | 870 | - |
| R.T | hr | 2 | 2 | - |
| $O_L$ | $m^3/m^2$/day | 22 | 22 | - |
| Ci | mg/L | 604 | 604 | - |
| Co | mg/L | 70 | 70 | - |
| Cu | mg/L | 5,000 | 5,000 | - |
| Qo | $m^3$/day | 1,200 | 800 | - |
| As | $m^2$ | 60 | 40 | - |
| Ls | m | 20 | 10 | - |
| Ws | m | 5 | 4 | - |
| Hs | m | 1.9 | 2.0 | - |
| Vs | $m^3$ | 110 | 80 | - |
| Qu | $m^3$/day | 120 | 70 | - |
| $H_2$ | m | 1.5 | 1.5 | - |
| H0 | m | 3.4 | 3.5 | - |

## 6. To removal nutrients, use wetland.

Only by aerated lagoon, only $BOD_5$ and SS are removed. For further treatment for nutrients another process is necessary.

Here, wetland was considered as an alternative for this purpose, considering cost efficiency.

Levels of nitrogen and phosphates are estimated as below based on the analysis of leachate during this Study.

| | | | |
|---|---|---|---|
| Total-N: | | 240 | mg/L |
| Total-P: | | 64 | mg/L |

In biological treatment nitrogen and phosphate are necessary. The ratio of N and P towards $BOD_5$ is 3:0.3:100

Therefore N and P after biological treatment, their levels are expected as below.

| | | | |
|---|---|---|---|
| Inlet $BOD_5$ | | 920 | mg/L |
| Therefore N to be removed by biological treatment | | 27.6 | mg/L |
| Therefore P to be removed by biological treatment | | 2.76 | mg/L |
| After aerated lagoon remained N | N | 212 | mg/L |
| | P | 61 | mg/L |

| Criteria* | |
|---|---|
| 20 | mg/L. as KTN |
| 10 | mg/L. as P |

*:Discharge criteria of industrial waste water into general public water body

Inlet T-P level will be reduced by using cover soil.

Therefore, only removal of nitrogen would be considered.

Here, subsurface-flow (SSF) systems was considered.

In a SSF wetland, the basin is filled with gravel or some other coarse substrate, and the water level is maintained below-ground. Water flows horizontally, or sometimes vertically, through the gravel and the root mat of the wetland vegetation.

Arrow arum (Polyandry spp.) and Pickerel weed (Pontederia spp.) have been used in constructed wetlands.

Also common reed (Phragmitescommunis) is used

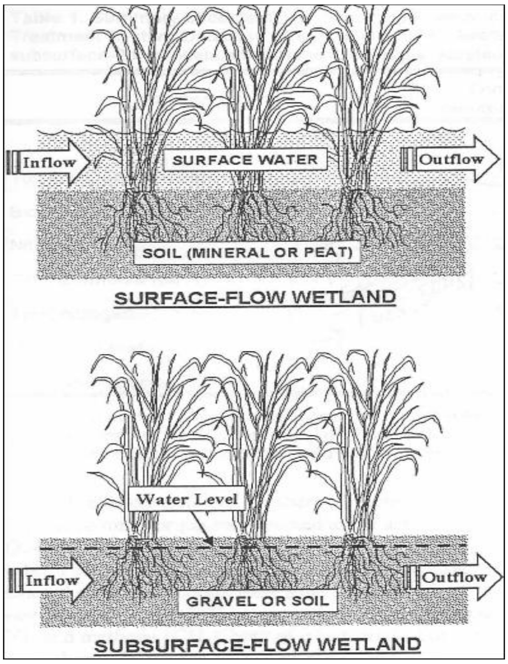



**Figure 9 Conceptual diagram of subsurface-flow wetlands**

**Example of determination of basin design for SFS wetlands system**

Nitrogen removal will proceed when $BOD_5$ level is less than 10 mg/L.

**1. Premises**

| | | |
|---|---|---|
| Influent $BOD_5$ | $C_0$ | 60 mg/L |
| Effluent $BOD_5$ | Ce | 8 mg/L |
| Inflow | Q | $m^3$/day |
| | | $m^3$/day |
| Vegetation type | | cattails |
| Minimum water temperature | T | 21°C |
| Basin media | coarse sand with 2 mm of maximum effective size | |
| Basin slope | S | 0.01 |

**2. Solution**

| | | | |
|---|---|---|---|
| 1. | Basin depth for use wit cattail | d | 0.3 m |
| 2. | Porosity | α | 0.39 |
| | Hydraulic conductivity | Ks | 480 $m^3/m^2$/day |
| | | $K_{20}$ | 1.35 |
| 3. | Temperature-dependent first order rate constant | | |
| | | $K_T$ at | 21°C |
| | | | 1.49 $d^{-1}$ |
| 4. | Pore-space detention time | t' = -1nCe/C0/Kt | d |
| 5. | Cross-sectional area | $A_C$ = Q/Ks/S | $m^2$ |
| 6. | Basin width | W = Ac/d | m |
| 7. | Basin length | L = t'Q/W/d/α | m |
| 8. | Required surface area | As = L*W | $m^2$ |
| | | | ha |
| 9. | Check hydraulic-loading rate or specific area requirements | | |
| | | Lw = Q/L/W | 150 to 500 $m^3$/ha/day |
| | | | 0.015 to 0.005 $m^3/m^2$/day |
| | or | Asp= 1/Lw for advanced treatment 2.1 ha/$10^3m^3$ | |
| 10. | Check $BOD_5$ loading rate | Max.$BOD_{5L}$ | 60 kg/ha/day |
| | $LBOD_5$ | | kg/day |
| | $BOD_{5L}$ | | kg/ha/day |
| 11. | Vegetation | | |
| | Reed can absorb | N | 18 to 21 g/kg |
| | | P | 2.0 to 3.0 g/kg |
| | Inlet N | | 212.4 mg/L |
| | Vd: vegetation density | | 10 kg/$m^2$ |

**Table 151 Specification of Wetland**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| $C_0$ | mg/L | 60 | 60 | - |
| Ce | mg/L | 8 | 8 | - |
| Q | $m^3$/day | 440 | 290 | - |
| T | °C | 21 | 21 | - |
| S | | 0.01 | 0.01 | - |
| d | m | 0.3 | 0.3 | - |
| α | | 0.39 | 0.39 | - |
| Ks | $m^3/m^2$/day | 480 | 480 | - |
| $K_{20}$ | | 1.35 | 1.35 | - |
| Kt | $d^{-1}$ | 1.49 | 1.49 | - |
| t' | day | 1.36 | 1.36 | - |
| Ac | $m^2$ | 92 | 60 | - |
| W | m | 310 | 210 | - |
| L | m | 16 | 16 | - |
| As | $m^2$ | 5,200 | 3,400 | - |
| Lw | $m^3/m^2$/day | 0.09 | 0.09 | - |
| Asp | ha/1000$m^3$ | 11.60 | 11.60 | - |
| L-$BOD_5$ | kg/day | 26.4 | 17.4 | - |
| $BOD_{5L}$ | kg/ha/day | 51 | 51 | - |
| V | $m^3$ | 1,560 | 1,020 | - |
| R.T | day | 3.5 | 3.5 | - |
| Inlet N | mg/L | 212 | 212 | - |
| Total N in WL | g | 340,000 | 220,000 | - |
| N absorption | g/kg | 18 | 18 | - |
| Nos. of reed | kg | 18,889 | 12,222 | - |
| Vd | kg/$m^2$ | 10 | 10 | - |
| Max Reed | kg | 52,000 | 34,000 | - |

**Alternative 6: Anaerobic Pond + Aerated Lagoon + Maturation Pond with recirculation -New Guanabacoa**

(Remarks): Dimensions are at mid-depth. Height allowance should be 50 cm at least.

This system is an alternative adding Anaerobic Pond to Alternative 1 to reduce area.

## 1. Premises

1.1 There are no discharge quality criteria for treated leachate. Therefore, a temporary guideline was proposed as follows.

**Table 152 Proposed Water Quality Criteria**

| Leachate Quality | Unit-mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of T-$BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

1.2 Recirculation rate of leachate 3 times/day toward the leachate generated

## 2. Anaerobic pond

| | | | |
|---|---|---|---|
| RTa: Retention time of anaerobic pond | | | 7 days |
| $BOD_5$ Removal rate | | | 60% |
| $BOD_5$ out-a | | | 368 mg/L |
| Da: Depth of the anaerobic pond | | | 3.5 m |
| Aa: Surface area | | | $m^2$ |
| Va: Anaerobic pond volume | | | $m^3$ |
| Dimension | Length | La | m |
| | Width | Wa | m |

$BOD_{5La}$: $BOD_5$ load of anaerobic pond 100 to 350 g-$BOD_5$/$m^3$-pond/day

**Table 153 Dimension of Anaerobic Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| R.T | days | 7 | 7 | - |
| Va | $m^3$ | 3,080 | 2,030 | - |
| Da | m | 3.5 | 3.5 | - |
| Aa | $m^2$ | 880 | 580 | - |
| La | m | 50 | 40 | - |
| Wa | m | 20 | 15 | - |
| $BOD_5$ | g/day | 404,800 | 266,800 | - |
| $BOD_{5La}$ | g/$m^3$/day | 131 | 131 | - |

Number of ponds: 1

## 3. Aerated Lagoon

### 3.1 Aerated Lagoon Process

Design Base:

| | Symbol | Unit | |
|---|---|---|---|
| Influent flow | Q | $m^3$/d | |
| Influent suspended solids | $SS_0$ | mg/L | 378 |
| Influent soluble $BOD_5$ | $S_0$ | mg/L | 368 |
| Effluent soluble $BOD_5$ | $S\text{-}BOD_{5\text{-}out}$ | mg/L | 30 |
| Effluent suspended solid after setting | SSe | mg/L | 70 |
| Kinetic coefficients: | | | |
| Y | | l/d | 0.65 |
| Ks | | mg-$BOD_5$/L | 100 |
| Kmax | | mg-$BOD_5$/L/d | 6.0 |
| Kd | | l/d | 0.07 |
| First order soluble $BOD_5$ removal rate constants at 20 °C | | | |
| | $k_{(20)}$ | l/d | 2.5 |
| Waste water temperature | Ti | °C | 21.0 |
| Aeration constants in leachate | | | |
| in leachate | α | | 0.6 |
| in treated water | β | | 0.9 |
| Oxygen concentration to be maintained in liquid | | mg - $O_2$/L | 1.5 |
| Lagoon depth | H | m | 3.5 |
| Design mean cell - residence time | θc | d | 7 |

3.2 Surface area of the lagoon A $m^2$

$\theta c = V/Q \quad \therefore V = \theta c * Q$ V: volume of the lagoon

A = V/H

Dimension

**Table 154 Dimension of Aerated Lagoon**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| V | $m^3$ | 3,080 | 2,030 | - |
| A | $m^2$ | 880 | 580 | - |
| L | m | 50 | 40 | - |
| W | m | 20 | 15 | - |
| H | m | 3.5 | 3.5 | - |
| A' (corrected A) | $m^2$ | 1,000 | 600 | - |
| V' (Corrected V) | $m^3$ | 3,500 | 2,100 | - |

3.3 Soluble effluent $BOD_5$ at the lagoon outlet: S-$BOD_5$-out

S-$BOD_5$out = { Ks (1 + 0c*kd) } / {θc (Y*kmax - kd) - I } (mg/L)

| Ks | θc*kd | 1+θc*kd | Ks (1+θc*kd) | θc | Y*kmax | Y*kmax-kd | θc (Y*kmax-kd)-1 | S-$BOD_5$ out |
|---|---|---|---|---|---|---|---|---|
| 100 | 0.49 | 1.49 | 149 | 7 | 3.9 | 3.83 | 25.8 | 5.8 |

3.4 Effluent $BOD_5$

(1) Correct the removal-rate for temperature effects

$k(t) = k(20)*\theta^{T-20}$ (l/d)

| Ti | $k_{(20)}$ | T-20 | θ | $\theta^{(T-20)}$ | $k_{(20)}\theta^{(T-20)}$ |
|---|---|---|---|---|---|
| 21.0 | 2.5 | 1 | 1.06 | 1.06 | 2.7 |

(2) Determine the effluent $BOD_5$: St-$_{out}$ (mg/L)

$St\text{-}out/S_0 = 1/(1+k\theta_H) = S/S_0 = 1/(1+kV/Q)$

| kt | V/Q | 1+kV/Q | 1/(1+kV/Q) | $S_0$ | St-out |
|---|---|---|---|---|---|
| 2.7 | 7 | 20 | 0.05 | 368 | 19 |

3.5 Concentration of biological solids produced: X (mg/L)

X =Y ($S_0$-S-$BOD_5$-out)/ ($1+k_d\theta_c$) (mg-VSS/L)

| Y | $S_0$-S-$BOD_{5\text{-out}}$ | $k_d$ | θc | $Y(S_0\text{-S-}BOD_{5\text{-out}})/(1+k_d\theta_c)$ |
|---|---|---|---|---|
| 0.65 | 362.2 | 0.07 | 7 | 158 |

3.6 Suspended solids in the lagoon before settling

SSi = Influent suspended solids + X/0.7(mg/L)

Ratio of volatile suspended solid 0.7

| SSo | X | SSi |
|---|---|---|
| 378 | 158 | 604 |

3.7 Oxygen requirements

$Q_2$ (kg/d) = Q ($S_0$-S-$BOD_{5\text{-out}}$)/f-1.42Px

f: conversion factor for $BOD_5$ to $BOD_L$ 0.68

Px = Q*(concentration of biological solids produced)

**Table 155 Required $O_2$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| $S_0$-s-$BOD_{5\text{-out}}$ | mg/L | 362 | 362 | - |
| f | - | 0.638 | 0.68 | - |
| Px | kg/day | 70 | 46 | - |
| Required $O_2$ | kg/day | 136 | 89 | - |

3.8 Ratio of oxygen required to $BOD_5$ removed

$BOD_5$ removed (kg/d)

$O_2$/$BOD_5$ removed

**Table 156 Removed $BOD_5$**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| So-S-$BOD_{5\text{-out}}$ | mg/L | 362.2 | 362.2 | - |
| $BOD_5$ removed | kg/day | 159 | 105 | - |
| $O_2$/$BOD_5$ | - | 0.9 | 0.9 | - |

3.9 Surface aerator power requirements

| | | | |
|---|---|---|---|
| assumption: kg-$O_2$/kw/h | kg-$O_2$/kw/h | No | 1.6 |
| a) Correction factor for surface aerators for summer conditions f | | | |
| f=No/N | | | |
| 1) Oxygen saturation concentration at 21 °C | Cs(21) | mg/L | 8.91 |
| 2) Cs(20) | | mg/L | 9.08 |
| 3) DO concentration in Lagoon | CL | mg/L | 1.5 |

f= {B*CsT-CL}/ Cs (20)*1.024T-20*α}

| Ti-20 | $1.024^{T-20}$ | α | B | f |
|---|---|---|---|---|
| 1 | 1.029 | 0.6 | 0.9 | 0.44 |

b) Field transfer rate: N

$N = fN_0$ kg-$O_2$/kw/h 0.71

Total amount of transfer $O_2$ kg-$O_2$/kw/d kg-$O_2$/kw/h 17.0

The total axis power required to meet the required oxygen

**Table 157 Required $O_2$ Supply**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Required $O_2$ | kg/day | 136 | 89 | - |
| Required power for $O_2$ supply | kW | 8.0 | 5.3 | - |

3.10 Energy requirements for mixing

**Table 158 Specifications of Aerator**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Power for Mixing | kW/$m^3$ | 0.005 | 0.005 | - |
| Lagoon volume | $m^3$ | 3,500 | 2,100 | - |
| Axis power for mixing | kW | 17.5 | 10.5 | - |
| Total efficiency | - | 0.75 | 0.75 | - |
| Required power | kW | 23 | 14 | - |
| Unit power | kW/No. | 11 | 11 | - |
| No. of Aerator | Nos. | (3+1) | (2+1) | - |

## 4. Leachate recirculation pump

Recirculation rate r times/leachate

Recirculation pump flow Qr $m^3$/day

Qr = r*Q

Required Power Ps

Ps = 0.163*Qr($m^3$/min)*H(m)/ή Horse power

Here

Total head of the pump H m

Total efficiency ή

Liquid density ρs 1.05

From the entrance of anaerobic lagoon to landfill

**Table 159 Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 1,320 | 870 | - |
| | $m^3$/min | 0.92 | 0.60 | - |
| Head | m | 40 | 40 | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 11.2 | 7.4 | - |
| | kW | 8.4 | 5.5 | - |
| Unit power | kW | 11 | 7.5 | - |
| Nos. of pumps | Nos. | (1+1) | (1+1) | - |

## 5. Maturation Pond

<u>Design criteria</u>

$D_m$: Depth of maturation pond 1.5 m

$RT_m$: Retention time of maturation pond 14 days

$A_m$: Area od maturation pond

Dimensions of maturation pond

Length Lm m

Width Wm m

**Table 160 Dimensions of Maturation Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| $RT_m$ | days | 14 | 14 | - |
| Vm | $m^3$ | 6,160 | 4,060 | - |
| Nos. of Ponds | - | 2 | 2 | - |
| Vm/Pond | $m^3$ | 3,080 | 2,030 | - |
| Dm/Pond | m | 1.5 | 1.5 | - |
| Am/Pond | $m^2$ | 2,100 | 1,400 | - |
| Lm/Pond | m | 70 | 60 | - |
| Wm/Pond | m | 30 | 25 | - |

Pond arrangement: Series

# C. Final Disposal:

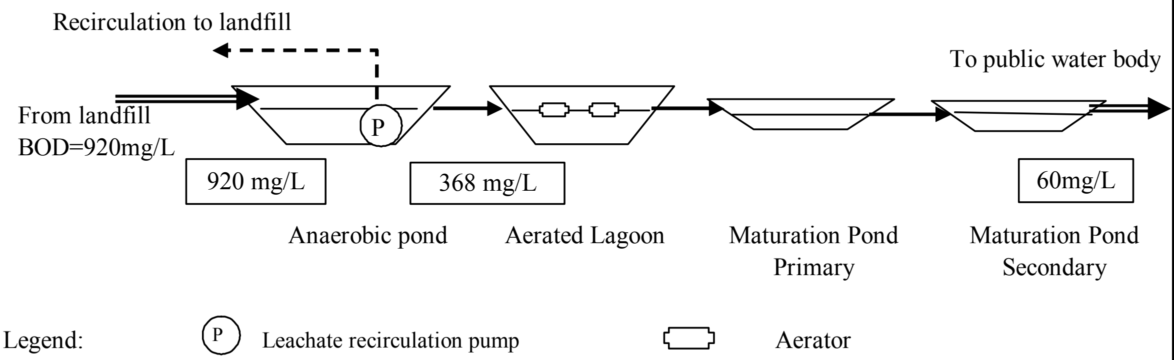
## C5 Supplemental Explanation on Leachate Treatment System

# C5 SUPPLEMENTAL EXPLANATION ON LEACHATE TREATMENT SYSTEM

Table of Contents

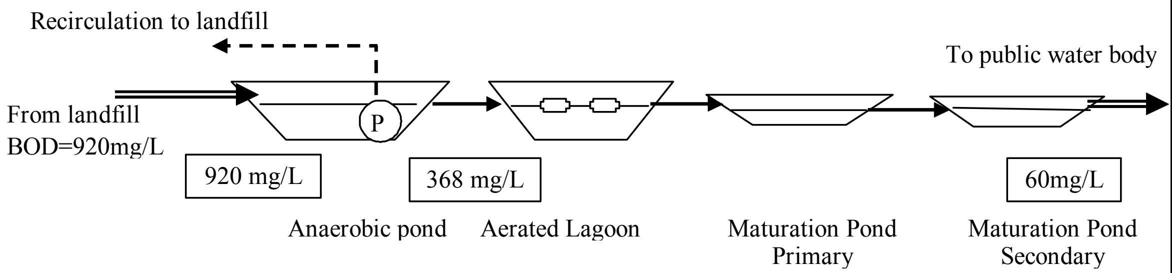
## 1. Adopted leachate treatment system in this project with flow diagram, quality and major facility

### 1.1 Location: NEW GUANABACOA




| | Anaerobic pond | Aerated Lagoon | Maturation Pond Primary / Secondary |
|---|---|---|---|
| Retention time | 7 days | 7 days | 14 days |
| 1st stage | Design flow = 440 $m^3$/day | | |
| 2nd stage | Design flow = 290 $m^3$/day | | |
| In T-$BOD_5$ (mg/L) | 920 | 368 | - |
| Out T-$BOD_5$ (mg/L) | 368 | - | 60 |
| BOD removal rate (%) | 60 | 84 | |
| In SS (mg/L) | 540 | 378 | - |
| Out SS (mg/L) | 378 | - | 70 |
| Size of pond | | | |
| 1st stage | | | |
| Width (m) | 20 | 20 | 30 |
| Length (m) | 50 | 50 | 70 |
| Effective depth (m) | 3.5 | 3.5 | 1.5 |
| No. of pond | 1 | 1 | 2 |
| Surface area ($m^2$) | 1,000 | 1,000 | 4,200 |
| Volume of pond ($m^3$) | 3,500 | 3,500 | 6,300 |
| 2nd stage | | | |
| Width (m) | 15 | 15 | 25 |
| Length (m) | 40 | 40 | 60 |
| Effective depth (m) | 3.5 | 3.5 | 1.5 |
| No. of pond | 1 | 1 | 2 |
| Surface area ($m^2$) | 600 | 600 | 3,000 |
| Volume of pond ($m^3$) | 2,100 | 2,100 | 4,500 |
| Specification of aerator | | | |
| 1st stage | 1.6kg-$O_2$/kwh x 11kw x (3+1) | | including 1 spare |
| 2nd stage | 1.6kg-$O_2$/kwh x 7.5kw x (2+1) | | including 1 spare |
| Specification of leachate recirculation pump | | | |
| 1st stage | 0.92$m^3$/min x 40mH x 11kw x (1+1) | | including 1 spare |
| 2nd stage | 0.60$m^3$/min x 40mH x 7.5kw x (1+1) | | including 1 spare |
| Specification of sludge pump | | | |
| 1st stage | 0.07$m^3$/min x70mH x2.2kw x (1+1) | | including 1 spare |
| 2nd stage | 0.05$m^3$/min x 70mH x 1.5kw x (1+1) | | including 1 spare |

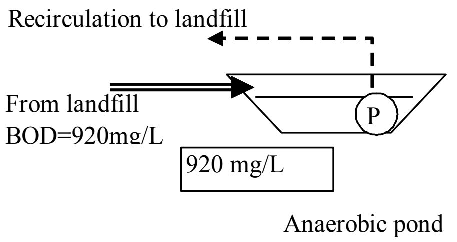
## 1.2 NEW SITE 1




Legend: (P) Leachate recirculation pump; Aerator

| | | | |
|---|---|---|---|
| Retention time | 7 days | 7 days | 14 days |
| 1st stage | Design flow = 970 $m^3$/day | | |
| 2nd stage | Design flow = 610 $m^3$/day | | |
| In T-$BOD_5$ (mg/L) | 920 | 368 | - |
| Out T-$BOD_5$ (mg/L) | 368 | - | 60 |
| BOD removal rate (%) | 60 | 84 | |
| In SS (mg/L) | 540 | 378 | - |
| Out SS (mg/L) | 378 | - | 70 |
| Size of pond | | | |
| 1st stage | | | |
| Width (m) | 30 | 30 | 40 |
| Length (m) | 70 | 70 | 120 |
| Effective depth (m) | 3.5 | 3.5 | 1.5 |
| No. of pond | 1 | 1 | 2 |
| Surface area ($m^2$) | 2,100 | 2,100 | 9,600 |
| Volume of pond ($m^3$) | 7,350 | 7,350 | 14,400 |
| 2nd stage | | | |
| Width (m) | 22 | 22 | 35 |
| Length (m) | 60 | 60 | 90 |
| Effective depth (m) | 3.5 | 3.5 | 1.5 |
| No. of pond | 1 | 1 | 2 |
| Surface area ($m^2$) | 1,320 | 1,320 | 6,300 |
| Volume of pond ($m^3$) | 4,620 | 4,620 | 9,450 |
| Specification of aerator | | | |
| 1st stage | 1.6kg-$O_2$/kwh x 11kw x (5+1) | | including 1 spare |
| 2nd stage | 1.6kg-$O_2$/kwh x7.5kw x (5+1) | | including 1 spare |
| Specification of leachate recirculation pump | | | |
| 1st stage | 1.01$m^3$/min x 50mH x15kw x (2+1) | | including 1 spare |
| 2nd stage | 1.27$m^3$/min x 50mH x 19kw x (1+1) | | including 1 spare |
| Specification of sludge pump | | | |
| 1st stage | 0.15$m^3$/min x80mH x5.5kw x (1+1) | | including 1 spare |
| 2nd stage | 0.10$m^3$/min x 80mH x 3.7kw x (1+1) | | including 1 spare |

## 1.3 Calle 100




Legend: (P) Leachate recirculation pump

| | | | |
|---|---|---|---|
| Retention time | 7 days | | |
| 1st stage | Design flow = 730m$^3$/day | | |
| 2nd stage | Design flow = 610m$^3$/day | | |
| In T-BOD$_5$ (mg/L) | 920 | | |
| Out T-BOD$_5$ (mg/L) | 368 | | |
| BOD removal rate (%) | 60 | | |
| In SS (mg/L) | 540 | | |
| Out SS (mg/L) | 378 | | |
| Size of pond | | | |
| 1st stage | | | |
| Width (m) | 25 | | |
| Length (m) | 60 | | |
| Effective depth (m) | 3.5 | | |
| No. of pond | 1 | | |
| Surface area (m$^2$) | 1,500 | | |
| Volume of pond (m$^3$) | 5,250 | | |
| 2nd stage | | | |
| Width (m) | 22 | | |
| Length (m) | 60 | | |
| Effective depth (m) | 3.5 | | |
| No. of pond | 1 | | |
| Surface area (m$^2$) | 1,320 | | |
| Volume of pond (m$^3$) | 4,620 | | |
| Specification of leachate recirculation pump | | | |
| 1st stage | 1.52m$^3$/min x50mH x19kw x (1+1) | | including 1 spare |
| 2nd stage | 1.27m$^3$/min x50mH x19kw x (1+1) | | including 1 spare |

## 2. Outline of adopted leachate treatment system

Leachate is discharged from the landfill to the treatment system. The proposed leachate treatment system consists of an anaerobic pond, aerated lagoon, and maturation pond.

In the anaerobic pond, high organic load is removed as it is best to pretreat strong wastes having a high solid content. The solids settle to the bottom where they are digested anaerobically. The retention time is set at 7 days and BOD removal ratio at 60%. The treated leachate in the anaerobic pond is sent to the aerated lagoon and is also recirculated to the landfill. The recirculated landfill undergoes contact filtration system, although the treatment efficiency is not considered in calculation.

In the aerated lagoon, BOD removal is estimated at about 85% for a 7-day retention time. The aerated lagoon is developed as a modified waste stabilization pond (facultative pond) for hot climates where mechanical aeration is used to supplement the algal oxygen supply. Aerators are installed to add oxygen into the pond and to mix water in the lagoon. The capacity of the aerators is designed based on the power required for mixing water in the lagoon. Treated wastewater at the aerated lagoon flows into the maturation pond.

The aerated lagoon effluent includes high BOD due to the presence of bacteria. The maturation pond predominantly reduces the bacterial cells, still the BOD is also considerably reduced. Moreover the maturation pond destroys pathogens. Two maturation ponds in series, each with a retention time of 7 days, are provided to achieve the treatment.

A sludge pump is provided to remove sludge from the maturation pond and anaerobic pond, and hence to facilitate maintenance of the ponds.

It is desirable to construct a storage pond to reduce the peak inflow and to stabilize the leachate quality to the leachate treatment system, but it is not included due to financial constraints. To mitigate the negative impact, when influent flow exceeds the design flow due to high rainfall, the following actions are taken, i) inflow is stopped by closing the inflow gate, ii) the inflow is stored in the ponds, iii) the recirculation of flow to the landfill site by the leachate recirculation pump is increased.

## 3. Example of the capacity calculation on the adopted treatment system

Capacity calculation of Alternative 6 for New Guanabacoa landfill is described below as an example of the adopted leachate treatment system. Parameters used in the calculation are obtained from "Wastewater Engineering, Metcalf & Eddy, Third Edition, 1991", although they shall be established based on experimental results. So, the retention time of ponds is set with a high safety factor.

**1. Premises)**

**1.1 Planned Leachate Quality**

There is no discharge quality criteria for treated leachate. Therefore, a temporally guideline was proposed as the following.

| Leachate quality | Unit: mg/L | | |
|---|---|---|---|
| | T-$BOD_5$ | SS | S-$BOD_5$ |
| Inlet | 920 | 540 | 600 |
| Outlet | 60 | 70 | 30 |
| Removal rate (%) | 93.5 | 87.0 | 95 |

Even though discharge quality criteria are established in the future, only removal of T-$BOD_5$ and SS is considered by this system.

There are some estimation formula for leachate generation, including the one with the consideration of evaporation, however, in case of using pond system as the final treatment, pond volume is designed with ignoring evaporation.

**1.2 Estimated Leachate Generation**

Landfill Area

| | | | |
|---|---|---|---|
| Stage 1 | $A_1$ | 6.0 ha | 60,000 $m^2$ |
| Stage 2 | $A_2$ | 4.0 ha | 40,000 $m^2$ |
| Stage 3 | $A_3$ | 0.0 ha | 0 $m^2$ |

Once surface liner facility is constructed in landfill site, it is assumed that no water flows into the landfill site.

q = f*C*A*I/1000 ($m^3$/day)

Where

q : Daily effluent amount of leachate water ($m^3$/day)

C: Leachate coefficient of on-going landfill section 0.4

I: Annual maximum rainfall (mm/day)

Maximum rainfall during 2000 to 2002 338 mm in September in 2002
11.3 mm/day

A: Landfill area ($m^2$)

f: Safety factor 1.6

Q : Daily effluent amount of leachate with safety factor ($m^3$/day)

| | Stage1 | Stage2 | Stage3 |
|---|---|---|---|
| Q ($m^3$/day) | 440 | 290 | - |

**2. Anaerobic Pond**

| | | | | |
|---|---|---|---|---|
| RTa : Retention time of anaerobic pond | | | 7 | days |
| $BOD_5$ Removal rate | | | 60 | % |
| $BOD_5$ out-a | | | 368 | mg/L |
| SS Removal rate | | | 30 | % |
| SSout | | | 378 | mg/L |
| Da: Depth of the anaerobic pond | | | 3.5 | m |
| Aa: Surface area required | | | | $m^2$ |
| Va: Anaerobic pond volume required | | | | $m^3$ |
| Dimension | Length | La | | m |
| | Width | Wa | | m |

$BOD_{5La}$ : $BOD_5$ load of anaerobic pond

100 to 350 g-$BOD_5$/ $m^3$-pond/day

**Dimensions of Anaerobic Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| R.T | days | 7 | 7 | - |
| Va | $m^3$ | 3,080 | 2,030 | - |
| **Da** | **m** | **3.5** | **3.5** | - |
| Aa | $m^2$ | 880 | 580 | - |
| **La** | **m** | **50** | **40** | - |
| **Wa** | **m** | **20** | **15** | - |
| $BOD_5$ | g/day | 404,800 | 266,800 | - |
| $BOD_{5La}$ | g/$m^3$/day | 131 | 131 | - |

**Number of ponds: 1**

## 3. Aerated Lagoon

### 3.1 Aerated Lagoon Process

Design Base :

| | | | |
|---|---|---|---|
| Influent flow volume estimated | Q (stage 1) | $m^3/d$ | 440 |
| | Q (stage 2) | $m^3/d$ | 290 |
| Influent suspended solids | $SS_0$ | mg/L | 378 |
| Influent soluble $BOD_5$ | $S_0$ | mg/L | 368 |
| Effluent soluble $BOD_5$ | $S\text{-}BOD_{5\text{-}out}$ | mg/L | 30 |
| Effluent suspended solid after settling | SSe | mg/L | 70 |
| Kinetic coefficients : | | | |
| Sludge conversion ratio from BOD5 removed | Y | 1/d | 0.65 |
| Saturation constant | Ks | mg-$BOD_5$/L | 100 |
| Maximum substrate usage velocity | Kmax | mg-$BOD_5$/L/d | 6.0 |
| Endogenous decay coefficient | $K_d$ | 1/d | 0.07 |
| First order soluble $BOD_5$ removal rate constants at 20 ℃ | $k_{(20)}$ | 1/d | 2.5 |
| Waste water temperature | Ti | ℃ | 21.0 |
| Aeration constants in leachate | | | |
| in leachate | | α | 0.6 |
| in treated water | | β | 0.9 |
| Oxygen concentration to be maintained in liquid | | mg - $O_2$/L | 1.5 |
| Lagoon depth | H | m | 3.5 |
| Design mean cell - residence time | θc | d | 7 |

### 3.2 Surface area of the lagoon

V required = θc*Q

V: volume oflagoon

A required = V required/H

**Dimensions of Aerated Lagoon**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| V required | $m^3$ | 3,080 | 2,030 | - |
| A required | $m^2$ | 880 | 580 | - |
| **L** | **m** | **50** | **40** | - |
| **W** | **m** | **20** | **15** | **-** |
| **H** | **m** | **3.5** | **3.5** | **-** |
| A designed | $m^2$ | 1,000 | 600 | - |
| V designed | $m^3$ | 3,500 | 2,100 | - |

### 3. 3 Soluble effluent $BOD_5$ at lagoon outlet: S-$BOD_5$-out

$S\text{-}BOD_5out = \{ K_s ( 1+ \theta_c*k_d ) \}/ \{\theta_c (Y * k_{max} - k_d ) - 1 \}$ (mg/L)

| $K_s$ | $\theta_c*k_d$ | $1 +\theta_c*k_d$ | $K_s ( 1+ \theta_c*k_d )$ | $\theta_c$ | $Y * k_{max}$ | $Y * k_{max} - k_d$ | $\theta_c (Y * k_{max} - k_d ) - 1$ | S-$BOD_5$-out |
|---|---|---|---|---|---|---|---|---|
| 100 | 0.49 | 1.49 | 149 | 7 | 3.9 | 3.83 | 25.8 | 5.8 |

### 3.4 Effluent $BOD_5$ :

3.4.1 Modify the removal-rate for temperature effects

$k(t) = k(20)*\theta^{T-20}$ (1/d)

| Ti | $k_{(20)}$ | T-20 | θ | $\theta^{(T-20)}$ | $k_{(20)}\theta^{(T-20)}$ |
|---|---|---|---|---|---|
| 21.0 | 2.5 | 1 | 1.06 | 1.060 | 2.7 |

3.4.2 Determine the effluent $BOD_5$ : St-$_{out}$ (mg/L)

$St\text{-}out/S_0 = 1/( 1 + k\theta_H ) = S/S_0 = 1/( 1+ kV/Q)$

| kt | V/Q | 1 + kV/Q | 1/( 1 + kV/Q | $S_0$ | St-out |
|---|---|---|---|---|---|
| 2.7 | 7 | 19.55 | 0.05 | 368 | 19 |

<60 OK

BOD removal rate at AL=1−60/368=84%

### 3.5 Concentration of biological solids produced : X (mg/L)

$X = Y(S_0 - S\text{-}BOD_{5\text{-}out})/( 1 + k_d\theta_c )$ ( mg - VSS /L )

| Y | $S_0$ - S-$BOD_{5\text{-}out}$ | $k_d$ | θc | $Y(S_0 - S\text{-}BOD_{5\text{-}out})/( 1 + k_d\theta_c )$ |
|---|---|---|---|---|
| 0.65 | 362.2 | 0.07 | 7 | 158 |

**3.6 Suspended solids in the lagoon before settling**

$SSi = SS_0 + X/0.7$ (mg/L)

0.7 = Ratio of volatile suspended solid

| $SS_0$ | X | SSi |
|---|---|---|
| 378 | 158 | 604 |

It is reduced to be less than 70 in MP . OK

**3.7 Oxygen requirements**

$O_2$ ( kg/d ) = Q ( $S_0$ - S-$BOD_{5\text{-out}}$)/f - 1.42$P_x$

f : conversion factor for $BOD_5$ to $BOD_L$ = 0.68

Px = Q*(concentration of biological solids produced )

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| So-S-$BOD_{5\text{-out}}$ | mg/L | 362 | 362 | - |
| f | - | 0.68 | 0.68 | - |
| Px | kg/day | 70 | 46 | - |
| Required $O_2$ | kg/day | 136 | 89 | - |

**3.8 Ratio of oxygen required to $BOD_5$ removed**

$BOD_5$ removed (kg/d )

$O_2$/$BOD_5$ removed

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| So-S-$BOD_{5\text{-out}}$ | mg/L | 362 | 362 | - |
| $BOD_5$ removal | kg/day | 159 | 105 | - |
| $O_2$/$BOD_5$ | - | 0.9 | 0.9 | - |

**3.9 Surface aerator power requirements**

assumed Unit Oxygen supply per power: No — kg-$O_2$/kw/h — 1.6

a ) Modification factor for surface aerators for summer conditions f — f = No/N

1) Oxygen saturation concentration at 21 ℃ — $C_{s(21)}$ — mg/L — 8.91

2) $C_{s(20)}$ — mg/L — 9.08

3) DO concentration in Lagoon — $C_L$ — mg/L — 1.5

$f = \{(\beta * C_{sT} - C_L) / C_{s(20)} * 1.024^{T-20} * \alpha\}$

| Ti-20 | $1.024^{T-20}$ | α | β | f |
|---|---|---|---|---|
| 1 | 1.024 | 0.6 | 0.9 | 0.44 |

b ) Field transfer rate : N

$N = f N_0$ — kg-$O_2$/kw/h — 0.71

Total amount of transfer $O_2$ — kg-$O_2$/kw/d — kg-$O_2$/kw/d — 16.9

The total axis power required to meet the required oxygen

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Required $O_2$ | kg/day | 136 | 89 | - |
| Required power for $O_2$ supply | kW | 8.0 | 5.3 | - |

**3.10 Energy requirements for mixing**

**Specifications of Aerator**

| | | Unit | Stage1 | Stage2 |
|---|---|---|---|---|
| Power for Mixing | | kW/$m^3$ | 0.005 | 0.005 |
| Lagoon volume | | $m^3$ | 3,500 | 2,100 |
| Axis power for mixing | | kW | 17.5 | 10.5 |
| Total efficiency | | - | 0.75 | 0.75 |
| Required power | | kW | 23 | 14 |
| **Unit power** | | **kW/No.** | **11** | **11** |
| **Number of Aerator** | | **Nos.** | **( 3 + 1 )** | **( 2 + 1 )** |

**4. Leachate recirculation pump**

1) Recirculation rate r times/leachate

Recirculation pump fl Qr $m^3$/day

$Qr = r*Q$

Required Power Ps

$Ps = 0.163*Qr(m^3/min)*H(m)/ή$ horse power

Here

Total head of the pump H m

Total efficiency ή

Liquid denisty ρs 1.05

From the entrance of aerated lagoon to landfill

**Specifications of Leachate Recirculation Pump**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| r | - | 3 | 3 | - |
| Qr | $m^3$/day | 1,320 | 870 | - |
| | **$m^3$/min** | **0.92** | **0.60** | - |
| **Head** | **m** | **40** | **40** | - |
| ή | - | 0.56 | 0.56 | - |
| Ps | Horse power | 11.2 | 7.4 | - |
| | kW | 8.4 | 5.5 | - |
| Unit power | kW/No. | **11** | **7.5** | - |
| No. of pumps | **Nos.** | **(1+1)** | **(1+1)** | - |

**5. Maturation Pond**

Design criteria

$D_m$ : Depth of maturation pond 1.5 m

$RT_m$ : Retention time of maturation 14 days

$A_m$ : Area od maturation pond

$V_m$ = Am x Dm

Dimensions of maturation pond.

Length Lm m

Width Wm m

**Dimensions of Maturation Pond**

| | Unit | Stage1 | Stage2 | Stage3 |
|---|---|---|---|---|
| Q | $m^3$/day | 440 | 290 | - |
| $RT_m$ | days | 14 | 14 | - |
| Vm | $m^3$ | 6,160 | 4,060 | - |
| **Nos. of Ponds** | **-** | **2** | **2** | - |
| Vm/Pond | $m^3$ | 3,080 | 2,030 | - |
| **Dm/Pond** | m | **1.5** | **1.5** | - |
| Am/Pond | $m^2$ | 2,100 | 1,400 | - |
| **Lm/Pond** | m | **70** | **60** | - |
| **Wm/Pond** | m | **30** | **25** | - |

**Pond arrangement: Series**

As described above, the retention time is set at 7 days in the anaerobic ponds, 7 days in the aerated lagoon and 14 days in the maturation ponds, and the total retention time is 28 days. And each pond characteristics are set followings,

Anaerobic pond with 7 days retention time reduces BOD by 60%.

Finally, aerated lagoon with 7 days retention time and two (2) maturation ponds with each 7 days retention time reduce BOD to less than 60 mg/L.

**4. Out line of alternative study on selecting leachate treatment system**

Alternative 6 is adopted, after studying characteristics of six (6) alternatives shown below.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Alternative 1 | Aerated Lagoon | ==> | Maturation Pond | | | | |
| Alternative 2 | Aerated Lagoon | ==> | Sedimentation Pond | ==> | Wet Land | | |
| Alternative 3 | Anaerobic Pond | ==> | Facultative Pond | ==> | Maturation Pond | | |
| Alternative 4 | Anaerobic Pond | ==> | Facultative Pond | ==> | Wetland | | |
| Alternative 5 | Anaerobic Pond | ==> | Aerated Lagoon | ==> | Sedimentation Pond | ==> | Wetland |
| Alternative 6 | Anaerobic Pond | ==> | Aerated Lagoon | ==> | Maturation Pond | | |

Characteristics of the ponds applied in the Alternative 6 are described below,

① Anaerobic Pond: Organic matter is reduced under anaerobic conditions, and it is effective for high load wastewater. If an aerobic treatment system is applied for high load wastewater, the cost of the aerobic equipment and O/M cost are higher.

② Aerated Lagoon : Required area and required sheet area are reduced by introducing the aerated lagoon system.

③ Maturation Pond : Suspended solids contained in the effluent from the aerated lagoon are settled in the maturation pond using a long retention time. Moreover, pathogens, faecal bacteria and viruses are removed in the inhospitable environment with sun light, high dissolved oxygen and high pH.

Reasons for not selecting the other alternatives are described below,

- Alternative 1 consists of aerated lagoon + maturation pond and it does not have an anaerobic pond. The system required a large scale aerated lagoon and the OM cost is very high. So, Alternative 1 is eliminated.
- Although wetland is utilized for $2^{nd}$ treatment or $3^{rd}$ treatment that would remove nutrients, it is difficult to select appropriate type of plants. Moreover it is labor intensive to cut and remove them. So, Alternatives 2, 4, and 5 are not selected.
- Required retention time of the facultative pond is around one (1) month or more to remove organic matter utilizing oxygen from algal photosynthesis and surface re-aeration. It does not require any mechanical equipment and electric power and the OM is easy. However, it requires large land area. So Alternative 3 is not selected.

## 5. References regarding wastewater treatment system and adopted treatment system with the design parameters

1. Reference

References used in the study and design of the leachate treatment system and the relevant design parameters are given below.

(1) Ref. 1: Design Manual for Waste Stabilization Ponds in Mediterranean Countries, European Investment Bank, 1998

| Kind of pond | Anaerobic Pond | Aerated Pond | Facultative Pond | Maturation Pond |
|---|---|---|---|---|
| Depth（m） | 2 - 5 | — | 1 - 2 | 1 – 1.5 |
| Retention time（day） | 1－7 | — | 4 - 5 | 1－7 |
| BOD removal rate (%) | 40 – 70<br>Temperature less 10℃: 40<br>Temperature over 25℃: 70 | — | 70 – 80<br>Temperature: over 20℃ | — |

(2) Ref. 2: Wastewater Engineering, Metcalf & Eddy, Third Edition, 1991

| Kind of pond | Anaerobic Pond | Aerated Pond | Facultative Pond | Maturation Pond |
|---|---|---|---|---|
| Retention time（day） | — | — | — | 18 - 20 |
| BOD removal rate (%) | 70 - 85 | Over 95 | — | — |

(3) Ref. 3: Sewage Treatment in Hot Climates, Duncan Mara, 1976

| Kind of pond | Anaerobic Pond | Aerated Pond | Facultative Pond | Maturation Pond |
|---|---|---|---|---|
| Depth（m） | 2-4m | 3 - 5 | 1-1.5m | 1-1.5m |
| Retention time（day） | 5 | 2-6 | — | 7 x 2ponds |
| BOD removal rate (%) | 70 | 90　以上 | — | 65 |
| Remark | Over 20℃ | | | bacteria coliform removal rate95% |

2. Adopted pond system and its specification for this project

Following specification is adopted based on engineering judgment referring to the above mentioned reference and field condition.

| Kind of pond | Anaerobic Pond | Aerated Pond | Maturation Pond |
|---|---|---|---|
| Depth（m） | 3.5m | 3.5 | 1.5m |
| Retention time（day） | 7 | 7 | 7x2ponds=14 |
| BOD removal rate (%) | 60 | Over 85% | |

## 6. Examples of leachate treatment systems in other parts of the world

Examples of leachate treatment systems in Latin America, Asia and Africa are described below. (Reference: Observations of Solid Waste Landfills in Developing Countries: Africa, Asia, and Latin America, Urban Development Division, The World Bank)

1. Instances in Latin America

Leachate treatment systems at landfill sites in Latin America

| Country | Brazil | Brazil | Brazil | Brazil | Brazil | Brazil | Brazil | Mexico |
|---|---|---|---|---|---|---|---|---|
| City | Curitiba | Caxias do Sul | Salvador | Belo Horizonte | Macae | Rio de Janeiro | Americana | Bordo Xochiaca |
| Waste type | -Domestic<br>-Demolition | -Domestic | -Domestic<br>-Demolition | -Domestic<br>-Demolition | -Domestic | -Domestic | -Domestic | -Domestic |
| Amount(t/d) | 1,800 | 150 | 3,000 | 4,500 | 150 | 6,500 | 150 | 1,700 |
| Leachate treatment | Lagoon | Biological + physical chemical | None | None | None | Recirculation | None | None |

| Country | Mexico | Mexico | Mexico | Argentina | Argentina | Chile | Chile | Colombia |
|---|---|---|---|---|---|---|---|---|
| City | Queretaro | Nuevo Laredo | Monterrey | Villa Dominico | Relleno Norte 3 | Santiago | Colihues La-Yesca | Bogotá |
| Waste type | -Domestic | -Domestic<br>-Non-hazardous industrial | -Domestic<br>-Non-hazardous industrial | -Domestic<br>-industrial | -Domestic<br>-Non-hazardous industrial | -Domestic | -Domestic | -Domestic |
| Amount(t/d) | 450 | 350 | 3,000 | 8,000 | 4,500 | 4,200 | 400 | 4,500 |
| Leachate treatment | Evaporation and recirculation | Evaporation and recirculation | Recirculation | None | Physico/chemical followed by biological anaerobic / aerobic<br>BOD in 3000ppm<br>BOD out 80ppm, | Recirculation | Recirculation / physico-chemical | Recirculation |

| Country | Colombia | Colombia | Colombia | Colombia | Colombia |
|---|---|---|---|---|---|
| City | Marinilla | Viboral | Medellin | Lima South | Zapalla |
| Waste type | -Domestic | -Domestic | -Domestic<br>-Demolition<br>-Industrial<br>-Health care | -Domestic | -Domestic |
| Amount(t/d) | 15 | 5 | 2,000 | 1,200-1,400 | 600-700 |
| Leachate treatment | Release of Leachate through fascine | Release of Leachate through fascine | None | None | None |

As shown above, the abundance of leachate management systems applied at Latin America landfill sites are in the following order:

1) No treatment system applied.
2) Circulation and evaporation system is applied, and both are adopted in this project.
3) Lagoon and pond system, including anaerobic and aerobic system, is applied.

In the references it is also reported that anaerobic + aerobic + physical/chemical treatment system, which is similar to the system adopted in this project, is utilized in Relleno Norte 3 in Argentina where influent BOD is 3000 mg/L and effluent BOD is 80 mg/L, although the details are not clear.

## 2. Instance in Asia

A series of aeration channels followed by settlement tanks is used in Asuwei landfill in China, and it is reported that influent BOD is 1000 mg/L and effluent BOD is 60 mg/L.

The Carmona and San Mateo land fills in the Philippines and the Bantar Geban landfill in Indonesia treat leachate in aerated and facultative ponds. Leachate is circulated in the Philippines and during the rainy season excess leachate is drained into an adjacent creek.

The Kuda landfill in Indonesia has a leachate treatment facility that consists of a facultative pond followed by an aerobic pond, after which the leachate flows through a reed bed (artificial wetland system) for polishing.

## 3. Instance in Africa

In Africa, leachate is generally not treated, but in Durban in South Africa and Ghana, located in a wet climate zone, pond systems for leachate treatment are applied. Wetlands are applied at some landfills and one (1) case was reported of the wetland being practically non-functional due to insufficient resources for maintenance.

## 4. Conclusion

As described above there are similar working examples of the adopted treatment system for this project (anaerobic pond + aerated lagoon + maturation pond).

# D. Financial Data

# D. FINANCIAL DATA

## List of Tables

**Table 1 SWM Expenditure of Havana City**

(Data of year 2003; Unit: CUP 000, CUC 000)

| | Sweeping *1 | | Collection *2 | | Landfill *2 | | Others *3 | | Administration | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CUP | CUC | CUP | CUC | CUP | CUC | CUP | CUC | CUP | CUC | CUP | CUC | Total*4 |
| Revenue | 12,531 | 107 | 13,241 | 1,542 | 0 | 0 | 1,491 | 0 | 1,000 | 100 | 28,263 | 1,749 | 30,012 |
| Expenditure | | | | | | | | | | | | | |
| Personnel cost | 14,929 | 0 | 36,611 | 0 | 2,428 | 0 | 4,461 | 0 | 7,380 | 0 | 65,809 | 0 | 65,809 |
| Materials | 3,455 | 127 | 24,945 | 393 | 2,472 | 59 | 739 | 16 | 13,187 | 108 | 44,798 | 702 | 45,500 |
| Clothing and provisions *5 | 0 | 85 | 0 | 166 | 0 | 9 | 0 | 24 | 0 | 156 | 0 | 440 | 440 |
| Fuel and energy cost | 575 | 6 | 3,236 | 23 | 320 | 3 | 123 | 0 | 1,966 | 1 | 6,220 | 33 | 6,253 |
| Administrative cost | 3,955 | 4 | 16,836 | 0 | 1,697 | 1 | 1,259 | 0 | 3,243 | 494 | 26,989 | 499 | 27,488 |
| Depreciation and investment | 1,604 | 0 | 9,361 | 315 | 639 | 0 | 404 | 0 | 1,058 | 0 | 13,065 | 315 | 13,380 |
| Total expenditure | 24,518 | 222 | 90,989 | 897 | 7,556 | 72 | 6,985 | 40 | 26,833 | 759 | 156,881 | 1,989 | 158,870 |
| Unit cost | 4.96 | 0.04 | 98.80 | 0.97 | 8.21 | 0.08 | | | | | 133.63 | 1.29 | 134.93 |
| (direct cost only) | (Peso/m2) | (Peso/m2) | (Peso/ton) | (Peso/ton) | (Peso/ton) | (Peso/ton) | | | | | (Peso/ton) | (Peso/ton) | (Peso/ton) |
| Unit cost | 5.98 | 1.03 | 119.19 | 1.57 | 9.90 | 0.13 | | | | | 161.21 | 2.09 | 163.30 |
| (including indirect cost) | (Peso/m2) | (Peso/m2) | (Peso/ton) | (Peso/ton) | (Peso/ton) | (Peso/ton) | | | | | (Peso/ton) | (Peso/ton) | (Peso/ton) |

*1: Street sweeping work was performed for 4,941,813 thousand m2 (3,676,813 by DMSC & Auroritas + 622,837 by Aurora Habana Vieja + 642,163 by Aurora Plaza). The wastes was collected in bins or trucks and sent to landfills. The volume of wastes collected by street sweeping was estimated at 36,720 tons a year, given that Havana City had 1,700 street cleaning cars of 200 liter capacity; the capacity utilization of a cleaning car is 40%; anual working days was 360; and the specific gravity fo the street waste is [illegible]

*2: The volume of solid wastes collected and landfilled was 7739.206 thousand m3 (5378.7 by DMSC & Auroritas + 1471.5 by UPPH + 567.7 by Aurora Plaza + 321.306 by Aurora Habana Vieja), which was considered as 920,895 tons, given that the average weight of wastes collected in Havana City was 2523 ton/dat. As a result, the average specific gravity of the wastes was 119kg/m3.

*3: Other activities include cleaning of monuments and public places, and gardener.

*4: CUP and CUC are added up at par.

*5: Item includes foodstuffs, soaps, clothes, and shoes.

Source: DPSC

**Table 2 SWM Staff distribution in Havana City**

| | Composition of workers | | | | | Number of workers | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Sweeping | | | Collection | | | | | | Landfill | Others *1 | | | Administration | | Total |
| | Sweep | Collect. | Landfill | Others | Admin. | Sweep | Park | Public places | Ditch | Collect. | Sanitation | Green area | Street | Garage | | Public place | Funeral, cemetry | Others | Admin. technical | Inspecter | |
| DPSC *2 | | | | | | | | | | | | | | | | | | | 80 | | 80 |
| UPPH *3 | 0% | 76% | 11% | 0% | 13% | | | | | 198 | 224 | | | 171 | 84 | | | | 93 | 12 | 782 |
| Aurora Plaza | 46% | 39% | 0% | 9% | 5% | 313 | | 76 | | 25 | 98 | 123 | 73 | 9 | | 76 | | | 46 | | 839 |
| Aurora Habana Vieja | 66% | 18% | 0% | 5% | 10% | 201 | 237 | 39 | | 64 | 35 | 21 | | 13 | | 39 | | | 71 | | 720 |
| Playa | 32% | 65% | 0% | 0% | 4% | 58 | 81 | | 19 | 34 | 56 | 135 | 19 | 22 | | | | | | 17 | 441 |
| Aurora Miramar *4 | 81% | 19% | 0% | 0% | 0% | 77 | | | | 7 | 11 | | | | | | | | | | 95 |
| Centro Habana | 60% | 36% | 0% | 0% | 4% | 108 | 43 | | | 1 | 35 | 21 | 19 | 14 | | | | | | 11 | 252 |
| Aurora Cayo Hueso *4 | 75% | 25% | 0% | 0% | 0% | 27 | | | | 3 | 6 | | | | | | | | | | 36 |
| Habana del Este | 16% | 74% | 3% | 4% | 1% | 86 | 31 | | | 28 | 123 | 329 | 41 | 10 | 25 | | 32 | | | 10 | 715 |
| Aurora Guanabo *4 | 68% | 32% | 0% | 0% | 0% | 60 | | | | 5 | 23 | | | | | | | | | | 88 |
| Regla | 23% | 45% | 0% | 15% | 17% | 44 | 35 | | 6 | 33 | 32 | 54 | 23 | 11 | | | 22 | 31 | 51 | 8 | 350 |
| Guanabacoa | 26% | 43% | 0% | 17% | 14% | 129 | 26 | | | 148 | | 72 | 17 | 15 | | | 98 | | 72 | 8 | 585 |
| San Miguel de Padron | 21% | 42% | 0% | 24% | 13% | 84 | 43 | | 54 | 121 | | 51 | 16 | 13 | | | 10 | 139 | 71 | 11 | 613 |
| 10 de octubre | 46% | 33% | 0% | 5% | 16% | 219 | 60 | | 8 | 117 | 1 | 33 | 23 | 15 | | | | 31 | 78 | 17 | 602 |
| Cerro | 35% | 45% | 0% | 4% | 17% | 115 | 48 | | 17 | 107 | | 54 | 10 | 20 | | | | 17 | 61 | 16 | 465 |
| Marianao | 30% | 43% | 0% | 15% | 11% | 104 | 26 | | 21 | 72 | | 76 | 15 | | | | 20 | 46 | 41 | 6 | 427 |
| Lisa | 26% | 34% | 0% | 27% | 13% | 147 | 25 | | 39 | 97 | | 66 | 12 | 9 | 2 | | 36 | 139 | 77 | 7 | 656 |
| Boyeros | 24% | 52% | 1% | 10% | 12% | 116 | 57 | | 13 | 237 | 49 | 36 | 24 | 14 | 10 | | 69 | 2 | 77 | 12 | 716 |
| Arroyo Naranjo | 23% | 56% | 1% | 10% | 11% | 186 | 51 | | 55 | 422 | | 80 | 19 | 7 | 15 | | 36 | 67 | 92 | 20 | 1,050 |
| Cotorro | 18% | 62% | 1% | 8% | 11% | 94 | 38 | | 7 | 126 | | 278 | 21 | 14 | 6 | | 33 | 27 | 75 | 6 | 725 |
| Total | 30% | 48% | 1% | 9% | 11% | 2,168 | 801 | 115 | 239 | 1,845 | 693 | 1,429 | 332 | 357 | 142 | 115 | 356 | 499 | 985 | 161 | 10,237 |

*1: Auroras and DMSCs have workers not involved in SWM such as maintenance and custody of monuments and public places, and funeral services.
*2: Total number of workers at DPSC is 120, of which 80 is considered as workers for SWM.
*3: Total of 225 workers (184 direct and 41 indirect) are working for recycling activities. Due to difficulty of cost separation, those workers are included in collection.
*4: Aurora Miramar, Cayo Hueso, and Guanabao are experimental units belonging to municipalities of Playa, Centro Habana and Habana del Este respectively.
Source: "Comportamiento de los componentes esenciales de la politica laboral y salarial en el sistema de comunales LL trimestre Ano2003" DPSC, and UPPH

**Table 3 SWM expenditure of UPPH**

(Data of year 2003; Unit: CUP 000, CUC 000)

| | Collection *1 | | Landfill | | Administration | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | CUP | CUC | CUP | CUC | CUP | CUC | CUP | CUC | Total*2 |
| Revenue *3 | 594 | 340 | | | | | 594 | 340 | 934 |
| Expenditure | | | | | | | | | |
| Personnel cost *4 | 15,847 | 0 | 2,294 | 0 | 2,711 | 0 | 20,851 | 0 | 20,851 |
| Materials *5 | 15,695 | 244 | 1,744 | 27 | 2,561 | 40 | 20,000 | 311 | 20,311 |
| Foodstuff | | 56 | | 8 | | 10 | | 74 | 74 |
| Fuel and energy cost *5 | 1,600 | 10 | 200 | 1 | 200 | 1 | 2,000 | 13 | 2,013 |
| Administrative cost *5 | 10,931 | 0 | 1,582 | 0 | 1,870 | 33 | 14,383 | 33 | 14,416 |
| Depreciation and investment*6*7 | 4,500 | 37 | 250 | 0 | 250 | 0 | 5,000 | 37 | 5,037 |
| Total expenditure | 48,573 | 347 | 6,070 | 36 | 7,591 | 83 | 62,234 | 467 | 62,701 |
| Unit cost | 277.39 | 1.98 | 34.66 | 0.21 | | | 312.05 | 2.19 | 314.24 |
| (direct cost only) | (Peso/ton) | (Peso/ton) | (Peso/ton) | (Peso/ton) | | | (Peso/ton) | (Peso/ton) | (Peso/ton) |
| Unit cost | 315.93 | 2.41 | 39.48 | 0.25 | | | 355.40 | 2.67 | 358.07 |
| (including indirect cost) | (Peso/ton) | (Peso/ton) | (Peso/ton) | (Peso/ton) | | | (Peso/ton) | (Peso/ton) | (Peso/ton) |

*1: The volume of solid waste collected was 1471.5 thousand m3 (equivalent to 175,109 tons, applying the specific gravity of 119kg/m3)

*2: CUP and CUC are added up at par.

*3: UPPH is the budgeted whose primary financing source depends on the government budget. However UPPH can also charge tariffs to some users and record them as revenues.

*4: Cost distribution among departments is considered same as staff distribution, which is sweeping (76%), collection (11%), and administration (13%). 225 workers working at recycling section are included in collection department.

*5: Total costs in CUP is estimated. Cost distribution among departments is supposedly same as that of CUC.

*6: Total costs in peso is estimated. Distribution of equipment invested is considered 90% for collection, 5% for landfill, and 5% for administration.

*7: UPPH only expenses its cost in cash basis. The amount of investment and payment of loan for equipment purchase is considered as capital cost instead of depreciation.

**Table 4 SWM Expenditure of Aurora Plaza**

(Data of year 2003; Unit: CUP 000, CUC 000)

| | Sweeping *1 | | Collection *2 | | Others *3 | | Administration | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | CUP | CUC | CUP | CUC | CUP | CUC | CUP | CUC | CUP | CUC | Total*4 |
| Revenue | 4,531 | 7 | 4,317 | 220 | 491 | 0 | | | 9,339 | 227 | 9,566 |
| Expenditure | | | | | | | | | | | |
| Personnel cost *5 | 2,799 | | 2,373 | | 548 | | 365 | | 6,085 | | 6,085 |
| Materials *6 | 5 | 1 | 133 | 22 | 0 | 0 | 31 | 5 | 169 | 28 | 197 |
| Clothing and provisions | | 28 | | 24 | | 5 | | 4 | | 60 | 60 |
| Fuel and energy cost *6 | 0 | 0 | 116 | 2 | 0 | 0 | 0 | 0 | 116 | 2 | 118 |
| Administrative cost *5 | 136 | 4 | 115 | 0 | 27 | 0 | 18 | 97 | 295 | 101 | 396 |
| Depreciation and investment*7 | 4 | 0 | 61 | 7 | 4 | 0 | 8 | 0 | 76 | 7 | 83 |
| Total expenditure | 2,944 | 33 | 2,798 | 55 | 578 | 5 | 421 | 106 | 6,741 | 198 | 6,939 |
| Unit cost | 4.58 | 0.05 | 41.42 | 0.81 | | | | | 84.99 | 1.29 | 86.29 |
| (direct cost only) | (Peso/m2) | (Peso/m2) | (Peso/ton) | (Peso/ton) | | | | | (Peso/ton) | (Peso/ton) | (Peso/ton) |
| Unit cost | 4.89 | 0.11 | 44.18 | 1.73 | | | | | 90.66 | 2.76 | 93.42 |
| (including indirect cost) | (Peso/m2) | (Peso/m2) | (Peso/ton) | (Peso/ton) | | | | | (Peso/ton) | (Peso/ton) | (Peso/ton) |

*1: Street sweeping work was performed for 642,163 thousand m2.

*2: The volume of solid waste collected was 567.7 thousand m3 (equivalent to 67,556 tons, applying the specific gravity of 119kg/m3)

*3: Other activities include cleaning and maintenance of monuments and public places.

*4: CUP and CUC are added up at par.

*5: Cost distribution among departments is considered same as staff distribution, which is sweeping (46%), collection (39%), others (9%), and administration (6%).

*6: Total costs in CUP is estimated. Cost distribution among departments is supposedly same as that of CUC.

*7: Distribution of depreciable equipment is considered 5% for sweeping, 80% for collection, 5% for others, and 10% for administration.

**Table 5 Balance Sheet of Aurora Plaza**

(At the end of 2003; Unit: Peso *)

| | |
|---|---|
| Assets | |
| Current assets | |
| Cash on hand | 2,800 |
| Cash to be deposited at bank (CUP) | 9,422 |
| Cash to be deposited at bank (CUC) | 1,420 |
| Cash at bank | 807,831 |
| Account receivable in short term (CUP) | 970,872 |
| Account receivable in short term (CUC) | 23,224 |
| Anticipated payment to suppliers | 48,095 |
| Debt from state budget | 51 |
| Materials and spare parts | 19,872 |
| Foodstuff | 2,263 |
| Utensils and tools in use | 73,923 |
| Utensils and tools in stock | 1,935 |
| Wardrobe and linen | 9,661 |
| Ornamental plants | 15,219 |
| Total current assets | 1,986,588 |
| Fixed assets | |
| Fixed tangible assets in use | 601,539 |
| Fixed tangible assets in stock | 23,822 |
| Fixed intangible assets | 18,404 |
| Depreciation of fixed tangible assets | (496,948) |
| Amortization of intangible fixed assets | (17,704) |
| Total fixed assets | 129,113 |
| Other assets | |
| Differed expenses in short term | (4,166) |
| Account receivable | 640 |
| Account receivable for countervalues | 36,691 |
| Account receivable from workers | 2,106 |
| Deposits and finance in CUC | 3,124 |
| Total other assets | 38,395 |
| Total assets | 2,154,096 |
| Liability | |
| Current liabilities | |
| Account payable in short term | 21,871 |
| Anticipated collection | 2,974 |
| Anticipated collection in CUC | 143 |
| Liabilities for social security in the state budg | 100,459 |
| Liabilities for profit account in the state budge | 785,031 |
| Social security payable to budget | 48,030 |
| Retention payable to L.G.V. | 397 |
| Retention payable to personal credits | 5,989 |
| Retention payable to judicial embargo | 70 |
| Retention payable for saving accounts | 190 |
| Provision for investments | 53,289 |
| Provision for vacations | 159,447 |
| Total current liabilities | 1,177,890 |
| Other liabilities | |
| Various accounts payable | 27,018 |
| Accounts payable for unclaimed salaries | 2,058 |
| Total other liabilities | 29,076 |
| Net worth | |
| State investment | 662,883 |
| Reserve for contingencies | 99,088 |
| Reserves for development | 185,159 |
| Total net worth | 947,130 |
| Total liabilities and net worth | 2,154,096 |

* CUP and CUC are added up at par.
Source: DPSC

**Table 6 Income Statements of Aurora Plaza**

(Year ending Dec. 2003; Unit: Peso 000 *)

| | |
|---|---|
| Revenue | |
| Sales | 9,561 |
| Other revenue | 118 |
| of which employee's restaurants | 67 |
| Total revenues | 9,679 |
| Expenditure | |
| Salaries | 4,422 |
| Laborforce utilization tax | 1,105 |
| Social security | 557 |
| Materials | 293 |
| Depriciation and amortization | 76 |
| Other monetary expenses | 240 |
| of which, energy costs | 152 |
| Restaurant and foodstuff | 45 |
| Financial expense | 30 |
| Other expenses (adjustment) | -39 |
| Total expenditure | 6,729 |
| Profit | 2,950 |
| Reserve for contingency | 29 |
| Income tax | 1,022 |
| Profit after tax | 1,898 |
| Reserve for development | 135 |
| Contiribution for state investment | 1,763 |

* CUP and CUC are added up at par.
Source: DPSC

**Table 7 SWM Expenditure of Aurora Habana Vieja**

(Data of year 2003; Unit: CUP 000, CUC 000)

| | Sweeping *1 | | Collection *2 | | Others *3 | | Administration | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | CUP | CUC | CUP | CUC | CUP | CUC | CUP | CUC | CUP | CUC | Total*4 |
| Revenue | 5,201 | | 2,988 | 61 | | | | 84 | 8,189 | 145 | 8,334 |
| Expenditure *5 | | | | | | | | | | | |
| Personnel cost *6 | 3,397 | 0 | 978 | 0 | 257 | 0 | 515 | 0 | 5,147 | 0 | 5,147 |
| Materials *7 | 58 | 8 | 102 | 14 | 11 | 1 | 192 | 26 | 363 | 49 | 412 |
| Clothing and provisions *6 | 0 | 34 | 0 | 10 | 0 | 3 | 0 | 5 | 0 | 51 | 51 |
| Fuel and energy cost *7 | 16 | 0 | 28 | 0 | 3 | 0 | 52 | 1 | 98 | 2 | 100 |
| Administrative cost *6 | 114 | 52 | 33 | 15 | 9 | 4 | 17 | 8 | 173 | 79 | 252 |
| Depreciation and investment*8 | 11 | 1 | 171 | 16 | 11 | 1 | 21 | 2 | 214 | 20 | 234 |
| Total expenditure | 3,596 | 95 | 1,311 | 55 | 291 | 9 | 798 | 42 | 5,995 | 201 | 6,196 |
| Unit cost | 5.77 | 0.15 | 34.29 | 1.43 | | | | | 128.33 | 3.92 | 132.25 |
| (direct cost only) | (Peso/m2) | (Peso/m2) | (Peso/ton) | (Peso/ton) | | | | | (Peso/ton) | (Peso/ton) | (Peso/ton) |
| Unit cost | 6.66 | 0.19 | 39.56 | 1.81 | | | | | 148.03 | 4.96 | 152.98 |
| (including indirect cost) | (Peso/m2) | (Peso/m2) | (Peso/ton) | (Peso/ton) | | | | | (Peso/ton) | (Peso/ton) | (Peso/ton) |

*1: Street sweeping work was performed for 622,837 thousand m2.

*2: The volume of solid waste collected was 321,306 m3 (equivalent to 38,236 tons, applying the specific gravity of 119kg/m3)

*3: Other activities include cleaning and maintenance of monuments and public places.

*4: CUP and CUC are added up at par.

*5: Cost distribution among departments is considered same as Aurora Plaza, which is as follows:

Between CUP and CUC

| | CUP | CUC |
|---|---|---|
| Personnel cost | 100% | 0% |
| Materials | 88% | 12% |
| Clothing and provisions | 0% | 100% |
| Fuel and energy cost | 98% | 2% |
| Administrative cost | 69% | 31% |
| Depreciation and investment | 92% | 8% |

*6: Cost distribution among departments is considered same as staff distribution, which is sweeping (66%), collection (19%), others (5%), and administration (10%).

*7: Cost distribution among departments is considered same as distribution of CUC expenses, which is sweeping (16%), collection (28%), others (3%), and administration (53%).

*8: Distribution of depreciable equipment is considered 5% for sweeping, 80% for collection, 5% for others, and 10% for administration.

**Table 8 Balance Sheet of Aurora Habana Vieja**

(At the end of 2003; Unit: Peso *)

| | |
|---|---|
| Assets | |
| Current assets | |
| Cash on hand | 500 |
| Cash at bank | 536,301 |
| Account receivable in short term | 970,232 |
| Anticipated payment to suppliers | 42,721 |
| Income tax payment | 1,571,214 |
| Profit contribution for state investment | 889,788 |
| Debt from state budget | 573 |
| Inventory | 226,796 |
| Total current assets | 4,238,125 |
| Fixed assets | |
| Fixed tangible assets | 326,222 |
| Depreciation | (202,090) |
| Total fixed assets | 124,132 |
| Total assets | 4,362,257 |
| Liability | |
| Current liabilities | |
| Account payable in short term | 103,193 |
| Liabilities for social security in the state budge | 38,260 |
| Income tax payable | 129,855 |
| Labor force tax payable | 79,708 |
| Contribution for state investment | 536,432 |
| Other contribution payable | 31,529 |
| Retention payable | 6,529 |
| Provision for vacations | 150,684 |
| Total current liabilities | 1,076,190 |
| Other liabilities | |
| Various accounts payable | 4 |
| Total other liabilities | 4 |
| Net worth | |
| State investment | 1,012,104 |
| Donation received | 23,168 |
| Reserve for contingencies | 109,252 |
| Accumulated profit | 2,141,539 |
| Total net worth | 3,286,063 |
| Total liabilities and net worth | 4,362,257 |

* CUP and CUC are added up at par.
Source: DPSC

**Table 9 Income Statements of Aurora Habana Vieja**

(Unit: Peso 000 *a)

| | | |
|---|---|---|
| Revenue | | |
| Sales | 8,254 | *b |
| Other revenue | 84 | |
| of which employee's restaurants | 54 | |
| Total revenues | 8,338 | |
| Expenditure | | |
| Salaries | 3,734 | |
| Laborforce utilization tax | 933 | |
| Social security | 480 | |
| Materials | 412 | |
| Depriciation and amortization | 234 | |
| Other monetary expenses | 334 | |
| of which, energy costs | 62 | |
| Restaurant and foodstuff | 51 | |
| Financial expense | 1 | |
| Other expenses (adjustment) | 18 | |
| Total expenditure | 6,196 | |
| Profit | 2,142 | |
| Reserve for contingency | 107 | |
| Income tax | 712 | |
| Profit after tax | 1,322 | |
| Reserve for development | | |
| Contiribution for state investment | 1,243 | |
| Distributable profit | 79 | |

*a: CUP and CUC are added up at par.
*b: Comprised of CUP8,158,764 and CUC94,594
Source: DPSC

**Table 10 SWM Expenditure of DMSC and Small Scaled Auroras**

(Data of year 2003 *a; Unit: CUP 000, CUC 000)

| | Sweeping *b | | Collection *c | | Landfill | | Others | | Administration | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CUP | CUC | CUP | CUC | CUP | CUC | CUP | CUC | CUP | CUC | CUP | CUC | Total*d |
| Revenue | 2,799 | 100 | 5,342 | 922 | 0 | 0 | 1,000 | 0 | 1,000 | 16 | 10,141 | 1,038 | 11,179 |
| Expenditure | | | | | | | | | | | | | |
| Personnel cost | 8,733 | 0 | 17,413 | 0 | 134 | | 3,656 | 0 | 3,790 | 0 | 33,726 | 0 | 33,726 |
| Materials | 3,392 | 119 | 9,015 | 113 | 728 | 32 | 728 | 14 | 10,403 | 36 | 24,266 | 314 | 24,580 |
| Foodstuff | 0 | 24 | 0 | 77 | 0 | 1 | 0 | 16 | 0 | 137 | 0 | 255 | 255 |
| Fuel and energy cost | 559 | 5 | 1,492 | 11 | 120 | 2 | 120 | -0 | 1,714 | -1 | 4,005 | 17 | 4,023 |
| Administrative cost | 3,705 | -52 | 5,757 | -15 | 115 | 1 | 1,223 | -4 | 1,338 | 357 | 12,138 | 286 | 12,425 |
| Depreciation and investment | 1,589 | -1 | 4,629 | 255 | 389 | | 389 | -1 | 779 | -2 | 7,775 | 251 | 8,026 |
| Total expenditure | 17,978 | 94 | 38,306 | 440 | 1,486 | 35 | 6,117 | 25 | 18,023 | 528 | 81,910 | 1,123 | 83,034 |
| Unit cost | 4.89 | 0.03 | 59.85 | 0.69 | 2.32 | 0.06 | | | | | 90.26 | 0.89 | 91.15 |
| (direct cost only) | (Peso/m2) | (Peso/m2) | (Peso/ton) | (Peso/ton) | (Peso/ton) | (Peso/ton) | | | | | (Peso/ton) | (Peso/ton) | (Peso/ton) |
| Unit cost | 5.41 | 0.03 | 66.18 | 0.72 | 2.32 | 0.06 | | | | | 115.72 | 1.68 | 117.40 |
| (including indirect cost) | (Peso/m2) | (Peso/m2) | (Peso/ton) | (Peso/ton) | (Peso/ton) | (Peso/ton) | | | | | (Peso/ton) | (Peso/ton) | (Peso/ton) |

*a: Data of sum of DMSC and 3 small Auroras is computed by subtracting quantity of Aurora Habana Vieja from the total of DMSC, Aurora Habana Vieja, and 3 small Auroras. Some values are negative as a result of artificial allocation of costs.

*b: Street sweeping work was performed for 3,676,813 m2.

*c: The volume of solid waste collected was 5378.7 thousand m3 (equivalent to 640,065 tons, applying the specific gravity of 119kg/m3)

*d: CUP and CUC are added up at par.

**Table 11: Tariff Scenario 1- Current Tariff Applicable to All Havana City**

**Table 11-1: Assumption of MSW generation (2005-2015) in Tariff Analysis**

| Category | No. of users | MSW generation assumption (liter/user /day) | Specific gravity | (kg/user) | (ton/cate-gory/day) |
|---|---|---|---|---|---|
| Inhabitant | 2,100,000 | 3.1 | 0.22 | 0.68 | 1,432 |
| Office (non-CUC earner) by communal bin | 7,700 | 30.0 | 0.30 | 9.00 | 69 |
| Office (non-CUC earner) by exclusive bin | 300 | 300.0 | 0.30 | 90.00 | 27 |
| Office (CUC earner) by communal bin | 1,700 | 30.0 | 0.30 | 9.00 | 15 |
| Office (CUC earner) by exclusive bin | 300 | 300.0 | 0.30 | 90.00 | 27 |
| Foreigner by communal bin | 700 | 30.0 | 0.30 | 9.00 | 6 |
| Foreigner with exclusive bin | 300 | 300.0 | 0.30 | 90.00 | 27 |
| Total | 2,111,000 | | | | 1,604 |

**Table 11-2: Assumption of Waste Collection in Tariff Analysis**

(ton/day)

| | 2005 |
|---|---|
| MSW to be collected by Havana City | 940 |
| MSW to be collected by other systems | 664 |
| Construction and bulk waste | 520 |
| Industrial waste | 350 |
| Total | 2,474 |

**Table 11-3 Landfill O/M cost to be recovered from MSW collected by Havana City**

(Peso '000, current prices)

| | 2003 | 2005 |
|---|---|---|
| CUC | 116 | 44 |
| CUP | 9,115 | 3,463 |

**Table 11-4 Collection O/M cost to be recovered from MSW collected by Havana City**

(Peso '000, current prices)

| | 2003 | 2005 |
|---|---|---|
| CUC | 1,450 | 753 |
| CUP | 109,763 | 57,004 |

**Table 11-5: Collection cost to be recovered**

(Peso '000)

| Cost item | CUC | CUP |
|---|---|---|
| Collection cost (annual) | ***797*** | ***60,467*** |
| Collection cost (monthly) | 66 | 5,039 |
| Recovery target (monthly) | ***66*** | ***1,364*** |
| Recovery rate | 100% | 27% |

**Table 11-6: Tariff for cost recovery**

(Peso/user/month)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0.0 | 0.4 |
| Office (non-CUC earner) by communal bin | 0.0 | 63.0 |
| Office (non-CUC earner) by exclusive bin | 0.0 | 114.0 |
| Office (CUC earner) by communal bin | 30.0 | 33.0 |
| Office (CUC earner) by exclusive bin | 45.0 | 69.0 |
| Foreigner by communal bin | 30.0 | 0.0 |
| Foreigner with exclusive bin | 120.0 | 0.0 |
| Efficiency of bill collection | ***95%*** | ***95%*** |
| Surplus/deficit (Peso/month) | 48,984 | 295 |

**Table 11-7: Cross Subsidy Coefficient**

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0.0 | 1.0 |
| Office (non-CUC earner) by communal bin | 0.0 | 16.3 |
| Office (non-CUC earner) by exclusive bin | 0.0 | 2.9 |
| Office (CUC earner) by communal bin | 6.7 | 8.5 |
| Office (CUC earner) by exclusive bin | 1.0 | 1.8 |
| Foreigner by communal bin | 6.7 | 0.0 |
| Foreigner with exclusive bin | 2.7 | 0.0 |

**Table 11-8: Per liter tariff** (Peso/liter)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0.000 | 0.004 |
| Office (non-CUC earner) by communal bin | 0.000 | 0.070 |
| Office (non-CUC earner) by exclusive bin | 0.000 | 0.013 |
| Office (CUC earner) by communal bin | 0.033 | 0.037 |
| Office (CUC earner) by exclusive bin | 0.005 | 0.008 |
| Foreigner by communal bin | 0.033 | 0.000 |
| Foreigner with exclusive bin | 0.013 | 0.000 |

**Table 11-9: Monthly revenue** (Peso '000)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0 | 798 |
| Office (non-CUC earner) by communal bin | 0 | 461 |
| Office (non-CUC earner) by exclusive bin | 0 | 32 |
| Office (CUC earner) by communal bin | 48 | 53 |
| Office (CUC earner) by exclusive bin | 13 | 20 |
| Foreigner by communal bin | 20 | 0 |
| Foreigner with exclusive bin | 34 | 0 |
| Total | 115 | 1,364 |

**Table 12: Tariff Scenario 2 - Full O/M Cost Recovery with Least Cross Subsidy**

**Table 12-1: Assumption of MSW generation (2005-2015) in Tariff Analysis**

| Category | No. of users | MSW generation assumption | | | |
|---|---|---|---|---|---|
| | | (liter/user /day) | Specific gravity | (kg/user) | (ton/cate-gory/day) |
| Inhabitant | 2,100,000 | 3.1 | 0.22 | 0.68 | 1,432 |
| Office (non-CUC earner) by communal bin | 7,700 | 30.0 | 0.30 | 9.00 | 69 |
| Office (non-CUC earner) by exclusive bin | 300 | 300.0 | 0.30 | 90.00 | 27 |
| Office (CUC earner) by communal bin | 1,700 | 30.0 | 0.30 | 9.00 | 15 |
| Office (CUC earner) by exclusive bin | 300 | 300.0 | 0.30 | 90.00 | 27 |
| Foreigner by communal bin | 700 | 30.0 | 0.30 | 9.00 | 6 |
| Foreigner with exclusive bin | 300 | 300.0 | 0.30 | 90.00 | 27 |
| Total | 2,111,000 | | | | 1,604 |

**Table 12-2: Assumption of Waste Collection in Tariff Analysis**

| | (ton/day) 2005 |
|---|---|
| MSW to be collected by Havana City | 940 |
| MSW to be collected by other systems | 664 |
| Construction and bulk waste | 520 |
| Industrial waste | 350 |
| Total | 2,474 |

**Table 12-3 Landfill O/M cost to be recovered from MSW collected by Havana City**

(Peso '000, current prices)

| | 2003 | 2005 |
|---|---|---|
| CUC | 116 | 44 |
| CUP | 9,115 | 3,463 |

**Table 12-4 Collection O/M cost to be recovered from MSW collected by Havana City**

(Peso '000, current prices)

| | 2003 | 2005 |
|---|---|---|
| CUC | 1,450 | 753 |
| CUP | 109,763 | 57,004 |

**Table 12-5: Collection cost to be recovered**

(Peso '000)

| Cost item | CUC | CUP |
|---|---|---|
| Collection cost (annual) | ***797*** | ***60,467*** |
| Collection cost (monthly) | 66 | 5,039 |
| Recovery target (monthly) | ***66*** | ***5,039*** |
| Recovery rate | 100% | 100% |

**Table 12-6: Tariff for cost recovery**

(Peso/user/month)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | ***0.0*** | ***1.9*** |
| Office (non-CUC earner) by communal bin | ***3.7*** | ***69*** |
| Office (non-CUC earner) by exclusive bin | ***37.0*** | ***690*** |
| Office (CUC earner) by communal bin | ***3.7*** | ***69*** |
| Office (CUC earner) by exclusive bin | ***37.0*** | ***690*** |
| Foreigner by communal bin | ***3.7*** | ***69*** |
| Foreigner with exclusive bin | ***37.0*** | ***690*** |
| Efficiency of bill collection | ***95%*** | ***95%*** |
| Surplus/deficit (Peso/month) | 695 | 3,571 |

**Table 12-7: Cross Subsidy Coefficient**

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0.0 | 1.0 |
| Office (non-CUC earner) by communal bin | 1.0 | 3.8 |
| Office (non-CUC earner) by exclusive bin | 1.0 | 3.8 |
| Office (CUC earner) by communal bin | 1.0 | 3.8 |
| Office (CUC earner) by exclusive bin | 1.0 | 3.8 |
| Foreigner by communal bin | 1.0 | 3.8 |
| Foreigner with exclusive bin | 1.0 | 3.8 |

**Table 12-8: Per liter tariff** (Peso/liter)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0.000 | 0.020 |
| Office (non-CUC earner) by communal bin | 0.004 | 0.077 |
| Office (non-CUC earner) by exclusive bin | 0.004 | 0.077 |
| Office (CUC earner) by communal bin | 0.004 | 0.077 |
| Office (CUC earner) by exclusive bin | 0.004 | 0.077 |
| Foreigner by communal bin | 0.004 | 0.077 |
| Foreigner with exclusive bin | 0.004 | 0.077 |

**Table 12-9: Monthly revenue** (Peso '000)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0 | 3,791 |
| Office (non-CUC earner) by communal bin | 27 | 505 |
| Office (non-CUC earner) by exclusive bin | 11 | 197 |
| Office (CUC earner) by communal bin | 6 | 111 |
| Office (CUC earner) by exclusive bin | 11 | 197 |
| Foreigner by communal bin | 2 | 46 |
| Foreigner with exclusive bin | 11 | 197 |
| Total | 67 | 5,043 |

**Table 13: Tariff Scenario 3 - 50% O/M Cost Recovery with Cross Subsidy**

**Table 13-1: Assumption of MSW generation (2005-2015) in Tariff Analysis**

| Category | No. of users | MSW generation assumption (liter/user/day) | Specific gravity | (kg/user) | (ton/category/day) |
|---|---|---|---|---|---|
| Inhabitant | 2,100,000 | 3.1 | 0.22 | 0.68 | 1,432 |
| Office (non-CUC earner) by communal bin | 7,700 | 30.0 | 0.30 | 9.00 | 69 |
| Office (non-CUC earner) by exclusive bin | 300 | 300.0 | 0.30 | 90.00 | 27 |
| Office (CUC earner) by communal bin | 1,700 | 30.0 | 0.30 | 9.00 | 15 |
| Office (CUC earner) by exclusive bin | 300 | 300.0 | 0.30 | 90.00 | 27 |
| Foreigner by communal bin | 700 | 30.0 | 0.30 | 9.00 | 6 |
| Foreigner with exclusive bin | 300 | 300.0 | 0.30 | 90.00 | 27 |
| Total | 2,111,000 | | | | 1,604 |

**Table 13-2: Assumption of Waste Collection in Tariff Analysis**

| (ton/day) | 2005 |
|---|---|
| MSW to be collected by Havana City | 940 |
| MSW to be collected by other systems | 664 |
| Construction and bulk waste | 520 |
| Industrial waste | 350 |
| Total | 2,474 |

**Table 13-3 Landfill O/M cost to be recovered from MSW collected by Havana City**

(Peso '000, current prices)

| | 2003 | 2005 |
|---|---|---|
| CUC | 116 | 44 |
| CUP | 9,115 | 3,463 |

**Table 13-4 Collection O/M cost to be recovered from MSW collected by Havana City**

(Peso '000, current prices)

| | 2003 | 2005 |
|---|---|---|
| CUC | 1,450 | 753 |
| CUP | 109,763 | 57,004 |

**Table 13-5: Collection cost to be recovered**

(Peso '000)

| Cost item | CUC | CUP |
|---|---|---|
| Collection cost (annual) | ***797*** | ***60,467*** |
| Collection cost (monthly) | 66 | 5,039 |
| Recovery target (monthly) | ***33*** | ***2,519*** |
| Recovery rate | 50% | 50% |

**Table 13-6: Tariff for cost recovery**

(Peso/user/month)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | ***0.0*** | ***1.1*** |
| Office (non-CUC earner) by communal bin | ***1.2*** | ***11*** |
| Office (non-CUC earner) by exclusive bin | ***12.0*** | ***110*** |
| Office (CUC earner) by communal bin | ***2.4*** | ***22*** |
| Office (CUC earner) by exclusive bin | ***24.0*** | ***220*** |
| Foreigner by communal bin | ***3.6*** | ***33*** |
| Foreigner with exclusive bin | ***36.0*** | ***330*** |
| Efficiency of bill collection | ***95%*** | ***95%*** |
| Surplus/deficit (Peso/month) | 2,347 | 1,073 |

**Table 13-7: Cross Subsidy Coefficient**

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0.0 | 1.0 |
| Office (non-CUC earner) by communal bin | 0.5 | 1.0 |
| Office (non-CUC earner) by exclusive bin | 0.5 | 1.0 |
| Office (CUC earner) by communal bin | 1.0 | 2.1 |
| Office (CUC earner) by exclusive bin | 1.0 | 2.1 |
| Foreigner by communal bin | 1.5 | 3.1 |
| Foreigner with exclusive bin | 1.5 | 3.1 |

**Table 13-8: Per liter tariff** (Peso/liter)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0.000 | 0.012 |
| Office (non-CUC earner) by communal bin | 0.001 | 0.012 |
| Office (non-CUC earner) by exclusive bin | 0.001 | 0.012 |
| Office (CUC earner) by communal bin | 0.003 | 0.024 |
| Office (CUC earner) by exclusive bin | 0.003 | 0.024 |
| Foreigner by communal bin | 0.004 | 0.037 |
| Foreigner with exclusive bin | 0.004 | 0.037 |

**Table 13-9: Monthly revenue** (Peso '000)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0 | 2,195 |
| Office (non-CUC earner) by communal bin | 9 | 80 |
| Office (non-CUC earner) by exclusive bin | 3 | 31 |
| Office (CUC earner) by communal bin | 4 | 36 |
| Office (CUC earner) by exclusive bin | 7 | 63 |
| Foreigner by communal bin | 2 | 22 |
| Foreigner with exclusive bin | 10 | 94 |
| Total | 36 | 2,521 |

## Table 14 Tariff Setting Example 1: Year 2015; Full Cost Recovery for CUC; 50% Cost Recovery for CUP; and Cross Subsidy 1:2:3 (partial presentation 1/3)

**Table 1: Assumption of MSW generation (2005-2015) in Tariff Analysis**

| Category | No. of users | MSW generation assumption | | | |
|---|---|---|---|---|---|
| | | (liter/user /day) | Specific gravity | (kg/user) | (ton/cate-gory/day) |
| Inhabitant | 2,100,000 | 3.1 | 0.22 | 0.68 | 1,432 |
| Office (non-CUC earner) by communal bin | 7,700 | 30.0 | 0.30 | 9.00 | 69 |
| Office (non-CUC earner) by exclusive bin | 300 | 300.0 | 0.30 | 90.00 | 27 |
| Office (CUC earner) by communal bin | 1,700 | 30.0 | 0.30 | 9.00 | 15 |
| Office (CUC earner) by exclusive bin | 300 | 300.0 | 0.30 | 90.00 | 27 |
| Foreigner by communal bin | 700 | 30.0 | 0.30 | 9.00 | 6 |
| Foreigner with exclusive bin | 300 | 300.0 | 0.30 | 90.00 | 27 |
| Total | 2,111,000 | | | | 1,604 |

**Table 2: Assumption of Waste Collection in Tariff Analysis** (ton/day)

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MSW to be collected by Havana City | 940 | 940 | 940 | 940 | 940 | 940 | 940 | 940 | 940 | 940 | 940 |
| MSW to be collected by other systems | 664 | 664 | 664 | 664 | 664 | 664 | 664 | 664 | 664 | 664 | 664 |
| Construction and bulk waste | 520 | 520 | 520 | 520 | 520 | 520 | 520 | 520 | 520 | 520 | 520 |
| Industrial waste | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 |
| Total | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 |

**Table 3: Collection O/M cost (with M/P) to be recovered from all SW**

(Peso '000, current prices)

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 2,164 | 2,317 | 2,348 | 2,379 | 2,746 | 3,043 | 3,082 | 3,121 | 3,161 | 3,201 | 27,560 |
| CUP | 119,665 | 122,499 | 125,316 | 128,199 | 131,402 | 135,207 | 138,317 | 141,498 | 144,752 | 148,082 | 1,334,936 |

**Table 4: Collection O/M cost (with M/P) to be recovered from MSW collected by Havana City**

(Peso '000, current prices)

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 1,124 | 1,203 | 1,219 | 1,235 | 1,426 | 1,581 | 1,601 | 1,621 | 1,641 | 1,662 | 14,313 |
| CUP | 62,146 | 63,618 | 65,081 | 66,578 | 68,242 | 70,218 | 71,833 | 73,485 | 75,175 | 76,904 | 693,282 |

**Table 5 Landfill O/M cost (without M/P)**

(Peso '000, current prices)

| | 2003 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 116 | 119 | 120 | 121 | 122 | 124 | 125 | 126 | 127 | 129 | 130 | 131 |
| CUP | 9,115 | 9,298 | 9,512 | 9,731 | 9,955 | 10,184 | 10,418 | 10,657 | 10,903 | 11,153 | 11,410 | 11,672 |

**Table 6 Collection O/M cost (without M/P)**

(Peso '000, current prices)

| | 2003 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 1,450 | 1,479 | 1,494 | 1,509 | 1,524 | 1,539 | 1,555 | 1,570 | 1,586 | 1,602 | 1,618 | 1,634 |
| CUP | 109,763 | 114,870 | 117,512 | 120,215 | 122,980 | 125,808 | 128,702 | 131,662 | 134,690 | 137,788 | 140,957 | 144,199 |

**Table 7: Landfill O/M cost (with M/P) to be recovered from all SW**

(Peso '000, current prices)

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 124 | 797 | 804 | 813 | 765 | 773 | 780 | 788 | 796 | 804 | 7,243 |
| CUP | 9,512 | 11,314 | 11,574 | 11,848 | 12,121 | 12,481 | 12,761 | 13,055 | 13,343 | 13,649 | 121,658 |

**Table 8: Landfill O/M cost (with M/P) to be recovered from MSW collected by Havana City**

(Peso '000, current prices)

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 41 | 244 | 247 | 250 | 237 | 237 | 240 | 244 | 244 | 247 | 2,230 |
| CUP | 2,906 | 3,455 | 3,534 | 3,620 | 3,702 | 3,812 | 3,898 | 3,987 | 4,076 | 4,169 | 37,158 |

**Table 9: Collection and landfill O/M cost (with M/P) to be recovered from MSW collected by Havana City**

(Peso '000, current prices)

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 1,165 | 1,447 | 1,466 | 1,486 | 1,663 | 1,817 | 1,841 | 1,864 | 1,885 | 1,909 | 16,543 |
| CUP | 65,053 | 67,073 | 68,615 | 70,198 | 71,944 | 74,030 | 75,731 | 77,472 | 79,251 | 81,073 | 730,439 |

**Table 10: Household income check (CUP/month)**

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Household income | 777 | 795 | 814 | 832 | 852 | 871 | 891 | 912 | 933 | 954 | 976 |
| 1% of income | 7.8 | 8.0 | 8.1 | 8.3 | 8.5 | 8.7 | 8.9 | 9.1 | 9.3 | 9.5 | 9.8 |
| 1% of income divided by 4 members | 1.9 | 2.0 | 2.0 | 2.1 | 2.1 | 2.2 | 2.2 | 2.3 | 2.3 | 2.4 | 2.4 |

## Table 15 Tariff Setting Example 1: Year 2015; Full Cost Recovery for CUC; 50% Cost Recovery for CUP; and Cross Subsidy 1:2:3 (partial presentation 2/3)

**Table 11: CUC cost recovery 100%, CUP cost recovery 50%, and cross subsidy 1:2:3**

(Peso/user/month)

| User Category | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Inhabitant | CUC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | CUP | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| Office (non-CUC earner) by communal bir | CUC | 3.3 | 4.1 | 4.1 | 4.2 | 4.7 | 5.1 | 5.2 | 5.3 | 5.3 | 5.4 |
| | CUP | 24.0 | 27.0 | 29.0 | 32.0 | 34.0 | 24.0 | 26.0 | 28.0 | 31.0 | 33.0 |
| Office (non-CUC earner) by exclusive bin | CUC | 33.0 | 41.0 | 41.0 | 42.0 | 47.0 | 51.0 | 52.0 | 53.0 | 53.0 | 54.0 |
| | CUP | 240.0 | 270.0 | 290.0 | 320.0 | 340.0 | 240.0 | 260.0 | 280.0 | 310.0 | 330.0 |
| Office (CUC earner) by communal bin | CUC | 6.6 | 8.2 | 8.2 | 8.4 | 9.4 | 10.2 | 10.4 | 10.6 | 10.6 | 10.8 |
| | CUP | 48.0 | 54.0 | 58.0 | 64.0 | 68.0 | 48.0 | 52.0 | 56.0 | 62.0 | 66.0 |
| Office (CUC earner) by exclusive bin | CUC | 66.0 | 82.0 | 82.0 | 84.0 | 94.0 | 102.0 | 104.0 | 106.0 | 106.0 | 108.0 |
| | CUP | 480.0 | 540.0 | 580.0 | 640.0 | 680.0 | 480.0 | 520.0 | 560.0 | 620.0 | 660.0 |
| Foreigner by communal bin | CUC | 9.9 | 12.3 | 12.3 | 12.6 | 14.1 | 15.3 | 15.6 | 15.9 | 15.9 | 16.2 |
| | CUP | 72.0 | 81.0 | 87.0 | 96.0 | 102.0 | 72.0 | 78.0 | 84.0 | 93.0 | 99.0 |
| Foreigner by exclusive bin | CUC | 99.0 | 123.0 | 123.0 | 126.0 | 141.0 | 153.0 | 156.0 | 159.0 | 159.0 | 162.0 |
| | CUP | 720.0 | 810.0 | 870.0 | 960.0 | 1,020.0 | 720.0 | 780.0 | 840.0 | 930.0 | 990.0 |
| Tipping fee (MSW hauled by Havana City) | CUC | 0.1 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| (unit: peso/ton) | CUP | 8.5 | 10.1 | 10.3 | 10.6 | 10.8 | 11.1 | 11.4 | 11.6 | 11.9 | 12.2 |
| Tipping fee (other SW) | CUC | 0.2 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 1.1 | 1.1 | 1.1 | 1.1 |
| (unit: peso/ton) | CUP | 12.7 | 15.1 | 15.5 | 15.8 | 16.2 | 16.7 | 17.0 | 17.4 | 17.8 | 18.2 |

**Table 12 (Table 6.15.9 of Main Report): Simulated Tariffs**

(unit: peso/user/month)

| User Category | | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Actual | Plan | Plan | Plan | Plan | Plan | Plan | Plan | Plan | Plan | Plan |
| Inhabitant | CUC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | CUP | 0.4 | 0.4 | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| Office (non-CUC earner) by communal bir | CUC | 0.0 | 3.3 | 4.1 | 4.1 | 4.2 | 4.7 | 5.1 | 5.2 | 5.3 | 5.3 | 5.4 |
| | CUP | 63.0 | 24.0 | 27.0 | 29.0 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 |
| Office (non-CUC earner) by exclusive bin | CUC | 0.0 | 33.0 | 41.0 | 41.0 | 42.0 | 47.0 | 51.0 | 52.0 | 53.0 | 53.0 | 54.0 |
| | CUP | 114.0 | 240.0 | 270.0 | 290.0 | 320.0 | 320.0 | 320.0 | 320.0 | 320.0 | 320.0 | 320.0 |
| Office (CUC earner) by communal bin | CUC | 30.0 | 6.6 | 8.2 | 8.2 | 8.4 | 9.4 | 10.2 | 10.4 | 10.6 | 10.6 | 10.8 |
| | CUP | 33.0 | 48.0 | 54.0 | 58.0 | 64.0 | 64.0 | 64.0 | 64.0 | 64.0 | 64.0 | 64.0 |
| Office (CUC earner) by exclusive bin | CUC | 45.0 | 66.0 | 82.0 | 82.0 | 84.0 | 94.0 | 102.0 | 104.0 | 106.0 | 106.0 | 108.0 |
| | CUP | 69.0 | 480.0 | 540.0 | 580.0 | 640.0 | 640.0 | 640.0 | 640.0 | 640.0 | 640.0 | 640.0 |
| Foreigner by communal bin | CUC | 30.0 | 9.9 | 12.3 | 12.3 | 12.6 | 14.1 | 15.3 | 15.6 | 15.9 | 15.9 | 16.2 |
| | CUP | 0.0 | 72.0 | 81.0 | 87.0 | 96.0 | 96.0 | 96.0 | 96.0 | 96.0 | 96.0 | 96.0 |
| Foreigner by exclusive bin | CUC | 120.0 | 99.0 | 123.0 | 123.0 | 126.0 | 141.0 | 153.0 | 156.0 | 159.0 | 159.0 | 162.0 |
| | CUP | 0.0 | 720.0 | 810.0 | 870.0 | 960.0 | 960.0 | 960.0 | 960.0 | 960.0 | 960.0 | 960.0 |
| Tipping fee (MSW hauled by Havana City) | CUC | 0.0 | 0.1 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| (unit: peso/ton) | CUP | 0.5 | 8.5 | 10.1 | 10.3 | 10.6 | 10.8 | 11.1 | 11.4 | 11.6 | 11.9 | 12.2 |
| Tipping fee (other SW) | CUC | 0.0 | 0.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |
| (unit: peso/ton) | CUP | 0.5 | 12.7 | 15.1 | 15.5 | 15.8 | 16.2 | 16.7 | 17.0 | 17.4 | 17.8 | 18.2 |

**Table 13: Expected Revenue under Proposed Tariff (With M/P)**

(Peso '000, current prices)

| User Category | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inhabitant | CUC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | CUP | 9,576 | 23,940 | 23,940 | 23,940 | 23,940 | 28,728 | 28,728 | 28,728 | 28,728 | 28,728 | 248,976 |
| Office (non-CUC earner) by communal bin | CUC | 290 | 360 | 360 | 369 | 413 | 448 | 456 | 465 | 465 | 474 | 4,099 |
| | CUP | 2,107 | 2,370 | 2,546 | 2,809 | 2,809 | 2,809 | 2,809 | 2,809 | 2,809 | 2,809 | 26,685 |
| Office (non-CUC earner) by exclusive bin | CUC | 113 | 140 | 140 | 144 | 161 | 174 | 178 | 181 | 181 | 185 | 1,597 |
| | CUP | 821 | 923 | 992 | 1,094 | 1,094 | 1,094 | 1,094 | 1,094 | 1,094 | 1,094 | 10,397 |
| Office (CUC earner) by communal bin | CUC | 128 | 159 | 159 | 163 | 182 | 198 | 202 | 205 | 205 | 209 | 1,810 |
| | CUP | 930 | 1,047 | 1,124 | 1,240 | 1,240 | 1,240 | 1,240 | 1,240 | 1,240 | 1,240 | 11,783 |
| Office (CUC earner) by exclusive bin | CUC | 226 | 280 | 280 | 287 | 321 | 349 | 356 | 363 | 363 | 369 | 3,194 |
| | CUP | 1,642 | 1,847 | 1,984 | 2,189 | 2,189 | 2,189 | 2,189 | 2,189 | 2,189 | 2,189 | 20,794 |
| Foreigner by communal bin | CUC | 79 | 98 | 98 | 101 | 113 | 122 | 124 | 127 | 127 | 129 | 1,118 |
| | CUP | 575 | 646 | 694 | 766 | 766 | 766 | 766 | 766 | 766 | 766 | 7,278 |
| Foreigner by exclusive bin | CUC | 339 | 421 | 421 | 431 | 482 | 523 | 534 | 544 | 544 | 554 | 4,791 |
| | CUP | 2,462 | 2,770 | 2,975 | 3,283 | 3,283 | 3,283 | 3,283 | 3,283 | 3,283 | 3,283 | 31,190 |
| Tipping fee (other SW) * | CUC | 96 | 569 | 574 | 585 | 585 | 585 | 559 | 569 | 569 | 574 | 5,266 |
| | CUP | 6,761 | 8,037 | 8,218 | 8,420 | 8,612 | 8,867 | 9,064 | 9,271 | 9,479 | 9,697 | 86,425 |
| Total | CUC | 1,269 | 2,027 | 2,033 | 2,079 | 2,257 | 2,399 | 2,408 | 2,454 | 2,454 | 2,495 | 21,876 |
| | CUP | 24,873 | 41,581 | 42,473 | 43,742 | 43,933 | 48,977 | 49,174 | 49,381 | 49,588 | 49,807 | 443,528 |

Note: Efficiency of bill collection is assumed to be ***95%***

* Tipping fee revenue from MSW hauled by Havana City system is offset by the same amount of tipping cost when the entire Havana City SWM accounting is consolidated.

**Table 14: Expected Revenue under Current Tariff (Without M/P)**

(Peso '000, current prices)

| | 2005* | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 1,108 | 1,119 | 1,130 | 1,142 | 1,153 | 1,165 | 1,176 | 1,188 | 1,200 | 1,212 | 1,224 | 11,710 |
| CUP | 6,877 | 6,945 | 7,015 | 7,085 | 7,156 | 7,227 | 7,300 | 7,373 | 7,446 | 7,521 | 7,596 | 72,663 |

*2005 revenues were estimated from 2003 revenues, taking account of the ratio of MSW collection and non-MSW collection.

CUC escalation 1% CUP escalation 2.3%

## Table 16 Tariff Setting Example 1: Year 2015; Full Cost Recovery for CUC; 50% Cost Recovery for CUP; and Cross Subsidy 1:2:3 (partial presentation 3/3)

**Year 2006 Tipping Fee**

**Table 16: Hauled SW**

| | SW volume (ton/category /day) | SW volume (ton/category /year) |
|---|---|---|
| MSW collected by Havana City | 940 | 343,100 |
| MSW collected by other systems | 664 | 242,360 |
| Construction and bulk waste | 520 | 189,800 |
| Industrial waste | 350 | 127,750 |
| Total waste collection | 2,474 | 903,010 |

**Table 17: Landfill Cost to Be Recoverd**

(Peso '000/year)

| | CUC | CUP |
|---|---|---|
| Landfill cost | 124 | 9,512 |
| Recovery target | 124 | 9,512 |
| Recovery rate | 100% | 100% |
| Efficiency of tariff collection | 95% | 95% |
| Billing target | 131 | 10,013 |

**Table 18: Cross Subsidy Coefficient in Tipping Fee**

| User Category | CUC | CUP |
|---|---|---|
| MSW collected by Havana City | 1.0 | 1.0 |
| MSW collected by other systems | 1.5 | 1.5 |
| Construction and bulk waste | 1.5 | 1.5 |
| Industrial waste | 1.5 | 1.5 |

**Table 19: Tipping Fee for Cost Recovery**

(Peso/ton)

| | CUC | CUP |
|---|---|---|
| MSW collected by Havana City | 0.12 | 8.47 |
| MSW collected by other systems | 0.18 | 12.71 |
| Construction and bulk waste | 0.18 | 12.71 |
| Industrial waste | 0.18 | 12.71 |

**Year 2006 Collection Fee:**
**(100% CUC recovery; 50% CUP recovery; Cross Subsidy 1:2:3)**

**Table 20: Collection cost to be recovered**

(Peso '000)

| Cost item | CUC | CUP |
|---|---|---|
| Collection cost (annual) | ***1,165*** | ***65,053*** |
| Collection cost (monthly) | 97 | 5,421 |
| Recovery target (monthly) | ***97*** | ***2,711*** |
| Recovery rate | 100% | 50% |

**Table 21: Tariff for cost recovery**

(Peso/user/month)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | ***0.0*** | ***1.0*** |
| Office (non-CUC earner) by communal bin | ***3.3*** | ***24*** |
| Office (non-CUC earner) by exclusive bin | ***33.0*** | ***240*** |
| Office (CUC earner) by communal bin | ***6.6*** | ***48*** |
| Office (CUC earner) by exclusive bin | ***66.0*** | ***480*** |
| Foreigner by communal bin | ***9.9*** | ***72*** |
| Foreigner with exclusive bin | ***99.0*** | ***720*** |
| Efficiency of bill collection | ***95%*** | ***95%*** |
| Surplus/deficit (Peso/month) | 746 | -4,162 |

**Table 22: Cross Subsidy Coefficient**

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0.0 | 1.0 |
| Office (non-CUC earner) by communal bin | 1.0 | 2.5 |
| Office (non-CUC earner) by exclusive bin | 1.0 | 2.5 |
| Office (CUC earner) by communal bin | 2.0 | 5.0 |
| Office (CUC earner) by exclusive bin | 2.0 | 5.0 |
| Foreigner by communal bin | 3.0 | 7.4 |
| Foreigner with exclusive bin | 3.0 | 7.4 |

**Table 23: Per liter tariff** (Peso/liter)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0.000 | 0.011 |
| Office (non-CUC earner) by communal bin | 0.004 | 0.027 |
| Office (non-CUC earner) by exclusive bin | 0.004 | 0.027 |
| Office (CUC earner) by communal bin | 0.007 | 0.053 |
| Office (CUC earner) by exclusive bin | 0.007 | 0.053 |
| Foreigner by communal bin | 0.011 | 0.080 |
| Foreigner with exclusive bin | 0.011 | 0.080 |

**Table 24: Monthly revenue** (Peso '000)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0 | 1,995 |
| Office (non-CUC earner) by communal bin | 24 | 176 |
| Office (non-CUC earner) by exclusive bin | 9 | 68 |
| Office (CUC earner) by communal bin | 11 | 78 |
| Office (CUC earner) by exclusive bin | 19 | 137 |
| Foreigner by communal bin | 7 | 48 |
| Foreigner with exclusive bin | 28 | 205 |
| Total | 98 | 2,706 |

**Year 2015 Tipping Fee**

**Table 16: Hauled SW**

| | SW volume (ton/category /day) | SW volume (ton/category /year) |
|---|---|---|
| MSW collected by Havana City | 940 | 343,100 |
| MSW collected by other systems | 664 | 242,360 |
| Construction and bulk waste | 520 | 189,800 |
| Industrial waste | 350 | 127,750 |
| Total waste collection | 2,474 | 903,010 |

**Table 17: Landfill Cost to Be Recoverd**

(Peso '000/year)

| | CUC | CUP |
|---|---|---|
| Landfill cost | 804 | 13,649 |
| Recovery target | 804 | 13,649 |
| Recovery rate | 100% | 100% |
| Efficiency of tariff collection | 95% | 95% |
| Billing target | 846 | 14,368 |

**Table 18: Cross Subsidy Coefficient in Tipping Fee**

| User Category | CUC | CUP |
|---|---|---|
| MSW collected by Havana City | 1.0 | 1.0 |
| MSW collected by other systems | 1.5 | 1.5 |
| Construction and bulk waste | 1.5 | 1.5 |
| Industrial waste | 1.5 | 1.5 |

**Table 19: Tipping Fee for Cost Recovery**

(Peso/ton)

| | CUC | CUP |
|---|---|---|
| MSW collected by Havana City | 0.72 | 12.15 |
| MSW collected by other systems | 1.08 | 18.23 |
| Construction and bulk waste | 1.08 | 18.23 |
| Industrial waste | 1.08 | 18.23 |

**Year 2015 Collection Fee:**
**(100% CUC recovery; 50% CUP recovery; Cross Subsidy 1:2:3)**

**Table 20: Collection cost to be recovered**

(Peso '000)

| Cost item | CUC | CUP |
|---|---|---|
| Collection cost (annual) | ***1,909*** | ***81,073*** |
| Collection cost (monthly) | 159 | 6,756 |
| Recovery target (monthly) | ***159*** | ***3,378*** |
| Recovery rate | 100% | 50% |

**Table 21: Tariff for cost recovery**

(Peso/user/month)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | ***0.0*** | ***1.2*** |
| Office (non-CUC earner) by communal bin | ***5.4*** | ***33*** |
| Office (non-CUC earner) by exclusive bin | ***54.0*** | ***330*** |
| Office (CUC earner) by communal bin | ***10.8*** | ***66*** |
| Office (CUC earner) by exclusive bin | ***108.0*** | ***660*** |
| Foreigner by communal bin | ***16.2*** | ***99*** |
| Foreigner with exclusive bin | ***162.0*** | ***990*** |
| Efficiency of bill collection | ***95%*** | ***95%*** |
| Surplus/deficit (Peso/month) | 956 | -5,919 |

**Table 22: Cross Subsidy Coefficient**

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0.0 | 1.0 |
| Office (non-CUC earner) by communal bin | 1.0 | 2.8 |
| Office (non-CUC earner) by exclusive bin | 1.0 | 2.8 |
| Office (CUC earner) by communal bin | 2.0 | 5.7 |
| Office (CUC earner) by exclusive bin | 2.0 | 5.7 |
| Foreigner by communal bin | 3.0 | 8.5 |
| Foreigner with exclusive bin | 3.0 | 8.5 |

**Table 23: Per liter tariff** (Peso/liter)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0.000 | 0.013 |
| Office (non-CUC earner) by communal bin | 0.006 | 0.037 |
| Office (non-CUC earner) by exclusive bin | 0.006 | 0.037 |
| Office (CUC earner) by communal bin | 0.012 | 0.073 |
| Office (CUC earner) by exclusive bin | 0.012 | 0.073 |
| Foreigner by communal bin | 0.018 | 0.110 |
| Foreigner with exclusive bin | 0.018 | 0.110 |

**Table 24: Monthly revenue** (Peso '000)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0 | 2,394 |
| Office (non-CUC earner) by communal bin | 40 | 241 |
| Office (non-CUC earner) by exclusive bin | 15 | 94 |
| Office (CUC earner) by communal bin | 17 | 107 |
| Office (CUC earner) by exclusive bin | 31 | 188 |
| Foreigner by communal bin | 11 | 66 |
| Foreigner with exclusive bin | 46 | 282 |
| Total | 160 | 3,372 |

# Table 17 Tariff Setting Example 2: Year 2015; 70% Cost Recovery for CUC and CUP CUP; and Cross Subsidy 2:3:4 (partial presentation 1/3)

**Table 1: Assumption of MSW generation (2005-2015) in Tariff Analysis**

| Category | No. of users | MSW generation assumption (liter/user /day) | Specific gravity | (kg/user) | (ton/cate-gory/day) |
|---|---|---|---|---|---|
| Inhabitant | 2,100,000 | 3.1 | 0.22 | 0.68 | 1,432 |
| Office (non-CUC earner) by communal bin | 7,700 | 30.0 | 0.30 | 9.00 | 69 |
| Office (non-CUC earner) by exclusive bin | 300 | 300.0 | 0.30 | 90.00 | 27 |
| Office (CUC earner) by communal bin | 1,700 | 30.0 | 0.30 | 9.00 | 15 |
| Office (CUC earner) by exclusive bin | 300 | 300.0 | 0.30 | 90.00 | 27 |
| Foreigner by communal bin | 700 | 30.0 | 0.30 | 9.00 | 6 |
| Foreigner with exclusive bin | 300 | 300.0 | 0.30 | 90.00 | 27 |
| Total | 2,111,000 | | | | 1,604 |

**Table 2: Assumption of Waste Collection in Tariff Analysis** (ton/day)

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MSW to be collected by Havana City | 940 | 940 | 940 | 940 | 940 | 940 | 940 | 940 | 940 | 940 | 940 |
| MSW to be collected by other systems | 664 | 664 | 664 | 664 | 664 | 664 | 664 | 664 | 664 | 664 | 664 |
| Construction and bulk waste | 520 | 520 | 520 | 520 | 520 | 520 | 520 | 520 | 520 | 520 | 520 |
| Industrial waste | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 |
| Total | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 | 2,474 |

**Table 3: Collection O/M cost (with M/P) to be recovered from all SW** (Peso '000, current prices)

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 2,164 | 2,317 | 2,348 | 2,379 | 2,746 | 3,043 | 3,082 | 3,121 | 3,161 | 3,201 | 27,560 |
| CUP | 119,665 | 122,499 | 125,316 | 128,199 | 131,402 | 135,207 | 138,317 | 141,498 | 144,752 | 148,082 | 1,334,936 |

**Table 4: Collection O/M cost (with M/P) to be recovered from MSW collected by Havana City** (Peso '000, current prices)

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 1,124 | 1,203 | 1,219 | 1,235 | 1,426 | 1,581 | 1,601 | 1,621 | 1,641 | 1,662 | 14,313 |
| CUP | 62,146 | 63,618 | 65,081 | 66,578 | 68,242 | 70,218 | 71,833 | 73,485 | 75,175 | 76,904 | 693,282 |

**Table 5 Landfill O/M cost (without M/P)** (Peso '000, current prices)

| | 2003 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 116 | 119 | 120 | 121 | 122 | 124 | 125 | 126 | 127 | 129 | 130 | 131 |
| CUP | 9,115 | 9,298 | 9,512 | 9,731 | 9,955 | 10,184 | 10,418 | 10,657 | 10,903 | 11,153 | 11,410 | 11,672 |

**Table 6 Collection O/M cost (without M/P)** (Peso '000, current prices)

| | 2003 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 1,450 | 1,479 | 1,494 | 1,509 | 1,524 | 1,539 | 1,555 | 1,570 | 1,586 | 1,602 | 1,618 | 1,634 |
| CUP | 109,763 | 114,870 | 117,512 | 120,215 | 122,980 | 125,808 | 128,702 | 131,662 | 134,690 | 137,788 | 140,957 | 144,199 |

**Table 7: Landfill O/M cost (with M/P) to be recovered from all SW** (Peso '000, current prices)

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 124 | 797 | 804 | 813 | 765 | 773 | 780 | 788 | 796 | 804 | 7,243 |
| CUP | 9,512 | 11,314 | 11,574 | 11,848 | 12,121 | 12,481 | 12,761 | 13,055 | 13,343 | 13,649 | 121,658 |

**Table 8: Landfill O/M cost (with M/P) to be recovered from MSW collected by Havana City** (Peso '000, current prices)

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 41 | 244 | 247 | 250 | 237 | 237 | 240 | 244 | 244 | 247 | 2,230 |
| CUP | 2,906 | 3,455 | 3,534 | 3,620 | 3,702 | 3,812 | 3,898 | 3,987 | 4,076 | 4,169 | 37,158 |

**Table 9: Collection and landfill O/M cost (with M/P) to be recovered from MSW collected by Havana City** (Peso '000, current prices)

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 1,165 | 1,447 | 1,466 | 1,486 | 1,663 | 1,817 | 1,841 | 1,864 | 1,885 | 1,909 | 16,543 |
| CUP | 65,053 | 67,073 | 68,615 | 70,198 | 71,944 | 74,030 | 75,731 | 77,472 | 79,251 | 81,073 | 730,439 |

**Table 10: Household income check (CUP/month)**

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Household income | 777 | 795 | 814 | 832 | 852 | 871 | 891 | 912 | 933 | 954 | 976 |
| 1% of income | 7.8 | 8.0 | 8.1 | 8.3 | 8.5 | 8.7 | 8.9 | 9.1 | 9.3 | 9.5 | 9.8 |
| 1% of income divided by 4 members | 1.9 | 2.0 | 2.0 | 2.1 | 2.1 | 2.2 | 2.2 | 2.3 | 2.3 | 2.4 | 2.4 |

# Table 18 Tariff Setting Example 2: Year 2015; 70% Cost Recovery for CUC and CUP CUP; and Cross Subsidy 2:3:4 (partial presentation 2/3)

**Table 11: CUC cost recovery 100%, CUP cost recovery 50%, and cross subsidy 1:2:3**

(Peso/user/month)

| User Category | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Inhabitant | CUC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | CUP | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| Office (non-CUC earner) by communal bin | CUC | 2.3 | 2.9 | 2.9 | 2.9 | 3.3 | 3.6 | 3.6 | 3.7 | 3.7 | 3.8 |
| | CUP | 61.0 | 65.0 | 68.0 | 71.0 | 74.0 | 65.0 | 68.0 | 72.0 | 75.0 | 79.0 |
| Office (non-CUC earner) by exclusive bin | CUC | 23.0 | 29.0 | 29.0 | 29.0 | 33.0 | 36.0 | 36.0 | 37.0 | 37.0 | 38.0 |
| | CUP | 610.0 | 650.0 | 680.0 | 710.0 | 740.0 | 650.0 | 680.0 | 720.0 | 750.0 | 790.0 |
| Office (CUC earner) by communal bin | CUC | 4.6 | 5.8 | 5.8 | 5.8 | 6.6 | 7.2 | 7.2 | 7.4 | 7.4 | 7.6 |
| | CUP | 122.0 | 130.0 | 136.0 | 142.0 | 148.0 | 130.0 | 136.0 | 144.0 | 150.0 | 158.0 |
| Office (CUC earner) by exclusive bin | CUC | 46.0 | 58.0 | 58.0 | 58.0 | 66.0 | 72.0 | 72.0 | 74.0 | 74.0 | 76.0 |
| | CUP | 1,220.0 | 1,300.0 | 1,360.0 | 1,420.0 | 1,480.0 | 1,300.0 | 1,360.0 | 1,440.0 | 1,500.0 | 1,580.0 |
| Foreigner by communal bin | CUC | 6.9 | 8.7 | 8.7 | 8.7 | 9.9 | 10.8 | 10.8 | 11.1 | 11.1 | 11.4 |
| | CUP | 183.0 | 195.0 | 204.0 | 213.0 | 222.0 | 195.0 | 204.0 | 216.0 | 225.0 | 237.0 |
| Foreigner by exclusive bin | CUC | 69.0 | 87.0 | 87.0 | 87.0 | 99.0 | 108.0 | 108.0 | 111.0 | 111.0 | 114.0 |
| | CUP | 1,830.0 | 1,950.0 | 2,040.0 | 2,130.0 | 2,220.0 | 1,950.0 | 2,040.0 | 2,160.0 | 2,250.0 | 2,370.0 |
| Tipping fee (MSW hauled by Havana City) | CUC | 0.1 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| (unit: peso/ton) | CUP | 8.5 | 10.1 | 10.3 | 10.6 | 10.8 | 11.1 | 11.4 | 11.6 | 11.9 | 12.2 |
| Tipping fee (other SW) | CUC | 0.2 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 1.1 | 1.1 | 1.1 | 1.1 |
| (unit: peso/ton) | CUP | 12.7 | 15.1 | 15.5 | 15.8 | 16.2 | 16.7 | 17.0 | 17.4 | 17.8 | 18.2 |

**Table 12: Proposed Tariff**

(unit: peso/user/month)

| User Category | | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Actual | Plan | Plan | Plan | Plan | Plan | Plan | Plan | Plan | Plan | Plan |
| Inhabitant | CUC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | CUP | 0.4 | 0.4 | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| Office (non-CUC earner) by communal bin | CUC | 0.0 | 2.3 | 2.9 | 2.9 | 2.9 | 3.3 | 3.6 | 3.6 | 3.7 | 3.7 | 3.8 |
| | CUP | 63.0 | 63.0 | 65.0 | 68.0 | 71.0 | 74.0 | 74.0 | 74.0 | 74.0 | 74.0 | 74.0 |
| Office (non-CUC earner) by exclusive bin | CUC | 0.0 | 23.0 | 29.0 | 29.0 | 29.0 | 33.0 | 36.0 | 36.0 | 37.0 | 37.0 | 38.0 |
| | CUP | 114.0 | 610.0 | 650.0 | 680.0 | 710.0 | 740.0 | 740.0 | 740.0 | 740.0 | 740.0 | 740.0 |
| Office (CUC earner) by communal bin | CUC | 30.0 | 4.6 | 5.8 | 5.8 | 5.8 | 6.6 | 7.2 | 7.2 | 7.4 | 7.4 | 7.6 |
| | CUP | 33.0 | 122.0 | 130.0 | 136.0 | 142.0 | 148.0 | 148.0 | 148.0 | 148.0 | 148.0 | 158.0 |
| Office (CUC earner) by exclusive bin | CUC | 45.0 | 46.0 | 58.0 | 58.0 | 58.0 | 66.0 | 72.0 | 72.0 | 74.0 | 74.0 | 76.0 |
| | CUP | 69.0 | 1,220.0 | 1,300.0 | 1,360.0 | 1,420.0 | 1,480.0 | 1,480.0 | 1,480.0 | 1,480.0 | 1,480.0 | 1,580.0 |
| Foreigner by communal bin | CUC | 30.0 | 6.9 | 8.7 | 8.7 | 8.7 | 9.9 | 10.8 | 10.8 | 11.1 | 11.1 | 11.4 |
| | CUP | 0.0 | 183.0 | 195.0 | 204.0 | 213.0 | 222.0 | 222.0 | 222.0 | 222.0 | 222.0 | 237.0 |
| Foreigner by exclusive bin | CUC | 120.0 | 69.0 | 87.0 | 87.0 | 87.0 | 99.0 | 108.0 | 108.0 | 111.0 | 111.0 | 114.0 |
| | CUP | 0.0 | 1,830.0 | 1,950.0 | 2,040.0 | 2,130.0 | 2,220.0 | 2,220.0 | 2,220.0 | 2,220.0 | 2,220.0 | 2,370.0 |
| Tipping fee (MSW hauled by Havana City) | CUC | 0.0 | 0.1 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| (unit: peso/ton) | CUP | 0.5 | 8.5 | 10.1 | 10.3 | 10.6 | 10.8 | 11.1 | 11.4 | 11.6 | 11.9 | 12.2 |
| Tipping fee (other SW) | CUC | 0.0 | 0.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |
| (unit: peso/ton) | CUP | 0.5 | 12.7 | 15.1 | 15.5 | 15.8 | 16.2 | 16.7 | 17.0 | 17.4 | 17.8 | 18.2 |

**Table 13: Expected Revenue under Proposed Tariff (With M/P)**

(Peso '000, current prices)

| User Category | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inhabitant | CUC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | CUP | 9,576 | 23,940 | 23,940 | 23,940 | 23,940 | 28,728 | 28,728 | 28,728 | 28,728 | 28,728 | 248,976 |
| Office (non-CUC earner) by communal bin | CUC | 202 | 255 | 255 | 255 | 290 | 316 | 316 | 325 | 325 | 334 | 2,870 |
| | CUP | 5,530 | 5,706 | 5,969 | 6,232 | 6,496 | 6,496 | 6,496 | 6,496 | 6,496 | 6,496 | 62,412 |
| Office (non-CUC earner) by exclusive bin | CUC | 79 | 99 | 99 | 99 | 113 | 123 | 123 | 127 | 127 | 130 | 1,118 |
| | CUP | 2,086 | 2,223 | 2,326 | 2,428 | 2,531 | 2,531 | 2,531 | 2,531 | 2,531 | 2,531 | 24,248 |
| Office (CUC earner) by communal bin | CUC | 89 | 112 | 112 | 112 | 128 | 140 | 140 | 143 | 143 | 147 | 1,267 |
| | CUP | 2,364 | 2,519 | 2,636 | 2,752 | 2,868 | 2,868 | 2,868 | 2,868 | 2,868 | 3,062 | 27,675 |
| Office (CUC earner) by exclusive bin | CUC | 157 | 198 | 198 | 198 | 226 | 246 | 246 | 253 | 253 | 260 | 2,237 |
| | CUP | 4,172 | 4,446 | 4,651 | 4,856 | 5,062 | 5,062 | 5,062 | 5,062 | 5,062 | 5,404 | 48,838 |
| Foreigner by communal bin | CUC | 55 | 69 | 69 | 69 | 79 | 86 | 86 | 89 | 89 | 91 | 783 |
| | CUP | 1,460 | 1,556 | 1,628 | 1,700 | 1,772 | 1,772 | 1,772 | 1,772 | 1,772 | 1,891 | 17,093 |
| Foreigner by exclusive bin | CUC | 236 | 298 | 298 | 298 | 339 | 369 | 369 | 380 | 380 | 390 | 3,355 |
| | CUP | 6,259 | 6,669 | 6,977 | 7,285 | 7,592 | 7,592 | 7,592 | 7,592 | 7,592 | 8,105 | 73,256 |
| Tipping fee (other SW) * | CUC | 96 | 569 | 574 | 585 | 585 | 585 | 559 | 569 | 569 | 574 | 5,266 |
| | CUP | 6,761 | 8,037 | 8,218 | 8,420 | 8,612 | 8,867 | 9,064 | 9,271 | 9,479 | 9,697 | 86,425 |
| Total | CUC | 914 | 1,601 | 1,606 | 1,617 | 1,759 | 1,866 | 1,839 | 1,885 | 1,885 | 1,926 | 16,897 |
| | CUP | 38,209 | 55,096 | 56,344 | 57,613 | 58,872 | 63,915 | 64,112 | 64,320 | 64,527 | 65,914 | 588,923 |

Note: Efficiency of bill collection is assumed to be *95%*

* Tipping fee revenue from MSW hauled by Havana City system is offset by the same amount of tipping cost when the entire Havana City SWM accounting is consolidated.

**Table 14: Expected Revenue under Current Tariff (Without M/P)**

(Peso '000, current prices)

| | 2005* | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CUC | 1,108 | 1,119 | 1,130 | 1,142 | 1,153 | 1,165 | 1,176 | 1,188 | 1,200 | 1,212 | 1,224 | 11,710 |
| CUP | 6,877 | 6,945 | 7,015 | 7,085 | 7,156 | 7,227 | 7,300 | 7,373 | 7,446 | 7,521 | 7,596 | 72,663 |

*2005 revenues were estimated from 2003 revenues, taking account of the ratio of MSW collection and non-MSW collection.

CUC escalation 1% CUP escalation 2.3%

# Table 19 Tariff Setting Example 2: Year 2015; 70% Cost Recovery for CUC and CUP CUP; and Cross Subsidy 2:3:4 (partial presentation 3/3)

**Year 2006 Tipping Fee**

**Table 16: Hauled SW**

| | SW volume (ton/category /day) | SW volume (ton/category /year) |
|---|---|---|
| MSW collected by Havana City | 940 | 343,100 |
| MSW collected by other systems | 664 | 242,360 |
| Construction and bulk waste | 520 | 189,800 |
| Industrial waste | 350 | 127,750 |
| Total waste collection | 2,474 | 903,010 |

**Table 17: Landfill Cost to Be Recoverd**

(Peso '000/year)

| | CUC | CUP |
|---|---|---|
| Landfill cost | 124 | 9,512 |
| Recovery target | 124 | 9,512 |
| Recovery rate | 100% | 100% |
| Efficiency of tariff collection | 95% | 95% |
| Billing target | 131 | 10,013 |

**Table 18: Cross Subsidy Coefficient in Tipping Fee**

| User Category | CUC | CUP |
|---|---|---|
| MSW collected by Havana City | 1.0 | 1.0 |
| MSW collected by other systems | 1.5 | 1.5 |
| Construction and bulk waste | 1.5 | 1.5 |
| Industrial waste | 1.5 | 1.5 |

**Table 19: Tipping Fee for Cost Recovery**

(Peso/ton)

| | CUC | CUP |
|---|---|---|
| MSW collected by Havana City | 0.12 | 8.47 |
| MSW collected by other systems | 0.18 | 12.71 |
| Construction and bulk waste | 0.18 | 12.71 |
| Industrial waste | 0.18 | 12.71 |

**Year 2006 Collection Fee:**

**(70% CUC recovery; 70% CUP recovery; Cross Subsidy 1:2:3)**

**Table 20: Collection cost to be recovered**

(Peso '000)

| Cost item | CUC | CUP |
|---|---|---|
| Collection cost (annual) | ***1,165*** | ***65,053*** |
| Collection cost (monthly) | 97 | 5,421 |
| Recovery target (monthly) | ***68*** | ***3,795*** |
| Recovery rate | 70% | 70% |

**Table 21: Tariff for cost recovery**

(Peso/user/month)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | ***0.0*** | ***1.0*** |
| Office (non-CUC earner) by communal bin | ***2.3*** | ***61*** |
| Office (non-CUC earner) by exclusive bin | ***23.0*** | ***610*** |
| Office (CUC earner) by communal bin | ***4.6*** | ***122*** |
| Office (CUC earner) by exclusive bin | ***46.0*** | ***1220*** |
| Foreigner by communal bin | ***6.9*** | ***183*** |
| Foreigner with exclusive bin | ***69.0*** | ***1830*** |
| Efficiency of bill collection | ***95%*** | ***95%*** |
| Surplus/deficit (Peso/month) | 226 | 8,309 |

**Table 22: Cross Subsidy Coefficient**

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0.0 | 1.0 |
| Office (non-CUC earner) by communal bin | 1.0 | 6.3 |
| Office (non-CUC earner) by exclusive bin | 1.0 | 6.3 |
| Office (CUC earner) by communal bin | 2.0 | 12.6 |
| Office (CUC earner) by exclusive bin | 2.0 | 12.6 |
| Foreigner by communal bin | 3.0 | 18.9 |
| Foreigner with exclusive bin | 3.0 | 18.9 |

**Table 23: Per liter tariff** (Peso/liter)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0.000 | 0.011 |
| Office (non-CUC earner) by communal bin | 0.003 | 0.068 |
| Office (non-CUC earner) by exclusive bin | 0.003 | 0.068 |
| Office (CUC earner) by communal bin | 0.005 | 0.136 |
| Office (CUC earner) by exclusive bin | 0.005 | 0.136 |
| Foreigner by communal bin | 0.008 | 0.203 |
| Foreigner with exclusive bin | 0.008 | 0.203 |

**Table 24: Monthly revenue** (Peso '000)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0 | 1,995 |
| Office (non-CUC earner) by communal bin | 17 | 446 |
| Office (non-CUC earner) by exclusive bin | 7 | 174 |
| Office (CUC earner) by communal bin | 7 | 197 |
| Office (CUC earner) by exclusive bin | 13 | 348 |
| Foreigner by communal bin | 5 | 122 |
| Foreigner with exclusive bin | 20 | 522 |
| Total | 68 | 3,803 |

**Year 2015 Tipping Fee**

**Table 16: Hauled SW**

| | SW volume (ton/category /day) | SW volume (ton/category /year) |
|---|---|---|
| MSW collected by Havana City | 940 | 343,100 |
| MSW collected by other systems | 664 | 242,360 |
| Construction and bulk waste | 520 | 189,800 |
| Industrial waste | 350 | 127,750 |
| Total waste collection | 2,474 | 903,010 |

**Table 17: Landfill Cost to Be Recoverd**

(Peso '000/year)

| | CUC | CUP |
|---|---|---|
| Landfill cost | 804 | 13,649 |
| Recovery target | 804 | 13,649 |
| Recovery rate | 100% | 100% |
| Efficiency of tariff collection | 95% | 95% |
| Billing target | 846 | 14,368 |

**Table 18: Cross Subsidy Coefficient in Tipping Fee**

| User Category | CUC | CUP |
|---|---|---|
| MSW collected by Havana City | 1.0 | 1.0 |
| MSW collected by other systems | 1.5 | 1.5 |
| Construction and bulk waste | 1.5 | 1.5 |
| Industrial waste | 1.5 | 1.5 |

**Table 19: Tipping Fee for Cost Recovery**

(Peso/ton)

| | CUC | CUP |
|---|---|---|
| MSW collected by Havana City | 0.72 | 12.15 |
| MSW collected by other systems | 1.08 | 18.23 |
| Construction and bulk waste | 1.08 | 18.23 |
| Industrial waste | 1.08 | 18.23 |

**Year 2015 Collection Fee:**

**(70% CUC recovery; 70% CUP recovery; Cross Subsidy 1:2:3)**

**Table 20: Collection cost to be recovered**

(Peso '000)

| Cost item | CUC | CUP |
|---|---|---|
| Collection cost (annual) | ***1,909*** | ***81,073*** |
| Collection cost (monthly) | 159 | 6,756 |
| Recovery target (monthly) | ***111*** | ***4,729*** |
| Recovery rate | 70% | 70% |

**Table 21: Tariff for cost recovery**

(Peso/user/month)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | ***0.0*** | ***1.2*** |
| Office (non-CUC earner) by communal bin | ***3.8*** | ***79*** |
| Office (non-CUC earner) by exclusive bin | ***38.0*** | ***790*** |
| Office (CUC earner) by communal bin | ***7.6*** | ***158*** |
| Office (CUC earner) by exclusive bin | ***76.0*** | ***1580*** |
| Foreigner by communal bin | ***11.4*** | ***237*** |
| Foreigner with exclusive bin | ***114.0*** | ***2370*** |
| Efficiency of bill collection | ***95%*** | ***95%*** |
| Surplus/deficit (Peso/month) | 1,262 | 6,305 |

**Table 22: Cross Subsidy Coefficient**

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0.0 | 1.0 |
| Office (non-CUC earner) by communal bin | 1.0 | 6.8 |
| Office (non-CUC earner) by exclusive bin | 1.0 | 6.8 |
| Office (CUC earner) by communal bin | 2.0 | 13.6 |
| Office (CUC earner) by exclusive bin | 2.0 | 13.6 |
| Foreigner by communal bin | 3.0 | 20.4 |
| Foreigner with exclusive bin | 3.0 | 20.4 |

**Table 23: Per liter tariff** (Peso/liter)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0.000 | 0.013 |
| Office (non-CUC earner) by communal bin | 0.004 | 0.088 |
| Office (non-CUC earner) by exclusive bin | 0.004 | 0.088 |
| Office (CUC earner) by communal bin | 0.008 | 0.176 |
| Office (CUC earner) by exclusive bin | 0.008 | 0.176 |
| Foreigner by communal bin | 0.013 | 0.263 |
| Foreigner with exclusive bin | 0.013 | 0.263 |

**Table 24: Monthly revenue** (Peso '000)

| User Category | CUC | CUP |
|---|---|---|
| Inhabitant | 0 | 2,394 |
| Office (non-CUC earner) by communal bin | 28 | 578 |
| Office (non-CUC earner) by exclusive bin | 11 | 225 |
| Office (CUC earner) by communal bin | 12 | 255 |
| Office (CUC earner) by exclusive bin | 22 | 450 |
| Foreigner by communal bin | 8 | 158 |
| Foreigner with exclusive bin | 32 | 675 |
| Total | 113 | 4,736 |

**Table 20 Population Benefited from Sanitary Landfill (inhabitants within a 1km radius of landfills)**

| No. | Landfill | Closing/operation status | Municipality | Landfill area (ha) | Outer 1km area (ha) | Net outer area (km2) | Population density (person/km2) | Population benefited |
|---|---|---|---|---|---|---|---|---|
| 1 | Ocho Vias | Operational until 2015 | Cotorro | 30.0 | 538.1 | 5.1 | 1,134 | 5,762 |
| 2 | Barreras | Operational until 2015 | Habana este | 10.0 | 436.1 | 4.3 | 1,280 | 5,454 |
| 3 | Lugardita | Closed by the end of 2008 | Boyeros | 1.5 | 358.9 | 3.6 | 1,407 | 5,029 |
| 4 | Prensa Latina | Closed by the end of 2008 | Boyeros | 2.0 | 366.1 | 3.6 | 1,407 | 5,123 |
| 5 | Rincon | Closed by the end of 2008 | Boyeros | 0.5 | 339.6 | 3.4 | 1,407 | 4,771 |
| 6 | Las Canas | Closed by the end of 2008 | Boyeros | 1.0 | 350.4 | 3.5 | 1,407 | 4,917 |
| 7 | El Vidrio | Closed by the end of 2008 | La Lisa | 2.5 | 372.5 | 3.7 | 3,408 | 12,611 |
| 8 | Los Perros | Closed by the end of 2008 | Cotorro | 2.0 | 366.1 | 3.6 | 1,134 | 4,129 |
| 9 | Campo Florido | Operational until 2015 | Habana este | 1.8 | 363.3 | 3.6 | 1,280 | 4,628 |
| 10 | New Guanabacoa | Operational until 2015 | Guanabacoa | 18.0 | 482.4 | 4.6 | 834 | 3,873 |
| 11 | New site | Operational from 2011 to 2015 | Boyeros | 60.0 | 648.5 | 5.9 | 1,407 | 8,280 |
| 12 | Calle 100 (existing) | Closed by the end of 2008 | Marianao | 80.0 | 711.0 | 6.3 | 6,464 | 40,787 |
| 13 | Calle 100 (extension) | Operational until 2010 | Marianao | 24.0 | 68.4 | 0.4 | 6,464 | 2,872 |
| | Closed landfill total (3+4+5+6+7+8+12) | | | 89.5 | 2,222.1 | 21.9 | | 39,451 |
| | Operational landfill total (1+2+9+10+11+13) | | | 143.8 | 2,468.4 | 23.5 | | 27,997 |
| | Total (1+2+3+4+5+6+7+8+9+10+11+12+13) | | | 233.3 | 4,690.5 | 45.4 | | 67,448 |

**Table 21 BOD Reduction by Leachate Treatment**

(BOD ton/year)

| | New Site 1 Stage 1 | New Site 1 Stage 2 | New Site 1 Stage 3 | New Guan. Stage 1 | New Guan. Stage 2 | Total BOD reduction |
|---|---|---|---|---|---|---|
| 2007 | 76 | | | 41 | | 117 |
| 2008 | 76 | | | 41 | | 117 |
| 2009 | 76 | | | 41 | | 117 |
| 2010 | 76 | | | 41 | | 117 |
| 2011 | 76 | | | 44 | 35 | 155 |
| 2012 | 81 | 47 | | 44 | 35 | 207 |
| 2013 | 81 | 47 | | 44 | 35 | 207 |
| 2014 | 81 | 50 | 47 | 44 | 35 | 256 |
| 2015 | 81 | 50 | 47 | 44 | 35 | 256 |
| Total | 704 | 193 | 94 | 382 | 176 | 1,549 |
| | | | | | Annual average | 172 |

Where:

BOD reduction is 940mg/L (=1000mg/L - 60mg/L)
Leachate generation coefficient = 0.4
Annual rainfall (year 2002) = 1,557 mm
Environmental load of Havana City (year 2003)= 28,501 BOD ton

Landfill area:

| | | | | |
|---|---|---|---|---|
| New site 1(stage1) = | 13 ha | = | 130,000 | m2 |
| New site 1(stage2) = | 8 ha | = | 80,000 | m2 |
| New site 1(stage3) = | 8 ha | = | 80,000 | m2 |
| New Guanabacoa (stage1) | 7 ha | = | 70,000 | m2 |
| New Guanabacoa (stage2) | 6 ha | = | 60,000 | m2 |

Precipitation at landfill:

| | | |
|---|---|---|
| New site 1(stage1) = | 202,410 | m3/year |
| New site 1(stage2) = | 124,560 | m3/year |
| New site 1(stage3) = | 124,560 | m3/year |
| New Guanabacoa (stage1) | 108,990 | m3/year |
| New Guanabacoa (stage2) | 93,420 | m3/year |

Leachate generation at landfill:

| | | |
|---|---|---|
| New site 1(stage1) = | 80,964 | m3/year |
| New site 1(stage2) = | 49,824 | m3/year |
| New site 1(stage3) = | 49,824 | m3/year |
| New Guanabacoa (stage1) | 43,596 | m3/year |
| New Guanabacoa (stage2) | 37,368 | m3/year |

BOD reduction before closure:

| | | |
|---|---|---|
| New site 1(stage1) = | 76 | ton/year |
| New site 1(stage2) = | 47 | ton/year |
| New site 1(stage3) = | 47 | ton/year |
| New Guanabacoa (stage1) | 41 | ton/year |
| New Guanabacoa (stage2) | 35 | ton/year |

BOD reduction after closure:

| | | |
|---|---|---|
| New site 1(stage1) = | 81 | ton/year |
| New site 1(stage2) = | 50 | ton/year |
| New site 1(stage3) = | 50 | ton/year |
| New Guanabacoa (stage1) | 44 | ton/year |
| New Guanabacoa (stage2) | 37 | ton/year |

**Table 22 Summary of Master Plan Cost**

(FC: US$ million, LC: CUP million, 2005 prices)

| Component | Capital cost | | | | | | O/M Cost | | Capital Cost + O/M Cost | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Direct Cost | | Indirect Cost | | Direct+Indirect | | | | | |
| | FC | LC | FC | LC | FC | LC | FC | LC | FC | LC |
| Composting (total) | 4.7 | 4.0 | 0.4 | 0.6 | 5.1 | 4.6 | 0.3 | 6.4 | 5.4 | 11.0 |
| Composting at Calle 100 | 2.1 | 2.2 | 0.1 | 0.3 | 2.3 | 2.5 | 0.1 | 2.2 | 2.4 | 4.7 |
| Composting at New Guanabacoa | 1.6 | 1.8 | 0.2 | 0.3 | 1.8 | 2.2 | 0.2 | 4.2 | 2.0 | 6.3 |
| Home composting | 1.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 |
| Recycling (total) | 4.0 | 3.9 | 0.3 | 0.5 | 4.3 | 4.4 | 0.3 | 14.2 | 4.5 | 18.6 |
| Recycling at Calle 100 | 2.3 | 2.2 | 0.2 | 0.3 | 2.5 | 2.5 | 0.2 | 9.8 | 2.6 | 12.3 |
| Recycling at New Guanabacoa | 1.7 | 1.7 | 0.1 | 0.2 | 1.8 | 1.9 | 0.1 | 4.4 | 1.9 | 6.3 |
| Collection and transportation (total) | 22.7 | 0.0 | 1.6 | 0.0 | 24.2 | 0.0 | 7.5 | 65.5 | 31.8 | 65.5 |
| Collection vehicle replacement | 13.9 | 0.0 | 1.0 | 0.0 | 14.9 | 0.0 | 6.3 | 57.0 | 21.2 | 57.0 |
| Improvement of waste bin | 5.4 | 0.0 | 0.4 | 0.0 | 5.8 | 0.0 | 0.3 | 0.0 | 6.1 | 0.0 |
| Maintenance workshop improvement | 3.3 | 0.0 | 0.2 | 0.0 | 3.6 | 0.0 | 1.0 | 8.5 | 4.5 | 8.5 |
| Landfill (total) | 42.0 | 26.8 | 6.0 | 4.0 | 48.0 | 30.9 | 4.3 | 11.0 | 52.3 | 41.8 |
| Construction of new site | 7.5 | 6.5 | 1.3 | 1.1 | 8.7 | 7.6 | 2.2 | 4.6 | 11.0 | 12.2 |
| Construction of New Guanabacoa | 10.7 | 4.9 | 1.5 | 0.8 | 12.2 | 5.6 | 1.0 | 2.9 | 13.2 | 8.5 |
| Extension of Calle 100 | 18.0 | 7.2 | 2.2 | 1.0 | 20.2 | 8.2 | 0.9 | 1.7 | 21.2 | 9.9 |
| Closure of special period dumping sites | 2.2 | 3.3 | 0.3 | 0.4 | 2.5 | 3.7 | 0.0 | 0.0 | 2.5 | 3.7 |
| Closure of Calle 100 | 1.9 | 2.9 | 0.4 | 0.5 | 2.4 | 3.3 | 0.0 | 0.0 | 2.4 | 3.3 |
| Closure of Extended Area of Calle 100 | 0.2 | 0.3 | 0.1 | 0.1 | 0.3 | 0.4 | 0.0 | 0.0 | 0.3 | 0.4 |
| Closure of Guanabacoa landfill | 1.2 | 1.7 | 0.2 | 0.2 | 1.4 | 2.0 | 0.0 | 0.0 | 1.4 | 2.0 |
| Central workshop improvement | 0.3 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.1 | 1.8 | 0.4 | 1.8 |
| Awareness raising | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 1.4 | 2.1 | 1.4 |
| Environmental monitoring | 0.3 | 0.1 | 0.0 | 0.0 | 0.3 | 0.1 | 0.3 | 0.0 | 0.6 | 0.1 |
| Total | 73.6 | 34.8 | 8.3 | 5.2 | 81.9 | 40.0 | 14.8 | 98.4 | 96.7 | 138.4 |

## Table 23 Disbursement Schedule of Master Plan Costs

(FC: US$'000, LC: CUP'000, Total: US$'000, constant prices)

| | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Composting (Total) | FC | 0 | 0 | 231 | 1,919 | 151 | 151 | 2,440 | 186 | 186 | 186 | 5,448 |
| | LC | 0 | 0 | 0 | 2,164 | 693 | 693 | 3,168 | 1,425 | 1,425 | 1,425 | 10,993 |
| Composting at Calle 100 | FC | | | | | | | 2,290 | 35 | 35 | 35 | 2,395 |
| | LC | | | | | | | 2,475 | 732 | 732 | 732 | 4,671 |
| Composting at New Guanabacoa | FC | | | | 1,803 | 35 | 35 | 35 | 35 | 35 | 35 | 2,013 |
| | LC | | | | 2,164 | 693 | 693 | 693 | 693 | 693 | 693 | 6,322 |
| Home composting | FC | | | 231 | 116 | 116 | 116 | 116 | 116 | 116 | 116 | 1,040 |
| | LC | | | | | | | | | | | 0 |
| Recycling (Total) | FC | | | | 2,475 | 28 | 28 | 1,836 | 56 | 56 | 56 | 4,535 |
| | LC | | | | 2,535 | 1,630 | 1,630 | 3,516 | 3,104 | 3,104 | 3,104 | 18,623 |
| Recycling at Calle 100 | FC | | | | 2,475 | 28 | 28 | 28 | 28 | 28 | 28 | 2,643 |
| | LC | | | | 2,535 | 1,630 | 1,630 | 1,630 | 1,630 | 1,630 | 1,630 | 12,315 |
| Recycling at New Guanabacoa | FC | | | | | | | 1,808 | 28 | 28 | 28 | 1,892 |
| | LC | | | | | | | 1,886 | 1,474 | 1,474 | 1,474 | 6,308 |
| Collection & transportation (Total) | FC | 0 | 0 | 8,319 | 928 | 5,384 | 5,721 | 948 | 8,279 | 1,097 | 1,097 | 31,772 |
| | LC | 0 | 0 | 6,481 | 6,481 | 7,115 | 8,564 | 8,564 | 9,421 | 9,421 | 9,421 | 65,470 |
| Collection vehicle replacement | FC | | | 7,419 | 891 | 3,331 | 2,832 | 780 | 4,069 | 930 | 930 | 21,181 |
| | LC | | | 5,461 | 5,461 | 6,094 | 7,480 | 7,480 | 8,337 | 8,337 | 8,337 | 56,986 |
| Improvement of waste bin | FC | | | | | 2,015 | | | 4,042 | | | 6,058 |
| | LC | | | | | | | | | | | 0 |
| Maintenance workshop improvement | FC | | | 899 | 38 | 38 | 2,889 | 167 | 167 | 167 | 167 | 4,534 |
| | LC | | | 1,021 | 1,021 | 1,021 | 1,084 | 1,084 | 1,084 | 1,084 | 1,084 | 8,485 |
| Final Disposal (Total) | FC | | 336 | 27,917 | 5,802 | 5,125 | 6,996 | 625 | 4,097 | 625 | 767 | 52,291 |
| | LC | | 229 | 12,233 | 8,480 | 6,483 | 5,267 | 1,596 | 4,398 | 1,575 | 1,575 | 41,837 |
| Construction of new site | FC | | 40 | 160 | 66 | 4,339 | 1,355 | 454 | 3,491 | 455 | 605 | 10,965 |
| | LC | | 33 | 125 | 48 | 4,867 | 994 | 928 | 3,403 | 913 | 913 | 12,224 |
| Construction of New Guanabacoa | FC | | | 7,812 | 144 | 299 | 4,289 | 144 | 218 | 148 | 144 | 13,196 |
| | LC | | | 3,868 | 415 | 494 | 2,076 | 411 | 411 | 411 | 411 | 8,498 |
| Extension of Calle 100 | FC | | 139 | 19,736 | 847 | 447 | 10 | | 10 | | | 21,188 |
| | LC | | 50 | 8,185 | 853 | 853 | | | | | | 9,942 |
| Closure of special period dumping sites | FC | | 25 | 7 | 2,455 | 11 | | | | | | 2,498 |
| | LC | | 25 | 5 | 3,654 | 10 | | | | | | 3,694 |
| Closure of Calle 100 | FC | | 95 | 23 | 2,240 | | | | | | | 2,358 |
| | LC | | 88 | 20 | 3,230 | | | | | | | 3,338 |
| Closure of Extended Area of Calle 100 | FC | | 37 | 34 | | | | 9 | 222 | | | 302 |
| | LC | | 33 | 30 | | | | 6 | 333 | | | 402 |
| Closure of Guanabacoa landfill | FC | | | | 32 | 7 | 1,325 | | | | | 1,364 |
| | LC | | | | 28 | 8 | 1,946 | | | | | 1,982 |
| Central workshop improvement | FC | | | 146 | 19 | 22 | 18 | 18 | 157 | 22 | 18 | 420 |
| | LC | | | | 251 | 251 | 251 | 251 | 251 | 251 | 251 | 1,757 |
| Awareness raising | FC | | 364 | 363 | 361 | 242 | 284 | 284 | 92 | 50 | 50 | 2,090 |
| | LC | | 257 | 256 | 254 | 162 | 194 | 194 | 46 | 14 | 14 | 1,391 |
| Environmental monitoring | FC | | 115 | 110 | 95 | 91 | 29 | 29 | 29 | 29 | 29 | 555 |
| | LC | | 13 | 31 | 17 | 11 | 5 | 5 | 5 | 5 | 5 | 97 |
| Total | FC | 0 | 815 | 36,940 | 11,581 | 11,019 | 13,208 | 6,162 | 12,738 | 2,042 | 2,185 | 96,691 |
| | LC | 0 | 499 | 19,002 | 19,930 | 16,094 | 16,354 | 17,043 | 18,400 | 15,545 | 15,545 | 138,412 |
| Grand Total (US$'000) | | 0 | 835 | 37,671 | 12,347 | 11,638 | 13,837 | 6,818 | 13,446 | 2,640 | 2,783 | 102,014 |

Grand Total at US$1 : CUP26

## Table 24-1 Cost Disbursement of Master Plan Components (2005 constant price: 1/4)

(FC: US$'000, LC: CUP'000, Total: US$'000, constant prices)

| | | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Composting at Calle 100 | Capital cost (direct) | FC | | | | | | | 2,140 | | | | 2,140 |
| | Capital cost (direct) | LC | | | | | | | 2,190 | | | | 2,190 |
| | Total capital cost (direct) *a | | | | | | | | 4,330 | | | | 4,330 |
| | Engineering cost *b | FC | | | | | | | 43 | | | | 43 |
| | Engineering cost *c | LC | | | | | | | 110 | | | | 110 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | 66 | | | | 66 |
| | Physical conting. *e | FC | | | | | | | 107 | | | | 107 |
| | Physical conting. *e | LC | | | | | | | 110 | | | | 110 |
| | O/M cost | FC | | | | | | | | 35 | 35 | 35 | 105 |
| | O/M cost | LC | | | | | | | | 732 | 732 | 732 | 2,196 |
| | Total FC portion | FC | | | | | | | 2,290 | 35 | 35 | 35 | 2,395 |
| | Total LC portion | LC | | | | | | | 2,475 | 732 | 732 | 732 | 4,671 |
| | Total FC + LC *f | | | | | | | | 2,385 | 63 | 63 | 63 | 2,574 |
| | Total FC + LC *a | | | | | | | | 4,765 | 767 | 767 | 767 | 7,066 |
| Composting at New Guanabacoa | Capital cost (direct) | FC | | | | 1,610 | | | | | | | 1,610 |
| | Capital cost (direct) | LC | | | | 1,834 | | | | | | | 1,834 |
| | Total capital cost (direct) *a | | | | | 3,444 | | | | | | | 3,444 |
| | Engineering cost *b | FC | | | | 32 | | | | | | | 32 |
| | Engineering cost *c | LC | | | | 92 | | | | | | | 92 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | 55 | | | | | | | 55 |
| | Physical conting. *e | FC | | | | 161 | | | | | | | 161 |
| | Physical conting. *e | LC | | | | 183 | | | | | | | 183 |
| | O/M cost | FC | | | | | 35 | 35 | 35 | 35 | 35 | 35 | 210 |
| | O/M cost | LC | | | | | 693 | 693 | 693 | 693 | 693 | 693 | 4,158 |
| | Total FC portion | FC | | | | 1,803 | 35 | 35 | 35 | 35 | 35 | 35 | 2,013 |
| | Total LC portion | LC | | | | 2,164 | 693 | 693 | 693 | 693 | 693 | 693 | 6,322 |
| | Total FC + LC *f | | | | | 1,886 | 62 | 62 | 62 | 62 | 62 | 62 | 2,256 |
| | Total FC + LC *a | | | | | 3,967 | 728 | 728 | 728 | 728 | 728 | 728 | 8,335 |
| Home composting | Capital cost (direct) | FC | | | 220 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 990 |
| | Capital cost (direct) | LC | | | | | | | | | | | 0 |
| | Total capital cost (direct) *a | | | | 220 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 990 |
| | Engineering cost *b | FC | | | | | | | | | | | 0 |
| | Engineering cost *c | LC | | | | | | | | | | | 0 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | | | | | 0 |
| | Physical conting. *e | FC | | | 11 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 50 |
| | Physical conting. *e | LC | | | | | | | | | | | 0 |
| | O/M cost | FC | | | | | | | | | | | 0 |
| | O/M cost | LC | | | | | | | | | | | 0 |
| | Total FC portion | FC | | | 231 | 116 | 116 | 116 | 116 | 116 | 116 | 116 | 1,040 |
| | Total LC portion | LC | | | | | | | | | | | 0 |
| | Total FC + LC *f | | | | 231 | 116 | 116 | 116 | 116 | 116 | 116 | 116 | 1,040 |
| | Total FC + LC *a | | | | 231 | 116 | 116 | 116 | 116 | 116 | 116 | 116 | 1,040 |
| Recycling at Calle 100 | Capital cost (direct) | FC | | | | 2,313 | | | | | | | 2,313 |
| | Capital cost (direct) | LC | | | | 2,243 | | | | | | | 2,243 |
| | Total capital cost (direct) *a | | | | | 4,556 | | | | | | | 4,556 |
| | Engineering cost *b | FC | | | | 46 | | | | | | | 46 |
| | Engineering cost *c | LC | | | | 112 | | | | | | | 112 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | 67 | | | | | | | 67 |
| | Physical conting. *e | FC | | | | 116 | | | | | | | 116 |
| | Physical conting. *e | LC | | | | 112 | | | | | | | 112 |
| | O/M cost | FC | | | | | 28 | 28 | 28 | 28 | 28 | 28 | 168 |
| | O/M cost | LC | | | | | 1,630 | 1,630 | 1,630 | 1,630 | 1,630 | 1,630 | 9,780 |
| | Total FC portion | FC | | | | 2,475 | 28 | 28 | 28 | 28 | 28 | 28 | 2,643 |
| | Total LC portion | LC | | | | 2,535 | 1,630 | 1,630 | 1,630 | 1,630 | 1,630 | 1,630 | 12,315 |
| | Total FC + LC *f | | | | | 2,572 | 91 | 91 | 91 | 91 | 91 | 91 | 3,117 |
| | Total FC + LC *a | | | | | 5,010 | 1,658 | 1,658 | 1,658 | 1,658 | 1,658 | 1,658 | 14,958 |
| Recycling at New Guanabacoa | Capital cost (direct) | FC | | | | | | | 1,690 | | | | 1,690 |
| | Capital cost (direct) | LC | | | | | | | 1,669 | | | | 1,669 |
| | Total capital cost (direct) *a | | | | | | | | 3,359 | | | | 3,359 |
| | Engineering cost *b | FC | | | | | | | 34 | | | | 34 |
| | Engineering cost *c | LC | | | | | | | 83 | | | | 83 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | 50 | | | | 50 |
| | Physical conting. *e | FC | | | | | | | 85 | | | | 85 |
| | Physical conting. *e | LC | | | | | | | 83 | | | | 83 |
| | O/M cost | FC | | | | | | | | 28 | 28 | 28 | 84 |
| | O/M cost | LC | | | | | | | | 1,474 | 1,474 | 1,474 | 4,422 |
| | Total FC portion | FC | | | | | | | 1,808 | 28 | 28 | 28 | 1,892 |
| | Total LC portion | LC | | | | | | | 1,886 | 1,474 | 1,474 | 1,474 | 6,308 |
| | Total FC + LC *f | | | | | | | | 1,881 | 85 | 85 | 85 | 2,135 |
| | Total FC + LC *a | | | | | | | | 3,694 | 1,502 | 1,502 | 1,502 | 8,200 |

## Table 24-2 Cost Disbursement of Master Plan Components (2005 constant price: 2/4)

(FC: US$'000, LC: CUP'000, Total: US$'000, constant prices)

| | | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Collection vehicle replacement | Capital cost (direct) | FC | | | 6,352 | 260 | 2,340 | 1,954 | | 2,990 | | | 13,895 |
| | Capital cost (direct) | LC | | | | | | | | | | | 0 |
| | Total capital cost (direct) *a | | | | 6,352 | 260 | 2,340 | 1,954 | | 2,990 | | | 13,895 |
| | Engineering cost *b | FC | | | 132 | | 146 | | | | | | 278 |
| | Engineering cost *c | LC | | | | | | | | | | | 0 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | | | | | 0 |
| | Physical conting. *e | FC | | | 318 | 13 | 117 | 98 | | 150 | | | 695 |
| | Physical conting. *e | LC | | | | | | | | | | | 0 |
| | O/M cost | FC | | | 618 | 618 | 728 | 780 | 780 | 930 | 930 | 930 | 6,312 |
| | O/M cost *g | LC | | | 5,461 | 5,461 | 6,094 | 7,480 | 7,480 | 8,337 | 8,337 | 8,337 | 56,986 |
| | Total FC portion | FC | | | 7,419 | 891 | 3,331 | 2,832 | 780 | 4,069 | 930 | 930 | 21,181 |
| | Total LC portion | LC | | | 5,461 | 5,461 | 6,094 | 7,480 | 7,480 | 8,337 | 8,337 | 8,337 | 56,986 |
| | Total FC + LC *f | | | | 7,629 | 1,101 | 3,565 | 3,119 | 1,068 | 4,390 | 1,250 | 1,250 | 23,372 |
| | Total FC + LC *a | | | | 12,880 | 6,351 | 9,425 | 10,311 | 8,260 | 12,406 | 9,267 | 9,267 | 78,166 |
| Improvement of waste bin | Capital cost (direct) | FC | | | | | 1,734 | | | 3,675 | | | 5,409 |
| | Capital cost (direct) | LC | | | | | | | | | | | 0 |
| | Total capital cost (direct) *a | | | | | | 1,734 | | | 3,675 | | | 5,409 |
| | Engineering cost *b | FC | | | | | 108 | | | | | | 108 |
| | Engineering cost *c | LC | | | | | | | | | | | 0 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | | | | | 0 |
| | Physical conting. *e | FC | | | | | 87 | | | 184 | | | 270 |
| | Physical conting. *e | LC | | | | | | | | | | | 0 |
| | O/M cost | FC | | | | | 87 | | | 184 | | | 270 |
| | O/M cost | LC | | | | | | | | | | | 0 |
| | Total FC portion | FC | | | | | 2,015 | | | 4,042 | | | 6,058 |
| | Total LC portion | LC | | | | | | | | | | | 0 |
| | Total FC + LC *f | | | | | | 2,015 | | | 4,042 | | | 6,058 |
| | Total FC + LC *a | | | | | | 2,015 | | | 4,042 | | | 6,058 |
| Maintenance workshop improvement | Capital cost (direct) | FC | | | 757 | | | 2,592 | | | | | 3,349 |
| | Capital cost (direct) | LC | | | | | | | | | | | 0 |
| | Total capital cost (direct) *a | | | | 757 | | | 2,592 | | | | | 3,349 |
| | Engineering cost *b | FC | | | 67 | | | | | | | | 67 |
| | Engineering cost *c | LC | | | | | | | | | | | 0 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | | | | | 0 |
| | Physical conting. *e | FC | | | 38 | | | 130 | | | | | 167 |
| | Physical conting. *e | LC | | | | | | | | | | | 0 |
| | O/M cost | FC | | | 38 | 38 | 38 | 167 | 167 | 167 | 167 | 167 | 951 |
| | O/M cost | LC | | | 1,021 | 1,021 | 1,021 | 1,084 | 1,084 | 1,084 | 1,084 | 1,084 | 8,485 |
| | Total FC portion | FC | | | 899 | 38 | 38 | 2,889 | 167 | 167 | 167 | 167 | 4,534 |
| | Total LC portion | LC | | | 1,021 | 1,021 | 1,021 | 1,084 | 1,084 | 1,084 | 1,084 | 1,084 | 8,485 |
| | Total FC + LC *f | | | | 939 | 77 | 77 | 2,931 | 209 | 209 | 209 | 209 | 4,860 |
| | Total FC + LC *a | | | | 1,920 | 1,059 | 1,059 | 3,973 | 1,252 | 1,252 | 1,252 | 1,252 | 13,019 |
| Construction of new site 1 | Capital cost (direct) | FC | | | | | 3,794 | 770 | | 2,734 | 8 | 151 | 7,456 |
| | Capital cost (direct) | LC | | | | | 4,356 | | | 2,186 | | | 6,542 |
| | Total capital cost (direct) *a | | | | | | 8,150 | 770 | | 4,920 | 8 | 151 | 13,998 |
| | Engineering cost *b | FC | | 26 | 100 | 41 | 110 | 62 | 4 | 30 | | | 373 |
| | Engineering cost *c | LC | | 13 | 50 | 19 | 30 | 28 | 2 | 30 | | | 172 |
| | Administration | FC | | 14 | 60 | 25 | 66 | 38 | 3 | 19 | | | 225 |
| | Administration *d | LC | | 20 | 75 | 29 | 45 | 42 | 3 | 45 | | | 259 |
| | Physical conting. *e | FC | | | | | 369 | 39 | | 261 | 0 | 8 | 677 |
| | Physical conting. *e | LC | | | | | 436 | | | 219 | | | 654 |
| | O/M cost | FC | | | | | | 447 | 447 | 447 | 447 | 447 | 2,234 |
| | O/M cost | LC | | | | | | 924 | 923 | 923 | 913 | 913 | 4,597 |
| | Total FC portion | FC | | 40 | 160 | 66 | 4,339 | 1,355 | 454 | 3,491 | 455 | 605 | 10,965 |
| | Total LC portion | LC | | 33 | 125 | 48 | 4,867 | 994 | 928 | 3,403 | 913 | 913 | 12,224 |
| | Total FC + LC *f | | | 41 | 165 | 68 | 4,526 | 1,393 | 489 | 3,622 | 490 | 640 | 11,435 |
| | Total FC + LC *a | | | 73 | 285 | 114 | 9,206 | 2,349 | 1,382 | 6,894 | 1,369 | 1,518 | 23,189 |
| Construction of New Guanabacoa | Capital cost (direct) | FC | | | 6,952 | | 3 | 3,631 | | 70 | 3 | | 10,659 |
| | Capital cost (direct) | LC | | | 3,422 | | | 1,434 | | | | | 4,856 |
| | Total capital cost (direct) *a | | | | 10,374 | | 3 | 5,065 | | 70 | 3 | | 15,515 |
| | Engineering cost *b | FC | | | 156 | | 94 | 99 | | | | | 349 |
| | Engineering cost *c | LC | | | 42 | | 31 | 33 | | | | | 106 |
| | Administration | FC | | | 93 | | 57 | 60 | | | | | 210 |
| | Administration *d | LC | | | 62 | | 47 | 50 | | | | | 159 |
| | Physical conting. *e | FC | | | 611 | | 0 | 355 | | 4 | 0 | | 969 |
| | Physical conting. *e | LC | | | 342 | | | 143 | | | | | 486 |
| | O/M cost | FC | | | | 144 | 144 | 144 | 144 | 144 | 144 | 144 | 1,009 |
| | O/M cost | LC | | | | 415 | 416 | 416 | 411 | 411 | 411 | 411 | 2,891 |
| | Total FC portion | FC | | | 7,812 | 144 | 299 | 4,289 | 144 | 218 | 148 | 144 | 13,196 |
| | Total LC portion | LC | | | 3,868 | 415 | 494 | 2,076 | 411 | 411 | 411 | 411 | 8,498 |
| | Total FC + LC *f | | | | 7,960 | 160 | 317 | 4,369 | 160 | 233 | 163 | 160 | 13,523 |
| | Total FC + LC *a | | | | 11,680 | 560 | 792 | 6,365 | 555 | 629 | 559 | 555 | 21,694 |

# Table 24-3 Cost Disbursement of Master Plan Components (2005 constant price: 3/4)

(FC: US$'000, LC: CUP'000, Total: US$'000, constant prices)

| | | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Extension of Calle 100 | Capital cost (direct) | FC | | | 17,674 | 331 | | 9 | | 9 | | | 18,024 |
| | Capital cost (direct) | LC | | | 7,234 | | | | | | | | 7,234 |
| | Total capital cost (direct) *a | | | | 24,908 | 331 | | 9 | | 9 | | | 25,258 |
| | Engineering cost *b | FC | | 100 | 359 | | | | | | | | 459 |
| | Engineering cost *c | LC | | 20 | 91 | | | | | | | | 111 |
| | Administration | FC | | 39 | 139 | | | | | | | | 178 |
| | Administration *d | LC | | 30 | 137 | | | | | | | | 167 |
| | Physical conting. *e | FC | | | 1,564 | 17 | | 0 | | 0 | | | 1,582 |
| | Physical conting. *e | LC | | | 723 | | | | | | | | 723 |
| | O/M cost | FC | | | | 499 | 447 | | | | | | 946 |
| | O/M cost | LC | | | | 853 | 853 | | | | | | 1,706 |
| | Total FC portion | FC | | 139 | 19,736 | 847 | 447 | 10 | | 10 | | | 21,188 |
| | Total LC portion | LC | | 50 | 8,185 | 853 | 853 | | | | | | 9,942 |
| | Total FC + LC *f | | | 141 | 20,051 | 880 | 480 | 10 | | 10 | | | 21,571 |
| | Total FC + LC *a | | | 189 | 27,921 | 1,700 | 1,300 | 10 | | 10 | | | 31,130 |
| Closure of special period dumping sites | Capital cost (direct) | FC | | | | 2,217 | | | | | | | 2,217 |
| | Capital cost (direct) | LC | | | | 3,308 | | | | | | | 3,308 |
| | Total capital cost (direct) *a | | | | | 5,525 | | | | | | | 5,525 |
| | Engineering cost *b | FC | | 16 | 4 | 10 | 7 | | | | | | 37 |
| | Engineering cost *c | LC | | 10 | 2 | 6 | 4 | | | | | | 22 |
| | Administration | FC | | 9 | 3 | 6 | 4 | | | | | | 22 |
| | Administration *d | LC | | 15 | 3 | 9 | 6 | | | | | | 33 |
| | Physical conting. *e | FC | | | | 222 | | | | | | | 222 |
| | Physical conting. *e | LC | | | | 331 | | | | | | | 331 |
| | O/M cost | FC | | | | | | | | | | | 0 |
| | O/M cost | LC | | | | | | | | | | | 0 |
| | Total FC portion | FC | | 25 | 7 | 2,455 | 11 | | | | | | 2,498 |
| | Total LC portion | LC | | 25 | 5 | 3,654 | 10 | | | | | | 3,694 |
| | Total FC + LC *f | | | 26 | 7 | 2,595 | 11 | | | | | | 2,640 |
| | Total FC + LC *a | | | 50 | 12 | 6,109 | 21 | | | | | | 6,192 |
| Closure of Calle 100 | Capital cost (direct) | FC | | | | 1,945 | | | | | | | 1,945 |
| | Capital cost (direct) | LC | | | | 2,852 | | | | | | | 2,852 |
| | Total capital cost (direct) *a | | | | | 4,797 | | | | | | | 4,797 |
| | Engineering cost *b | FC | | 59 | 14 | 62 | | | | | | | 135 |
| | Engineering cost *c | LC | | 35 | 8 | 37 | | | | | | | 80 |
| | Administration | FC | | 36 | 9 | 38 | | | | | | | 83 |
| | Administration *d | LC | | 53 | 12 | 56 | | | | | | | 121 |
| | Physical conting. *e | FC | | | | 195 | | | | | | | 195 |
| | Physical conting. *e | LC | | | | 285 | | | | | | | 285 |
| | O/M cost | FC | | | | | | | | | | | 0 |
| | O/M cost | LC | | | | | | | | | | | 0 |
| | Total FC portion | FC | | 95 | 23 | 2,240 | | | | | | | 2,358 |
| | Total LC portion | LC | | 88 | 20 | 3,230 | | | | | | | 3,338 |
| | Total FC + LC *f | | | 98 | 24 | 2,364 | | | | | | | 2,486 |
| | Total FC + LC *a | | | 183 | 43 | 5,470 | | | | | | | 5,696 |
| Closure of Extended Area of Calle 100 | Capital cost (direct) | FC | | | | | | | | 202 | | | 202 |
| | Capital cost (direct) | LC | | | | | | | | 303 | | | 303 |
| | Total capital cost (direct) *a | | | | | | | | | 505 | | | 505 |
| | Engineering cost *b | FC | | 22 | 20 | | | | 9 | | | | 51 |
| | Engineering cost *c | LC | | 13 | 12 | | | | 6 | | | | 31 |
| | Administration | FC | | 15 | 14 | | | | | | | | 29 |
| | Administration *d | LC | | 20 | 18 | | | | | | | | 38 |
| | Physical conting. *e | FC | | | | | | | | 20 | | | 20 |
| | Physical conting. *e | LC | | | | | | | | 30 | | | 30 |
| | O/M cost | FC | | | | | | | | | | | 0 |
| | O/M cost | LC | | | | | | | | | | | 0 |
| | Total FC portion | FC | | 37 | 34 | | | | 9 | 222 | | | 302 |
| | Total LC portion | LC | | 33 | 30 | | | | 6 | 333 | | | 402 |
| | Total FC + LC *f | | | 38 | 35 | | | | 9 | 235 | | | 318 |
| | Total FC + LC *a | | | 70 | 64 | | | | 15 | 556 | | | 705 |
| Closure of Guanabacoa landfill | Capital cost (direct) | FC | | | | | | 1,175 | | | | | 1,175 |
| | Capital cost (direct) | LC | | | | | | 1,742 | | | | | 1,742 |
| | Total capital cost (direct) *a | | | | | | | 2,917 | | | | | 2,917 |
| | Engineering cost *b | FC | | | | 20 | 4 | 20 | | | | | 44 |
| | Engineering cost *c | LC | | | | 11 | 3 | 12 | | | | | 26 |
| | Administration | FC | | | | 12 | 3 | 12 | | | | | 27 |
| | Administration *d | LC | | | | 17 | 5 | 18 | | | | | 40 |
| | Physical conting. *e | FC | | | | | | 118 | | | | | 118 |
| | Physical conting. *e | LC | | | | | | 174 | | | | | 174 |
| | O/M cost | FC | | | | | | | | | | | 0 |
| | O/M cost | LC | | | | | | | | | | | 0 |
| | Total FC portion | FC | | | | 32 | 7 | 1,325 | | | | | 1,364 |
| | Total LC portion | LC | | | | 28 | 8 | 1,946 | | | | | 1,982 |
| | Total FC + LC *f | | | | | 33 | 7 | 1,399 | | | | | 1,440 |
| | Total FC + LC *a | | | | | 60 | 15 | 3,271 | | | | | 3,346 |

## Table 24-4 Cost Disbursement of Master Plan Components (2005 constant price: 4/4)

(FC: US$'000, LC: CUP'000, Total: US$'000, constant prices)

| | | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Central workshop improvement | Capital cost (direct) | FC | | | 135 | | 4 | | | 132 | 4 | | 275 |
| | Capital cost (direct) | LC | | | | | | | | | | | 0 |
| | Total capital cost (direct) *a | | | | 135 | | 4 | | | 132 | 4 | | 275 |
| | Engineering cost *b | FC | | | | | | | | | | | 0 |
| | Engineering cost *c | LC | | | | | | | | | | | 0 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | | | | | 0 |
| | Physical conting. *e | FC | | | 7 | | 0 | | | 7 | 0 | | 14 |
| | Physical conting. *e | LC | | | | | | | | | | | 0 |
| | O/M cost | FC | | | 4 | 19 | 18 | 18 | 18 | 18 | 18 | 18 | 132 |
| | O/M cost | LC | | | | 251 | 251 | 251 | 251 | 251 | 251 | 251 | 1,757 |
| | Total FC portion | FC | | | 146 | 19 | 22 | 18 | 18 | 157 | 22 | 18 | 420 |
| | Total LC portion | LC | | | | 251 | 251 | 251 | 251 | 251 | 251 | 251 | 1,757 |
| | Total FC + LC *f | | | | 146 | 29 | 32 | 28 | 28 | 166 | 32 | 28 | 488 |
| | Total FC + LC *a | | | | 146 | 270 | 273 | 269 | 269 | 408 | 273 | 269 | 2,177 |
| Awareness raising | Capital cost (direct) | FC | | | | | | | | | | | 0 |
| | Capital cost (direct) | LC | | | | | | | | | | | 0 |
| | Total capital cost (direct) *a | | | | | | | | | | | | 0 |
| | Engineering cost *b | FC | | | | | | | | | | | 0 |
| | Engineering cost *c | LC | | | | | | | | | | | 0 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | | | | | 0 |
| | Physical conting. *e | FC | | | | | | | | | | | 0 |
| | Physical conting. *e | LC | | | | | | | | | | | 0 |
| | O/M cost | FC | | 364 | 363 | 361 | 242 | 284 | 284 | 92 | 50 | 50 | 2,090 |
| | O/M cost | LC | | 257 | 256 | 254 | 162 | 194 | 194 | 46 | 14 | 14 | 1,391 |
| | Total FC portion | FC | | 364 | 363 | 361 | 242 | 284 | 284 | 92 | 50 | 50 | 2,090 |
| | Total LC portion | LC | | 257 | 256 | 254 | 162 | 194 | 194 | 46 | 14 | 14 | 1,391 |
| | Total FC + LC *f | | | 374 | 373 | 371 | 248 | 291 | 291 | 94 | 51 | 51 | 2,144 |
| | Total FC + LC *a | | | 621 | 619 | 615 | 404 | 478 | 478 | 138 | 64 | 64 | 3,481 |
| Environmental monitoring | Capital cost (direct) | FC | | 85 | 72 | 72 | 36 | | | | | | 265 |
| | Capital cost (direct) | LC | | 10 | 27 | 12 | 6 | | | | | | 55 |
| | Total capital cost (direct) *a | | | 95 | 99 | 84 | 42 | | | | | | 321 |
| | Engineering cost *b | FC | | | | | | | | | | | 0 |
| | Engineering cost *c | LC | | | | | | | | | | | 0 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | | | | | 0 |
| | Physical conting. *e | FC | | 4 | 4 | 4 | 2 | | | | | | 13 |
| | Physical conting. *e | LC | | 1 | 1 | 1 | 0 | | | | | | 3 |
| | O/M cost | FC | | 26 | 34 | 20 | 53 | 29 | 29 | 29 | 29 | 29 | 276 |
| | O/M cost | LC | | 3 | 3 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 40 |
| | Total FC portion | FC | | 115 | 110 | 95 | 91 | 29 | 29 | 29 | 29 | 29 | 555 |
| | Total LC portion | LC | | 13 | 31 | 17 | 11 | 5 | 5 | 5 | 5 | 5 | 97 |
| | Total FC + LC *f | | | 116 | 111 | 96 | 91 | 29 | 29 | 29 | 29 | 29 | 559 |
| | Total FC + LC *a | | | 128 | 141 | 112 | 102 | 34 | 34 | 34 | 34 | 34 | 652 |

| | | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | Capital cost (direct) | FC | | 85 | 32,161 | 8,858 | 8,020 | 10,241 | 3,940 | 9,922 | 125 | 261 | 73,614 |
| | Capital cost (direct) | LC | | 10 | 10,683 | 10,249 | 4,362 | 3,176 | 3,859 | 2,489 | | | 34,828 |
| | Total capital cost (direct) *a | | | 95 | 42,844 | 19,107 | 12,382 | 13,417 | 7,799 | 12,411 | 125 | 261 | 108,442 |
| | Engineering cost *b | FC | | 223 | 852 | 211 | 469 | 181 | 90 | 30 | | | 2,056 |
| | Engineering cost *c | LC | | 91 | 205 | 277 | 68 | 73 | 201 | 30 | | | 945 |
| | Administration | FC | | 113 | 318 | 81 | 130 | 110 | 3 | 19 | | | 774 |
| | Administration *d | LC | | 138 | 307 | 233 | 103 | 110 | 119 | 45 | | | 1,055 |
| | Physical conting. *e | FC | | 4 | 2,552 | 732 | 581 | 744 | 197 | 631 | 6 | 13 | 5,459 |
| | Physical conting. *e | LC | | 1 | 1,067 | 912 | 436 | 318 | 193 | 249 | | | 3,175 |
| | O/M cost | FC | | 390 | 1,057 | 1,699 | 1,819 | 1,932 | 1,932 | 2,137 | 1,911 | 1,911 | 14,787 |
| | O/M cost | LC | | 260 | 6,740 | 8,259 | 11,125 | 12,677 | 12,672 | 15,587 | 15,545 | 15,545 | 98,408 |
| | Total FC portion | FC | | 815 | 36,940 | 11,581 | 11,019 | 13,208 | 6,162 | 12,738 | 2,042 | 2,185 | 96,691 |
| | Total LC portion | LC | | 499 | 19,002 | 19,930 | 16,094 | 16,354 | 17,043 | 18,400 | 15,545 | 15,545 | 138,412 |
| | Total FC + LC *f | | | 835 | 37,671 | 12,347 | 11,638 | 13,837 | 6,818 | 13,446 | 2,640 | 2,783 | 102,014 |
| | Total FC + LC *a | | | 1,314 | 55,942 | 31,511 | 27,113 | 29,562 | 23,205 | 31,138 | 17,587 | 17,730 | 235,102 |

*a. FC portion (US$) and LC portion (CUP) are added up at exchange rate of US$1=CUP 1

*b. Engineering cost in FC portion will be incurred at the designing stage, which is 2% of the direct capital cost.

*c. Engineering cost in LC portion will be incurred at the designing stage, which is 5% of the direct capital cost.

*d. Administration cost will be incurred during construction/acquisition period, which is 3% of direct capital cost of LC portion.

*e. Physical contingency is 10% of direct construction cost and 5% of direct equipment cost, both for FC and LC portions.

*f. FC portion (US$) and LC portion (CUP) are added up at exchange rate of US$1= CUP26

## Table 25-1 Fund Requirement of Master Plan Components (2005 constant price: 1/4)

(FC: US$'000, LC: CUP'000, Total: US$'000, current prices)

| | | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Composting at Calle 100 | Capital cost (direct) | FC | | | | | | | 2,294 | | | | 2,294 |
| | Capital cost (direct) | LC | | | | | | | 2,568 | | | | 2,568 |
| | Total capital cost (direct) *a | | | | | | | | 4,862 | | | | 4,862 |
| | Engineering cost *b | FC | | | | | | | 46 | | | | 46 |
| | Engineering cost *c | LC | | | | | | | 128 | | | | 128 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | 77 | | | | 77 |
| | Physical conting. *e | FC | | | | | | | 115 | | | | 115 |
| | Physical conting. *e | LC | | | | | | | 128 | | | | 128 |
| | O/M cost | FC | | | | | | | | 38 | 38 | 39 | 115 |
| | O/M cost | LC | | | | | | | | 878 | 898 | 919 | 2,695 |
| | Total FC portion | FC | | | | | | | 2,455 | 38 | 38 | 39 | 2,570 |
| | Total LC portion | LC | | | | | | | 2,902 | 878 | 898 | 919 | 5,597 |
| | Total FC + LC *f | | | | | | | | 2,567 | 72 | 73 | 74 | 2,785 |
| | Total FC + LC *a | | | | | | | | 5,357 | 916 | 937 | 958 | 8,167 |
| Composting at New Guanabacoa | Capital cost (direct) | FC | | | | 1,675 | | | | | | | 1,675 |
| | Capital cost (direct) | LC | | | | 2,009 | | | | | | | 2,009 |
| | Total capital cost (direct) *a | | | | | 3,684 | | | | | | | 3,684 |
| | Engineering cost *b | FC | | | | 34 | | | | | | | 34 |
| | Engineering cost *c | LC | | | | 100 | | | | | | | 100 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | 60 | | | | | | | 60 |
| | Physical conting. *e | FC | | | | 168 | | | | | | | 168 |
| | Physical conting. *e | LC | | | | 201 | | | | | | | 201 |
| | O/M cost | FC | | | | | 37 | 37 | 38 | 38 | 38 | 39 | 226 |
| | O/M cost | LC | | | | | 776 | 794 | 813 | 831 | 850 | 870 | 4,935 |
| | Total FC portion | FC | | | | 1,876 | 37 | 37 | 38 | 38 | 38 | 39 | 2,103 |
| | Total LC portion | LC | | | | 2,370 | 776 | 794 | 813 | 831 | 850 | 870 | 7,305 |
| | Total FC + LC *f | | | | | 1,968 | 67 | 68 | 69 | 70 | 71 | 72 | 2,384 |
| | Total FC + LC *a | | | | | 4,247 | 813 | 831 | 850 | 869 | 889 | 909 | 9,408 |
| Home composting | Capital cost (direct) | FC | | | 227 | 114 | 116 | 117 | 118 | 119 | 120 | 122 | 1,052 |
| | Capital cost (direct) | LC | | | | | | | | | | | 0 |
| | Total capital cost (direct) *a | | | | 227 | 114 | 116 | 117 | 118 | 119 | 120 | 122 | 1,052 |
| | Engineering cost *b | FC | | | | | | | | | | | 0 |
| | Engineering cost *c | LC | | | | | | | | | | | 0 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | | | | | 0 |
| | Physical conting. *e | FC | | | 11 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 53 |
| | Physical conting. *e | LC | | | | | | | | | | | 0 |
| | O/M cost | FC | | | | | | | | | | | 0 |
| | O/M cost | LC | | | | | | | | | | | 0 |
| | Total FC portion | FC | | | 238 | 120 | 121 | 123 | 124 | 125 | 126 | 128 | 1,105 |
| | Total LC portion | LC | | | | | | | | | | | 0 |
| | Total FC + LC *f | | | | 238 | 120 | 121 | 123 | 124 | 125 | 126 | 128 | 1,105 |
| | Total FC + LC *a | | | | 238 | 120 | 121 | 123 | 124 | 125 | 126 | 128 | 1,105 |
| Recycling at Calle 100 | Capital cost (direct) | FC | | | | 2,407 | | | | | | | 2,407 |
| | Capital cost (direct) | LC | | | | 2,457 | | | | | | | 2,457 |
| | Total capital cost (direct) *a | | | | | 4,864 | | | | | | | 4,864 |
| | Engineering cost *b | FC | | | | 48 | | | | | | | 48 |
| | Engineering cost *c | LC | | | | 123 | | | | | | | 123 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | 74 | | | | | | | 74 |
| | Physical conting. *e | FC | | | | 120 | | | | | | | 120 |
| | Physical conting. *e | LC | | | | 123 | | | | | | | 123 |
| | O/M cost | FC | | | | | 29 | 30 | 30 | 30 | 31 | 31 | 181 |
| | O/M cost | LC | | | | | 1,826 | 1,868 | 1,911 | 1,955 | 2,000 | 2,046 | 11,607 |
| | Total FC portion | FC | | | | 2,575 | 29 | 30 | 30 | 30 | 31 | 31 | 2,756 |
| | Total LC portion | LC | | | | 2,776 | 1,826 | 1,868 | 1,911 | 1,955 | 2,000 | 2,046 | 14,383 |
| | Total FC + LC *f | | | | | 2,682 | 100 | 102 | 104 | 106 | 108 | 110 | 3,310 |
| | Total FC + LC *a | | | | | 5,351 | 1,856 | 1,898 | 1,941 | 1,986 | 2,031 | 2,077 | 17,140 |
| Recycling at New Guanabacoa | Capital cost (direct) | FC | | | | | | | 1,812 | | | | 1,812 |
| | Capital cost (direct) | LC | | | | | | | 1,957 | | | | 1,957 |
| | Total capital cost (direct) *a | | | | | | | | 3,769 | | | | 3,769 |
| | Engineering cost *b | FC | | | | | | | 36 | | | | 36 |
| | Engineering cost *c | LC | | | | | | | 98 | | | | 98 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | 59 | | | | 59 |
| | Physical conting. *e | FC | | | | | | | 91 | | | | 91 |
| | Physical conting. *e | LC | | | | | | | 98 | | | | 98 |
| | O/M cost | FC | | | | | | | | 30 | 31 | 31 | 92 |
| | O/M cost | LC | | | | | | | | 1,768 | 1,809 | 1,850 | 5,427 |
| | Total FC portion | FC | | | | | | | 1,939 | 30 | 31 | 31 | 2,031 |
| | Total LC portion | LC | | | | | | | 2,211 | 1,768 | 1,809 | 1,850 | 7,639 |
| | Total FC + LC *f | | | | | | | | 2,024 | 98 | 100 | 102 | 2,324 |
| | Total FC + LC *a | | | | | | | | 4,150 | 1,798 | 1,839 | 1,881 | 9,669 |

## Table 25-2 Fund Requirement of Master Plan Components (2005 constant price: 2/4)

(FC: US$'000, LC: CUP'000, Total: US$'000, current prices)

| | | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Collection vehicle replacement | Capital cost (direct) | FC | | | 6,544 | 271 | 2,459 | 2,074 | | 3,238 | | | 14,586 |
| | Capital cost (direct) | LC | | | | | | | | | | | 0 |
| | Total capital cost (direct) *a | | | | 6,544 | 271 | 2,459 | 2,074 | | 3,238 | | | 14,586 |
| | Engineering cost *b | FC | | | 136 | | 153 | | | | | | 289 |
| | Engineering cost *c | LC | | | | | | | | | | | 0 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | | | | | 0 |
| | Physical conting. *e | FC | | | 327 | 14 | 123 | 104 | | 162 | | | 729 |
| | Physical conting. *e | LC | | | | | | | | | | | 0 |
| | O/M cost | FC | | | 636 | 643 | 765 | 828 | 836 | 1,007 | 1,017 | 1,027 | 6,759 |
| | O/M cost *g | LC | | | 5,846 | 5,980 | 6,828 | 8,573 | 8,771 | 10,000 | 10,230 | 10,466 | 66,694 |
| | Total FC portion | FC | | | 7,644 | 927 | 3,501 | 3,006 | 836 | 4,406 | 1,017 | 1,027 | 22,363 |
| | Total LC portion | LC | | | 5,846 | 5,980 | 6,828 | 8,573 | 8,771 | 10,000 | 10,230 | 10,466 | 66,694 |
| | Total FC + LC *f | | | | 7,869 | 1,157 | 3,763 | 3,335 | 1,174 | 4,791 | 1,410 | 1,429 | 24,929 |
| | Total FC + LC *a | | | | 13,490 | 6,907 | 10,328 | 11,579 | 9,607 | 14,407 | 11,247 | 11,493 | 89,058 |
| Improvement of waste bin | Capital cost (direct) | FC | | | | | 1,822 | | | 3,979 | | | 5,801 |
| | Capital cost (direct) | LC | | | | | | | | | | | 0 |
| | Total capital cost (direct) *a | | | | | | 1,822 | | | 3,979 | | | 5,801 |
| | Engineering cost *b | FC | | | | | 114 | | | | | | 114 |
| | Engineering cost *c | LC | | | | | | | | | | | 0 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | | | | | 0 |
| | Physical conting. *e | FC | | | | | 91 | | | 199 | | | 290 |
| | Physical conting. *e | LC | | | | | | | | | | | 0 |
| | O/M cost | FC | | | | | 91 | | | 199 | | | 290 |
| | O/M cost | LC | | | | | | | | | | | 0 |
| | Total FC portion | FC | | | | | 2,118 | | | 4,377 | | | 6,495 |
| | Total LC portion | LC | | | | | | | | | | | 0 |
| | Total FC + LC *f | | | | | | 2,118 | | | 4,377 | | | 6,495 |
| | Total FC + LC *a | | | | | | 2,118 | | | 4,377 | | | 6,495 |
| Maintenance workshop improvement | Capital cost (direct) | FC | | | 780 | | | 2,751 | | | | | 3,531 |
| | Capital cost (direct) | LC | | | | | | | | | | | 0 |
| | Total capital cost (direct) *a | | | | 780 | | | 2,751 | | | | | 3,531 |
| | Engineering cost *b | FC | | | 69 | | | | | | | | 69 |
| | Engineering cost *c | LC | | | | | | | | | | | 0 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | | | | | 0 |
| | Physical conting. *e | FC | | | 39 | | | 138 | | | | | 177 |
| | Physical conting. *e | LC | | | | | | | | | | | 0 |
| | O/M cost | FC | | | 39 | 39 | 40 | 178 | 180 | 181 | 183 | 185 | 1,025 |
| | O/M cost | LC | | | 1,093 | 1,118 | 1,144 | 1,243 | 1,271 | 1,301 | 1,331 | 1,361 | 9,862 |
| | Total FC portion | FC | | | 927 | 39 | 40 | 3,067 | 180 | 181 | 183 | 185 | 4,802 |
| | Total LC portion | LC | | | 1,093 | 1,118 | 1,144 | 1,243 | 1,271 | 1,301 | 1,331 | 1,361 | 9,862 |
| | Total FC + LC *f | | | | 969 | 82 | 84 | 3,115 | 228 | 231 | 234 | 237 | 5,181 |
| | Total FC + LC *a | | | | 2,020 | 1,158 | 1,184 | 4,310 | 1,451 | 1,482 | 1,514 | 1,546 | 14,664 |
| Construction of new site | Capital cost (direct) | FC | | | | | 3,987 | 817 | | 2,960 | 9 | 167 | 7,940 |
| | Capital cost (direct) | LC | | | | | 4,881 | | | 2,622 | | | 7,503 |
| | Total capital cost (direct) *a | | | | | | 8,868 | 817 | | 5,582 | 9 | 167 | 15,443 |
| | Engineering cost *b | FC | | 27 | 103 | 43 | 116 | 66 | 4 | 33 | | | 390 |
| | Engineering cost *c | LC | | 14 | 54 | 21 | 34 | 32 | 2 | 36 | | | 192 |
| | Administration | FC | | 14 | 62 | 26 | 69 | 40 | 3 | 21 | | | 236 |
| | Administration *d | LC | | 21 | 80 | 32 | 50 | 48 | 4 | 54 | | | 289 |
| | Physical conting. *e | FC | | | | | 388 | 41 | | 283 | 0 | 8 | 721 |
| | Physical conting. *e | LC | | | | | 488 | | | 262 | | | 750 |
| | O/M cost | FC | | | | | | 474 | 479 | 484 | 489 | 494 | 2,419 |
| | O/M cost | LC | | | | | | 1,059 | 1,083 | 1,107 | 1,121 | 1,146 | 5,516 |
| | Total FC portion | FC | | 41 | 165 | 69 | 4,560 | 1,439 | 487 | 3,780 | 498 | 669 | 11,706 |
| | Total LC portion | LC | | 35 | 134 | 53 | 5,453 | 1,139 | 1,089 | 4,082 | 1,121 | 1,146 | 14,250 |
| | Total FC + LC *f | | | 42 | 170 | 71 | 4,770 | 1,482 | 528 | 3,937 | 541 | 713 | 12,254 |
| | Total FC + LC *a | | | 75 | 299 | 121 | 10,013 | 2,577 | 1,575 | 7,862 | 1,619 | 1,815 | 25,956 |
| Construction of New Guanabacoa | Capital cost (direct) | FC | | | 7,163 | | 3 | 3,854 | | 76 | 3 | | 11,100 |
| | Capital cost (direct) | LC | | | 3,663 | | | 1,644 | | | | | 5,307 |
| | Total capital cost (direct) *a | | | | 10,826 | | 3 | 5,498 | | 76 | 3 | | 16,407 |
| | Engineering cost *b | FC | | | 161 | | 99 | 105 | | | | | 365 |
| | Engineering cost *c | LC | | | 45 | | 35 | 38 | | | | | 118 |
| | Administration | FC | | | 96 | | 60 | 64 | | | | | 219 |
| | Administration *d | LC | | | 66 | | 53 | 57 | | | | | 176 |
| | Physical conting. *e | FC | | | 629 | | 0 | 376 | | 4 | 0 | | 1,010 |
| | Physical conting. *e | LC | | | 366 | | | 164 | | | | | 531 |
| | O/M cost | FC | | | | 150 | 151 | 153 | 155 | 156 | 158 | 159 | 1,082 |
| | O/M cost | LC | | | | 455 | 466 | 477 | 482 | 493 | 504 | 516 | 3,393 |
| | Total FC portion | FC | | | 8,048 | 150 | 314 | 4,553 | 155 | 236 | 161 | 159 | 13,775 |
| | Total LC portion | LC | | | 4,141 | 455 | 553 | 2,380 | 482 | 493 | 504 | 516 | 9,525 |
| | Total FC + LC *f | | | | 8,207 | 167 | 335 | 4,644 | 173 | 255 | 181 | 179 | 14,142 |
| | Total FC + LC *a | | | | 12,189 | 605 | 867 | 6,933 | 636 | 729 | 666 | 675 | 23,300 |

## Table 25-3 Fund Requirement of Master Plan Components (2005 constant price: 3/4)

(FC: US$'000, LC: CUP'000, Total: US$'000, current prices)

| | | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Extension of Calle 100 | Capital cost (direct) | FC | | | 18,209 | 344 | | 10 | | 10 | | | 18,574 |
| | Capital cost (direct) | LC | | | 7,745 | | | | | | | | 7,745 |
| | Total capital cost (direct) *a | | | | 25,954 | 344 | | 10 | | 10 | | | 26,319 |
| | Engineering cost *b | FC | | 102 | 370 | | | | | | | | 472 |
| | Engineering cost *c | LC | | 21 | 97 | | | | | | | | 118 |
| | Administration | FC | | 40 | 143 | | | | | | | | 183 |
| | Administration *d | LC | | 31 | 147 | | | | | | | | 178 |
| | Physical conting. *e | FC | | | 1,612 | 17 | | 1 | | 1 | | | 1,630 |
| | Physical conting. *e | LC | | | 774 | | | | | | | | 774 |
| | O/M cost | FC | | | | 519 | 470 | | | | | | 989 |
| | O/M cost | LC | | | | 934 | 956 | | | | | | 1,890 |
| | Total FC portion | FC | | 142 | 20,334 | 881 | 470 | 11 | | 11 | | | 21,848 |
| | Total LC portion | LC | | 52 | 8,763 | 934 | 956 | | | | | | 10,706 |
| | Total FC + LC *f | | | 144 | 20,671 | 917 | 506 | 11 | | 11 | | | 22,259 |
| | Total FC + LC *a | | | 194 | 29,097 | 1,815 | 1,425 | 11 | | 11 | | | 32,553 |
| Closure of special period dumping sites | Capital cost (direct) | FC | | | | 2,307 | | | | | | | 2,307 |
| | Capital cost (direct) | LC | | | | 3,623 | | | | | | | 3,623 |
| | Total capital cost (direct) *a | | | | | 5,930 | | | | | | | 5,930 |
| | Engineering cost *b | FC | | 16 | 4 | 10 | 7 | | | | | | 38 |
| | Engineering cost *c | LC | | 10 | 2 | 7 | 4 | | | | | | 24 |
| | Administration | FC | | 9 | 3 | 6 | 4 | | | | | | 23 |
| | Administration *d | LC | | 16 | 3 | 10 | 7 | | | | | | 35 |
| | Physical conting. *e | FC | | | | 231 | | | | | | | 231 |
| | Physical conting. *e | LC | | | | 362 | | | | | | | 362 |
| | O/M cost | FC | | | | | | | | | | | 0 |
| | O/M cost | LC | | | | | | | | | | | 0 |
| | Total FC portion | FC | | 26 | 7 | 2,554 | 12 | | | | | | 2,599 |
| | Total LC portion | LC | | 26 | 5 | 4,002 | 11 | | | | | | 4,044 |
| | Total FC + LC *f | | | 27 | 7 | 2,708 | 12 | | | | | | 2,754 |
| | Total FC + LC *a | | | 52 | 13 | 6,556 | 23 | | | | | | 6,643 |
| Closure of Calle 100 | Capital cost (direct) | FC | | | | 2,024 | | | | | | | 2,024 |
| | Capital cost (direct) | LC | | | | 3,124 | | | | | | | 3,124 |
| | Total capital cost (direct) *a | | | | | 5,148 | | | | | | | 5,148 |
| | Engineering cost *b | FC | | 60 | 14 | 65 | | | | | | | 139 |
| | Engineering cost *c | LC | | 37 | 9 | 41 | | | | | | | 86 |
| | Administration | FC | | 37 | 9 | 40 | | | | | | | 86 |
| | Administration *d | LC | | 55 | 13 | 61 | | | | | | | 130 |
| | Physical conting. *e | FC | | | | 202 | | | | | | | 202 |
| | Physical conting. *e | LC | | | | 312 | | | | | | | 312 |
| | O/M cost | FC | | | | | | | | | | | 0 |
| | O/M cost | LC | | | | | | | | | | | 0 |
| | Total FC portion | FC | | 97 | 24 | 2,330 | | | | | | | 2,451 |
| | Total LC portion | LC | | 92 | 21 | 3,538 | | | | | | | 3,651 |
| | Total FC + LC *f | | | 100 | 25 | 2,467 | | | | | | | 2,591 |
| | Total FC + LC *a | | | 189 | 45 | 5,868 | | | | | | | 6,102 |
| Closure of Extended Area of Calle 100 | Capital cost (direct) | FC | | | | | | | | 219 | | | 219 |
| | Capital cost (direct) | LC | | | | | | | | 363 | | | 363 |
| | Total capital cost (direct) *a | | | | | | | | | 582 | | | 582 |
| | Engineering cost *b | FC | | 22 | 21 | | | | 10 | | | | 53 |
| | Engineering cost *c | LC | | 14 | 13 | | | | 7 | | | | 34 |
| | Administration | FC | | 15 | 14 | | | | | | | | 30 |
| | Administration *d | LC | | 21 | 19 | | | | | | | | 40 |
| | Physical conting. *e | FC | | | | | | | | 22 | | | 22 |
| | Physical conting. *e | LC | | | | | | | | 36 | | | 36 |
| | O/M cost | FC | | | | | | | | | | | 0 |
| | O/M cost | LC | | | | | | | | | | | 0 |
| | Total FC portion | FC | | 38 | 35 | | | | 10 | 241 | | | 323 |
| | Total LC portion | LC | | 35 | 32 | | | | 7 | 400 | | | 474 |
| | Total FC + LC *f | | | 39 | 36 | | | | 10 | 256 | | | 341 |
| | Total FC + LC *a | | | 72 | 67 | | | | 17 | 640 | | | 797 |
| Closure of Guanabacoa landfill | Capital cost (direct) | FC | | | | | | 1,247 | | | | | 1,247 |
| | Capital cost (direct) | LC | | | | | | 1,997 | | | | | 1,997 |
| | Total capital cost (direct) *a | | | | | | | 3,244 | | | | | 3,244 |
| | Engineering cost *b | FC | | | | 21 | 4 | 21 | | | | | 46 |
| | Engineering cost *c | LC | | | | 12 | 3 | 14 | | | | | 29 |
| | Administration | FC | | | | 12 | 3 | 13 | | | | | 28 |
| | Administration *d | LC | | | | 19 | 6 | 21 | | | | | 45 |
| | Physical conting. *e | FC | | | | | | 125 | | | | | 125 |
| | Physical conting. *e | LC | | | | | | 200 | | | | | 200 |
| | O/M cost | FC | | | | | | | | | | | 0 |
| | O/M cost | LC | | | | | | | | | | | 0 |
| | Total FC portion | FC | | | | 33 | 7 | 1,406 | | | | | 1,447 |
| | Total LC portion | LC | | | | 31 | 9 | 2,231 | | | | | 2,270 |
| | Total FC + LC *f | | | | | 34 | 8 | 1,492 | | | | | 1,534 |
| | Total FC + LC *a | | | | | 64 | 16 | 3,637 | | | | | 3,717 |

## Table 25-4 Fund Requirement of Master Plan Components (2005 constant price: 4/4)

(FC: US$'000, LC: CUP'000, Total: US$'000, current prices)

| | | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Central workshop improvement | Capital cost (direct) | FC | | | 139 | | 4 | | | 143 | 4 | | 291 |
| | Capital cost (direct) | LC | | | | | | | | | | | 0 |
| | Total capital cost (direct) *a | | | | 139 | | 4 | | | 143 | 4 | | 291 |
| | Engineering cost *b | FC | | | | | | | | | | | 0 |
| | Engineering cost *c | LC | | | | | | | | | | | 0 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | | | | | 0 |
| | Physical conting. *e | FC | | | 7 | | 0 | | | 7 | 0 | | 15 |
| | Physical conting. *e | LC | | | | | | | | | | | 0 |
| | O/M cost | FC | | | 4 | 20 | 19 | 19 | 19 | 20 | 20 | 20 | 141 |
| | O/M cost | LC | | | | 275 | 281 | 288 | 294 | 301 | 308 | 315 | 2,062 |
| | Total FC portion | FC | | | 151 | 20 | 23 | 19 | 19 | 170 | 24 | 20 | 446 |
| | Total LC portion | LC | | | | 275 | 281 | 288 | 294 | 301 | 308 | 315 | 2,062 |
| | Total FC + LC *f | | | | 151 | 30 | 34 | 30 | 31 | 181 | 36 | 32 | 525 |
| | Total FC + LC *a | | | | 151 | 295 | 305 | 307 | 314 | 471 | 332 | 335 | 2,508 |
| Awareness raising | Capital cost (direct) | FC | | | | | | | | | | | 0 |
| | Capital cost (direct) | LC | | | | | | | | | | | 0 |
| | Total capital cost (direct) *a | | | | | | | | | | | | 0 |
| | Engineering cost *b | FC | | | | | | | | | | | 0 |
| | Engineering cost *c | LC | | | | | | | | | | | 0 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | | | | | 0 |
| | Physical conting. *e | FC | | | | | | | | | | | 0 |
| | Physical conting. *e | LC | | | | | | | | | | | 0 |
| | O/M cost | FC | | 371 | 374 | 376 | 254 | 301 | 304 | 100 | 55 | 55 | 2,191 |
| | O/M cost | LC | | 269 | 274 | 278 | 182 | 222 | 227 | 55 | 17 | 18 | 1,542 |
| | Total FC portion | FC | | 371 | 374 | 376 | 254 | 301 | 304 | 100 | 55 | 55 | 2,191 |
| | Total LC portion | LC | | 269 | 274 | 278 | 182 | 222 | 227 | 55 | 17 | 18 | 1,542 |
| | Total FC + LC *f | | | 382 | 385 | 386 | 261 | 310 | 313 | 102 | 55 | 56 | 2,250 |
| | Total FC + LC *a | | | 640 | 648 | 654 | 436 | 524 | 532 | 155 | 72 | 73 | 3,733 |
| Environment. monitoring | Capital cost (direct) | FC | | 87 | 74 | 75 | 38 | | | | | | 274 |
| | Capital cost (direct) | LC | | 11 | 29 | 13 | 7 | | | | | | 59 |
| | Total capital cost (direct) *a | | | 98 | 103 | 88 | 45 | | | | | | 333 |
| | Engineering cost *b | FC | | | | | | | | | | | 0 |
| | Engineering cost *c | LC | | | | | | | | | | | 0 |
| | Administration | FC | | | | | | | | | | | 0 |
| | Administration *d | LC | | | | | | | | | | | 0 |
| | Physical conting. *e | FC | | 4 | 4 | 4 | 2 | | | | | | 14 |
| | Physical conting. *e | LC | | 1 | 1 | 1 | 0 | | | | | | 3 |
| | O/M cost | FC | | 26 | 35 | 21 | 55 | 31 | 31 | 31 | 31 | 32 | 293 |
| | O/M cost | LC | | 3 | 3 | 4 | 6 | 6 | 6 | 6 | 6 | 6 | 46 |
| | Total FC portion | FC | | 118 | 113 | 99 | 95 | 31 | 31 | 31 | 31 | 32 | 581 |
| | Total LC portion | LC | | 14 | 34 | 18 | 13 | 6 | 6 | 6 | 6 | 6 | 108 |
| | Total FC + LC *f | | | 118 | 114 | 100 | 96 | 31 | 31 | 31 | 32 | 32 | 585 |
| | Total FC + LC *a | | | 131 | 147 | 118 | 108 | 36 | 37 | 37 | 38 | 38 | 689 |

| | | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | Capital cost (direct) | FC | | 87 | 33,136 | 9,218 | 8,430 | 10,871 | 4,224 | 10,744 | 137 | 288 | 77,135 |
| | Capital cost (direct) | LC | | 11 | 11,437 | 11,225 | 4,887 | 3,640 | 4,525 | 2,986 | | | 38,711 |
| | Total capital cost (direct) *a | | | 98 | 44,573 | 20,443 | 13,317 | 14,512 | 8,749 | 13,730 | 137 | 288 | 115,845 |
| | Engineering cost *b | FC | | 227 | 878 | 220 | 493 | 192 | 96 | 33 | | | 2,139 |
| | Engineering cost *c | LC | | 95 | 219 | 303 | 76 | 84 | 236 | 36 | | | 1,050 |
| | Administration | FC | | 115 | 328 | 84 | 137 | 117 | 3 | 21 | | | 804 |
| | Administration *d | LC | | 144 | 329 | 256 | 115 | 126 | 139 | 54 | | | 1,163 |
| | Physical conting. *e | FC | | 4 | 2,629 | 761 | 610 | 790 | 211 | 683 | 7 | 14 | 5,710 |
| | Physical conting. *e | LC | | 1 | 1,142 | 999 | 488 | 364 | 226 | 299 | | | 3,519 |
| | O/M cost | FC | | 398 | 1,089 | 1,768 | 1,912 | 2,051 | 2,072 | 2,314 | 2,090 | 2,111 | 15,803 |
| | O/M cost | LC | | 272 | 7,216 | 9,045 | 12,464 | 14,530 | 14,858 | 18,696 | 19,075 | 19,514 | 115,671 |
| | Total FC portion | FC | | 832 | 38,059 | 12,051 | 11,581 | 14,021 | 6,607 | 13,794 | 2,234 | 2,413 | 101,591 |
| | Total LC portion | LC | | 522 | 20,344 | 21,828 | 18,032 | 18,744 | 19,984 | 22,071 | 19,075 | 19,514 | 160,114 |
| | Total FC + LC *f | | | 852 | 38,841 | 12,890 | 12,275 | 14,742 | 7,375 | 14,643 | 2,967 | 3,164 | 107,750 |
| | Total FC + LC *a | | | 1,354 | 58,403 | 33,879 | 29,613 | 32,765 | 26,591 | 35,864 | 21,309 | 21,927 | 261,705 |

| Price Escalation Index | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Escalation rate of US$ | 1.0% | 1.01 | 1.02 | 1.03 | 1.04 | 1.05 | 1.06 | 1.07 | 1.08 | 1.09 | 1.10 |
| Escalation rate of CUP | 2.3% | 1.02 | 1.05 | 1.07 | 1.10 | 1.12 | 1.15 | 1.17 | 1.20 | 1.23 | 1.26 |

*a. FC portion (US$) and LC portion (CUP) are added up at exchange rate of US$1=CUP 1

*b. Engineering cost in FC portion will be incurred at the designing stage, which is 2% of the direct capital cost.

*c. Engineering cost in LC portion will be incurred at the designing stage, which is 5% of the direct capital cost.

*d. Administration cost will be incurred during construction/acquisition period, which is 3% of direct capital cost of LC portion.

*e. Physical contingency is 10% of direct construction cost and 5% of direct equipment cost, both for FC and LC portions.

*f. FC portion (US$) and LC portion (CUP) are added up at exchange rate of US$1= CUP26

## Table 26 Financial Cash Flow of the Master Plan (2005 constant price)

(FC:US$ million, LC:CUP million)

| Year | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cost | | | | | | | | | | | |
| Composting | FC | 0.0 | 0.0 | 0.2 | 1.9 | 0.2 | 0.2 | 2.4 | 0.2 | 0.2 | 0.2 |
| | LC | 0.0 | 0.0 | 0.0 | 2.2 | 0.7 | 0.7 | 3.2 | 1.4 | 1.4 | 1.4 |
| Recycling | FC | 0.0 | 0.0 | 0.0 | 2.5 | 0.0 | 0.0 | 1.8 | 0.1 | 0.1 | 0.1 |
| | LC | 0.0 | 0.0 | 0.0 | 2.5 | 1.6 | 1.6 | 3.5 | 3.1 | 3.1 | 3.1 |
| Collection & Transportation | FC | 0.0 | 0.0 | 8.3 | 0.9 | 5.4 | 5.7 | 0.9 | 8.3 | 1.1 | 1.1 |
| | LC | 0.0 | 0.0 | 6.5 | 6.5 | 7.1 | 8.6 | 8.6 | 9.4 | 9.4 | 9.4 |
| Final Disposal | FC | 0.0 | 0.3 | 27.9 | 5.8 | 5.1 | 7.0 | 0.6 | 4.1 | 0.6 | 0.8 |
| | LC | 0.0 | 0.2 | 12.2 | 8.5 | 6.5 | 5.3 | 1.6 | 4.4 | 1.6 | 1.6 |
| Awareness raising | FC | 0.0 | 0.4 | 0.4 | 0.4 | 0.2 | 0.3 | 0.3 | 0.1 | 0.1 | 0.1 |
| | LC | 0.0 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 |
| Environmental monitoring | FC | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | LC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| MP Cost Total | FC | 0.0 | 0.8 | 36.9 | 11.6 | 11.0 | 13.2 | 6.2 | 12.7 | 2.0 | 2.2 |
| | LC | 0.0 | 0.5 | 19.0 | 19.9 | 16.1 | 16.4 | 17.0 | 18.4 | 15.5 | 15.5 |
| Salvage Value | FC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -21.9 |
| | LC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | -9.7 |
| TOTAL | FC | 0.0 | 0.8 | 36.9 | 11.6 | 11.0 | 13.2 | 6.2 | 12.7 | 2.0 | -19.7 |
| | LC | 0.0 | 0.5 | 19.0 | 19.9 | 16.1 | 16.4 | 17.0 | 18.4 | 15.5 | 5.9 |
| Total Cost* | | 0.0 | 0.8 | 37.7 | 12.3 | 11.6 | 13.8 | 6.8 | 13.4 | 2.6 | -19.5 |
| Benefit | | | | | | | | | | | |
| Compost Products | LC | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 3.3 | 3.7 | 9.8 | 10.8 | 11.8 |
| Recycle Products | FC | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.2 | 0.6 | 0.7 | 0.7 |
| | LC | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 | 0.7 | 0.9 | 2.1 | 2.4 | 2.8 |
| Tariff Revenue from Inhabitants | FC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | LC | 0.0 | 5.2 | 5.6 | 5.9 | 6.3 | 6.7 | 7.1 | 7.5 | 7.8 | 8.2 |
| Tariff Revenue from Institute | FC | 0.0 | 0.7 | 0.8 | 0.8 | 0.9 | 0.9 | 1.0 | 1.1 | 1.1 | 1.2 |
| | LC | 0.0 | 3.6 | 3.8 | 4.1 | 4.4 | 4.6 | 4.9 | 5.2 | 5.5 | 5.7 |
| Tipping Fee Revenue | FC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | LC | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 |
| Total | FC | 0.0 | 0.7 | 0.8 | 0.8 | 1.1 | 1.2 | 1.2 | 1.7 | 1.8 | 1.9 |
| | LC | 0.0 | 8.8 | 9.4 | 10.1 | 13.9 | 15.6 | 16.8 | 24.7 | 26.8 | 28.8 |
| Total Benefit* | | 0.0 | 1.1 | 1.1 | 1.2 | 1.6 | 1.8 | 1.9 | 2.6 | 2.8 | 3.0 |
| Balance | | 0.0 | 0.2 | -36.5 | -11.1 | -10.0 | -12.1 | -4.9 | -10.8 | 0.2 | 22.5 |
| | | | | | | | | | | | |
| Base Case | | | | | | | | | | | |
| O&M Cost | FC | 0.0 | 0.4 | 1.1 | 1.7 | 1.8 | 1.9 | 1.9 | 2.1 | 1.9 | 1.9 |
| | LC | 0.0 | 0.3 | 6.7 | 8.3 | 11.1 | 12.7 | 12.7 | 15.6 | 15.5 | 15.5 |
| Bakance | FC | 0.0 | 0.3 | -0.3 | -0.9 | -0.8 | -0.8 | -0.7 | -0.5 | -0.1 | -0.0 |
| | LC | 0.0 | 8.5 | 2.7 | 1.8 | 2.8 | 2.9 | 4.1 | 9.1 | 11.3 | 13.2 |
| | | 0.0 | 0.7 | -0.2 | -0.8 | -0.6 | -0.7 | -0.5 | -0.1 | 0.3 | 0.5 |
| Alternative Case | | | | | | | | | | | |
| Balance | FC | 0.0 | -0.1 | -36.2 | -10.7 | -10.0 | -12.1 | -4.9 | -11.1 | -0.3 | 21.6 |
| | LC | 0.0 | 8.3 | -9.6 | -9.9 | -2.2 | -0.8 | -0.2 | 6.3 | 11.3 | 22.9 |
| | | 0.0 | 0.2 | -36.5 | -11.1 | -10.0 | -12.1 | -4.9 | -10.8 | 0.2 | 22.5 |

# E. Industrial and Medical Waste:

## E1 Questionnaire Survey for Industries

# E1 QUESTIONNAIRE SURVEY TO INDUSTRIES

## 1. Objective of Survey

To collect information about the existing operational conditions and opinions on the industrial solid waste management system generated in the factory in Havana City and problem issues, and future plan for treatment of hazardous waste.

## 2. Area Subject to Survey and Number of Sampling

15 factories located inside of Havana City

## 3. Method of Survey

Data collection with questionnaire, by means of direct interview by visit or indirect inquiry by mailing to sample industries

## 4. Main Items Included in Questionnaire

| Subject | Questions |
|---|---|
| General conditions | Name of factory, Products of factory, Number of workers, Constructed/Established year, etc. |
| Conditions of waste | Waste generation, Quantity, Type of waste, Type of bins/containers, Hazardous waste, etc. |
| Collection of waste | Times of waste collection per week, Segregation and separate collection, Requirement of collection and disposal, etc. |
| Recycling | Items of recycling, |
| Disposal and dumping of waste | Name of dumping site, Operation of disposal, In charge of transportation and dumping, Methodology of treatment, Monitoring, Waste treatment system, etc. |
| Future Plan | Future plan, etc. |

## 5. Analysis and Data Processing

Being based on the results of the answered questionnaires:

- To analyze the existing conditions of industrial waste disposal and treatment
- To clarify issues related to industrial waste and environmental conditions
- To statistically edit the survey data, especially for generated hazardous waste

## 6. Survey Duration: 10 days

This survey was conducted in the last ten days of March, 2004

## 7. Output

- Survey Reports
- Filled questionnaires

Date:__________________

QUESTIONNAIRE TO FACTORIES

1. Name of factory:___________________________________________________________

2. Number of workers:_________________________________________________________

3. Address of Factory: ________________________________________________________

4. Constructed/Established year:________________________________________________

5. Name of products:__________________________________________________________

6. Production: Name

(1)______________________________unit: __________(___/month_)

(2)______________________________unit:__________ (___/month_)

(3)______________________________unit:__________ (___/month_)

7. Volume of generated waste in factory:

7.1 Municipal solid waste________________ $m^3$/day

7.2 Industrial waste (A+B) _______________ $m^3$/day

-Hazardous waste (A): ______________________ $m^3$/day

-Non-hazardous waste (B):___________________ $m^3$/day

8. Type of hazardous waste: ___________________________________________________

9. Is there hazardous waste treatment facilities in your factory ?

9.1 Yes 9.2 No

10. For those who answered "Yes", please answer following

10.1 Type and name of facilities:_________________________________________

10.2 Capacity: __________________________________kg/day

10.3 Year of Construction/Installation: _____________

11. Number of bins and containers installed in factory

    11.1 Bins: _____________Nos.    Size: ___________________________________

    11.2 Containers: ________Nos.    Size: ___________________________________

12. Times of waste collection per week: ________________Times

13. Do you carry out segregation and separate collection for waste ?

    13.1 Yes    13.2 No

14. For those who answered "Yes", please describe categories:

    Example;    Steel, woods, Glass, Aluminum, Copper,

___________________________________________________________________________

15. Do you have a contract of waste transportation to dumping site and/or treatment of waste?

    15.1 Yes    15.2 No

16. For those who answered "Yes", please describe following:

    16.1 Name of operation companies: ______________________________________

    16.2 Scope of contract: ________________________________________________

    16.3 Amount ($) _____________________ /month

17. Dumping site of industrial waste and municipal solid waste: please select the location:

    1) Calle 100
    2) Guanabacoa
    3) Ocho Vias
    4) Municipal landfill site
    5) Provincial landfill site
    6) Others

18. Volume of solid waste dumping to landfill site: _____ $m^3$/week

19. Times of dumping to landfill site per week: ________________Times

20. Do you want equipment or facilities for the treatment of industrial waste?
    20.1 Yes 20.2 No

21. For those who answered “Yes”, please describe required items below:

________________________________________________________________________

________________________________________________________________________

22. Do you have plans of construction/ installation of waste treatment facilities?
    22.1 Yes 22.2 No

23. For those who answered “Yes”, please describe following:

    23.1 Proposed year: ______________________________________________

    23.2 Name of facilities: __________________________________________

24. Do you have willing to carry out monitoring of hazardous waste?
    24.1 Yes 24.2 No

25. How do you think treatment of hazardous waste in future?
    25.1 Recommend self treatment system by each factory
    25.2 Would like to request other company
    25.3 Recommend construction of centralized plant for treatment
    25.4 No idea

26. Do you want to preserve environment in Havana City area as it is?
    26.1 Yes, never change by any development
    26.2 Yes, but some developments to improve residents’ life are acceptable.
    26.3 No, I do not mind any development is done.
    26.4 No, but if living and natural environment can be kept as it is or better.

27. If you have comments, opinions and troubles concerning the industrial waste management, please describe below:

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

Thank you very much for your kind cooperation.

# Survey Data of Questionnaire for Industries

## Survey Data of Industries (1/4)

| No. | Enterprises | Solid Waste | Quantity | Unit | Reuse | Quantity | Unit |
|---|---|---|---|---|---|---|---|
| 1 | *"El Lucero" Pasteurizing Factory* | Polyethylene | 30 | t | NR (contaminated with milk) | | |
| | | Broken Boxes | 300 | u | Recycling | 300 | u |
| 2 | *"Beatriz" Pasteurizing Factory* | Paper | 5,800 | B | For cereal boxes | 4,385 | B |
| | | Pots 125 cc | 3 | Kg/y | NR (the raw material enterprise does not collect it, because of the lithography. | | |
| | | Plastic buckets | 850 | | For yogurt and ice cream pots. | 800 | |
| | | Broken baskets | 400 | | Reprocessing | 400 | |
| | | White glass | 30 | t | Reprocessing | 30 | t |
| 3 | *"Havana" Refractory Factory (for firebricks)* | Small pieces and sweepings | 11,800 | t/y | As raw materials for maintenance | 11,800 | t/y |
| 4 | *Coppelia Ice cream Factory* | Ordinary Paper | 1,833 | t | Raw material Enterprise | 1,833 | t |
| | | Cans of 5 gallons | 437 | u | Raw material Enterprise | 437 | u |
| | | Polyethylene | 4,118 | t | Raw material Enterprise | 4,118 | t |
| | | Polypropylene bags | 2,502 | u | Raw material Enterprise | 2,502 | u |
| | | Jute bags | 250 | u | Raw material Enterprise | 250 | u |
| | | Plastic buckets | 32,000 | u | | 32,000 | u |
| | | Large buckets | 1,100 | u | Raw material Enterprise | 1,100 | u |
| | | Tops of buckets | 2, 000 | u | | 2,000 | u |
| | | Egg shells | 0.633 | t | NR | | |
| 5 | *COLFA* | Iron inner part | 90 | u/y | For the production of dry and low voltage transformers. | 90 | u/y |
| | | Copper | 23 | t/y | As raw materials | 23 | t/y |
| | | Scrap iron | 290 | t/y | As raw materials | 290 | t/y |
| 6 | *Suchel Camacho SA* | Plastic Flasks | 56 | t/y | As raw materials | 56 | t/y |
| | | Glass Flasks | 43 | t/y | As raw materials | 43 | t/y |
| | | Cardboard Boxes | 25 | t/y | As raw materials | 25 | t/y |
| 7 | *HILATEX Textile Factory* | Burlap | 7.3 | t/y | It is used in the same enterprise in the maintenance workshops. | 7.3 | t/y |
| | | Scrapings | 10 | t/y | To manufacture dishcloth, remnant, layettes, etc | 10 | t/y |
| 8 | *Jose Marti Airport* | Iron Scraps | 21 | t/y | As raw materials | 21 | t/y |
| | | Paper and Cardboard | 3 | t/y | As raw materials | 3 | t/y |

**Survey Data of Industries (2/4)**

| No. | Enterprises | Solid Waste | Quantity | Unit | Reuse | Quantity | Unit |
|---|---|---|---|---|---|---|---|
| 9 | *Electronically Factory* | Steel, tin.<br>Plastic waste<br>Cardboard and paper | 38<br><br>7 | t/y<br><br>t/y | As raw materials<br>It is reinserted in the production process<br>As raw materials | 38<br><br>7 | t/y<br><br>t/y |
| 10 | *LABIOFAM (PU 1-2 and 5)* | Plastic divisions<br>Cardboard divisions<br>Defective pots and burrs<br>Food waste | 8,640<br>8,640<br>172.8<br>5,184 | cb/y<br>cb/y<br>t/y<br>t/y | Division of pots<br>For file manufacturing<br>It is reinserted in the production process<br>Food supplement | 8,640<br>8,640<br>172.8<br>5,184 | cb/y<br>cb/y<br>t/y<br>t/y |
| 11 | *Santiago de las Vegas Slaughterhouse of poultry* | Feather, entrails, heads | 50 | t/y | Production of flour for animal consumption | 50 | t/y |
| 12 | *"Villena Revolucion" Pigs Raising Farm* | Offal of agriculture (straw, pods, etc)<br>Animal manure | 60<br>1,200 | t/y<br>t/y | Ground, it is part of the fodder for animal consumption<br>For the production of Compost and vermin production | 60<br>1,200 | t/y<br>t/y |
| 13 | *"La Estrella" Candies Factory* | Cardboard Boxes<br>Sweepings | 1,200<br>2,000 | u<br>t/y | As raw materials<br>For animal consumption | 1,120<br>2,000 | u<br>t/y |
| 14 | *Managua Cheese Factory* | Soy bean shell (20.1 t) | | | For animal Consumption (20.1 t) | | |
| 15 | *"8 de octubre" Rural Junior High School* | Crops waste, leaves, cattle manure, waste in general | 350 | $m^{3/}y$ | Organic fertilizer | 350 | $m^{3/}y$ |
| 16 | *"La Vaquita" Veal Factory* | Small pieces of leather for shoe making<br>Shavings of leather for shoe making | 4,000<br>80 | $m^2/y$<br>t/y | To manufacture the gloves used for cutting cane<br>For conglomerates | | |
| 17 | *Antillana de Acero Factory (Steel factory)* | Fragmented silica sand.<br>Metal scraps<br>Shells from the mill | 720<br>1,055<br>100 | t/y<br>t/y<br>t/y | In other activities that do not require special granulometry<br>For steel melting<br>Other uses | 720<br>1,055<br>100 | t/y<br>t/y<br>t/y |
| 18 | *"Guido Lopez" Beer Enterprise* | Bran | 1,926 | t/y | For animal consumption | 1,926 | t/y |
| 19 | *Havana Complex for Dairy Products* | Soy beans skin<br>Metal scrap<br>Reusable Plastics | 95.6<br>136<br>31.5 | t/y<br>t/y<br>t/y | For animal consumption<br>As raw materials<br>As raw materials for the production of high demand products. | 95.6<br>136<br>31.5 | t/y<br>t/y<br>t/y |

**Survey Data of Industries (3/4)**

| No. | Enterprises | Solid Waste | Quantity | Unit | Reuse | Quantity | Unit |
|---|---|---|---|---|---|---|---|
| 20 | *"9 de Abril" Textile Factory* | Textile remnant and cotton sweepings | 1,102 | kg/y | For the production of mattresses | 1,102 | kg/y |
| | | Steel scraps | 1,557 | t/y | As raw materials | 1,557 | kg/y |
| 21 | *"Aulet y Casals" Joints Factory* | Steel scraps | 340 | t/y | As raw materials | 245 | t/y |
| 22 | *Regil Roasting Factory* | Shells | 235 | t/y | For animal consumption | 200 | t/y |
| 23 | *"Diaz Machado" Fusing Factory. (Metal fittings plant)* | Scunps, defective parts, metal chips, shavings, and strapping scraps. | 400 | t/y | As raw materials | 400 | t/y |
| 24 | *Factory for Guarina Ice creams* | Boxes 125 cc | 500 | u/y | As raw materials | 480 | u/y |
| | | Boxes 250 cc | 900 | u/y | As raw materials | 850 | u/y |
| | | Large buckets of 5.5 | 1,400 | u/y | As raw materials | 1,150 | u/y |
| | | Pots of 2 L | 30 | u/y | As raw materials | 25 | u/y |
| | | Pots of ½ | 130 | u/y | As raw materials | 130 | u/y |
| 25 | *"La Lechera" Pasteurizing Factory* | Sweepings | 3.32 | t | For animal consumption 3.32 t | 3.32 | t |
| 26 | *INDAL* | Fish offal | 203 | t/y | For animal consumption | 203 | t/y |
| 27 | *Glass Factory* | Broken glass | 1,200 | t/y | It is reinserted in the production process | 1,080 | t/y |
| | | Mold of rejected cast iron | 7 | | It is given to Vulcano forging center | 7 | t/y |
| | | Iron scraps | | t/y | | | |
| | | Remnants of cardboard and packing | 250 | t/y | As raw materials | 250 | t/y |
| | | Sand rejected by the sieve | App 5 | | As raw materials | 4.75 | t/y |
| | | | | t/y | | | |
| | | | 35 | | To build houses for the workers. | 33.5 | t/y |
| 28 | *COPEXTEL* | Plastics | 7 | t/y | They are recycled at the same enterprise | 7 | t/y |
| | | Ferrous metals | 22 | t/y | As raw materials | 22 | t/y |
| | | Non-ferrous metals | 11 | t/y | As raw materials | 11 | t/y |
| | | Paper and cardboard | 3 | t/y | As raw materials | 3 | t/y |
| 29 | *"Chenard Piña" Factory* | Sweepings for the production of powder soft drinks, jellies, custards, chocolate, small cakes, and flavored desserts (all in powder) | 1,040 | t/y | As raw materials | 1,040 | t/y |

**Survey Data of Industries (4/4)**

| No. | Enterprises | Solid Waste | Quantity | Unit | Reuse | Quantity | Unit |
|---|---|---|---|---|---|---|---|
| 30 | *"J.A. Echeverria" Cereals Factory* | Bran, thick and fine bran of wheat, also wheat germ derived from the production of wheat flour | 36,000 | t/y | Fodder and human consumption | 36,000 | t/y |
| 31 | *"Ñico Lopez" Refinery* | The recovered slop in the treatment system | 14 | t | Mainly, it is reinserted in the distillation plant | | |
| 32 | *PRODAL Enterprise* | Solid waste from the production | 576 | t/y | Animal consumption | 576 | t/y |
| 33 | *T. Lima Grains Mill* | Bran, thick and fine bran of wheat, also wheat germ derived from the production of wheat flour | 9,500 | t/y | Fodder and human consumption | 9,500 | t/y |
| 34 | *Roasting Factory for Pilon Coffee* | Shells | 1,050 | t/y | For animal consumption | 970 | t/y |

Data Source: CITMA 2003

Remarks:

| | | | |
|---|---|---|---|
| Kg: kilogram | t/y: tons per year | u: units | t: ton |
| B: bag | cb/y: cardboards per year | NR: not reused | u/y: unit per year |

# Table. The Result of QA Survey (1/4)

| No. | Item | Answer | | | | |
|---|---|---|---|---|---|---|
| 1 | **Name** | **Mario Muñoz Pharmaceuticals Lab** | **La Estrella Candy Factory** | **PRODAL Enterprise** | **INDAL** | **Habana Dairy Complex** |
| 2 | **Total staff** | 96 | 427 | 1 000 | 300 | 1 124 |
| 3 | **Address of the factory** | Hacendado #1, Habana Vieja | Calle Vega y Via Blanca, Cerro | Pereira y Litoral s/n , Regla | Calle Hacendado # 55, H. Vieja | Ave Monumental Km 23 1/2, Cotorro |
| 4 | **Construction year** | 1939 | | 1964 | 1964 | 1974 |
| 5 | **Type of product(s)** | Natural medicine and medicine obtained by synthesis | Chocolates, candies, cookies (1 643 ton/y) | Sausages and canned chicken | Fish sausages and canned food | Natural yogurt, milk, ice cream, cheese |
| | a) Yield | See remarks | all mentioned above (149.36 ton /m) | all mentioned above (496 t/m) | canned food (1 700 t/y) | cheese (1 200 t/y) ice cream (1 480 000 gallons/year) milk (7 988 t/y) yogurt (2 733 t/y) |
| 6 | **Amount of generated waste** | | | | | |
| | a) Urban solid waste in m3/day | 0.048 | 0.21 | 0.5 | 0.15 | 0.56 |
| | b) Industrial waste in m3/day | -2 | 0.7 | | | 0.3 |
| 7 | **Type of hazardous waste** | NA | NA | NA | NA | NA |
| 8 | **No. of Containers and Amplirolls** | | | | | |
| | a) Containers (of 0.8 m3) | 2 | 2 | 2 | 2 | 3 |
| | b) Amplirolls | | | | | |
| 9 | **Frequency of collection in a week** | 3 times | 2 times (done by the enterprise) | 2 times (done by the enterprise) | 2 times (done by the enterprise) | 2 times (done by the enterprise) |
| 10 | **Segregation of waste for collection** | Yes | Yes | Yes | Yes | Yes |
| | a) Examples | Glass, cardboard, paper, polyethylene bags | Cardboard boxes | Cardboard | Wood | Plastics, metal scraps |
| 11 | **Contract for transport to dumping site or waste treatment** | Yes | No | No | No | No |
| | a) Name of the enterprise | Aurora | | | | |
| | b) Scope of the contract | Collect and discharge at dumping site | | | | |
| | c) Monthly cost | 120 Cuban pesos | | | | |
| 12 | **Dumping site used for industrial waste and USW** | Ocho Vias | Ocho Vias | Ocho Vias | Ocho Vias | Ocho Vias |
| 13 | **Amount of waste carried to dumping site in m3 per week** | 0.3 | 1.3 | 3 | 1 | 5 |
| 14 | **Frequency of discharge at the dumping site per week** | 3 times | 2 times | 2 times | 2 times | 2 times |
| 15 | **Need for treatment equipment or facilities as to industrial waste** | No | No | No | No | No |
| | a) Name the equipment | | | | | |
| 16 | **Plans of building or installing a new treatment plant** | No | No | No | No | No |
| | a) Mention date | | | | | |
| 17 | **waste** | Yes | Yes | Yes | Yes | Yes |
| 18 | **In your opinion, how the hazardous waste management should be done** | I recommend the implementation of treatment systems by every factory | I recommend the implementation of treatment systems by every factory | I recommend the implementation of treatment systems by every factory | I recommend the implementation of treatment systems by every factory | I recommend the implementation of treatment systems by every factory |
| 19 | **Do you wish that the capital's current environmental condiditions continue?** | No, but I would only agree to accept changes that do not harm the environment | No, but I would only agree to accept changes that do not harm the environment | No, but I would only agree to accept changes that do not harm the environment | No, but I would only agree to accept changes that do not harm the environment | No, but I would only agree to accept changes that do not harm the environment |
| 20 | **Remarks:** | **Natural products:**<br>Vimang - 1.5 -2 ton/month<br>Propolis extract - 100-150kg/month<br>Aloe extract - 2 500 l/month<br>Aloe shampoo- 20 000 containers of 200 ml/month | Reuse of waste:<br>cardboard boxes-1 200 for raw material<br>sweepings- 2 000 t /y for animal<br>consumption | Of the waste generated by the production of canned chicken and sausages<br>270 t/y are devoted to animal foods.<br>* The non hazardous waste is reused in the production of animal foods. | 203 t/y of fish waste is used in the production of animal foods | Reuse of waste:<br>soy shells - 95.6 t/y for animal foods<br>metal scraps- 136 t/y for raw materials<br>recyclable plastic- 31.5 t/y for raw material |

RME : Law materials Recovery Enterprise

# Table. The Result of QA Survey (2/4)

| Item | Answer | | | | |
|---|---|---|---|---|---|
| Name | Beatriz Pasteurizing Factory | El Lucero Pasteurizing Factory | Guarina Ice creams Factory | Coppelia Ice creams Factory | Suchel Camacho |
| **Total staff** | 220 | 360 | 120 | 180 | 240 |
| **Address of the factory** | Sta. Beatriz # 71 e/1ra y 2da, Vibora, Arroyo Naranjo | Carretera Lucero # 35, Calzada Managua, Arroyo Naranjo | oncho 54, esquina Via Blana, H. Viej | e. Independencia, Km 7 1/2 , Boyero | Boyeros |
| **Construction year** | | | 1933 | | |
| **Type of products)** | Natural yogurt, soy yogurt, goat's milk | Concentrated milk, fresh cream, soy milk | Ice cream production | Ice creams | Perfumes, toilet soap, detergent |
| a) Yield | Natural yogurt - 3 612 t/y<br>Soy yogurt - 5 800 t/y<br>Goat's milk - 60 t/y | Concentrated milk- 14 130 t/y<br>Fresh cream- 20t/y Soy milk- 860 t/y | Ice creams - 700 gallons per year | Ice creams - 980 gallons per day | Total production - 114.6 t/y |
| **Amount of generated waste** | | | | | |
| a) Urban solid waste in m3/day | 0.11 | 0.18 | 0.06 | 0.09 | 0.12 |
| b) Industrial waste in m3/day | | | | | 0.45 |
| **Type of hazardous waste** | NA | NA | NA | NA | NA |
| **No. of Containers and Amplirolls** | | | | | |
| a) Containers (of 0.8 m3) | 2 | 2 | 2 | 2 | 3 |
| b) Amplirolls | | | | | |
| **Frequency of collection in a week** | 1 time (done by the enterprise) | 2 times (done by the enterprise) | 1 time | 1 time | 2 times |
| **Segregation of waste for collection** | Yes | Yes | Yes | Yes | Yes |
| a) Examples | Glass, paper, plastic buckets | Broken plastic boxes | Boxes and plastic pots | Paper, cans, sacks, plastic buckets | Glass , plastics, boxes, cardboards |
| **Contract for transport to dumping site or waste treatment** | No | No | No | No | No |
| a) Name of the enterprise | | | | | |
| b) Scope of the contract | | | | | |
| c) Monthly cost | | | | | |
| **Dumping site used for industrial waste and USW** | Ocho Vias | Ocho Vias | Ocho Vias | Ocho Vias | Ocho Vias |
| **Amount of waste carried to dumping site in m3 per week** | 0.11 | 1.08 | 0.36 | 0.54 | 3.4 |
| **Frequency of discharge at the dumping site per week** | I time | 2 times | 1 time | 1 time | 2 times |
| **Need for treatment equipment or facilities as to industrial waste** | No | No | No | No | No |
| a) Name the equipment | | | | | |
| **Plans of building or installing a new treatment plant** | No | No | No | No | No |
| a) Mention date | | | | | |
| **Will to monitor hazardous and infectious waste** | Yes | Yes | Yes | Yes | Yes |
| **In your opinion, how the hazardous waste management should be done** | I recommend the implementation of the treatment system by every factory | I recommend the implementation of the treatment system by every factory | I recommend the implementation of the treatment system by every factory | I recommend the implementation of the treatment system by every factory | I recommend the implementation of the treatment system by every factory |
| **Do you wish that the capital's current environmental conditions continue?** | No, but I would only agree to accept changes that do not harm the environment | No, but I would only agree to accept cahnges that do not harm the environment | No, but I would only agree to accept changes that do not harm the environment | No, but I would only agree to accept changes that do not harm the environment | No, but I would only agree to accept the ones that do not harm the environment |
| **Remarks:** | Reuse of waste:<br>Paper - 5 800 sacks for cereal boxes<br>Plastic buckets - 850 for yogurt and ice cream pots<br>White glass - 30 t for RME.<br>125 cc pots - 3kg/y are not reusable | Reuse of waste:<br>300 boxes per year are devoted to recycling activities<br>* Industrial waste is reused in the production process | Reuse of waste:<br>125 cc boxes - 500 u/y for RME<br>250 cc boxes - 900 u/y for RME<br>I liter pots - 300 u/y for RME<br>1/2 liter pots - 1 30 u/y for RME<br>* | Reuse of waste:<br>Paper - 1 833 t/y for RME<br>5 gallons cans - 437 u/y for RME<br>Polypropylene sacks - 250 u/y for RME<br>Plastic buckets 32 000 u/y for RME | Reuse of the waste:<br>Plastic containers - 56 t/y for RME<br>Glass containers - 43 t/y for RME<br>Cardboard boxes - 25 t/y for RME |

# Table. The Result of QA Survey (3/4)

| No. | Item | Answer | | | |
|---|---|---|---|---|---|
| 1 | **Name** | **Guido Pérez brewery** | **Antillana de Acero(Steelworks)** | **Ñico López Refinery** | **Power Station Maintenance Company** |
| 2 | **Total staff** | 520 | 1167 | 700 | 320 |
| 3 | **Address of the factory** | Carretera Central, km 18, Cotorro | 20 # 10522, Cotorro | Via Blanca y Belot | Calle 100 # 69, Lisa |
| 4 | **Construction year** | 1948 | 1961 | 1955 | |
| 5 | **Type of products)** | Beer | Steelworks | Oil by-products(gasoline,LP6, Asphalt, Kerosene, Diesel) | Manufacture of Air-conditioning systems, repair of electric fans, repair of high-voltage transformers, manufacture of parts |
| | a) Yield | 1524190 packs/year | plain and corrugated bars: 5833.3 kg/month sheets: 1666666 kg/m reinforcement beams: 18333333kg/m | 1449692.83 $m^3$/y total production | |
| 6 | **Amount of generated waste** | | | | |
| | a) Urban solid waste in m3/day | 0.26 | 0.58 | 0.35 | 0.16 |
| | b) Industrial waste in m3/day | | | | |
| 7 | **Type of hazardous waste** | NA | NA | NA | NA |
| 8 | **No. of Containers and Amplirolls** | | | | |
| | a) Containers (of 0.8 m3) | 2 | 5 | 3 | 2 |
| | b) Amplirolls | | 2 | | |
| 9 | **Frequency of collection in a week** | 1 time | 2 times (done by the enterprise) | 2 times (done by the enterprise) | 2 times |
| 10 | **Segregation of waste for collection** | Yes | Yes | Yes | Yes |
| | a) Examples | Glass | steel scrap) | Paper, Slop | |
| 11 | **Contract for transport to dumping site or waste treatment** | No | No | No | No |
| | a) Name of the enterprise | | | | |
| | b) Scope of the contract | | | | |
| | c) Monthly cost | | | | |
| 12 | **Dumping site used for industrial waste and USW** | Ocho Vias | Ocho Vias | Ocho Vias | Ocho Vias |
| 13 | **Amount of waste carried to dumping site in m3 per week** | 1.56 | 3.48 | 2.1 | 1 |
| 14 | **Frequency of discharge at the dumping site per week** | I time | 2 times | 2 times | 2 times |
| 15 | **Need for treatment equipment or facilities as to industrial waste** | No | No | No | No |
| | a) Name the equipment | | | | |
| 16 | **Plans of building or installing a new treatment plant** | No | No | No | No |
| | a) Mention date | | | | |
| 17 | **Will to monitor hazardous and infectious waste** | Yes | Yes | Yes | Yes |
| 18 | **In your opinion, how the hazardous waste management should be done** | I recommend the implementation of the treatment system by every factory | I recommend the implementation of the treatment system by every factory | I recommend the implementation of the treatment system by every factory | I recommend the implementation of the treatment system by every factory |
| 19 | **Do you wish that the capital's current environmental conditions continue?** | No, but I would only agree to accept changes that do not harm the environment | No, but I would only agree to accept changes that do not harm the environment | No, but I would only agree to accept changes that do not harm the environment | No, but I would only agree to accept changes that do not harm the environment |
| 20 | **Remarks:** | Reuse of waste: use 1926 mt/y bran for animal feed | Reuse of waste: silica sand for other works-720 t/y scrap to recycle 1055 t/y filings for other uses 100 t/y | Reuse of waste: The solid waste similar to the domestic waste are disposed with the company's trucks Slop recovered at the treatment systems-14 t/m to inject to distillation plant | Reuse of waste: |

# Table. The Result of QA Survey (4/4)

| No. | Item | Answer | | | | |
|---|---|---|---|---|---|---|
| 1 | **Name** | **Pilón Coffee Roasting Factory** | **El Lucero Pasteurizing Factory** | **Guarina Ice creams Factory** | **Coppelia Ice creams Factory** | **Suchel Camacho** |
| 2 | **Total staff** | 80 | 360 | 120 | 180 | 240 |
| 3 | **Address of the factory** | 26 y 51, Plaza | Carretera Lucero # 35, Calzada Managua, Arroyo Naranjo | Concho 54, esquina Via Blana, H. Vieja | Ave. Independencia, Km 7 1/2 , Boyeros | Boyeros |
| 4 | **Construction year** | 1950 | | 1933 | | |
| 5 | **Type of products)** | Coffee | Concentrated milk, fresh cream, soy milk | Icecream production | Ice creams | Perfumes, toilet soap, detergent |
| | a) Yield | Coffee - 604.7 t/y | Concentrated milk- 14 130 t/y Fresh cream- 20t/y Soy milk- 860 t/y | Ice creams - 700 gallons per year | Ice creams - 980 gallons per day | Total production - 114.6 t/y |
| 6 | **Amount of generated waste** | | | | | |
| | a) Urban solid waste in m3/day | 0.04 | 0.18 | 0.06 | 0.09 | 0.12 |
| | b) Industrial waste in m3/day | | | | | 0.45 |
| 7 | **Type of hazardous waste** | NA | NA | NA | NA | NA |
| 8 | **No. of Containers and Amplirolls** | | | | | |
| | a) Containers (of 0.8 m3) | 2 | 2 | 2 | 2 | 3 |
| | b) Amplirolls | | | | | |
| 9 | **Frequency of collection in a week** | 1 time (done by the enterprise) | 2 times (done by the enterprise) | 1 time | 1 time | 2 times |
| 10 | **Segregation of waste for collection** | Yes | Yes | Yes | Yes | Yes |
| | a) Examples | Glass, paper, plastic buckets | Broken plastic boxes | Boxes and plastic pots | Paper, cans, sacks, plastic buckets | Glass , plastics, boxes, cardboards |
| 11 | **Contract for transport to dumping site or waste treatment** | No | No | No | No | No |
| | a) Name of the enterprise | | | | | |
| | b) Scope of the contract | | | | | |
| | c) Monthly cost | | | | | |
| 12 | **Dumping site used for industrial waste and USW** | Ocho Vias | Ocho Vias | Ocho Vias | Ocho Vias | Ocho Vias |
| 13 | **Amount of waste carried to dumping site in m3 per week** | 0.11 | 1.08 | 0.36 | 0.54 | 3.4 |
| 14 | **Frequency of discharge at the dumping site per week** | I time | 2 times | 1 time | 1 time | 2 times |
| 15 | **Need for treatment equipment or facilities as to industrial waste** | No | No | No | No | No |
| | a) Name the equipment | | | | | |
| 16 | **Plans of building or installing a new treatment plant** | No | No | No | No | No |
| | a) Mention date | | | | | |
| 17 | **Will to monitor hazardous and infectious waste** | Yes | Yes | Yes | Yes | Yes |
| 18 | **In your opinion, how the hazardous waste management should be done** | I recommend the implementation of the treatment system by every factory | I recommend the implementation of the treatment system by every factory | I recommend the implementation of the treatment system by every factory | I recommend the implementation of the treatment system by every factory | I recommend the implementation of the treatment system by every factory |
| 19 | **Do you wish that the capital's current environmental conditions continue?** | No, but I would only agree to accept changes that do not harm the environment | No, but I would only agree to accept changes that do not harm the environment | No, but I would only agree to accept changes that do not harm the environment | No, but I would only agree to accept changes that do not harm the environment | No, but I would only agree to accept the ones that do not harm the environment |
| 20 | **Remarks:** | Reuse of waste:<br>Paper - 5 800 sacks for cereal boxes<br>Plastic buckets - 850 for yogurt and ice cream pots<br>White glass - 30 t for RME.<br>125 cc pots - 3kg/y are not reusable | Reuse of waste:<br>300 boxes per year are devoted to recycling activities<br>* Industrial waste is reused in the production process | Reuse of waste:<br>125 cc boxes - 500 u/y for RME<br>250 cc boxes - 900 u/y for RME<br>I liter pots - 300 u/y for RME<br>1/2 liter pots - 1 30 u/y for RME<br>* | Reuse of waste:<br>Paper - 1 833 t/y for RME<br>5 gallons cans - 437 u/y for RME<br>Polypropylene sacks - 250 u/y for RME<br>Plastic buckets 32 000 u/y for RME | Reuse of the waste:<br>Plastic containers - 56 t/y for RME<br>Glass containers - 43 t/y for RME<br>Cardboard boxes - 25 t/y for RME |

# E. Industrial and Medical Waste:

## E2 Questionnaire Survey for Hospitals

# E2 QUESTIONNAIRE SURVEY TO HOSPITAL

## 1. Objective of Survey

To collect information about the existing conditions and opinions on the medical solid waste management system in hospitals in Havana City and problem issues, and future plan for treatment of generated waste in hospitals.

## 2. Area Subject to Survey and Number of Sampling

5 hospitals located inside of Havana City

## 3. Method of Survey

Data collection with questionnaire, by means of direct interview by visit or indirect inquiry by mailing to sample hospitals

## 4. Main Items Included in Questionnaire

| Subject | Questions |
|---|---|
| General conditions | Name of hospital, Number of beds, Number of doctors and stuff, Constructed/Established year, etc. |
| Conditions of waste | Waste generation, Quantity, Type of waste, Number and type of incinerators, Number of bins/containers, etc. |
| Collection of waste | Times of waste collection per week, Segregation and separate collection, Operation company (organization), Necessity of the segregation, etc. |
| Recycling | Items of recycling, |
| Disposal and dumping of waste | Name of dumping site, Operation of disposal, In charge of transportation and dumping, Methodology of treatment, Monitoring, Waste treatment system, etc. |
| Future Plan | Future plan, etc. |

## 5. Analysis and Data Processing

Being based on the results of the answered questionnaires:

・To analyze the existing conditions of medical waste disposal and treatment
・To clarify issues related to medical waste and environmental conditions
・To statistically edit the survey data, especially for generated hazardous waste

## 6. Survey Duration

This survey was conducted in the last ten days of March, 2004.

## 7. Output

- Survey Reports
- Filled questionnaires

Date:__________________

QUESTIONNAIRE TO HOSPITALS

1. Name of hospital: ______________________________________________

2. Number of beds:______________________________________________

3. Number of doctors and staff:______________________________________

4. Constructed/Established year:____________________________________

5. Type of hospital:______________________________________________

6. Volume of generated waste in hospital (total =a+b):

    6.1 Municipal solid waste (a): __________________$m^{3/}$day

    6.2 Medical waste (b): _________________________$m^3$/day

        (Breakdown) :

        - Hazardous/ infectious waste: __________ $m^3$/day

        - Non Hazardous/ infectious waste: ______ $m^3$/day

        - Non flammable waste: _______________ $m^3$/day

7. Is there incinerator in your hospital?

    7.1 Yes    7.2 No

8. For those who answered "Yes", please answer following:

    Number: _________________set

    Model: __________________

    Capacity: ________________kg/day

    Year of Construction/Installation: _____________

9. Number of bins and containers

Bins: ____________________Nos.

Containers (for medical waste): ________________Nos.

10. Times of waste collection per week: ________________Times

11. Do you carry out segregation and separate collection for medical waste?

11.1 Yes     11.2 No

12. For those who answered "Yes", please describe categories:

Example: Example; syringe, clothes, infectious waste, chemicals, bottles, glass

______________________________________________________________________

13. Do you have a contract of waste transportation to dumping site and/or treatment of waste?

13.1 Yes     13.2 No

14. For those who answered "Yes", please describe following:

14.1 Name of operation companies: _____________________________________

14.2 Scope of contract: ______________________________________________

14.3 Amount ($) _____________________ /month

15. Do you carry out treatment of hazardous/infectious waste?

15.1 Yes     15.2 No

16. For those who answered "Yes", please describe methodology

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

17. Do you have a contract of waste transportation and /or treatment of waste?

    17.1 Yes 17.2 No

18. For those who answered "Yes", please answer following:

    Name of Operation Company: ____________________________________________

    Scope of contract: ______________________________________________________

    Amount ($): ______________________/month

19. Dumping site of medical waste and municipal solid waste, please select the location:

    1) Calle 100
    2) Guanabacoa
    3) Ocho Vias
    4) Municipal landfill
    5) Provincial landfill
    6) Others

20. Volume of solid waste dumping to landfill site: _____________ $m^3$/day

    Number of Bin: _____________Nos.

21. Times of dumping to landfill site per week: _________________Times

22. Do you want equipment or facilities for treatment of medical waste?

    22.1 Yes 22.2 No

23. For those who answered "Yes", please describe required items:

______________________________________________________________________________

______________________________________________________________________________

24. Do you have plans of construction/ installation of new incinerators for medical waste?

    24.1 Yes 24.2 No

25. For those who answered "Yes", please describe proposed year: ____________________

26. Do you have willing to carry out monitoring of hazardous/infectious waste?

    26.1 Yes 26.2 No

27. How do you think treatment of hazardous/infectious waste?

    27.1 Would like to do self treatment in the hospital

    27.2 Would like to request other company/organization by contract

    27.3 Recommend construction of centralized plant for treatment

    27.4 No idea

28. If you have comments, opinion and troubles for the medical waste management, please describe below.

____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

Thank you very much for your kind cooperation.

## Survey Data of Questionnaire for Hospitals

**Survey Data of Hospital**

| No | Item | Answers | | | | |
|---|---|---|---|---|---|---|
| 1 | **Name of Hospital** | *America Arias* | *Calixto Garcia* | *Miguel Enrique* | *Pediatrico de Centro Habana* | *Salvador Allende* |
| 2 | **No. of beds** | 273 | 1 000 | 897 | 303 | 1 085 |
| 3 | **Total staff** | 380 | 2 700 | 1 200 | 430 | 1 548 |
| 4 | **Construction year** | 1892 | 1896 | 1891 | 1895 | 1886 |
| 5 | **Type of Hospital** | Maternity | Clinical and Surgical | Clinical and Surgical | Pedriatic | Teaching Clin. & Surgical |
| 6 | **Amount of generated waste** | | | | | |
| | a) MSW in $m^3$/day | 1.6 | 6.7 | 5.3 | 1.8 | 6.5 |
| | b) Medical waste in $m^3$/day | 0.2 | 1.6 | 1.3 | 0.2 | 1.62 |
| 7 | **Incinerator at the hospital** | Yes | Yes | Yes | Yes | Yes (under repair) |
| | a) Quantity | 1 | 2 | 1 | 1 | 1 |
| | b) Model | Creole | Creole | Creole | Creole | Creole |
| | c) Capacity in kg/day | 65 | 300 | 250 | 70 | 300 |
| 8 | **Year of installation** | 100 years ago | ~100 years ago | ~1891 | ~100 years ago | N/A |
| 9 | **No. of Containers and Amplirolls** | | | | | |
| | a) Containers | 6 | 35 | 6 | 15 | 28 |
| | b) Amplirolls | | | | | |
| 10 | **Frequency of collection** | Daily | Daily | Daily | Daily | Daily |
| 11 | **Segregation waste for collection** | Yes | Yes | Yes | Yes | Yes |
| | **a) Examples** | (all mentioned in the questionnaire) | (all mentioned in the questionnaire) | (all mentioned in the questionnaire) | (all mentioned in the questionnaire) | (all mentioned in the questionnaire) |
| 12 | **Contract for transport to dumping site or waste treatment** | Yes | Yes | Yes | Yes | Yes |
| | a) Name of the enterprise | *Aurora* Hospitals | *Aurora* Hospitals | *Aurora* Hospitals | *Aurora* Hospitals | *Aurora* Hospitals |
| | b) Scope of the contract | free of charge | free of charge | free of charge | free of charge | free of charge |
| | c) Monthly cost | free of charge | free of charge | free of charge | free of charge | free of charge |
| 13 | **Treatment for hazardous and infectious waste** | Yes | Yes | Yes | Yes | Yes |
| | a) Method used | incineration | incineration | incineration | incineration | incineration |
| 14 | **Contract for waste treatment or transport** | Yes | Yes | Yes | Yes | Yes |
| | a) Name of the enterprise | Communal | Communal | Communal | Communal | Communal |
| | b) Scope of the contract | free of charge | free of charge | free of charge | free of charge | free of charge |

**Survey Data of Hospital (Continue)**

| | | | | | | |
|---|---|---|---|---|---|---|
| | **c) Monthly cost** | free of charge | free of charge | free of charge | free of charge | free of charge |
| 15 | **Dumping site used for hospital waste and MSW** | Calle 100 | Calle 100 | Calle 100 | Calle 100 | Calle 100 |
| 16 | **Amount of waste carried to dumping site in m3** | 1.6 | 6.7 | 5,3 | 1,8 | 6,5 |
| | **a) No. of containers** | 6 | 35 | 6 | 15 | 28 |
| 17 | **Frequency of discharge at the dumping site** | Daily | Daily | Daily | Daily | - |
| 18 | **Need for treatment equipment as to hospital waste** | Yes | Yes | Yes | Yes | Yes |
| | a) Name the equipment | Furnace type incinerator | Furnace type incinerator (more modern) | Furnace type incinerator (two chambers) | Furnace type incinerator | Furnace type incinerator (two chambers) |
| 19 | **Plans of building or installing a new incinerator** | Yes | Yes | Yes | Yes | Yes |
| | a) Mention date | In the next 3-years term | In the next 3-years term | In the next 3-years term | In the next 3-years term | In the next 3-years term |
| | Will to monitor hazardous and infectious waste | Yes | Yes | Yes | Yes | Yes |
| 20 | **In your opinion, how the hazardous waste management should be done** | *Waste management shall be done every hospitals | *Waste management shall be done every hospitals | *Waste management shall be done every hospitals | *Waste management shall be done every hospitals | *Waste management shall be done every hospitals |
| 21 | **Remarks:** | *Continue improving the hospital waste management program, that includes the systematic monitoring of this activity. | *Continue improving the hospital waste management program, that includes the systematic monitoring of this activity. | *Continue improving the hospital waste management program, that includes the systematic monitoring of this activity. | *Continue improving the hospital waste management program, that includes the systematic monitoring of this activity. | *Continue improving the hospital waste management program, that includes the systematic monitoring of this activity. |