Observations of Solid Waste Landfills in Developing Countries:

Africa, Asia, and Latin America

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Author Notes

This overview of landfill practices was compiled by Lars Mikkel Johannessen from visits and observations made by the main author to over 50 landfills in Africa, Asia, and Latin America as part of a Danida-supported project to prepare disposal guidance notes. Gabriela Boyer contributed to the writing of this report. Additional material for this overview was provided by Johannessen and other field contacts, together with further comments and suggestions from: Carl Bartone and colleagues at the World Bank, Washington, DC; Rod Ball, Jarrod Ball & Associates; Philip Rushbrook, World Health Organization, Regional Office for Europe; Adrian Coad, Swiss Center for Development Cooperation in Technology and Management; and practitioners and specialists from the visited regions. (*Please see Annex A for a list of regional contacts.*)

Acronyms

BOD	Biological Oxygen Demand
BOT	Build, Operate, and Transfer
CEAMSE	Metropolitan Areas Environmental Authority—Argentina
COD	Chemical Oxygen Demand
DAMA	Administrative Department for the Environment—Colombia
EIA	Environmental Impact Assessment
HDPE	High Density Polyethylene
HZW	Hazardous Waste
JICA	Japan International Cooperation Agency
LAC	Latin America and the Caribbean
MMA	Mexico Medio Ambiente
MoH	Ministry of Health—Chile
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
PE	Polyethylene

1. Executive Summary

The report documents observations from visits in 1997-98 to landfills in the Africa, East Asia and Pacific, and Latin America and Caribbean regions. Specifically, it identifies emerging features, practices, and necessary improvements in the final disposal of solid waste. Also discussed are trends in the regulatory area, private sector involvement, tipping fees, and the impact of waste pickers on sanitary landfills. Finally, the report identifies cross-regional observations, and offers recommendations for improvements in World Bank projects that have solid waste components.

These trends have significant local and even global environmental implications. Information on the environmental effects of methane, for example, was not well disseminated among landfill managers and owners. Of the landfills visited in all three regions, only Hong Kong, Chile, Brazil, and one landfill in South Africa practiced active pumping and flaring of landfill gas. And, while there is potential for *productive uses* of landfill gas, only a few landfills in Chile practiced gas recovery.

The application of daily cover in landfills is a significant issue that should be examined closely. In some cases this application of extra soil accounts for 50% of operating costs. When a low-permeability, clay-type soil is used as a cover, it impedes the subsequent movement of moisture through the deposited waste, slowing bio-degradation of the waste and hindering recirculation of the leachate. The application of soil cover may increase dust levels during dry weather and make walking and driving on the site difficult during wet weather. Daily cover was not being applied at one Hong Kong landfill, and there were no serious nuisances observed there.

Drawing from observations from visits to over 50 landfills, the authors identify three cross-regional findings in waste disposal: the extensive use of daily soil cover on newly deposited or compacted waste, little management of landfill gas, and problematic and often inadequate leachate management measures.

The document is divided into five chapters. Chapter 1 is the executive summary. Chapter 2 provides background, introduces the types of landfills visited, and considers the perceptions, costs, and impacts of the three main environmental concerns associated with landfills. Chapters 3, 4, and 5 review waste disposal in Africa, Asia, and Latin America, respectively.

For each region there are tables describing the sites that were visited, with entries according to the following categories:

- Landfill category
- Waste types received
- Daily tonnage received
- Organization operating at the site
- Tipping fees charged
- Area for waste disposal
- Activities of waste pickers
- Environmental setting
- Type of impervious liner
- Leachate collection system
- Leachate treatment system
- Description of operating techniques
- Equipment (plant) used

The landfills visited in the Africa Region ranged from open dumps to sanitary landfills. Most African countries have a GNP/capita/year of less than US$500 and in many countries much of the basic infrastructure (water supply, wastewater treatment, and solid waste collection) has not been established. While decision-makers in the region were aware that their countries had to upgrade open dumps to sanitary landfills, this was not regarded as a priority in most countries. At the national and municipal levels, few countries have taken steps to construct, operate, or maintain sanitary landfills. Except for South Africa, most countries in Africa practiced open dumping for final disposal of solid waste. Furthermore, South Africa was the only country with specific regulations and guidelines in place governing solid waste landfills.

Nevertheless, several countries in Africa are improving waste disposal practices. Both Ghana and Uganda had plans to initiate properly sited, designed, and constructed landfills under World Bank-financed projects. Other countries, including Tanzania, Botswana, Namibia, and Rwanda, were selecting sites for new landfills. Countries such as Botswana were preparing landfill guidelines, using South Africa's Minimum Requirements as a model.

In 1998, countries in the East Asia and Pacific Region formed one of the most active groups in terms of World Bank investments in solid waste projects. World Bank involvement, combined with bilateral donor activities in the solid waste sector, had increased regional awareness of proper landfill practices among local and national decision-makers. Generally speaking, landfills visited in the region were being upgraded from open dumps to sanitary landfills. While most capital cities in the region were serviced with some level of landfill practice, the majority of the waste in the region was disposed of in open dumps.[1]

All the landfill sites visited in Asia had impermeable liners, typically constructed of clay or plastic. In one case, a bentonite liner was used, and one small landfill had a concrete liner.

In addition to liners, all the landfills provided for leachate collection and some form of treatment. Treatment of leachate using electrically powered aerators was the most common method, but electricity costs seemed to restrict the extent to which the aerators are used, calling into question this concept of treatment. At sites in the Philippines and Malaysia, leachate was being recirculated. Evaporation can reduce volumes of leachate. Records of the efficiency of treatment were not kept during the time of the visits.

Many of the landfills had new operating equipment donated by bilateral organizations. During the visits, however, it was noted that modern equipment often remains idle, as landfill operators do not have proper training or sufficient funds to operate the equipment.

National and regional authorities record and inspect incoming waste but seldom monitor the environmental effects of waste disposal, leading in some cases to weak enforcement of environmental mitigation measures (e.g., a decrease in leachate treatment, or a greater tolerance for open fires on a landfill).

The presence of waste pickers on disposal sites can have a major impact on how the site is operated. Waste pickers pose a safety hazard to themselves and to landfill employees, reducing productivity by interfering with operations at the tipping face and starting fires, which cause serious air pollution. The negative impacts of scavenging have been reduced in some places by formalizing this work, either by employing waste pickers directly or by engaging contractors to do their work. A landfill in San Mateo, the Philippines, employs some of the inhabitants from the nearest squatter community to work at the site. Scavenging was not observed at any of the well-operated landfills visited.

All the landfills visited in Asia were owned by the local municipal or metropolitan government. Supervised by local government employees, private companies increasingly supply and operate equipment at landfills under short-term arrangements (1-5 years). In a best practice example, the Hong Kong government has concession agreements with three private contractors to design, build, and operate their landfills for a period of 30 years. Malaysia has opted to privatize waste disposal by dividing the country into four concession zones.

Few of the landfills visited charged tipping fees for incoming waste upon entry, but in general the fees were enough to cover all costs of the operation. Other forms of revenue collection observed included a landfill tax for the municipality hosting the landfill. The estimated costs for fees in Hong Kong and the Philippines were approximately US$10/tonne, but these did not reflect real disposal costs or cover the cost of leachate treatment.

The Latin America and Caribbean Region accounts for the most active portfolio of World Bank projects that include a municipal solid waste management (MSWM) component. This conforms to historical trends in Bank lending in this region for MSWM activities.

In Latin America, decision-makers and technical specialists are aware of the importance of proper waste disposal but, many countries in the region have limited legislation, regulations, and guidelines. Some countries have made

[1] For an extensive review of solid waste management components in Bank projects in the Latin America and Caribbean, Asia, Europe and Central Asia, Middle East and North Africa, and Africa regions, *see* Gopalan, P., and Bartone, C. "Assessment of Investments in Solid Waste Management: Strategies for Urban Environmental Improvement." World Bank, Washington, DC, 1997, Draft.

headway in this area. In Chile, the government has introduced a series of standards and guidelines in different parts of the country, including requirements for environmental impact assessments (EIAs) and leachate management. These guidelines pay special attention to the influence that climatic conditions may have on waste landfills.

Regardless of the climatic and geological or hydrogeological environment, leachate management for conventional landfills require liners—often composite liner systems—and leachate collection and treatment. Leachate treatment methods ranged from advanced physico-chemical and biological treatment in Argentina and Brazil, to development of pond treatment and enhanced evaporation techniques in Chile. Recirculation of leachate (anticipating storage and eventual evaporation) was also a predominant practice in the region, but in the case of Bogota, Colombia, it was suspected to be the cause of a large slippage or landslide.

In Brazil, good landfill management practices were observed during the visits. Most sites limited waste lifts to approximately 2 meters (m), had limited tipping fronts, were equipped with compaction machinery and bulldozers, and tracked waste accepted for landfilling. Waste pickers were seen working at most open dumps, but not at conventional landfills. Many disposal sites in Brazil have formalized the work of waste pickers. One landfill in Rio de Janeiro provided workers with picking belts; the city of Belo Horizonte had formalized waste picker access to recyclable materials before solid waste arrived at the landfill.

Increasingly, the private sector in Latin America is becoming more involved in waste disposal responsibilities. Private firms customarily operate landfills under concessions of 10-30 years under build, operate, and transfer (BOT) or BOT hybrid contracts (e.g., the municipality invests in and owns the property). A landfill in the Santiago metropolitan area of Chile was the only fully privately owned landfill visited; under the 15-year contract, a private company will receive and transport municipal solid waste (MSW) from selected Santiago municipalities. Other municipalities in Chile came together to form a metropolitan company to build and operate landfills.[2] Under this scenario, the municipalities supervised private contractor services, including the inspection and recording of incoming waste, and the collection of charge fees. Municipal managers, however, may not have the proper training or budget to monitor private companies effectively.

The fees charged for waste disposal averaged US$10 per tonne throughout the region (*see Table 1*). The price did not reflect the landfill size or type of contractual agreement.

Table 1: Tipping Fees and GNP Comparison in Developing Country Landfills

Country	Tipping Fees US$/tonne (app. Range)	1996 GNP Per Capita (US$)
Argentina	5-18	8,410
Chile	5-17	4,920
Brazil	5-18	4,360
Malaysia	1.2	4,300
Mexico	4-17	3,640
South Africa	12	3,140
Peru	5	2,410
Colombia	11	2,190
Philippines	9.7	1,190
Indonesia	1.3	1,090
China	2.5	750
Hong Kong	10	* 22,010

* 1994 data

[2] Farias, Ramon. "La Experiencia de la Municipalidad de San Joaquin, Santiago de Chile," *Seminario Internacional: Capitalizacion de Experiencias en El Manejo de Residuos Solidos en America Latina y El Caribe*, Honduras, July 16-17, 1998.

2. Introduction

2.1 Purpose and Scope of Study

Based on the experiences gained through visits to over 50 final disposal landfills, this report documents observations from landfills in low- and middle-income countries. The landfill visits encompassed Africa (September 21–October 9, 1997), Latin America (June 14–June 29, 1997, and November 9–November 26, 1997), and Asia (January 2–January 19, 1998).

The three regions were selected to research landfill operations in parts of the world where there is a shortage of documented knowledge on the subject. The report complements–and expands–the substantial literature on solid waste management that currently exists in many of the countries visited. Staff from the Ministries of Environment and the Ministries of Health assisted in selecting the sites for the visits.[3]

The report identifies several categories of landfills in these regions and considers three long-term environmental impacts of landfill operations. This document reviews how these environmental impacts are generally perceived, the costs that are involved in controlling them, and their magnitude. The information, as presented in graphical form (*see Figure 1*), indicates that there is a mismatch between the public perception of the importance and the true environmental significance of solid waste management, particularly in the case of pollution by leachate. The graphic provides a framework for the analysis of the *good practice* examples covered in the succeeding chapters. Specifically, the paper discusses waste disposal trends in:

- the regulatory area
- leachate management
- leachate treatment
- landfill gas management
- the impact of waste pickers on sanitary landfills
- tipping fees
- private sector involvement

2.2 Types of Landfills

The following section discusses the different types of landfills visited in the East Asia and Pacific, Latin America and Caribbean, and Africa regions. The *open dump* approach is the primitive stage of landfill development and remains the predominant waste disposal option in most of the countries visited. A default strategy for municipal solid waste management, open dumps involve indiscriminate disposal of waste and limited measures to control operations, including those related to the environmental effects of landfills. As *this is not* an upgrading solution to landfill waste, the open dump approach will be mentioned, but not discussed further in this report.

An operated or semi-controlled dump is often the first stage in a country's efforts to upgrade landfills. Controlled dumps operate with some form of inspection and recording of incoming wastes, practice extensive compaction of waste, and control the tipping front and the application of soil cover. Operated dumps, however, implement only limited measures to mitigate other environmental impacts. Operated dumps still practice *unmanaged contaminant release* and do not take into account environmental cautionary measures such as leachate and landfill gas management. This is especially relevant where leachate is produced and is unconstrained by permeable underlying rock or fissured geology. This issue may be less critical in semi-arid and arid climates, where dumps do not generate leachate in measurable quantities.

As cities grow and produce more waste and their solid waste collection systems become more efficient, the environmental impact from open dumps becomes increasingly intolerable. The conversion of open or operated dumps to engineered landfills and sanitary landfills is an essential step to avoid future costs from present mismanagement.

The first step and challenge in upgrading open dumps to sanitary landfills involves reducing nuisances such as odors, dust, vermin, and birds. The term *sanitary landfill* is generally used for landfills that engage in waste

[3] See Annex A for organizations and practitioners interviewed during the visits.

compaction and apply daily soil cover to reduce nuisances. In many cases, however, as much as 50% of the operational budget is consumed on daily cover. To the extent that soil cover is required to limit vermin, odors, and flies, limited and not daily application is recommended.

The medium- and long-term environmental effects of solid waste management are not well known in the three regions visited. Landfill managers and decision-makers consider the overall design and operation of a disposal site a low priority. Often, complete information is not available on leachate and landfill gas practices. Leachate will continue to be generated even after a landfill is closed, and landfill gas can have significant risks and environmental impacts even if the gas is contained within the boundaries of the site.[4] Landfill gas contains approximately 50% methane, which, when released into the atmosphere, can contribute 2-4% of the total global release of greenhouse gases.[5] Methane has 21 times the global warming impact of carbon dioxide on a weight basis over a 100-year time horizon, and thus is a powerful global warming agent. Simple and often inexpensive measures, including flaring or gas recovery for energy purposes, may be a possible source of income and significantly reduce the environmental effects of methane gas.

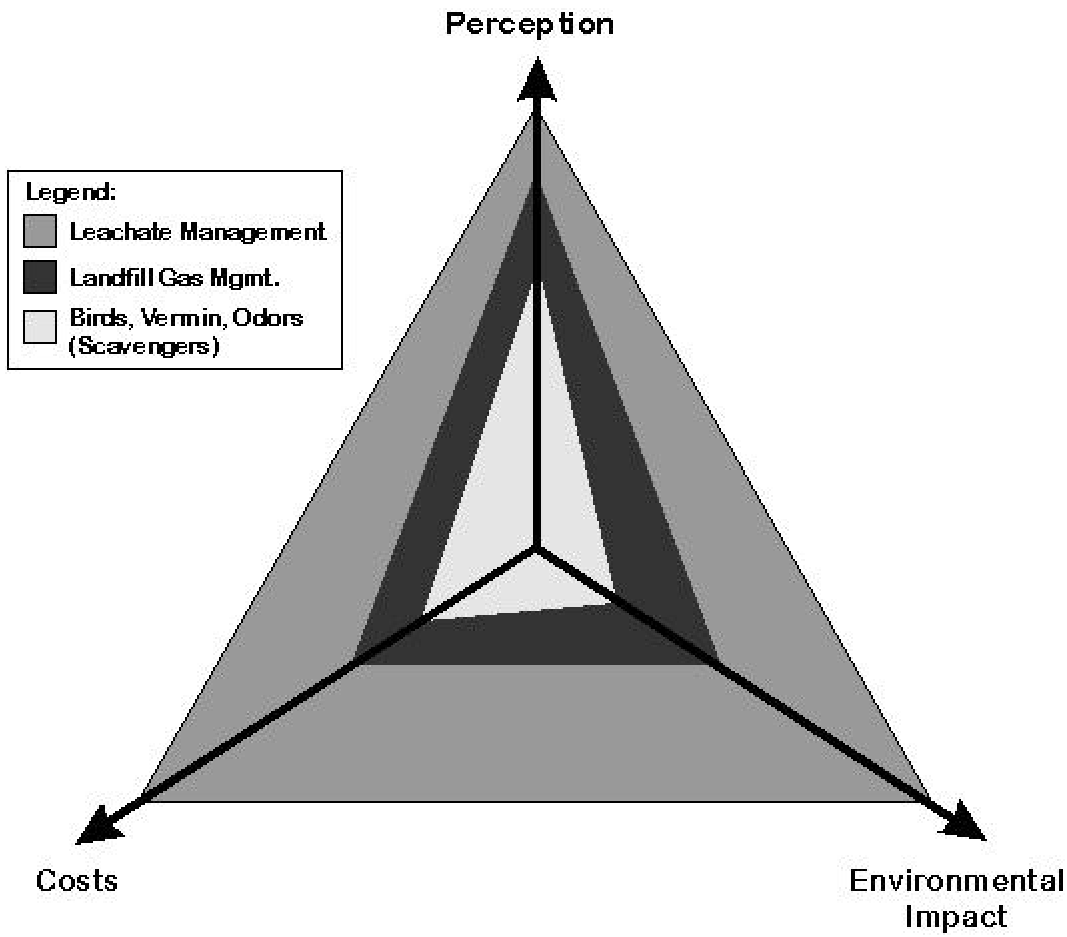
Solid waste management practitioners in many of the landfill sites visited have begun to master leachate collection techniques, particularly in landfills located in wet climates.

Generally, however, the environmental impacts and economic damages of poor leachate management practices on groundwater and receiving surface waters are not clearly understood. With this context in mind, the paper considers three long-term environmental impacts, reviews how they are generally perceived, the costs involved in controlling them, and the magnitude of their environmental impacts. The information is illustrated in Figure 1.

[4] See, e.g., Hjelmar, O, *et al*. "Management and Composition of Leachate for Landfills," Report to Commission of European Communities, 1994.

[5] See Intergovernmental Panel on Climate Change (IPCC), "Climate Change: The IPCC Scientific Assessment." Report prepared for the Intergovernmental Panel on Climate Change by Working Group 1, 1990.

Figure 1: Landfill Triangle for Assessing Long-Term Environmental Impacts



The framework includes several assumptions. The figure considers pre-existing sites, not including costs associated with site selection. Leachate management as represented in this figure includes all costs related to leachate management until it no longer poses a threat to the environment—expenditures that are rarely included in the overall budget for landfill operations.

This assessment indicates that there is a mismatch between the public perception of importance and the true environmental significance, particularly in the case of pollution by leachate. The long-term environmental effects of birds, vermin, and odors are negligible in comparison with the possible pollution of leachate and the environmental effects of landfill gas management. After general nuisances, landfill gas management is perceived by the public as having implications for long-term environmental problems. The costs and the environmental effects of landfill gas are slightly higher than those associated with general nuisances but lower than those related to the possible pollution of leachate.

2.2.1 Landfill Classifications

A number of general characteristics distinguish a *sanitary landfill* from an open dump, but these characteristics vary from region to region, from nation to nation, and even from site to site. As stated previously, an operated dump may inspect and record incoming waste and include limited compaction by bulldozer and compactor. Engineered landfills embody further attempts to minimize environmental impacts. Sanitary landfills incorporate a full set of measures to control gas and collect and treat leachate, apply a daily soil cover on waste, and implement plans for closure and aftercare long after waste has ceased coming to the site (*see Table 2*).

Table 2: Landfill Classifications

	Engineering Measures	Leachate Management	Landfill Gas Management	Operation Measures
Semi-Controlled Dumps	None	Unrestricted contaminant release	None	Few, some placement of waste –still scavenging
Controlled Dump	None	Unrestricted contaminant release	None	Registration and placement/ compaction of waste
Engineered Landfill	Infrastructure and liner in place	Containment and some level of leachate treatment	Passive ventilation or flaring	Registration and placement/ compaction of waste; uses daily soil cover
Sanitary Landfill	Proper siting, infrastructure; liner and leachate treatment in place	Containment and leachate treatment (often biological and physico-chemical treatment)	Flaring	Registration and placement/ compaction of waste; uses daily soil cover. Measures for final top cover
Sanitary Landfill with Top Seal	Proper siting, infrastructure; liner and leachate treatment in place. Liner as top seal	Entombment	Flaring	Registration and placement/ compaction of waste; uses daily soil cover
Controlled Contaminant Release Landfill	Proper siting, infrastructure, with low-pearmeability liner in place. Potentially low-pearmeability final top cover	Controlled release of leachate into the envionment, based on assessment and proper siting	Flaring or passive ventilation through top cover	Registration and placement/ compaction of waste; uses daily soil cover. Measures for final top cover

There are some styles of landfill management that are particular to each country. For example, bio-remediation in Brazil is used to describe a sanitary landfill design aimed at remediating existing open dumps. Sanitary landfill cells are constructed and filled with a combination of old waste from the open dump and fresh waste in proportions of 70:30 w/w (50:50 v/v). Leachate from the new landfill cells is collected, treated anaerobically, and recirculated back to the cell—a process leading to the rapid stabilization of the solid waste deposited in the cell, the accelerated generation of landfill gas rich in methane content, and ultimately to steady-state conditions with low pollution potential.[6]

A sanitary landfill involves appropriate attention to all technical aspects of landfill development: siting, design, operation, and long-term environmental impacts. In principle, operating techniques vary only slightly (e.g., thickness of the layer in which waste is compacted, the amount of daily soil cover applied, the organization of tipping fronts) and are typically influenced by landfill management. Leachate management and control approaches, on the other hand, can vary significantly (*see Table 3*). In some places some of these measures may not be necessary to maintain a well-operated landfill. Three different strategies can be identified from the visits with respect to leachate management:

1. **Entombment** or the *dry tomb* approach aims to prevent water from coming into contact with waste. While this approach minimizes the volume of leachate produced, it slows the bio-degradation of the waste so that the potential hazard of the waste is not reduced after time. The entrance of water into waste at any time in the future will cause the encapsulation to fail and, consequently, generate

[6] Bartone, Carl. "Brazil: Managing Pollution Problems," The Brown Environmental Agenda, Vol. II – Annexes, June 27 1997, Draft.

significant pollution of water resources. This strategy can be characterized as a preliminary waste storage approach and is not a viable long-term leachate management or landfill option.

2. The **containment** strategy protects the environment by containing leachate and treating it before discharge. This strategy is based on the *eternal* system philosophy, which acknowledges that the production of leachate may continue for 30-50 years after closure. Success of the operation will rest on the continuing operation of the leachate treatment facility. Problems such as inadequate maintenance and power cuts may cause the approach to fail eventually, releasing uncontrolled leachate and posing environmental risks in the long-term future. Unless coordinated with other options, the containment strategy is an unsustainable alternative. Even high-income countries that had initially implemented the containment strategy are now changing their approach.

3. The **controlled containment release** approach allows leachate to enter the environment in such a way that it is not expected to have a serious impact. This technique takes into account proper siting, environmental considerations, and careful monitoring. The strategy may serve best for hydrogeological settings and semi-arid climates, but it could be problematic in wet climatic zones where leachate containment release goes from controlled to unrestricted. This may result in pollution of ground and surface waters.[7]

Controlled contaminant release is seen as the most economically realistic and environmentally sustainable approach for low- and middle-income countries. Siting issues warrant special attention, and the costs of setting up controlled release systems may be high.

Table 3: Types of Landfills Visited

Number of Landfills Visited Within Each Category				
Country	Conventional		Controlled Landfills	Operated/Semi-Controlled Dumps
	Entombment [8]	Containment		
Ghana		3		
Republic of South Africa	1	3	3	3
Uganda			1	
China		2		
Hong Kong	1	1		
Philippines		1	1	
Malaysia			1	
Indonesia		1		
Argentina	1	1	1	
Brazil	2	2	3	2
Chile	1	2		
Peru				2
Colombia		2[9]		2
Mexico		3		1

[7] See Johannessen, L.M., "Guidance Note on Leachate Management for Municipal Solid Waste Landfills." The World Bank, 1999, Draft.
[8] These landfills were planned to be operated as entombment facilities, but are being operated as a containment landfills. The landfills are also marked under the category *containment*.
[9] Leachate treatment is not applied at one landfill, discharging it to the adjacent river. The other landfill collapsed as a result of extensive recirculation.

3. Observations from Landfills in Africa

3.1 Overview of the Emerging Landfill Approach in Africa

The author visited the Africa Region from September 21 to October 9, 1997, observing dumps and landfills in Ghana, Uganda, and South Africa. The landfills visited in Africa ranged from open dumps to sanitary landfills. In many African countries, much of the basic infrastructure for water supply, wastewater treatment, and solid waste collection has yet to be established. While decision-makers in the region were aware that their countries had to upgrade open dumps to sanitary landfills, this was not regarded as a priority in most countries. At the national and municipal levels, few countries have taken steps towards constructing, maintaining, or operating landfills. The majority of African countries used open dumps to dispose of solid waste. The exception was South Africa, which was also the only country with specific regulations and guidelines governing solid waste landfills.

Of all the regions, Africa has the lowest level of investment of World Bank funds in the solid waste sector. Despite a stand-alone solid waste and drainage project in Nigeria in the pre-1988 period, repeating such large investments in the solid waste sector has been contemplated only recently. The level of investment in the solid waste sector as a fraction of total project costs is also low when compared with other regions. The average investment in the solid waste sub-components in 15 projects in the Africa region is 6.8%, with a high of 27.6% and a low of less than 1%.[10]

Nevertheless, some countries in Africa are taking important steps to improve waste disposal practices. Under a World Bank-financed project, Kampala City, Uganda, has constructed a landfill; and under the World Bank's "Urban Environmental Sanitation Project," Ghana has plans to build its first properly sited, designed, and constructed landfills in three of its major cities. Other countries, including Tanzania, Botswana, Namibia, and Rwanda, were selecting sites for new landfills. And, following the specific guidelines and regulations on waste landfills developed in South Africa, Botswana is preparing guidelines and regulations for landfill management.

This section will focus on landfill practices observed in South Africa to assess the emerging approach in the region. South Africa's Minimum Requirements emphasize proper leachate management and the potential environmental impact of leachate, and the importance of site selection. The regulations note that it is not necessary for landfills in arid climates and sometimes semi-arid climates to apply leachate management.

Many countries in Africa have incorporated long-term sustainability of landfills, including careful siting of landfills in arid or semi-arid climates and *natural flow* leachate management. The preferred method for leachate treatment involves the use of ponds and artificial and natural wetland areas. Artificial and natural wetlands are used as filters with the intention that the plants in these wetlands will use nutrients available in the leachate and partially evaporate part of the liquids.

3.2 Recommendations for the Africa Region

To improve the disposal of solid waste in Africa and maximize resources, projects that aim to landfill waste should focus on the following:

1. ***Local conditions.*** The first steps in the gradual process of upgrading to sanitary landfills may include guidance on technical issues and proper siting of new waste disposal sites. Projects should adjust landfill design and operation to local conditions (both geographical and economic). A controlled landfill approach, without compromising public health and environmental impacts, may be an interim step.

2. ***Realistic objectives.*** The adjusted approach may require accepting relaxed standards for daily covering of waste. This landfill approach may imply accepting partial collection and treatment of leachate and partial controlled release for attenuation, dilution, and dispersion.

[10] See Gopalan and Bartone, "Assessment of Investments in Solid Waste Management: Strategies for Urban Environmental Improvement," Draft.

3.3 Landfills Visited in Africa

The landfills visited in Africa included: open dumps in Ghana (Accra, Kumasi, and Takoradi); Bisasar Road, Marianhill, Shongweni, Bulbul Drive landfill in Mobeni, Brits, Krugersdorp, Marie Louise, Goudkoppies, and Boipatong in South Africa. Several unnamed dumps were visited in South Africa. The Mpewere landfill in Kampala, Uganda, was viewed on video *(see Table 4).*

Table 4: Overview of Observations at Landfills Visited in South Africa

Region	KwaZulu/Natal	KwaZulu/Natal	KwaZulu/Natal	KwaZulu/Natal	North West	North West	Guateng	Guateng	Guateng
	Durban Bisasar Rd.	Durban Marianhill	Durban Shongweni	Durban Mobeni	Brits	Krugersdorp	Marie Louise Johannesburg	Goudkoppies Soweto	Boipatong
Landfill category	H+h (G:L:B+)	h+MSW (G:L:B+)	H+h	H+h	Regional landfill	Regional landfill	City landfill	City landfill	Township landfill
Waste types	MSW Low HZW	MSW	MSW and HZW	MSW and HZW	MSW	MSW HZW	MSW	MSW + sewerage sludge	MSW
Tonnes per day	2,400	300 (capacity 600 t/d)	MSW : 700 and 150m3 HZW	MSW: 1000 HZW (liquid): 200-250	25-100	Not known – estimated 500-1000	1900-2000	MSW: 1000 Sludge: 100	300
Operator	Municipality	Municipality	Privately owned and operated	Privately owned and operated	Co-operated by two municipalities	Municipality	Municipality- owned Privately operated (5-year contract)	Municipality- owned Privately operated (5-year contract)	Municipality owned Privately operated (5-year contract)
Tipping fee US$/tonne	MSW: 9 HZW: 42	MSW: 9	MSW: 11 HZW: 37-51	MSW: 11 HZW: 37-51	Waste registration– No tipping fees	None	12	12	MSW: 4-5
Disposal area	20 ha	1 cell: 5 ha	1 cell: 2.3 ha	5 ha	2.5 ha	15 ha	20 ha	10 ha	10 ha
Waste pickers	1 community of approx. 200 families, allowed to scavenge after 4:30 pm	No scavenging is allowed	Limited scavenging	None	Approx. 10-15 waste pickers living on-site	Extensive scavenging. 600 waste pickers living on and immediately off-site	None	None	100 registered waste pickers scavenging at the tipping front
Environmental setting	Gorge draining to adjacent river	Gorge draining to adjacent river	Hillside draining to adjacent river	Hillside/head of valley	Filling of old quarry in flat landscape	Filling of depression in landscape near old mine dump	Filling sloping land between old mine shafts and a stream valley	Filling of flat land draining to river	Filling of flat land (wet) draining to wetland
Climatic zone	Wet	Wet	Wet	Wet	Arid	Arid	Semi-arid	Semi-arid	Wet
Liner	Compacted clay liner	Multi-barrier liner	Multi-barrier liner with leak-detection layer	Multi-barrier liner with leak-detection layer	None	None	None	None	None
Leachate collection	Limited collection	Leachate collection and storage	Leachate drainage using old tires	Drains and leachate storage tanks	None	None	None	None	Diversion of run-on surface water and collection of leachate
Leachate treatment	Collected leachate discharged to municipal sewer	Discharge to municipal sewer	Storage and truck haul to nearest municipal sewer treatment plant	Municipal sewer	None	None	None	None	Leachate treated at sewage works. Sent via sewer pump station
Gas management	Active gas collection and flaring	None at present	None at present	Active gas collection and flaring	None	None	None	None	None
Operating techniques	Cell/area methods with down up compaction. HZW in trenches adding lime. Daily soil cover	Cell methods with down up compaction. Daily soil cover	Cell methods with daily soil cover	Comment: 1 cell has just collapsed and slid into new cell under construction	Grading of waste by bulldozer and random covering with soil	Grading and random compaction. Periodic soil covering	Cell methods operated with limited tipping front and daily soil cover	Cell methods operated with limited tipping front and daily soil cover	Cell methods operated with limited tipping front and daily soil cover
Equipment	4 weighbridges 3 compactors 2 bulldozers 1 payloader 2 excavators 2 dump tractors 1 tipper truck 2 water tankers Staff: 43	2 weighbridges 2 compactors 1 payloader 1 bulldozer 2 trucks Staff: 13	1 weighbridge 1 compactor 1 bulldozer 2 bucket loaders 1 dump tractor 1 excavator Staff: 32	N/a	No weighbridge 1 bulldozer	No weighbridge 2 compactors	2 weighbridges 1 compactor 1 excavator 1 bucket loader 2 tractors	2 weighbridges 1(2) compactor 1 bulldozer Staff: 28	1 weighbridges 1 compactor 1 front-end loader 1 bulldozer 1 water tanker Staff: 9

3.4 Regulatory Framework

In recent years, South Africa has legislated and passed minimum regulatory requirements on waste landfills, classifying them according to size of waste stream, climatic conditions (with a focus on leachate generation), and type of waste received. The 1st Edition Minimum Requirements was published in 1994 and the 2nd Edition was published in October 1998. The Minimum Requirements are based on graded standards that ensure appropriate use of landfill technology and affordable environmental protection (*see Box 1*). All new landfills must comply with these requirements, whereas existing landfills and dumps must either comply with the Minimum Requirements or close. Some flexibility is permitted in site-specific cases that have been properly researched.

The guidelines take into consideration climatic conditions. Landfills in arid climates, and often those in semi-arid climates, are not required to follow leachate management per South Africa's Minimum Requirements guidelines. For instance, the city of Johannesburg, located in a semi-arid area with an annual precipitation of some 500-750 mm and high evaporation rates, does not have to comply with leachate collection. As the Minimum Requirements read, a water balance calculation will most likely show that no significant leachate will be generated.

Box 1: South African Minimum Requirements for Landfilling of Waste*

The Minimum Requirements classify landfills according to :

- **Waste types**: General waste (primarily non-hazardous solid wastes); or hazardous waste (HZW) (rating according to degree of hazard);
- **Size of waste stream**: Communal sites (1-25 tonnes per day), Small (25-150 tonnes per day), Medium (150-500 tonnes per day) and Large (>500 tonnes per day);
- **Climatic water balance**: Significant leachate generation (in wet areas, where leachate collection and treatment is required) and no significant leachate generation (in arid and semi-arid areas where leachate collection is not required).

*Stringency increases with hazardness of waste, size of the landfill, and possible leachate generation.

3.5 Important Features of Visited Landfills

The following section describes the main features of visited landfills: liners, leachate collection and treatment, landfill gas management, and operational procedures.

3.5.1 Leachate Management

Per South Africa's Minimum Requirements, leachate management varied by landfill site (primarily depending upon the area's climatic conditions) and types of waste received. Only landfills in wet climatic zones were equipped with liners and practiced leachate collection and treatment.

Located in a wet climatic zone with annual precipitation of 900-1,200 mm, the Durban landfills required leachate collection and treatment. The Bisasar Road landfill was built with a compacted clay liner. Leachate was collected in a trench at the bottom of the slope of the liner and discharged to the municipal sewerage system, with the remains released through the clay liner. The landfill was constructed in 1982, prior to the implementation of the Minimum Requirements.

The recently inaugurated Marianhill landfill, also in Durban, was constructed using a multi-barrier composite liner: 500 mm compacted clay; 2 mm HDPE liner; geofabric; 500 mm compacted clay; 300 mm coarse gravel and stone drainage (and protection) layer.

Other landfills in the Durban metropolitan area were also constructed with multi-barrier composite liners. The Shongweni and Mobeni landfills, two hazardous waste landfills (co-disposal landfills), were equipped with a multi-barrier liner system that included a leak-detection layer. The construction included graded stones (leak-detection layer), a 150 mm layer of compacted clay, a 1.5 mm PP liner and 150 mm clay layer, and a drainage and protection layer *(see Box 2)*. South African landfills with leachate containment and collection discharged biologically treated leachate to a municipal sewerage treatment plant. The level of treatment for leachate was unknown.

South Africa's Minimum Requirements allowed for attenuation and dispersion of leachate in landfills sited in arid and semi-arid climates. The two semi-controlled dumps visited in Krugersdorp and Brits were located in arid zones, where negligible leachate was generated and leachate management was not applied. Many of the dumps visited were sited in wet climatic zones and operated as landfills, where the procedure for leachate management consisted of surface water cut-off drains. This was the case at the Boipatong landfill in the Guateng region of South Africa, where run-on surface water was observed. However, leachate from this site was collected and drained to a sewer pump station, and then pumped to a sewage works, where it was treated.

The three landfills planned for construction in Ghana will include a low-pearmeability clay liner and leachate collection system that discharges leachate into a pond system for co-treatment with septage for the involved cities. After treatment in natural wetlands, effluent from the treatment plants will be released into adjacent rivers.

Many countries in Africa may not be able to sustain sanitary landfill designs. The Mpewere landfill serving the city of Kampala, Uganda, was built with an on-site low-pearmeability clay liner and *natural flow* (using gravity only) leachate management. The aim was to treat leachate in an artificial wetland system before diffuse release into the natural wetland area downstream from the landfill. The landfill included leachate and landfill gas management. In line with the *eternal* leachate philosophy, all aspects of sustainability were built-in, but resources were insufficient to fund maintenance of the artificial wetland system and the landfill operations. A year after its construction, the landfill operated as an open dump and the artificial wetland treatment plant was practically non-functional.

3.5.2 Landfill Gas Management

The Minimum Requirements instituted in South Africa offer only limited guidance on landfill gas management. Only two of the landfills visited in South Africa practiced landfill gas management: the Bisasar Road landfill and the Durban Mobeni landfill. The Bisasar Road landfill had installed an active gas flaring system, which pumped approximately 2,000 m^3 of gas per hour from 24 wells. The gas was flared in a mechanized system. Investment costs for the gas-flaring system were 6.6 million R (US$1.5 million) and the operating costs were unknown. The Durban Mobeni landfill had an active landfill gas management system, comprising 8 wells and a flaring system. It may well be expanded in the near future. Other landfills visited in the Africa Region did not practice gas management.

3.5.3 Landfill Operation

With the exception of South Africa, most solid waste in Africa is disposed of in open dumps, without any form of site management. Landfills in South Africa, for the most part, registered waste and collected tipping fees accordingly. Landfills that received over 1,000 tonnes of waste per day had two or more weighing bridges to register incoming and outgoing trucks.

Additionally, the vast majority of landfills used compactors to grade and compact waste in layers 2 m thick, applying soil as daily cover. At the Boipatong landfill, waste was compacted into thin layers at a limited tipping front and only a limited amount of soil was used for daily cover.

Co-disposal of hazardous industrial waste with municipal solid waste is practiced in South Africa, when it meets specific design and registration criteria. The Minimum Requirements accept a maximum loading ratio of 1:9 (hazardous waste:general non-hazardous waste). As an operational practice, hazardous industrial waste is disposed of in trenches 1-2 m deep in the municipal waste layer. At the Bisasar Road landfill, lime was added on top of the hazardous waste before the trenches were covered with other waste. Open trenches were covered by a plastic tent until full. The Shongweni landfill co-disposed of hazardous waste in trenches, without any form of stabilization. Many of the co-disposal landfills visited lacked guidelines on appropriate disposal of hazardous waste (e.g., the criteria suitable for maintaining methane-producing conditions at the bottom of the landfill).

Box 2: The Mobeni Landfill Collapse

Equipped to receive hazardous industrial waste for co-disposal with MSW, the Mobeni landfill near Durban, South Africa, collapsed in November 1997. Approximately 20-25% of the waste accepted at the landfill was considered hazardous liquid waste. The collapse took place in an 18-month-old cell, constructed on the side of an old section of the landfill. The lower part of this cell was equipped with a polyethylene (PE) liner toward the older part of the landfill. The remaining part of the cell had been isolated towards the old landfill slope by compacted clay. The collapse took place between the old part of the landfill and the 18-month-old cell at the clay-covered slope. At the time of the visit, the reasons for the collapse were not known. One theory speculated that the high moisture content from the liquid hazardous waste and precipitation might have caused a slip between the PE liner and the clay liner, leading to its eventual collapse. The collapse resulted in extensive odor problems in neighboring communities and extensive costs entailed in restoring the landfill.

At Uganda's Mpewere landfill, inaugurated in 1995, operational difficulties caused the landfill to revert to an open dump before its one-year anniversary. The landfill, owned and operated by the Kampala City Council, was under the supervision of an experienced landfill operator from South Africa for the first six months of operations. Officials blamed its subsequent failure on the landfill's small operational budget and the lack of local managerial expertise in operating a new landfill.

3.6 Waste Pickers

On-site scavenging disrupts landfill operations in many parts of Africa. In Accra, Ghana, waste pickers sorted through waste from incoming garbage trucks, before and immediately after unloading. Waste pickers often prevented the compactor from leveling and compressing the newly disposed waste. Elsewhere in Ghana, scavenging was uncommon, as the cost of transporting recyclable materials to recycling industries in Accra and Côte d'Ivoire exceeded the value of the recyclables.

Uncontrolled scavenging at controlled and semi-controlled dumps also took place in South Africa. At the Krugersdorp landfill in the North West Province, an entire village of waste pickers had sprung up close to the dump site. More than 600 waste pickers subsisted on income generated from sorting waste, interfering with daily operations by starting fires in order to access metals and glass. Their actions prevented landfill operators from making optimal use of compactors at the tipping face.

At the Bisasar Road landfill in Durban, a more controlled form of scavenging took place. Registered waste pickers living in a squatter community immediately adjacent to the landfill were allowed into the site after regular hours. Part of the tipping face remained open for the waste pickers at the end of each working day. During regular working hours, armed guards kept waste pickers out of the landfill. Scavenging at Bisasar Road generated approximately US$15,500 to support close to 200 families, equivalent to approximately US$77 per family per month.

The scavenging community next to the landfill also benefited from waste delivered from a local bread factory. The community recovered edible bread before the landfill operator removed the remaining waste for disposal. Plans for a more official platform to distribute unused bread were under consideration in July 1997.

Landfill operators also allowed for controlled scavenging at the Boipatong landfill. Waste pickers at this landfill were registered and limited to 100.

3.7 Private Sector Involvement in Waste Landfills

Most of the landfills visited in Africa were owned by the municipal government and built and operated by private contractors. In the South African province of Guateng, private firms operated municipally owned landfills under five-year contracts. The operation was based on a fee per tonne of waste handled in the landfill and a fixed annual fee. Co-disposal landfills were owned and operated by the private sector and tipping fees were regulated by free competition; most of the waste came from industries. For the privately owned landfills, the environmental damage liability insurance covered up to 30 years for after-closure care.

Ghana is considering private sector involvement in building and operating its three proposed landfills. International involvement is being considered as one of the proposals, although international support may be difficult to attract, as landfills are relatively small.

3.8 Tipping Fees

Of the landfill sites visited in the Africa Region, only landfills in South Africa charged tipping fees, ranging from US$9-12/tonne for MSW and other non-hazardous waste, and US$35-51/tonne for HZW on co-disposal landfills. One operator claimed that charging tipping fees for hazardous waste was good for business because handling such wastes varied little from handling municipal solid waste. The costs of liability insurance were marginal for receiving hazardous waste.[11]

Payment of tipping fees varied significantly. Some landfills received a cash payment from each load of waste received at the landfill (e.g., Marianhill, Durban). One scheme that worked with great success was charging fees for each visit to the waste hauler's electric bill. The waste haulers were ultimately responsible for collecting the tipping fee from the waste generators.

[11] See private sector involvement for further information on liability aspects.

4. Observations from Landfills in Asia

4.1 Overview of the Emerging Landfill Approach in Asia

Countries of the East Asia and Pacific Region have been active borrowers of World Bank funds dedicated to solid waste projects. China and Indonesia have undertaken a number of solid waste projects, accounting for 14 of the 21 World Bank projects in Asia that contain a solid waste sub-component. In terms of investment, these 14 projects account for over 93% of the total investments in the solid waste sector in Asia. China is currently undertaking the most intensive investment in the solid waste sector of all Bank borrowers. Investments for the solid waste sub-component in projects in China alone tally US$269 million (of a total of US$372.52 million in solid waste-related projects in Asia) with an average of about US$38 million per project. China also has had the most active solid waste portfolio in the 1990s—all seven of its projects containing solid waste sub-components were implemented after 1990.[12]

World Bank funding and bilateral donor activities have increased awareness of the importance of proper landfilling among decision-makers in Asia. The general trend is to upgrade open dumps to engineered landfills. While most of the region's capital cities are serviced with some level of landfill, the great majority of waste in the region is still disposed of in open dumps.

Almost all the landfills visited in the region applied liners, by compacting the existing clay on site or applying a plastic liner. One site in China used bentonite, and one small landfill in Bali, Indonesia, had a concrete liner. All the landfills included leachate collection and some form of leachate treatment. Treatment of leachate using electrically powered aerators was the most common method, but electricity costs seem to restrict the extent to which the aerators were actually used. In the Philippines and Malaysia, leachate was being recirculated. However, regular monitoring of the leachate composition before and after leachate treatment was rarely carried out and therefore the efficacy of the leachate treatment methods was unknown.

Landfill gas was managed through installation of vertical gas wells at all the sites visited for passive ventilation (mostly methane and carbon dioxide). Passive ventilation through pipes installed in the landfilled waste releases large quantities of methane directly into the atmosphere, thereby promoting global warming through the greenhouse effect. Some landfills burn gas in flares, and a small number utilize the gas, so that the global warming effects are significantly reduced. Only one landfill in Asia, in Hong Kong, actively pumped and flared landfill gas. Throughout the region, difficulties with contractual arrangements with power companies and low power prices often discouraged the exploitation of landfill gas for electricity generation.

At the local level, landfill operators understood what encompassed good operational practices, but some techniques were not always fully understood. In some cases, waste was compacted in 2-4 m lifts, which could influence the quality of compaction and lead to extensive settlements in the waste. Many landfills had compactors donated by bilateral organizations, but these were only used to a limited extent. Lack of operational know-how or high fuel consumption in comparison to bulldozers prevented landfill operators from making efficient use of compactors.

Daily soil cover was rarely used but when landfills were well operated no nuisances were observed. At these landfills an intermediate cover was applied periodically, achieving the same objective as daily soil cover. An intermediate cover, in this case, refers to the area covered with soil where the working face will not be used for some time.

National and regional authorities recorded and inspected incoming waste but rarely monitored the environmental effects of waste disposal. In some cases, this practice has led to relaxed application of environmental mitigation measures, including a decrease in the treatment of leachate, and greater tolerance of open fires on a landfill. Stronger national and regional institutions may help improve environmental enforcement in the region.

[12] See Gopalan and Bartone, "Assessment of Investments in Solid Waste Management: Strategies for Urban Environmental Improvement," Draft.

The presence of waste pickers was observed at some of the landfills in the region, though not at the well-operated sites visited. These activities presented safety issues to the waste pickers themselves and to landfill employees. In addition, waste pickers reduced productivity by hampering operations at the tipping face and sometimes set fires to separate the metals from the rest of the waste. A landfill in San Mateo, Philippines, employed inhabitants from the nearest squatter community to work at the site.

The local municipal or metropolitan government owned all the landfills visited in Asia. Under supervision of local government employees, private companies are increasingly hired under short-term contracts (1-5 years) to supply and operate equipment at landfills. The Hong Kong government has made concessions with three private contractors to design, build, operate, and finance their landfills for a period of 30 years. Malaysia was in the process of privatizing waste disposal by dividing the country into four concession zones. At the time of the visits, only Kuala Lumpur had privatized its waste disposal services.

4.2 Recommendations for the East Asia and Pacific Region

In order to improve solid waste management disposal practices, the following recommendations may be adopted in China, Philippines, Malaysia, and Indonesia:

1. ***Institutional strengthening—monitoring and supervision of landfill operation and the landfill's effects on the surrounding environment.*** There is a need to develop simple and affordable programs to monitor the environmental effects of waste disposal and to provide local decision-makers with the necessary guidance and supervision to implement technically appropriate and environmentally sustainable approaches for landfill operation.

2. ***Re-assessment of passive gas ventilation systems.*** Passive ventilation should be compared with the possibility of flaring landfill gas to seek further reductions in methane gas emissions. The possibilities for recovery of landfill gas for electric power production or utilization of the gas for industrial purposes should be followed up at landfills that utilize good operational practices.

3. ***Closer evaluation of the environmental effects from treated leachate discharged into freshwater courses.*** New policy proposals should include development of possible achievable effluent standards for different types of treated leachate discharged into different water courses.

4. ***The introduction of tipping fees.*** Assessing the real costs in waste disposal may improve consideration of tipping fees in the overall landfill budget. Tipping fees that are already included in the landfill budget may provide the necessary resources to sustain good landfill practices.

4.3 Landfills Visited in Asia

The landfills visited in Asia include: sanitary landfills in China (Asuwei, Beijing; Laogang, Shanghai; and WENT, Hong Kong); sanitary landfills in the Philippines (Carmona, San Mateo, and rehabilitation program of Smokey Mountain); a controlled landfill in Malaysia (Permetang Pauh); and sanitary landfills in Indonesia (Bantar Gebang, Jakarta; Kuda and Bangli, Bali). Several unnamed dumps were also visited. Observations from the landfills visited between January 2–January 19, 1998, are summarized in Table 5.

Table 5: Overview of Observations at Landfills Visited in Asia

Country	China		Hong Kong	Philippines		Malaysia	Indonesia		
	Asuwei Landfill (Beijing)	Laogang landfill (Shanghai)	WENT landfill	Carmona landfill	San Mateo landfill	Permetang Pauh Seberang Perai	Bantar Gebang Jakarta	Kuda, Bali	Bangli, Bali
Landfill category	Sanitary landfill	Sanitary landfill	Sanitary landfill	Sanitary landfill	Sanitary landfill	Controlled landfill	Sanitary landfill operated as an open dump	Sanitary landfill	Sanitary landfill
Waste types	MSW	MSW	MSW and some commercial waste	MSW	MSW	MSW	MSW and commercial waste	MSW	MSW
Tonnes per day	1,500	7,800	5,000	1,500	2,500	350	5,500	58-82	
Operator	Local government	Local government	Private under a 30-year DBO contract	Metro Manila Development Agency (MMDA)	MMDA with private equipment operator	Municipal council with private equipment operators	Government of Capital City Jakarta	Local government of Kuda	Local government of Bangli
Tipping fee	None–calculated to US$2.5/tonne	None	None–estimated costs US$10/tonne	None–estimated costs US$9.7/tonne	None–estimated costs US$9.7/tonne	US$1.2/tonne	US$1.3/tonne (8,000 Rp)	None	None
Disposal area	Phase I: 26ha Phase II: 20 ha	260 ha	100 ha; total void space 60 million m^3	N/A	73 ha	20 ha	108 ha; disposal area 87 ha	~ 1.5 ha	~ 0.5 ha
Waste pickers	None	None	None	100 primarily from squatter community inside landfill	None	Less than 20 doing random scavenging	638 registered waste pickers	None	None
Environmental setting	In agricultural land with sub-surface soil of 9 m clay	Saltwater wetland area near sea	Partly mountainous and reclamation of land	Rolling hills draining to large lake	Mountainous area within water protection zone	Marsh land near River	Flat landscape in wetland-like area	Flat paddy fields near river	Mountainous terrain
Liner	Bentonite liner	Natural clay liner	Multi-barrier liner with leak detection	HDPE liner	HDPE liner	No liner as such– clay deposits under the landfill	Some cells compacted clay; other cells HDPE	Compacted clay liner	Concrete lining
Leachate collection	Herringbone drainage system	Pumping wells	Herringbone structured drainage system	Leachate collection layer and drains	Leachate collection layer and drains	Leachate collection drains	Herringbone structured drainage system	3 lengthwise drains	Drains placed in squares, consisting of pipe and sago palm fibers
Leachate treatment	Aeration in channel system	Aeration lagoons and anaerobic lagoons	Pumping to public primary treatment plant	Treatment in aeration and facultative ponds before recirculation	Treatment in aeration and facultative ponds before recirculation	Treatment in three aeration systems with recirculation and following discharge to river	Treatment for each cell with forced aeration lagoons	Facultative pond, aeration pond, polishing in wet bed, aerated biofilter, final polish pond	Three ponds with intentional settlements followed by wet polishing lagoon
Gas management	Passive ventilation	Passive ventilation	Gas extraction and flaring	Passive ventilation	Passive ventilation	Passive ventilation	Passive ventilation	Passive ventilation	Passive ventilation
Operating technique	Cell method, compaction in 2 m layers. Extensive use of daily cover (20-30 cm)	Cell method, compaction in 2 m layers by bulldozers – compaction just introduced. Daily soil cover not used	Cell method with compaction in thin layers. No daily soil cover used	Cell method. 5 meter uncomplicated followed by 4 m layers with compaction. Daily soil covering	Cell method. Compaction in layers of some 2-4 meters. Large tipping front covered continuously by soil	Cell method, with compaction in thin layers. Relatively large tipping front and periodic soil covering	Open dumping, with random operation of several tipping faces. Burning (by waste pickers) to recover metals	Tipping along access road, dozed into piles by bulldozer–daily cover not applied	Visited on opening day
Equipment	1 weighbridge 3 compactors 2 bulldozer 2 excavators 9 trucks 2 loader 2 tanker trucks 1 road roller 1 water truck 96 employees	2 weighbridges (not in used) 4 compactors 22 bulldozers 3 excavators 7 loaders 80 trucks (for transfer) 200 (lf) employees	4 weighbridges 4 compactors 4 bulldozers 3 excavators 3 trucks 1 loader 100 employees	no weighbridge 2 compactors 10 bulldozers 40 employees	1 weighbridge (non functional) 1 compactor 6 bulldozers 1 excavator 2 trucks 1 loader 70 employees	1 weighbridge 2 bulldozers 1 excavator 1 truck with water tank 20 employees	1 weighbridge 3 compactors (1) 18 bulldozers (2) 4 excavators 17 wheel loaders 3 trucks 1 crane truck 1 street sweeper (0) 2 water tanker trucks	1 bulldozer 1 excavator 18 employees	No permanent equipment–wheel loader to be shared with Public Works department. No permanent landfill staff–10 employees doing manual composting

4.4 Regulatory Framework

Of the countries visited, China has developed the most comprehensive set of policies governing MSWM. Other countries have sought to improve disposal practices by launching programs of a managerial and technical nature. And others have adopted international standards to address different aspects of solid waste disposal.

The national entity responsible for solid waste disposal in China is the Ministry of Construction, Department of Urban Construction. The agency has developed guidelines and requirements for management of solid waste disposal, including landfills (regarded as the primary disposal option), composting, and incineration. In its guidelines, China addresses siting criteria (such as minimum distance to drinking water sources, limitations on geological formations and requirements for hydrogeological surveys), liner criteria (such as clay liner thickness of 2-2.5 m and $k<10^{-7}$ m/sec permeability), and a series of guidelines on disposal techniques and management procedures. The licensing procedure involves a required EIA process and approval from the local Environmental Protection Bureau, advised by a competent technical institute (a so-called Class A institute). The EIA process involves public consultation and a possible compensation package that includes direct economic benefits to the affected parties. If the project exceeds US$24 million, the Chinese government must review and approve the project.

National action plans were initiated in other Asian countries to address problems related to waste disposal. With support from the Japan International Cooperation Agency (JICA), the government of Malaysia developed a national plan for action in 1998 that identified a total of 13 program areas.

4.5 Important Features of Visited Landfills

4.5.1 Leachate Management

At the sanitary landfills visited, impermeable liners were in use, usually constructed of clay, and sometimes with welded PE sheets. At the Permetang Pauh landfill in Malaysia, the clay deposits were used to reduce the release of leachate as the landfill had only introduced leachate collection after waste disposal had begun (*see Box 3*). In China, the Laogang (Shanghai) landfill had a base 17 m deep that achieved a permeability coefficient of 10^{-9} m/sec. The Asuwei landfill in Beijing had improved the natural clay deposits with a bentonite liner.

Artificial liners of polyethylene were applied at landfills in the Philippines, where the San Mateo and the Carmona landfills were equipped with a 2.5 mm high-density PE liner. The new sections of the Bantar Gebang landfill, Indonesia, also included a polyethylene liner.

Partly situated on land that has been reclaimed by the Hong Kong government from the sea, the WENT landfill in Hong Kong was constructed with a multi-barrier liner and a leak-detection system, preventing possible leachate flows into the sea. For the first five years of landfill operation, the private operator will not be responsible for treating leachate before it is discharged into the municipal mechanical sewerage treatment system. The municipal system, however, provides ineffective treatment of leachate.

All the other landfills visited in the region had leachate collection and some form of leachate treatment. Aerated lagoons were the dominant leachate treatment method applied in the region.

Box 3: Upgrading a Dump with Leachate Management, Permetang Pauh, Malaysia

With assistance from JICA, leachate management was introduced in the existing dump. Leachate collection pipes were placed in previously disposed of waste (1-2 m thick). The natural clay deposits under the dump retained part of the leachate and ensured the possibility of collection. The collected leachate was mechanically aerated in a sprinkling system to reduce the organic load in the leachate before recirculation back into the landfill. Part of the leachate from the aeration treatment was discharged into a small stream leading to a wetland area adjacent to the main river. With a constant hydraulic head of leachate on top of the clay, it is recognized that part of the leachate is released into the groundwater and attenuated and dispersed before reaching the river. The system designer claimed that the reduction in the organic matter of the leachate occurred from a *semi-aerobic* landfill concept. The methane generated in the landfill indicates, however, that the reduction of organic load in the leachate may as well occur from methanogenic (and strict anaerobic) conditions in the bottom of the landfill.

The Asuwei landfill in China was divided into two large leachate collection systems. Collected leachate was pumped to a treatment plant that holds 1,000 m3 leachate per day and had a series of aeration channels followed by settlement tanks.[13] The settlement tanks were being used. Laboratory analysis showed that organic strength of leachate at the inlet to the treatment plant was at 2,000 mg chemical oxygen demand (COD) per liter (l) and 1,000 mg biological oxygen demand (BOD) per liter and the effluent strength was 120 mg COD/1 and 60 mg BOD/1. These results were relatively high in comparison to upper- and middle-income country standards but were the best reported among the landfills visited. The leachate treatment facility pumped effluent to a major river approximately 4 km from the site.

At the Laogang landfill in Shanghai, China, collected leachate was pumped into one of the two treatment plants on site. Both included anaerobic and aerobic processes before they discharged leachate for final *polishin*g into the weed bed zone, located between the landfill and the sea. The aerated lagoons proved to be efficient in treating leachate (*see Table 6*), but the aerators depended on the availability of electric power.

Table 6: Leachate Treatment Results at Laogang Landfill (Shanghai, China)

Parameter	Leachate Strength	After Treatment Plant	After Weed Bed Polishing
COD mg/1	2076	1118	487
BOD mg/1	492	268	117
NH4-N mg/1	348	147	67

The Carmona and San Mateo landfills in the Philippines and the Bantar Geban landfill in Indonesia treated leachate in aerated and facultative ponds. Leachate was being recirculated in the Philippines; during the rainy season excess leachate was drained into an adjacent creek.

The Kuda landfill in Indonesia had a leachate treatment facility that consisted of a facultative pond followed by an aerobic pond, after which the leachate flowed into a reed bed (artificial wetland system) for polishing. The treated leachate was then pumped to a series of three aerobic ponds and then to a final reed bed for monitoring. Treated leachate was tested for final discharge by monitoring live fish placed in the final pond.

[13] The annual precipitation in the Beijing metropolitan area is between 500-600 mm. Seventy percent of precipitation and evaporation is anticipated to take place during the rainy season (summer months).

4.5.2 Landfill Gas Management

Many of the landfills had arrangements for passive venting of the landfill gas, releasing the greenhouse gas methane without proper treatment. The Asuwei landfill in Beijing and the Laogang landfill in Shanghai, China, had a passive gas-venting system consisting of approximately 4 wells per ha of perforated center pipe surrounded by a 1 m in diameter perforated center pipe surrounded by stone fill. Operators at the Laogang landfill tested gas recovery for energy purposes but failed to pass the acceptable concentration of methane (40%) in a combustion engine. A future program at the Asuwei landfill will include recovery of gas for energy purposes.

The Bantar Geban landfill, Indonesia, had arrangements for passive venting using vertical wells. A private contractor expressed interest in buying a concession to use the generated landfill gas from this landfill to generate electric power but no final agreement had been reached. The anticipated figures for landfill gas recovery in Indonesia are covered in Table 7.

At the WENT landfill in Hong Kong, gas was extracted from vertical and horizontal drains and burned in flares in a large combustion facility. The aim was for landfill gas to be recovered for energy generation purposes (1.2 MW). The potential for energy generation was an estimated 4 MW. Energy potential was not expected to be maximized because landfill operators were unable to reach an agreement with the local power company and prices for energy were low.

Table 7: Examples from Indonesia on Landfill Gas Recovery Costs and Benefits

Amount of waste per year	tonnes/year	700,000
Total amount of waste (a)	tonnes	5,700,000
Annual gas production (over 10-20 years)	m^3 LFG	22,000,000
Power generation effect (b)	kW	4,500
Annual predicted power production (c)	kWh	36,000,000
Investment: Collection system	US$	410,000
Investment: Extraction system	US$	1,300,000
Investment: Gas engine/generator	US$	3,600,000
Planning, design, engineering	US$	1,300,000
Total investments (d)	US$	6,660,000
Investment costs per kW_e installed exclusive economic support (d)/(b)	US$/$kW_e$	1,480
Investment costs per tonne of waste (d)/(a)	US$/tonne	1.17
Annual operation and maintenance costs	US$	500,000
Total operation and maintenance costs (20 years) (g)	US$	10,000,000
Sales price for electricity (h)	US$/$kW_e$h	0.054
Annual revenue from energy sale (i) = (c)* (h)	US$/year	1,900,000
Total revenue per tonne of waste (k) = (20*(i)/(a))	US$/tonne	6.82
Revenue balance (k) – (((d)+(g))/(a))	US$/tonne	3.89

4.5.3 Landfill Operation

The rapidly growing metropolitan centers of Asia raise a number of problems for landfill operation. Congested traffic makes transport of waste to the landfills increasingly difficult. In China, the Laogang landfill, situated 60 km southeast of the city of Shanghai, receives a daily average of 7,800 tonnes of waste. Shanghai generates a total of 12,000 tonnes/day. Waste was transported from the city's harbor front via barge along channels to the landfill. Large cranes with shovels transferred the waste from the barges to the trucks, which carried the waste the final distance to the disposal area. Hong Kong also shipped waste in containers during night hours to avoid the congested city traffic. Containers were unloaded during landfill operating hours between 8:00 am and 8:00 pm, 360 days per year.

In the Philippines, Metro Manila, with a population of 9.8 million and an annual growth rate of 5 percent, also faces severe traffic congestion. To avoid the most severe traffic problems, the Carmona landfill, 40 km outside Metro Manila, received 1,500 tonnes of waste per day between 6:00 pm and 6:00 am, delivered primarily by transfer trucks. The other Metro Manila landfill in San Mateo received waste during the daytime, with implication that some waste trucks were in transit for more than three hours to dispose of their waste.

Most of the landfills visited were equipped with weighbridges to register incoming waste. They operated with a limited tipping front and used compactors to unload and compact waste in 2-meter lifts. At one landfill, however, much of the operating equipment lay idle, reportedly because the landfill operator could only afford to keep a few bulldozers running (*see Box 4*). One landfill used extensive amounts of soil for daily cover (0.2-0.3 m), acquired from new cell development. Clayey material was used as daily cover—clay materials can form barriers between the waste layers and generate perched leachate when saturated conditions occur in the deposited waste.

The Laogang landfill, China, the WENT landfill, Hong Kong, and the Permetang Pauh landfill, Malaysia, compacted waste into thin layers instead of using daily cover. The WENT landfill achieved a compaction rate of 1 tonne/m^3, while the Asuwei landfill in Beijing achieved a compaction rate of 0.93 tonne/m^3. The Hong Kong and Malaysian landfills covered areas that were not immediately used for disposal of waste with a thin layer of permeable sand.

The WENT landfill in Hong Kong was the only landfill visited that monitored on a regular basis the effects of leachate on the environment. Equipped with government-accredited laboratories, the program provided extensive monitoring and analysis of landfill gas and leachate at the disposal area and analysis of surface run-off water, groundwater, and ocean waters, as well as bio-monitoring of the surrounding ocean.

Landfills in Beijing and Shanghai monitored leachate composition and effluent from their leachate treatment plants on a periodical basis. Other landfills visited did not conduct any form of official monitoring apart from inspection and recording of waste.

Box 4: Landfill Operated as Open Dump, Jakarta, Indonesia

The Jakarta landfill, Bantar Gebang, was designed and constructed based on modern principles, including proper lining and leachate collection and treatment. Leachate was treated in aerated lagoons but because electric power costs were high, only one of the two lagoons was under full operation. The landfill was equipped with 3 compactors, 18 bulldozers, 4 excavators, 17 wheel loaders, and 3 trucks. At the tipping front, only a few bulldozers were grading the waste at the time of the visits. Equipment such as bulldozers and compactors, which had been donated by JICA, were not being used reportedly because landfill budgets could not cover their operation. The landfill had several fires at the tipping fronts and in areas where landfilling had been inactive. Approximately 640 registered waste pickers were present at the landfill.

4.6 Waste Pickers

Waste pickers were not present at landfills in China and Hong Kong. At the San Mateo landfill in the Philippines, the operator reduced some of the negative effects of scavenging by employing several people from the local squatter community. The Carmona landfill in the Philippines had between 25 and 50 waste pickers at the tipping front, primarily women and children. Fires were set to reveal metals from waste. Limited and organized scavenging took place at the Permetang Pauh landfill, Malaysia. Waste pickers at this landfill limited scavenging to one section of the large tipping face.

At the Bantar Gebang landfill, Jakarta, Indonesia, approximately 640 waste pickers were officially registered by the landfill operator. Migrants from rural areas in search of employment, they lived in an area adjacent to the landfill, a section that was used to sort recyclable materials for sale to the recycling industry. Interfering with the operation of the landfill, the waste pickers set fires to recover metals and other non-combustible materials and waste truck traffic. A number of severe health problems were reported. The majority of waste pickers worked without proper protection, sometimes lacking basic protection such as shoes.

4.7 Private Sector Involvement

The landfills visited in Asia were owned by their respective municipal governments. In some cases, the private sector was in charge of some aspects of landfill operations. In Hong Kong, the government was responsible for siting a series of landfills and contracting private services under a design, build, and operate (DBO) contract, an arrangement that involves the integration of three stages into a single procurement. Under a contract of 30 years and 30 years aftercare and liability, the investments in construction and equipment for the landfill were made by the government, and the construction carried out by the contract holders. The municipality paid the contractor a fixed amount for each tonne of waste handled at the landfill. The government monitored the incoming waste strictly through the weighbridges and receiving area procedures.

The solid waste management action plan for Malaysia divides the country into four zones, three on Peninsula Malaysia and one in East Malaysia. Each zone will have one concession given to a private contractor to handle all waste collection and disposal within the zone. The private contractor will be responsible for selecting the appropriate technology, conducting the required environmental impact assessments, and obtaining the required licenses. The city of Kuala Lumpur forms part of the central zone, which will eventually be managed by one of the four concessionaires. As of November 1998, none of the concession agreements had been finalized. However, management of the four zones is being awarded to the respective companies on short-term contracts pending the finalization of the concessions.

In the Philippines, the San Mateo landfill, which was owned by the Metro Manila government, had a contract with a local firm to supply and operate the landfill equipment. The contract was negotiated for a year and based on an hourly rate for each type of equipment in operation.

4.8 Tipping Fees and Landfill Costs

Permetang Pauh, Malaysia, and Bantar Gebang, Indonesia, were the only two landfills that charged a tipping fee at the landfill entrance—both at a level of US$1.2[14] per tonne. The landfill costs were part of the overall municipal budget in China. The estimated waste disposal costs for northeast Beijing are listed in Box 5.

In the Philippines, each municipality charged a basic tax for every load of incoming waste. The municipality of San Mateo collected US$1 per 4-wheeled truck (10 m^3) and US$1.5 per 6-wheeled truck (15 m^3), while the municipality of Carmona landfill charged US$5 per incoming truck. Taxes charged by the municipalities were not included in the landfill's operational budget. The estimated landfill cost for the two Metro Manila landfills was approximately US$10 per tonne of disposed of waste.

In Hong Kong, in contrast, the government was responsible for financing solid waste services: neither residents nor industries were charged. Landfills did not charge tipping fees regardless of waste origin. Operators at the WENT landfill estimated the costs to be approximately US$10 per tonne of waste, excluding the costs associated with leachate treatment.

Box 5: Estimated Costs for Collection, Transfer, and Disposal in Northeast Beijing, China

Collection	US$3.6/tonne
Transfer	US$3.6-4.2/tonne
Disposal	US$2.4-3.6/tonne
Total costs	**US$9.6-11.4/tonne**

[14] The tipping fees were: Malaysia 5 MYR/tonne and Indonesia 8,000 IDR/tonne. Exchange rate to US$ is of mid-January 1998.

5. Observations from Landfills in Latin America

5.1 Overview of the Emerging Landfill Approach in Latin America

The Latin America and Caribbean (LAC) Region accounts for the most active portfolio of World Bank projects that include MSWM components. This conforms to the historical trends in Bank lending in this region for MSWM activities. Of all Bank borrowers, Brazil has been the most active in implementing MSWM components within broader project objectives. Colombia has embarked on a comprehensive urban-environmental management project which will first build capacity and institutions for planning and delivery of basic environmental services (including solid waste management) in four of its largest cities, as well as a dozen secondary cites, and subsequently provide follow-up investments in the solid waste sector. Other countries in the LAC Region have exhibited various levels of involvement in MSWM projects. New projects with solid waste components are currently being prepared in Argentina, Paraguay, and Brazil.[15]

In addition to an active World Bank portfolio, there is growing awareness among the region's leadership of the importance of landfilling of waste. Chile has introduced a number of standards that focus on climatic conditions, including requirements for EIAs and leachate management in different areas of the country. Nevertheless, many countries in the region have only limited legislation, regulations, and guidelines for proper landfilling.

Regardless of the climatic and geological or hydrogeological environment, leachate management for conventional landfills in the region included liners and often composite liner systems, and leachate collection and treatment. Leachate treatment methods ranged from advanced physico-chemical and biological treatment in Argentina and Brazil, to development of pond treatment and enhanced evaporation systems in Chile. A more predominant practice in the region was simple recirculation of collected leachate, anticipating storage and eventual evaporation. At one site in Colombia, however, this practice was suspected to have caused a large slippage or landslide.

Apart from Brazil, most guidelines in Latin America required passive venting of gas from wells located in the waste body. Chile had the most successful examples of utilization of landfill gas.

Generally well-managed and operated, the landfills in the region:

- kept good records of waste accepted for landfilling,
- had limited tipping fronts,
- compacted waste with compactors and/or bulldozers, and
- limited waste lifts to 2 meters.

Some practices, such as the excessive application of daily soil cover to *hide* waste, may need revision. Clay material was often used as soil cover, though the use of this type of soil for daily cover can prevent proper recirculation of leachate and can make vehicle movements difficult in the wet season and worsen dust levels in dry weather. In some cases, the application of a daily soil cover often proved a heavy burden on the landfill's operating budget.

Increasingly, the public sector in Latin America is delegating waste disposal management responsibility to the private sector. Private sector involvement ranges from having private contractors operate the landfills under 10-30 year concession contracts to hybrid BOT contracts (e.g., the municipality invests in and owns the property). The Santiago metropolitan area, Chile, was the site of the one privately owned landfill visited in Latin America. A private company will receive and transport MSW from Santiago under a 15-year contract.

Municipal authorities monitored both public and privately operated waste reception, including inspection, weighing and recording of waste loads, and collected tipping fees. Fees charged for depositing waste ranged from US$4-18 per tonne of waste, at an average of US$10/tonne. The fees charged at each landfill had no bearing on whether the landfill was large or small, or public or privately owned.

[15] See Gopalan and Bartone, "Assessment of Investments in Solid Waste Management: Strategies for Urban Environmental Improvement," Draft.

5.2 Recommendations for the Latin America and Caribbean Region

To improve solid waste management disposal practices, the following recommendations may be adopted in the LAC Region:

1. ***Technical and institutional guidance.*** At the national level, Latin American and Caribbean countries need guidance on siting of landfills with regard to conventional and non-conventional environmental protection measures.[16] In particular, the climatic and hydrogeological aspects of leachate management need to be incorporated into landfill policies.

2. ***Development of the "full concept" of leachate management.*** First, countries need to improve the criteria for liners and leachate collection systems to assure appropriate technology investments. The use of the *entombment* concept, questioned in the scientific community as unsustainable, should be carefully considered and re-assessed. In addition, the region must advance the concept of recirculation, including the benefits and risks, the principles of simple treatment methods and their functions, and education of the principle of attenuation and dispersion. The benefits from evaporation should also be further developed in some countries.

3. ***Re-assessment of passive gas-ventilation systems.*** Passive ventilation must be compared with the option of flaring landfill gas in order to reduce methane emissions. The possibilities for recovery of landfill gas for electric power production or utilization of the gas for industrial purposes should be followed up.

4. ***Re-evaluation of daily cover use.*** Most landfills in the region use clay materials that may prevent proper recirculation of leachate. Moreover, soil is often used in excessive quantities, constituting up to 50% of the operating budget for landfills in some countries.

5. ***General knowledge of environmental monitoring.*** Many countries have introduced monitoring of leachate and groundwater but selected parameters are too many yet indicators are inadequate. Simple approaches with a few important indicator parameters may yield better results. For instance, monitoring chemical oxygen demand (COD), biological oxygen demand (BOD), total nitrogen, and chloride levels may increase understanding of the pollution potential in the landfills and provide an early warning for groundwater contamination.

6. ***Assessing the real costs of tipping fees***. The actual costs associated with landfilling of waste in the region are unknown. To assess a comprehensive fee table for depositing waste, costs should include investment, depreciation, operational, and long-term aftercare costs.

5.3 Landfills Visited in Latin America

The landfills visited in Latin America included: landfills in Argentina (Villa Dominico and Relleno Norte III; Buenos Aires); landfills in Chile (Loma Los Colorados, Santiago; Colihues-La Yesca, which serves 11 municipalities south of Santiago); landfills in Peru (Portillo Grande and Zapalla, Lima); landfills in Colombia (Doña Juana, Bogota; Marinilla; Medellin). Seven separate landfills were visited in Brazil (Salvador, Belo Horizonte, Macae, Rio de Janeiro, Americana, Curitiba, and Caxias do Sul); four landfills were visited in Mexico (Bordo Xochiaca, Queretaro, Nuevo Laredo, and Monterrey). A total of 20 landfills were visited in the region, along with several unnamed dumps. *(See tables 8, 9, and 10 for overviews of observations at landfills visited in Brazil from June 14 to June 29, 1997, and the other Latin American countries from November 9 to November 26, 1997.)*

[16] Conventional measures refer to liners, leachate collection, and biological and physico-chemical leachate treatment. Non-conventional measures refer to controlled contaminant release, treatment of leachate by recirculation before release to a wetland system or passive ventilation of LFG through landfill top cover.

Table 8: Overview of Observations at Landfills Visited in Brazil

City	**Salvador**	**Belo Horizonte**	**Macae**	**Rio de Janeiro**	**Americana**	**Curitiba**	**Caxias do Sul**
Approx. no. of inhabitants in city	2.2 million	1.8 million	200,000	7.8 million	200,000 + 600,000 on workdays	2.2 million	400,000
Landfill category	Semi-controlled dump	Controlled landfill	Sanitary landfill	Controlled landfill	Controlled landfill (bio-remediated dump)	Sanitary landfill	Sanitary landfill/Bio-remediated dump
Waste types	MSW and demolition waste	MSW and demolition waste and MSW	MSW	MSW	MSW	MSW and demolition waste	MSW
Tonnes per day	2000 + 1000	1500 + 2000 + 1000	150	6500	130	1600 + 200	150
Operator	Private contractor	Private contractor/ municipality	Private contractor (BOT)	Private contractor	Municipality	Private contractor	Municipality
Quoted disposal costs R$/tonne	7.5	5.21	18	4.07	app. 10	4.8	N/A
Disposal area	62 ha	40 ha	3 ha	130 ha	19 ha (6 ha)	13 ha	3 ha (2 ha)
Waste pickers	Scavenging takes place at the tipping front	Waste pickers work under program in city	No waste pickers–jobs available in other areas	Program for waste pickers at the landfill–work at designated area	No waste pickers–jobs available in other areas	Waste pickers kept out by guard–scavenging takes place in city	No waste pickers–jobs available in other areas
Environmental setting	Wide gorge	Gorge with a stream passing the middle of the disposal area	Excavation in hillside, near sea	Mangrove in the Guagabara Bay	Hillside near artificial lake and forest	Depression in landscape facing a wetland area	Steep hillside
Liner	None	None–will be applied to new cell under preparation	Yes–compacted soil $k<10^{-4}$m/sec	Vertical liner in perimeter of disposal area	None	Compacted clay	Compacted clay HDPE liner at new cell
Leachate collection	Provisional drains in the waste matrix	None at present	Gravel drains every 15 meters	Some in drains along perimeter	Leachate collection at various levels	Drains in grids at bottom and at each lift–connected by gas wells	Drains at various levels
Leachate treatment	None	None at present	None–planned for recirculation	Recirculation	None–recirculation was earlier performed	Lagoons	Biological + physical chemical treatment
Gas management	Venting	Flaring	Venting	Flaring	Random flaring/venting	Flaring/venting	Active suction and flaring
Operating technique	Random dumping; leveling of waste with bulldozers	Limited and well-operated working face–compaction down-up with bulldozer. Cover of top of lift	Limited and well-operated working face –random compaction with bulldozer. Continuous cover applied	Limited and well-operated tipping fronts. Leveling of waste and compaction with bulldozer. Daily cover of soil applied	Limited tipping front–Random compaction down-up. Applying more than 0.5 meter of daily cover	Large open tipping face with lifts of 2-3 meters leveled by bulldozer. Compaction of last layer in each lift with compactor	Limited tipping front–compaction with bulldozer
Equipment	1 weighbridge 8 bulldozers 2 excavators 3 wheel loaders 10 trucks 1 compactor (for roads) 1 grader	2 weighbridges 7 bulldozers 2 wheel loaders 7 trucks 1 tractor 2 graders	No weighbridge 1 bulldozer 1 back hoe tractor 1 truck	2 weighbridges 10 bulldozers 2 back hoe tractors 10 tractors 17 trucks 1 compactor (for roads) 1 grader	No weighbridge 1 bulldozer 1 back hoe tractor 2 trucks	1 weighbridge (in/out) 2 bulldozers 1 back hoe tractor 2 (3) trucks 1 compactor (rebuilt wheel loader)	No weighbridge 1 bulldozer 1 truck

Table 9: Overview of Observations at Landfills Visited in Mexico

Country	**Mexico**			
	Bordo Xochiaca	Queretaro	Nuevo Laredo	Monterrey
Landfill category	Controlled dump	Containment	Containment	Containment
Waste types	All types	Domestic waste	Domestic waste Non-hazardous industrial waste	Domestic waste Non-hazardous industrial waste
Tonnes per day	1,700	450	350	3,000
Operator	Privately operated	Privately operated	Privately operated; 15-year BOT	State-owned and operated
Tipping fee US$/tonne	4-9 per load	Public: 7-13 Private: 11.5	Municipal: 10.5-17 Private: 10	5/tonne, expected to be increased by 20%
Disposal area	21 ha	20 ha, divided into 3 cells of equal size	20 ha; each cell is 3 ha	192 ha divided into "trenches" of 6 ha
Waste pickers	Approx. 900	None	None	None
Environmental setting	Desert-like area in the outskirts of Mexico City	Mountainous area with adjacent quarry activities	Flat area with surrounding farmland	Flat area outside industrial area
Environmental protection	None	Liner and leachate collection	Liner and leachate collection	Liner and leachate collection
Liner	None	1 mm HDPE liner	Natural clay liner– compacted to k< 1.6×10^{-8} m/sec	Bentonite–enhanced clay and natural clay
Leachate collection	None	Base with soil drainage layer; sides with used tires	Drainage layer with herringbone drains	Drainage (w/ pipe) in depression of the cell
Leachate treatment	None	Evaporation and recirculation	Evaporation and recirculation	Recirculation
Gas management	None	Passive gas ventilation in grids of 35x35 m	Passive ventilation, 8 vents per 3 ha	None
Operating technique	Cell method, with periodic soil covering	Cell method, with 0.2 m daily soil cover	Cell method, with 0.2-0.3 m daily soil cover	Cell method, with extensive daily soil cover
Equipment	no weighbridge 3 bulldozers 1 water tanker	1 weighbridge 1 bulldozer 1 loader 1 truck 16 employees	1 weighbridges 1 compactor 1 bulldozer 1 loader 2 dumpers 15 employees	2 weighbridges 2 compactors 3 bulldozers 5 loaders 1 scraper 2 trucks 3 dumpers 75 employees

Table 10: Overview of Observations at Landfills Visited in the Rest of Latin America

Country	**Argentina**		**Chile**		**Peru**		**Colombia**		
	Villa Dominico	Relleno Norte III	Loma Los Colorados (Santiago)	Colihues La-Yesca	Portillo Grande (Lima South)	Zapalla	Doña Juana (Bogota)	1) Marinilla 2) Viboral (Antioquia)	Medellin
Landfill category	Controlled landfilling	Containment	Containment	Containment	Controlled landfilling	Controlled landfilling	Containment	Manual	Containment
Waste types	Domestic Industrial	Domestic Industrial (non-hazardous)	Domestic waste	Domestic waste	Domestic waste	Domestic waste	Domestic	1) Domestic 2) Source separated domestic	Domestic Industrial Demolition Health care waste
Tonnes per day	8,000	4,500	4,200	400	1,200-1,400	600-700	4,500	15 tonnes 5 tonnes	2,000
Operator	Privately operated	Privately operated	Privately owned	Privately operated (BOT)	Privately operated (BOT)	Privately operated (BOT)	Privately operated	Municipal operated	Municipal operated
Tipping fee US$/tonne	10	Municipalities 10 Private 10 Industrial 18	4.8 11.25 incl transfer (excl VAT)	12-17	5 15 incl. transfer and transport	5	13.8% of collection tax. Government stated 7.8 US$/tonne	No charge–estimated costs 8 US$/tonne	11 US$/tonne
Disposal area	400 ha; Max filling height 21m. Ave. 6m	64 ha, 40 ha in use. Max filling height 19m	200 ha disposal area Cells of 8 ha; Max filling height 140 m	18.5 ha disposal area. Cells of approx. 2.5 ha	357 ha	470 ha	350 ha available. 60 ha disposal area	1) 4.5 ha 2) 2 ha	73 ha disposal area
Waste pickers	None–scavenging takes place in the city	None	None	None	None	Organized scavenging	None	Formal scavenging by workers	None
Environmental setting	Wetland area near river	Wetland area near river	Valley in mountainous terrain	Valley in mountainous terrain, near river	Desert-like mountainous terrain	Desert-like mountainous terrain	Mountainous near river	1) Hillside next to wetland 2) Old quarry	Mountain side next to river
Liner	Natural clay liner 2-7 m thick; $k<10^{-9}$m/s	PE liner (1 mm) overlaid by 0.3 meter clay	Composite liner (0.2 m clay; 1.5 mm HDPE)	Composite liner (0.5 m clay; 1.5 mm HDPE)	None	None	Newest disposal areas lined with PE liner	None	PE liner
Leachate collection	None	Vertical wells placed within at strategic points within the lined area. Submersible pumps.	0.3 m drainage layer with side drains leading to double piped main drainage canal. Pumping sump outside disposal area	PE drainage grid, geo textile and 0.1 m gravel (stones) draining to sump pumps	None	None	Drainage in stone drains	None	Drainage at bottom of depression, discharged into a 200 m^3 tank
Leachate treatment	Natural attenuation	Physico/chemical followed by biological anaerobic/aerobic	Pond storage and preparing for evaporation	Pond storage and recirculation. Planned physico-chemical treatment	None	None	Extensive recirculation. Ponds used for storage	Release of leachate through fascine	Direct discharge to river from 200 m^3 tank.
Gas management	None	Passive ventilation	Expected utilization for power generation	Passive gas ventilation	Passive venting and flaring	Passive venting and flaring	Vertical gas drains for passive ventilation	None	Gas ventilation wells installed for passive ventilation
Operating technique	Cell method, 3 cells at the time	Cell method	Cell method with extensive daily cover	Cell method; extensive daily cover	Cell method at two separate cells; extensive daily cover	Cell method; extensive daily covering	Cell method–daily covering was not observed	Manual operation, with periodic soil covering. No formal waste registration	Cell method– 10 tipping fronts; demolition waste is used for daily cover
Equipment	4 weighbridges 5 compactors 9 bulldozers 5 excavators 2 water trucks 36 employees	4 weighbridges 2 compactors 4 bulldozers 1 excavator 8 trucks 1 scraper	1 weighbridge 3 compactors 1 bulldozer 3 excavators 7 trucks 1 loader 2 container trucks 36 employees	1 weighbridge 2 compactors 1 loader/bulldozer 1 excavator 4 trucks 2 water trucks 1 scraper 1 roller 30 employees	1 weighbridge (at LF) 2 bulldozers 1 loader 2 trucks 1 water truck 20 employees	1 weighbridge 2 bulldozers 1 loader 2 trucks 1 water truck	2 weighbridges (compactor available) 2 bulldozers	shovels rakes 6 employees	

5.4 Regulatory Framework

Regulatory institutions governing municipal solid waste management varied considerably throughout Latin America. In Chile, the Ministry of Health (MoH) Department of Environmental Programs is the principal agency with jurisdiction over management of urban wastes. At the national and regional levels, the MoH has jurisdiction over monitoring and enforcing the guidelines. Chile's 1994 environmental legislation set two goals for solid waste management: a) full coverage of waste collection; and b) environmentally sound final disposal of waste, primarily via sanitary landfilling (*see Box 6*). In many respects, these goals have yielded results. In 1994, Chile had a waste collection coverage of 99.1%, with 82.9% of the waste disposed of in conventional landfills. Since passage of the legislation, environmentally sound disposal rates have risen to 85%, while waste collection coverage has remained a steady 99.2%.

Box 6: The Regulatory Framework in Chile

Chile has passed several regulations and guidelines aimed at proper management of waste disposal. Most recently, the Chilean Congress approved legislation that requires landfills to follow an EIA procedure to meet MoH licensing requirements.

Chile's official regulatory leachate management strategy is the *entombment* concept.[17] Chile has different requirements depending on the climatic conditions in different parts of the country. In the arid northern part of the country, leachate collection systems and liners are not required; leachate collection, without treatment, is required in the central part. Only landfills in the wet climatic zones in southern Chile are required to both collect and treat leachate, until covered with an impermeable seal.[18]

One aspect missing from the MoH guidelines is a proper definition of liability for landfill owners after closure. This loophole may pose a heavy economic burden, as the municipality would be left with the responsibility for landfill operation and maintenance of environmental protection and control measures after closure of a privately owned landfill.

Colombia has a decentralized structure for legislating waste disposal, with each state maintaining control over its regulations. The state of Antioquia, for instance, issued a decree in 1990 mandating that all municipalities dispose of solid waste in landfills. By 1994, 22 out of 26 municipalities had some form of solid waste landfill, supervised and monitored by the competent authority within the state.

5.5 Important Features of Visited Landfills

5.5.1 Leachate Management

Most of the sanitary landfills visited in Latin America had impermeable liners and practiced leachate collection and treatment. Liners were usually constructed of compacted natural clay, reaching a permeability coefficient of 10^{-8}m/sec. Landfills in Peru did not have a leachate management program, reflecting the country's arid coastal climate. In the northern part of Brazil, landfill operators rarely applied liners or treated leachate, whereas some landfills in the southern and more prosperous part of the country did both.

In the Monterrey, Mexico landfill, low permeability was achieved by using bentonite-enhanced compacted clay. The landfills in Caxias do Sul, Brazil, Medellin, Colombia, and Queretaro, Mexico, had polyethylene liners; a sand layer 0.3 m thick was applied for liner protection and leachate collection. At the Queretaro landfill, rubber tires were placed on side slopes for protection and drainage layer purposes.

[17] See also Chapter 3.2.
[18] For a similar approach in the Republic of South Africa, see Chapter 4.4.

Composite liners[19] of a low-pearmeability clay covered directly with a polyethylene liner were applied at the visited landfills in Chile. At the Relleno Norte III landfill in Argentina, a composite liner was constructed by first applying a polyethylene liner and directly on top of that compacting a 0.3 m layer of clay.[20]

In Monterrey, Mexico, the original below-grade cells were constructed with vertical walls. Presently, slopes are constructed with a gradient of 1:3 (vertical:horizontal), lined with polyethylene liners to avoid possible complications with the applications of liners to vertical slopes.

Most of the landfills visited with liners also collected leachate from the bottom of the landfill and provided some form of leachate treatment. One exception was the Medellin landfill in Colombia, which collected leachate to a buffer tank before discharging it into main river. Several landfills in Brazil included liners but did not collect or treat leachate.

The recirculation of leachate, a process used to evaporate or store some of the leachate, was a common practice in the region. Recirculation was used as a leachate treatment technique at the Rio de Janeiro landfill, Brazil; Loma Los Colorados and Colihues La-Yesca, Chile; Doña Juana, Colombia; and all the landfills visited in Mexico. At the Doña Juana landfill, recirculation of leachate may have led to its collapse (*see Box 7*).

To enhance evaporation of leachate, the Loma Los Colorados landfill in Chile was in the process of expanding its treatment capacity. Collected leachate will be discharged into two ponds where part of the evaporation will take place. The landfill designers were devising the evaporation steps at the time of the visits: leachate will be pumped to a high point in the landfill and then released into a series of steps with a very limited slope, protected by a black polyethylene liner. The designers anticipate that by implementing this approach, the leachate will eventually evaporate. The issue of handling residuals after the evaporation process still needs to be resolved.

The landfill at Relleno Norte III, Argentina, had more advanced methods for leachate treatment than most countries in the region. The treatment plant had a daily capacity of 120 m^3 and was currently using 40 m^3 per day–the treatment consists of a physico-chemical step before a two-step (aerobic followed by anaerobic) biological process. COD was reportedly reduced from 3,000 mg/l at inlet to 80 mg/l at outlet. Ammonia-N at outlet measured 16 mg/l and at inlet the level was unknown, but was estimated at 500-1,000 mg/l). The Caxias do Sul landfill in Brazil conducted a similar method of leachate treatment.

[19] For advantages of composite liners, see Johannessen, L.M., "Guidance Note on Leachate Management for Municipal Solid Waste Landfills."
[20] The physical effects on the underlying plastic liner was not known or checked, but may be significant.

Box 7: The Doña Juana Landslide, Bogota, Colombia

Background

Based on the research findings from the Bogota DC Department of Engineering, the same department decided that a private contractor should build and operate the Doña Juana landfill. The private contractor made significant changes in the liner design and leachate management plan before its implementation in 1993, without consulting the original designers. Leachate management changed from storage of leachate in ponds to recirculation. The landfill operated primarily by grading waste with bulldozers and providing daily soil cover. The compaction rate of the waste was reportedly low. Extensive recirculation of leachate took place, partly through the installation of vertical gas ventilation wells. Landfill operators never used the on-site leachate treatment plant.

Months before the first phase of the landfill closed, operators noticed cracks in the intermediate cover. Leachate was also seeping from the slopes of the final cover. Just days after the last batch of waste was deposited in the first phase, the landfill collapsed and more than 1 million tonnes of waste slid more than 1 km. The slide took place from approximately 10:00 am to 6:00 pm, with no reported injuries. While the cause of the collapse was not confirmed, officials at the Administrative Department for the Environment (DAMA) had several theories: a) the private contract was poorly conceived; b) the contractor failed to follow the original landfill design and instructions for operation; and c) the authorities had incomplete information to ensure adequate monitoring and supervision.

The private operator opened a new section of the landfill, but the collapse has led to neither a change in construction nor to a change in landfill operations. With the assistance of the World Bank, DAMA began a remediation program for the collapsed part of the landfill, redesigned the new section, and installed a treatment plant. As a result of the collapse, recirculation of leachate has been banned at the Doña Juana landfill.

5.5.2 Landfill Gas Management

The landfills visited generally managed landfill gas through passive ventilation, releasing without treatment the ozone-depleting greenhouse gas methane. Chile had the most successful example of recovery and utilization of landfill gas (*see Box 8*). The Lomo Los Lindos landfill was researching the feasibility of using recovered landfill gas to generate electricity and evaporate leachate. Many of the landfills visited in Brazil flared gas from the wells installed in the waste. At the Caxias do Sul landfill, for example, gas was pumped to the highest point of the landfill and flared. The Rio de Janeiro landfill was also considering utilization of landfill gas.

Box 8: Landfill Gas Recovery in Santiago de Chile

At two recently closed sites in Santiago, landfill gas production was enhanced by recirculating. The landfill operator planned to continue leachate recirculation for at least another four years, the period during which landfill gas is still being generated in quantities feasible to utilize. Landfill gas from the two landfills was extracted by partial vacuum and cleaned for hydrogen sulfide and other contaminants by cooling through a water trap before being injected into the city gas network. Only 30% of the landfill gas could be utilized because of its high concentration of carbon dioxide. Forty percent of landfill gas in the network is considered the minimum to ensure good gas combustion in household applications (cooking and heating water). In the gas distribution network, the concentration of landfill gas permitted was approximately 40% in Santiago and 30% in Bakaris.

5.5.3 Landfill Operation

The landfills visited in Latin America tracked incoming waste by weight with the exception of a small landfill in Brazil, which received less than 150 tonnes daily and recorded waste based on the number of incoming trucks.

Tipping fronts at several landfills were operated by compactors grading and compacting the waste and bulldozers applying soil cover. In Brazil, landfill operators were doing most of their work with bulldozers at the tipping front, but practices varied throughout the region. At the Curitiba landfill, for example, the last shift of waste deposited on a cell was graded and compressed by compactor. In Medellin, Colombia, a compactor was used to compact waste into layers 10 m thick. Demolition waste, crushed by a bulldozer, was used as daily cover material.

In general, significant amounts of soil were used for daily cover, sometimes by default, but at other times because the local authorities require it. In Mexico, landfill operators applied a soil cover more than 0.2 m thick at the end of each working day; at Americana, Brazil, landfill operators applied more than 0.5 m of clayish soil for each 1-2 m of waste. Several operators claimed that as much as 50% of their operating costs was spent on the use of daily soil cover. In most cases, operators applied daily cover to meet a local requirement, not because they believed it was necessary.

The tipping fronts were generally small and well-managed, with a few exceptions (*see Box 9*). At the larger landfills of Rio de Janeiro and Belo Horizonte, Brazil, Villa Dominico, Argentina, and Monterrey, Mexico, operators used several tipping fronts to ensure small tipping faces and control the large number of trucks arriving at the landfill.

Box 9: Landfill "Mismanagement"

One landfill, which shall remain nameless, serves to highlight a number of poor landfill practices. Managed by the private sector, the operation was initially a good example of landfill management. The landfill registered incoming waste, limited its tipping fronts, used compactors to compact waste, applied a soil cover on the compacted waste, and restricted waste pickers on the landfill.

Two years after the initial landfill design, however, there was a change in the local administration in the responsible municipality. The new authorities did not allocate funds to pay the contractor. After several months without payment, the contractor abandoned the landfill and operations were taken over by municipal staff who had limited, if any, experience in landfill operation. The landfill began to operate as an open dump; several uncontrolled tipping fronts were used to unload waste, and bulldozers were used to grade and compact the waste. Additionally, the landfill no longer had compactor equipment and several hundred waste pickers interfered with daily operations. This particular example shows the importance of political support and the willingness of authorities to allocate resources for ensuring adequate landfill management.

The landfills at Relleno Norte III, Argentina, and Caxias do Sul, Brazil, monitored leachate composition according to performance guidelines. Villa Dominico and Relleno Norte III, Argentina, and Caxias do Sul, Brazil, had extensive groundwater monitoring programs which included testing for the presence of heavy metals. Good indicator parameters, such as chloride levels, were not used. At the Caxias do Sul and Americana landfills in Brazil, old and new waste were mixed to boost bio-degration (*see Box 10*).

Box 10: Bio-remediation Landfills in Brazil

In the Brazilian context, bio-remediation means "to excavate an old dump"; mix the excavated old waste with fresh refuse in a 70:30 w/w ratio (50:50 v/v); treat the generated leachate in a biochemical-physical process; add an engineered microorganism; recirculate the leachate back into the landfilled waste; and let leachate levels build up inside the landfilled waste body. Part of this process (engineered microorganisms are not added) is currently being applied at one landfill—the remediated part of the old Caxias do Sul landfill. Analyses of the leachate analyses show clear indications of strict methanogenic conditions in the waste and thus a high degree of bio-degradation.

Over a four-year period, the Americana landfill re-disposed of 10-year-old waste mixed with fresh refuse, leachate treatment, and recycling of microorganism-enriched leachate. The leachate treatment process was discontinued in 1991 due to lack of funds for landfill operation.

Excavation tests included a batch of bio-remediated waste and a batch that had not been mixed with recirculated leachate. At the time of the tests the bio-remediated waste extracted was a mixture of 16- and 6-year-old waste and the non-bio-remediated waste was approximately 5 years old. The waste that was 5 years old showed poor levels of bio-degradation and the odor from the excavation suggested that the bio-degradation was still acethenogenic. The excavation of the older waste (70% 16-year-old waste; 30% 6-year-old) showed extensive bio-degradation, by visual assessment. The odor suggested that there was methanogenic bio-degradation of the waste. Similar results were observed in other waste digs in which waste was approximately the same age. Mixing the waste and recirculating the leachate may have contributed significantly to its bio-degradation. But it is still unclear whether a high level of microorganisms under bio-degradation in old waste will additionally enhance the bio-degradation process. Scientific proof was not available at this point. Visual observations from the results did not indicate any difference from MSW landfills operated elsewhere as a bio-reactor landfill with normal recirculation of leachate.

5.6 Waste Pickers

Waste pickers were prevalent in the less prosperous parts of Latin America and many depended on waste recovery for their livelihood. Unorganized scavenging did not take place at any of the well-managed landfills visited.

In Mexico City, 300 to 500 waste pickers were organized at the Bordo Xochiaca dump, with little opposition from landfill operators. Waste pickers occasionally set fires to recover non-combustible materials (primarily metals). At the Zapalla landfill in Peru, two organized waste-picker cooperatives shared operations. The cooperatives selected valuable materials from the waste at the tipping front and sorted it off-site. According to municipal authorities, the waste pickers had to wear blue uniforms during operations to be allowed on the landfill premises.

The municipality of Belo Horizonte, Brazil, organized waste pickers through a city program, providing opportunities to recover reusable and recyclable materials before waste collection. Waste pickers in Rio de Janeiro were removed from the landfill's tipping front and given a designated space near the reception area of the landfill. The municipality allowed waste pickers to select trucks from high-income areas and pick from the waste to recover aluminum cans, plastic bottles, metal scrap, cardboard, and paper. The landfill operator then removed the container with the residuals from the picking belt. The waste pickers were organized into a cooperative—everyone was paid an equal amount of money at the end of each week, depending on income generated by the sale of recyclable materials. The average income for a waste picker was R$400, well above Brazil's minimum wage of R$106 in June 1997.

5.7 Private Sector Involvement

In general, the local government owns a landfill site and contracts a private firm on a hybrid BOT basis, for an average period of 15-30 years. The Lomo Los Colorados landfill in Chile was the only privately owned landfill visited. Owned by the private company KDM, the landfill had exclusive rights to receive waste from larger parts of the metropolitan area of Santiago de Chile for a 15-year period.

The nature of BOT contracts varied depending on the landfill operation. In Buenos Aires, Argentina, transfer stations and four landfills were operated by private contractors under BOT contracts with the Metropolitan Areas Environmental Authority (CEAMSE). The operator at the Villa Dominico landfill, for example, had entered into a 20-year BOT contract in 1978. The contract included construction of landfill cells, daily operation and compaction of waste, supply and maintenance of operating equipment and roads, groundwater monitoring, and installation of the final top cover. Under the contract, the company has a liability and maintenance responsibility for three years after its completion.

Relleno Norte III, also in Buenos Aires, was operated by a private firm under a 5-year BOT contract. Signed in 1994, the contract included construction of landfill cells, daily operation and compaction of waste, application of an intermediate cover, leachate treatment, supply and maintenance of operating equipment, maintenance of roads, groundwater monitoring, and installation of the final top cover. As the 5-year contract expires, disposal areas that are still vacant must be provided with bottom liners and drainage systems. CEAMSE supervised and monitored waste inspection and recording at both of these landfills.

Mexico’s Queretaro landfill was built and operated by the private company Mexico Medio Ambiente (MMA), a sister firm to the Spanish-owned company FGF. The contract included closure of the existing dump site and construction, operation, and completion of the new landfill. After the 15-year contract expires, the local municipality that already owns the land and pays property taxes will take over the operation of the landfill. Similarly, the private firm Setasa operated the Nuevo Laredo landfill, a 100% Mexican company owned by the large civil construction company. Setasa has a contract with the municipality of Nuevo Laredo for 15 years to carry out city cleaning and waste disposal. After the contract expires, the local municipality will take over the landfill and movable equipment. The local municipalities monitored the contracts primarily through information on waste registered, as provided by the contractors. At another Mexican landfill, a state-owned landfill operated much as a private entity (*see Box 11*).

Landfills in Brazil were mostly owned and built by the metropolitan governments and operated by a private contractor. This was the case in Curitiba, where a private contractor was responsible for all landfill operations, including registration of waste received at the landfill. The metropolitan government employed an official to monitor waste registration and two to supervise the operation of the landfill.

Solid waste collection in Bogota, Colombia, was privatized in 1991. A civil construction contractor with limited experience in landfill construction and operation won the bid to build and operate the Doña Juana landfill. At the time, few procedures or guidelines governing solid waste management existed in Colombia, which, according to DAMA, has contributed to inefficient and ineffective monitoring and supervision.

Box 11: The Monterrey Landfill—A State-Owned Landfill, Private Style, in Mexico

The SIMEPRODE Monterrey, Mexico, operated three transfer stations and the landfill for the state of Nuevo Leone. The transfer stations served the metropolitan area of Monterrey, with approximately 3.5 million inhabitants. The landfill served the metropolitan area of Monterrey and 75-80% of the remaining state of Nuevo Leone.

The management of SIMEPRODE is by political appointment. Recent elections in the State of Nuevo Leone had changed the organization's administration. The new upper management at SIMEPRODE came from the private sector and was paid private sector equivalents.

SIMEPRODE operates as a private company—with its own budget—and is responsible only to its board of directors, comprised of the governor, three mayors, and representatives from industry and the unions.

5.8 Tipping Fees

Most of the landfills visited in Latin America have established some form of tipping fees based on weight and, in some cases, based on load per waste hauler. The exception was the Doña Juana landfill in Colombia, where the contractor was paid 13.8% of the collection tax, estimated at US$8 per tonne of waste. Few landfills discriminated between types of waste received. The tipping fees ranged from US$4-18 per tonne of waste, with an average of US$10/tonne. In many cases, tipping fees were charged to the municipality, not the waste hauler.

Tipping fees generally reflected the landfill operator's wage costs rather than real landfill costs (construction, after-care costs, etc.). At the Monterrey landfill in Mexico, for example, the tipping fees covered only operational and maintenance costs.

Annex A: Regional Contacts

SOUTH AFRICA	
Company	***Name***
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Jarrod Ball & Associates	J. M. (Rod) Ball and Peter A. Legg
WS Waste Services	Nancy de Jager
Water Affairs and Forestry	Leon Bredanhann and Merinda Lindick
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Company	***Name***
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GOPA	Jurgen Meinel
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Ministry of Construction	Shen Jianguo Ning Kai Tao Hua
ASW	Qian Da Sheng
BESA	Jin Yongqi
Beijing Municipal Environment Protection Bureau	Ming Dengli
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