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Landfill in Asia

Improving sanitation of landfill sites

Improving those landfill sites which take MSW will be a big step for most Asian countries. What are the problems they face, and how can they make landfiling sustainable?

**Are there
feasible
alternatives to
landfilling in
developing
countries?**

More than 8 million tonnes of solid waste is produced per day in developing countries.¹ Over 95% of this is disposed of in landfills, open dumps, riverbanks and the sea or simply combusted on-site due to insufficient waste collection and final-disposal systems. The many environmental and health risks associated with open dumping put landfiling at the bottom of the waste hierarchy in the industrialized world. But are there feasible alternatives to landfiling in developing countries?

Low and middle-income Asian countries face the accelerated generation of solid waste caused by an ever-increasing population, migration from the countryside, urbanization and industrialization. This article examines municipal solid waste management (MSW) issues in such countries, focusing on the current status and appropriate landfill technologies under Asian conditions.

Three types of disposal site are referred to here. An open dump is an uncontrolled land disposal site. Disposal at these sites is gradually being phased out in many countries and replaced by disposal in sanitary landfills. A sanitary landfill is a site where waste is isolated from the environment through engineering procedures, and where emissions such as leachate and gases are properly collected and treated. The term 'landfill' generally refers to options intermediate to open and sanitary landfills.

Solid waste generation and composition

The rates of waste generation in low- and middle-income Asian countries reflect their levels of socio-economic development, urbanization and industrialization, and climate and local conditions for production. In general, urban inhabitants produce two to three times more MSW than those in rural areas. Average generation in low-income countries varies from 0.4–0.9 kg/person/day; in middle-income countries the range is 0.5–1.1 kg/person/day; in high income countries it varies from 1.1–2.0 kg/person/day but can be more, as in the case of Hong Kong, where the figure is 5.1 kg/person/day.¹

The recent economic development and urbanization of Asian countries has not only resulted in them producing more waste but also in changes in the composition of their

TABLE 1. MSW composition (% of wet weight)^{2,3}

	Paper and cardboard	Textiles	Leather and rubber	Plastic	Metal	Glass	Wood	Ash, dust, etc	Biowaste
China	6.9	4.7		7.3	0.5	1.6	6.9	19.2	52.6
India	7.6	4.7	1.3	3.8	1.7	2.1		40.1	39.6
Sri Lanka	12.3			6.8	3.7	3.0	10.2		64.7
Thailand	7.7	2.7	3.0	13.7	3.1	4.3	3.6	5.0	56.2
Kathmandu, Nepal	11.0	4.8	1.0	8.4	0.3	2.2	0.3	5.2	66.8
European average	32.0	4.0		7.0	8.0	10.0		9.0	30
California, US	41.0	2.4	2.6	10.7	7.9	5.8	5.0	0.5	24.1

waste (Table 1). Organics dominate in Asian rural areas whereas MSW in urban areas contains much higher amounts of paper, plastics, hazardous waste and electronics alongside the still dominating organic waste. Significant amounts of ash and dust are found where mainly coal and wood are used for heating and cooking.²

Household waste generation is often underestimated in low and middle-income regions because part of the reusable material is sorted out in the households and the streets before it is classified as waste. In addition, some organic wastes become animal feed or compost. For example, waste generation in the city of Kathmandu in Nepal has increased to 0.371 kg/person/day but the generation rate of 0.225 kg/person/day in the valley has remained constant over the years.³

The moisture content of waste arriving at landfills and dumps can reach 60%–70% due to the use of open bins for storage and, in many cases, open transport under intense and frequent rainfall. The waste thus has a very low calorific value, which makes it less attractive for incineration. Because scavenging often deprives the waste of bulking agents, immediate and fast biodegradation takes place, generating highly polluted wastewater and nuisance.



Collection

In modern areas or the rich town districts, the standard of cleansing and waste management is similar to that in western cities. Daily collection is common in big cities, but inadequate coverage is common in low-income areas, leading to waste littering and dumping in backyards and open spaces.

Household waste is often disposed of either on the streets or in public waste containers. The municipal sweepers clean the streets and collect the waste, usually using handcarts, before it is transferred to either tractors or trucks.

Currently 90% of the waste generated by Kathmandu’s 670,000 inhabitants is collected by the private and public sectors either by roadsides, door-to-door or through container collection at a rate of 895 m³/day.³ The waste is collected and taken to Teku Transfer Station, which takes 40% of the total municipal waste. Here it is unloaded on a concrete

Household waste is often disposed of either on the streets or in public waste containers

platform or directly at the dumping site at Balkhu river. There is generally a lack of maintenance and technical staff.

Final disposal: the open dump approach

Most Asian countries face similar problems regarding final disposal. In Thailand and India, for example, 70%–90% of the final disposal sites are open dumps.² As cities grow, the few existing landfills are filled up quickly and the length of time it takes to develop a new landfill frequently results in a return to open dumping.

Insufficient allocation of financial resources in the waste management sector, acceptance of the status quo and a lack of awareness among both the public and politicians of environmental and health concerns are the root causes of the low quality of waste services. The population frequently lights fires on waste heaps to reduce their volume, their smell and access to them by animals. Open burning and scavenging are also common practices at dump sites to reduce volumes and to remove valuable goods from the waste.

Scavenging depends on markets for the recovered materials and the existence of people who are compelled to do the poorly paid, hazardous work which has a low status.^{4,5} Scavengers live near the dump sites in simple houses and often use the methane gas from landfill for cooking. The

waste management company or dealers may provide the scavengers with houses and tools such as gloves and boots.

From open dump to sanitary landfill

For developing countries, it is a big step to move from existing open dumps and uncontrolled disposal sites to sanitary landfills. The locations of most landfills and dumps in Asia are based on convenience rather than hydrogeological considerations. They are usually large and shallow holes in the ground into which the waste is dumped. They are often located in environmentally sensitive areas such as marshlands, abandoned mines and river beds.²

The most common operational approach includes:⁶

- spreading the solid waste in thin layers
- compacting the waste to the smallest practical volume
- applying and compacting cover material at the end of each operating day.

In most cases, the conditions created by the monsoon are not considered, and feasibility and environmental impact assessment studies in accordance with the national and local regulations have not been carried out.



FACING PAGE Dumping on the riverbanks at Balkhu, Nepal **ABOVE** Scavengers sorting out recyclables at a transfer station in Nepal

The replacement of dump sites by landfills with higher sanitary standards will therefore only happen in the medium to long term. The following initial steps are recommended:⁵

- eliminating fires on dump sites
- restricting waste tipping into small areas following a disposal plan

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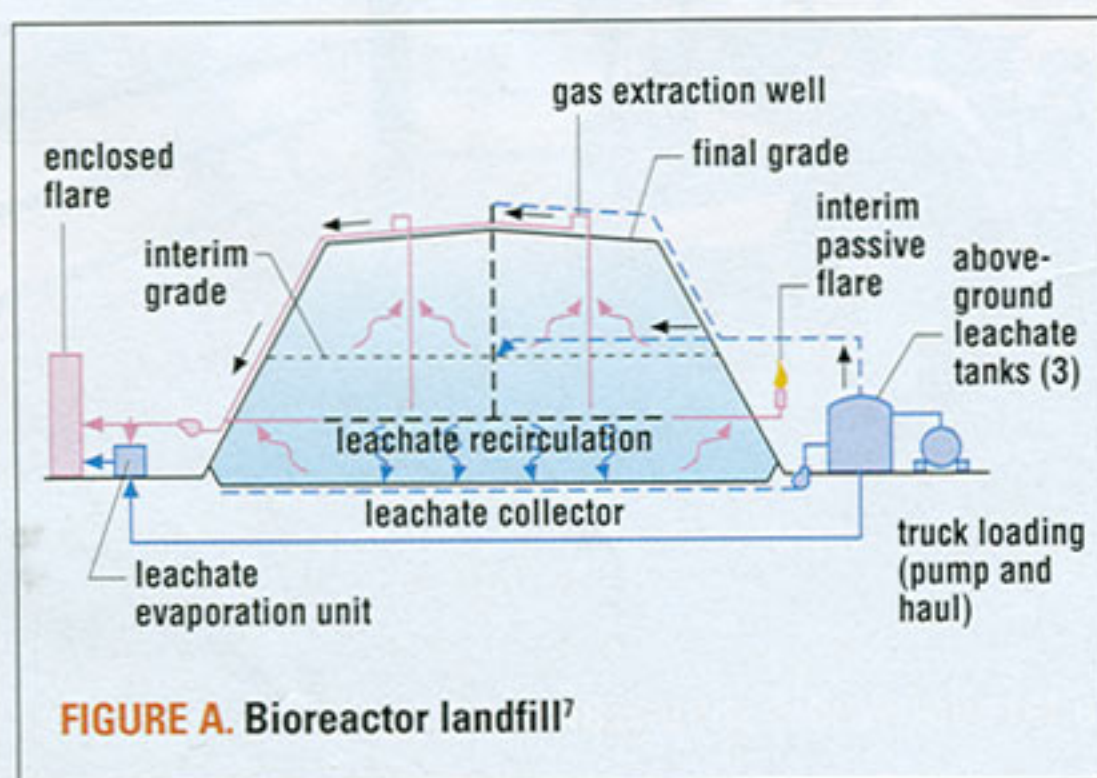
Sustainable landfills in an Asian scenario

The design of a sustainable landfill should incorporate:²

- a liner system at the base and sides of the landfill to prevent migration of leachate or gas to the surrounding environment
- leachate and gas collection, together with treatment systems to meet regulatory requirements
- final cover of the landfill that enhances surface drainage, prevents infiltration of water and supports surface vegetation
- surface water drainage system that collects and removes surface run-off from the site
- environmental monitoring system that periodically collects and analyses air, surface water, soil and ground water samples around the landfill site.

The waste should be treated within the lifetime of each generation and remaining residues should be stabilized under environmental safe conditions. To achieve this under Asian conditions requires a controlled breakdown of the biodegradable fraction to accelerate the degradation process and increase the efficiency in which the dry tomb concept is transformed to a landfill bioreactor (see Figure A).¹⁰

The leachate is collected and recycled in the anaerobic bioreactor and stabilized within less than 10 years. The amount of methane generated in this type of bioreactor is directly related to the amount of organic material in the waste stream diverted to the reactor. The sustainable landfill combines the principles of bioreactor landfill to enhance the process of stabilization and landfill mining to recover the space for reuse while salvaging decomposed organic matter for agricultural use.



- depositing wastes in thin layers of about 50 cm with appropriate compaction
- covering the newly deposited waste with about 15 cm of soil or similar material daily
- installing systems for the collection of landfill gas and diversion of rainwater

- keeping the site-access roads in good condition to enable vehicles to deposit wastes at designated places as quickly as possible
- protecting the disposal site from scavengers or the public by building boundary walls and access gates
- maintaining records of waste deliveries and tipping
- carrying out environmental monitoring (from simple visual inspection to complex chemical analysis)
- providing a site with essential manpower, such as a landfill manager, an office clerk, security staff, a traffic controller, landfill equipment drivers and a mechanic.

These steps would enable a gradual transformation and rehabilitation of existing MSW dump sites and allow municipal authorities to bring about sustainable solid waste management practices.

The upgrading of dump sites should include:²

- controlled tipping
- dump site mining followed by landfill upgrading combined with pre-treatment of MSW before landfilling; engineered landfilling
- leachate storage during the rainy season and recycling during the dry season (similar to bioreactor operation to enhance biodegradation)
- top cover design with available and appropriate soil (methane oxidation).

Pre-treatment of MSW prior to landfill should be adopted in Asia

Figure 1 shows an approach to sustainable landfill management in Asia. It combines the principles of a bioreactor landfill (see box, this page) to enhance the process of stabilization with those of landfill mining (see below) to recover space for reuse. At the same time, it allows for decomposed organic matter to be salvaged for agricultural use or soil amendment.

In addition, pre-treatment of MSW prior to landfill through aerobic processing, anaerobic digestion or a combination of both should be adopted in Asia. This would reduce the total amount of waste to be disposed of and simultaneously diminish the need for leachate treatment and landfill gas management, geotechnical problems due to landfill settlements, and the length of the aftercare period.⁷ Compaction and appropriate cover would reduce the risk of waste spreading.

Coping with the monsoon

Southern Asia and Indo-China are in the northern tropics and have dry and wet climates. The monsoon wind brings rain to some regions while others are left relatively dry. The length of the summer monsoon season varies from year to year, but the warm and humid air produces precipitation from May to

November. The winter monsoon is characterized by dry and cold winds which, after a long journey over sea, expose coastal areas such as south-eastern India, north-eastern Sri Lanka and the eastern part of the Philippines to heavy rain. These same areas are relatively dry during the summer monsoon.²

The rainfall characteristics for local climates must be considered when designing:

- top and bottom liners
- the leachate drainage and treatment system
- gas collection systems
- the final cover.

Protection against erosion should be incorporated and the stormwater run-off collected and conveyed out of the area without coming into contact with the waste. Stormwater from sorting areas, the weighbridge area (if it exists) and workshop area for vehicle repair should be collected and treated.

The extreme monsoon rainfall can create a high amount of leachate and stormwater run-off over a short period, while the very high evaporation of the subsequent dry season is likely to have the opposite effect.

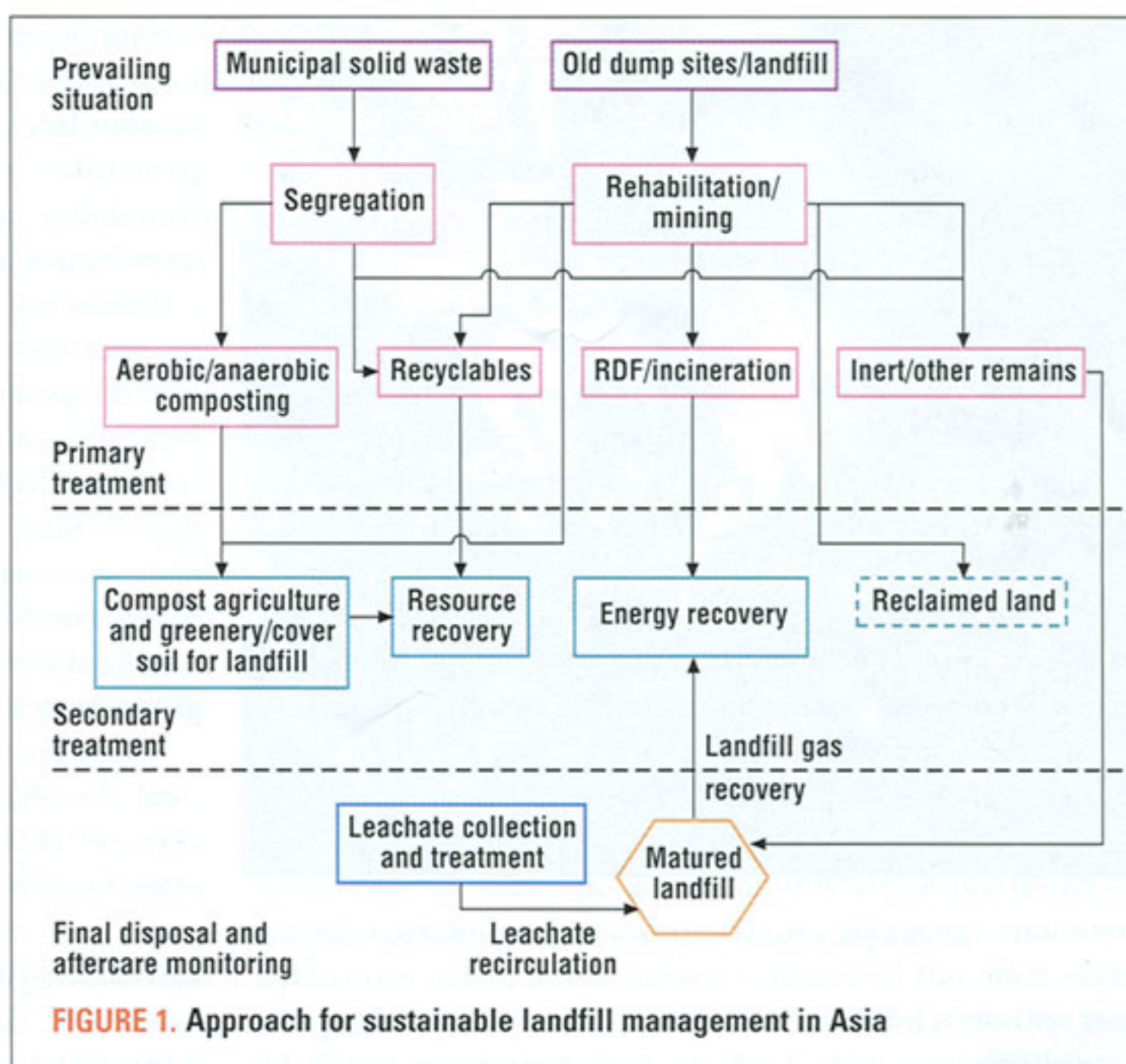


FIGURE 1. Approach for sustainable landfill management in Asia

The dry regions are characterized by conditions caused by arid climates. Here, leachate generation can cease. In both climate conditions, it is essential to design the bottom liner

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Shallow groundwater well near a dump site at Kathmandu in Nepal

and other elements of the leachate control system accordingly.

Leachate quality

Asian countries need to improve the criteria for liners and leachate collection systems, particularly the use of the

entombment concept. In addition, there need to be improvements to the concept of recirculation with a secure bottom liner system (including the benefits and risks), the principles of simple treatment methods and their functions, and education about the principles of attenuation and dispersion.

Many countries have national regulations that require monitoring of leachate and groundwater. However, the selected parameters are often too numerous and the selected indicators of pollution are inadequate. Selection of a few of the most relevant parameters as indicators of leachate quality may yield better results. For instance, monitoring chemical oxygen demand (COD), total nitrogen and selected heavy metals would increase understanding of the pollution potential from the landfills and provide an early warning for groundwater contamination.

Changes in the measured pH, electrical conductivity, total dissolved solids (TDS), COD and biological oxygen demand (BOD) of the leachate from a particular site can often be correlated with rainfall patterns.

Landfill gas management

Anaerobic decomposition of MSW in landfill generates large amounts of greenhouse gases and other trace gases. Landfills and dumps contribute an estimated 25% of anthropogenic methane emissions and 20% of total global anthropogenic methane emissions.⁸ In Asia, about 90% of open dumps without any top cover or preventative

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measures contribute to methane emissions from the MSW (shallow dump sites with layers of only a few metres of waste generate less gas due their more or less anoxic status).

Biological oxidation of methane by indigenous bacterial populations can be an inexpensive mechanism for treating waste gas. However, enhanced biological oxidation of the landfill gas depends on factors such as soil properties, bacterial population, moisture content and nutrient supplement. It is therefore necessary to identify appropriate controlling parameters for better landfill gas management under Asian conditions where landfill gas recovery is usually not feasible due to factors of size and economy. The design of controlled and engineered landfills of the future in Asia will have to incorporate elements to reduce methane emissions or to oxidize the methane before it enters the atmosphere.

Final cover

The final cover of the Gokarna dump site outside Kathmandu in Nepal is typical of landfills and dumps in Asia. It has just a thin soil layer with some grass growing on it. There is no gas or leachate collection, monitoring or treatment. The slopes surrounding the landfill are vulnerable to landslides as they have been left steep and bare after excavation for soil for use as cover material. Dense settlements have grown up around the site due to the expansion of nearby villages. In the poorest area, the sanitation conditions are bad and the shallow

TABLE 2. Composition of MSW found during excavation at the Gokarna landfill, Nepal^a

Material	Fraction (%)
Organic waste/soil	90.3
Plastic (all types)	3.2
Glass/ceramics	1.7
Textiles	1.4
Bricks/construction material	1.3
Leather	0.5
Paper (partially degraded)	0.5
Wood	0.4
Metal (all types)	0.3
Rubber (including foam)	0.3

groundwater near the landfill is used as drinking water (see photo on page 92).

Land remediation and landfill mining

Landfill mining (LFM) is the excavation and treatment of waste from an active or closed landfill. Following feasibility studies carried out on a case-by-case basis, the municipal authorities must choose between closure of the open dump or upgrading it to a sustainable landfill. The photo on page 94 shows excavation work at the Gokarna landfill site in Nepal. No leachate was found during the deep excavation of this site. Table 2 shows the high organic content in the waste excavated from Gokarna landfill, Nepal.

LFM involves the excavation, screening and separation

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Excavating the Gokarna landfill site in Nepal

of material from the former (generally unlined) landfill into various components including soil, recyclable materials, hazardous materials and residues. It can be an option as long as the dump site is in an area where groundwater pollution is not a critical issue and it has sufficient remaining life to justify the cost and effort of conversion. Detailed investigations based on test excavations and waste

characterization are required, and the amount of valuable waste fraction for recovery must be estimated. LFM projects have been carried out around the world over the last 50 years.⁹ The purposes of these projects have included:

- recovery or conservation of landfill space
- reduction in landfill area
- extending landfill lifetime
- elimination of a potential source of contamination
- mitigation or removal of an existing contamination source
- energy recovery
- recycling of recovered materials
- reduction in management system costs
- site redevelopment.

Landfill mining for the remediation of old landfill sites has become increasingly common in Asia. Landfilling can be seen not only as a disposal system but also as a method for large-scale processing of waste combined with recovery and recycling processes for the management of MSW.¹⁰

Figure 2 shows the mining methodology used to carry out studies at the Kodungaiyur and Perungudi dump sites in India. (No decision has been made so far on whether to fully excavate the landfills.) These studies evaluated whether to close the sites or to convert them to sanitary landfills and focused on:



- resource recovery through LFM
- bio-rehabilitation of MSW dump sites

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- leachate and landfill gas characterization at dump sites
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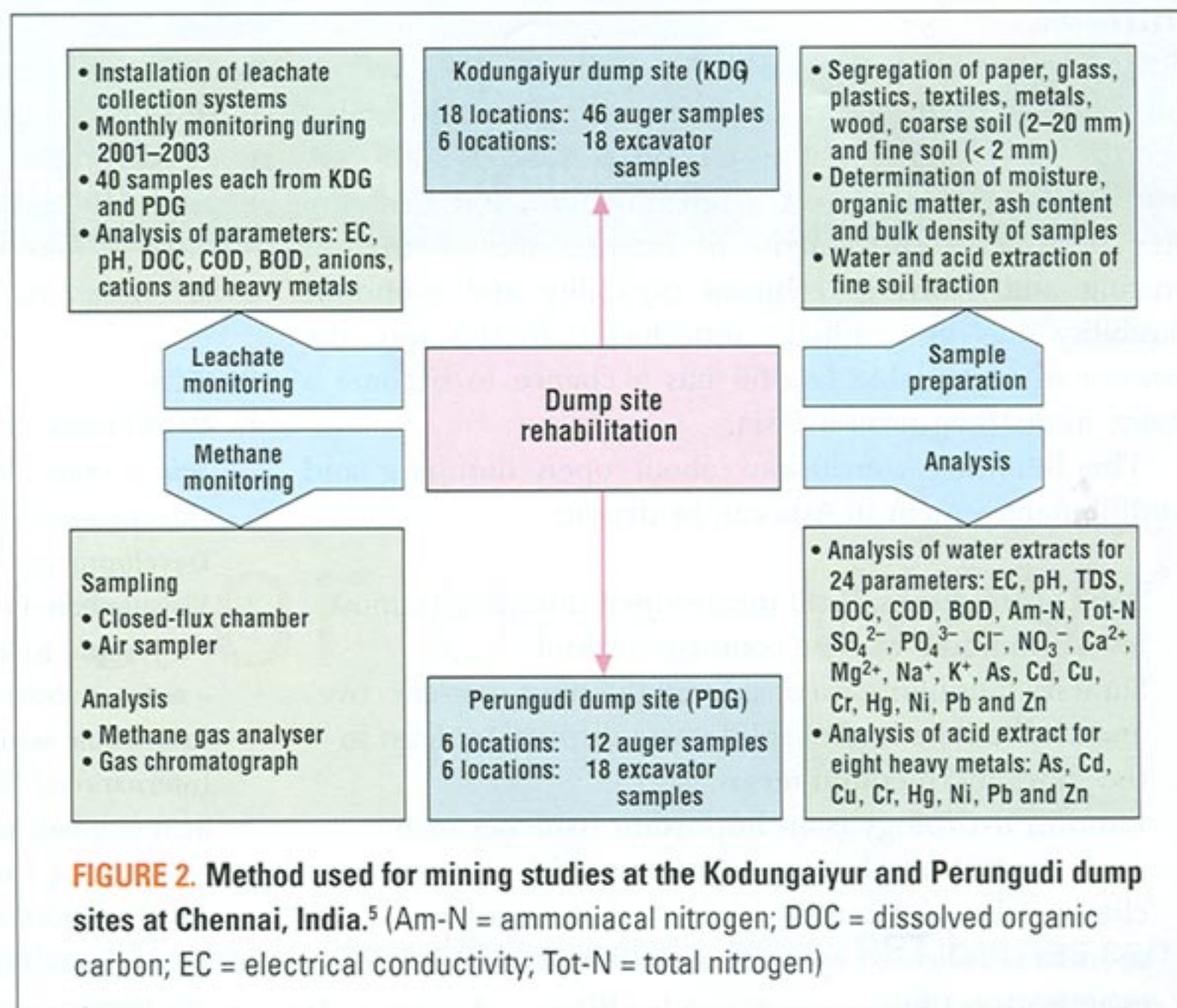
Sequential extraction on a sample collected from Kodungaiyur dump revealed the presence of heavy metals. About 30% of the total metal content was found to be available for potential introduction into biological systems; zinc contributed the most and chromium the least.¹¹

Major research programme

A seven year research programme on landfilling and waste management in Asia has recently been implemented to improve the protection of human health and the environment. This initiative includes five universities from China, India, Sri Lanka and Thailand and is supported by the Swedish International Co-operation Agency and its Department for Research Co-operation. The programme is being co-ordinated by the Asian Institute of Technology in Thailand.

The Asian Regional Research Program on Environmental Technology (www.serd.ait.ac.th/sidaSWM) is seen as an important step towards replacing open dumps in Asia with

sanitary landfills. The main aim is to mobilize and improve research competence at national research institutions in Asia and to create links between them and regional incentives towards sustainable sanitary landfills and a better urban environment.



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Outlook

There are plans to construct thousands of new landfills during the next 10 years in Asian countries. The principle of 'keep it simple and make it sustainable' instead of 'high-tech' solutions holds the key for the rehabilitation of MSW dump sites in Asia. Improvements to existing dumps that fit existing and evolving technical capability and economic feasibility may be gradually introduced. In this way, the concept of sustainable landfill has a chance to become a reality in the long-term in Asia.

The following conclusions about open dumping and landfill management in Asia can be drawn:

- Solid waste disposal still means open dumping in most low and middle-income countries in Asia.
- Sanitary landfilling is considered the most cost-effective and realistic method of solid waste disposal, at least in the short and medium terms.
- Landfill hydrology is an important issue because most landfills are located in regions with a monsoon climate where extremely high rainfall for a few months is followed by a dry season with high evaporation rates.
- In low and middle income countries in Asia, MSW is dominated by biowaste. The ash and dust fraction is high in areas where coal and wood are used for heating and cooking.
- Market incentives and penalties, and sufficient allocation of financial resources for the waste management sector are necessary. Educational campaigns alone are not enough.
- Decision-makers and the public in Asian countries need to be better informed about the environmental and health impacts of poor waste management practices at local, regional and global levels.
- Research should focus on pre-treatment options applicable to the composition of the MSW, degradation processes and modelling of landfill gas or leachate production under monsoon conditions, landfill design and operation.

Landfilling is likely to remain the dominant method of handling MSW in developing countries because it appears to be the most cost-effective, provided that land is available for it.

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Notes

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