DECISION-MAKER'S GUIDE TO SOLID WASTE LANDFILLS

SUMMARY

This report is a summary of a technical document on the planning, siting, design and operation of landfills in middle and lower-income countries. The full technical report is intended for professional waste managers.

This summary aims to identify the most important factors involved in decision-making, and is a guide for local politicians and others.

The practice of open dumping must be stopped on the grounds of public health and safety.

A higher standard of waste disposal is achievable at affordable cost by moving towards sanitary landfilling.

Practical guidance is available to waste managers to achieve these standards.

It requires only the political will to lead a municipality away from open dumping.

Author Notes

This Summary was compiled by Maggie Thurgood from the full text of the 'Solid Waste Landfills in Middle- and Lower-income Countries: A Technical Guide to Planning, Design, and Operation' written by Philip Rushbrook and Mike Pugh, WHO Nancy Project Office, France. Additional material for this Summary was provided by them, together with further comments and suggestions from: Carl Bartone, Gabriela Boyer, Lars Mikkel Johannessen, and colleagues at the World Bank, Washington DC, USA; Jürg Christen and colleagues at SKAT, St Gallen, Switzerland; and various other individuals and organisations. Specialist assistance to enhance further the practical information presented was provided by Binnie, Black & Veatch. Funding for this project was provided for the Swiss Agency for Development and Cooperation and the World Bank.

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FOREWORD

Where will all the waste go? The conversion of the open dumps characteristic of many cities around the world to controlled and sanitary landfills is a critical step for protecting public health and the environment. As cities grow and produce more waste, and their waste collection systems become more efficient, open dumping becomes increasingly intolerable. This guide serves as a tool for decision-makers in the solid waste management policy discourse to make gradual improvements in the short term by upgrading disposal of wastes at modest cost while still providing acceptable levels of environmental protection. In the medium to long term, the target should be to achieve full sanitary landfilling together with comprehensive policies and programs to reduce waste generation and increase recycling when it is economically viable. A more comprehensive technical document on landfill siting, design, construction, operation and closure, which is aimed at professional waste managers, will also be published.

In releasing this publication jointly, the World Bank, the Swiss Agency for Development and Cooperation (SDC), the World Health Organization Regional Office for Europe, and the Swiss Centre for Development Cooperation in Technology and Management (SKAT) hope to guide local politicians and decision-makers with the planning, siting, design and operational aspects of waste disposal. We must all cultivate the political will to stop open dumping, and promote an affordable and higher standard of waste disposal while protecting human health and the environment.

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INTRODUCTION

Disposal of waste to land is an inevitable part of every solid waste management system. Even where waste is processed in some way, for example for recycling or energy recovery, there will still always be a residue which needs land disposal. Wastes which are incorrectly disposed of cause many problems.

This Guide aims to help municipalities make improvements in solid waste management by upgrading the standard of land disposal of wastes at modest cost while still providing acceptable levels of environmental protection. It should also aid in strategic decision-making on what standards are to be adopted, what capacity is needed, and whether in-house technical resources are available.

Many current problems with waste have resulted from increased urban population with its inevitable increase in waste generation. In addition, there are often less resources provided for solid waste management, and waste management staff often have a low professional status.

Waste management is a vitally important municipal service and it requires high-calibre managers able to make complex decisions if a good quality service is to be provided and maintained.

Waste managers need the support of their political leaders to achieve and maintain real improvements in the standard of service they provide.

PROBLEMS WITH INADEQUATE DISPOSAL

When wastes are dumped along roads and riverbanks, or in abandoned quarries, it is inevitable that the contaminants in that waste will affect human health and pollute water supplies as well as affect the aquatic food chain. Grazing animals on dumps can pass diseases via the terrestrial food chain, as well as by pests through infestation. People living on or near a dump are also at risk. Open dumping is thus mistakenly believed to be the cheapest disposal method.

MAIN POINTS

- Landfill will always be needed
- Support of political leaders vital
- Open dumping damages human health
- Upgraded landfills protect health and the environment
- Improvements can be achieved at modest cost

Adopting a general philosophy that open dumping is acceptable because *"we cannot afford to do anything else"* is wrong.

It is not acceptable to protect the health of the majority, by taking away their waste, at the expense of those people who live near an open dump or who may be affected by the contamination it causes.

WHAT IS A SANITARY LANDFILL?

Sanitary landfills are sites where waste is isolated from the environment until it is safe.

It is considered safe when it has completely degraded biologically, chemically and physically. In high-income countries, the level of isolation achieved may be high. However, such an expensive high level of isolation may not be technically necessary to protect public health. Four basic conditions should be met before a site can be regarded as a sanitary landfill *(see below)*. The ways of doing this should be adapted to local conditions. The immediate goal is to meet, to the best extent possible, the four stated basic sanitary landfill conditions, with a longer term goal to meet them eventually in full.

Small incremental improvements in landfill design and operation over several years are more likely to succeed than attempts to make a single, large leap in engineering expectations.

Large landfills will require more investment to improve standards than smaller sites. However, the unit cost of these improvements (measured per tonne of waste landfilled or per head of population served) will decrease with increasing site size. There are financial and other benefits to sites with long operating lifetimes (ten years or more). Large regional sites serving two or more cities could be economically beneficial, providing waste transport costs are not too high.

Basic requirements

As a minimum, four basic conditions should be met by any site design and operation before it can be regarded as a sanitary landfill:

Full or partial hydrogeological isolation - if a site cannot be located on land which naturally contains leachate securely, additional lining materials should be brought to the site to reduce leakage from the base of the site (leachate) and help reduce contamination of groundwater and surrounding soil. If a liner - impermeable or semi-permeable - is provided without a system for leachate collection, all leachate will eventually reach the surrounding environment. Leachate collection and treatment must be stressed as a basic requirement.

Formal engineering preparations - designs should be developed from local geological and hydrogeological investigations. A waste tipping plan and a final restoration plan should also be developed.

Permanent control - trained staff should be based at the landfill to supervise site preparation and construction, the depositing of waste and the regular operation and maintenance.

Planned waste emplacement and covering - waste should be spread in layers and compacted. A small working area which is covered daily helps make the waste less accessible to pests and vermin.

WASTE CHARACTERISTICS

In all communities, people generate domestic wastes. At the most basic level, these consist of food wastes, animal manure, ashes, broken tools and utensils, and old clothing. In an agricultural community this waste is readily absorbed into the natural cycle.

However, since the last century, there has been an increase in the number of people living in towns. Urbanisation and industrial development have rapidly increased the range and the diversity, as well as the quantity, of wastes being produced which require collection and disposal.

Within a municipality there are seven main sources of waste which require management. If the community has only a landfill for disposal, all of these wastes will need to be landfilled. The waste manager needs to know about the sources and types of waste in the town, as well as the quantities, in order to dispose of the wastes safely.

1. Domestic Waste

Wastes produced from household activities, including food preparation, cleaning and fuel burning plus garden wastes, old clothes and furniture, abandoned equipment, packaging and newsprint.

Domestic waste (also called residential or household waste) consists of a wide variety of materials. These include:

- food wastes
- plastics
- paper
- leather and hide
- ash, soil, pottery and china
- metal
- glass
- rubber
- textiles

In lower-income countries, domestic waste is dominated largely by food and ash wastes, while in middle- and higher-income countries there is a larger proportion of paper, plastic, metal, glass and discarded manufactured items.

MAIN POINTS

To manage wastes properly, it is important to know:

- how much waste is being produced
- the composition of wastes from each of the different sources (residential, commercial, industrial etc)
- how the quantity and composition of wastes might change in the future

2. Commercial Waste

Wastes from shops, offices, restaurants, hotels and similar commercial establishments. The waste typically consists of packaging materials, office supplies, and food wastes, and has a close similarity to domestic waste. In lower-income countries, food markets may contribute a large proportion of commercial waste.

3. Institutional Waste

Waste from schools, hospitals, government offices, military bases. Institutional waste is similar to both domestic and commercial waste, although there is generally a larger proportion of paper than food waste. Hospital wastes inevitably include potentially infectious and hazardous materials such as used bandages, sharp objects like syringes and needles, and items contaminated with body fluids. It is important to separate the hazardous and non-hazardous components in healthcare waste to reduce the risk to health.

4. Street Sweepings

Dominated by dust and soil, together with varying amounts of paper, metal and other litter that is picked up from the streets. In some countries street sweepings may also include drain cleanings, plus varying amounts of household waste dumped at the side of the road, plant remains and animal manure.

5. Construction and Demolition Waste

The composition depends on the type of building materials used in a particular area but is typically soil, stone, brick, wood, clay, reinforced concrete and ceramic materials. Inevitably some construction waste will need disposal, even though some may be recycled within the construction site.

6. Sanitation Waste (night soil)

Where no sewage networks exist within towns human waste may be

ASSESSING WASTE CHARACTERISTICS

After assessing the quantity, the other characteristics of waste needed to select the most appropriate waste disposal option include: moisture content, potential to biodegrade, heating value and density.

Moisture content - the percentage of the weight of wastes which is water. This can be determined by drying a known weight of waste and measuring the weight change.

Biodegradable material - the proportion of biodegradable material in the waste can be calculated by first removing non-biodegradable organic wastes like plastics and rubber, and then drying the waste at a temperature high enough to burn off the remaining organics.

Calorific value - this is the amount of heat energy that can be produced if all of the combustible parts of the waste are burned. If a town or city is considering waste incineration, this information is crucial to establish whether the waste will burn without the use of additional fuel such as oil or gas.

Waste density - this is important at each stage in collection and disposal. For planning waste collection, the density achieved in each collection vehicle influences how many are needed to collect the waste in a particular area.

Waste density is also important at the landfill site, as an indication of how much space each delivery of waste will take before and after compaction and as a consequence, how long the total landfill space will last.

collected separately and used for agriculture or disposed of in landfills. If improperly disposed of, this material can contaminate water courses and be a source of infectious diseases.

7. Industrial Waste

The composition of industrial waste depends on the industries involved. Much industrial waste is relatively similar to waste from commercial and domestic sources, and includes packaging, plastics, paper and metal items. However, wastes from some industries are chemically hazardous. Disposal routes for hazardous wastes are usually different from those for non-hazardous wastes, and depend on the composition of each waste type. Hazardous wastes pose a risk of polluting drinking water supplies, watercourses or land, or harming waste workers, and may need pre-treatment to reduce their toxicity if they are to be disposed of on land.

WASTE GENERATION AND COMPOSITION

The compositions of the seven solid waste types are highly variable. They are influenced strongly by: climate and seasonal variation, the economy of the region, the physical characteristics of the city, and social and religious customs. Variations in solid waste composition are most significant when a municipality is making decisions about the suitability of a specific treatment or disposal method, such as composting or incineration.

It is important for a waste manager in a city to have an indication of the composition of waste in the locality. Sampling of the wastes is not technically difficult, and must be done in one or more areas which are statistically representative.

In this way, information on waste composition and characteristics can be obtained to aid in decision-making about the viability of waste treatment processes, collection equipment changes and recycling initiatives.

GENERAL TRENDS

- In general, waste generation per person in high-income countries is much greater than in lower-income countries
- Typically, wastes as collected in high-income countries are less dense, as more packaging and lighter materials are discarded, and less ash and food waste.
- Moisture content is higher in lower-income countries because of the water in food wastes. Wastes from higher-income countries with proportionately less food waste have lower moisture levels.

KEY POINTS FOR DECISION-MAKERS

- **How much waste is being produced in the area?**

  It is helpful if this is further broken down into districts and different sources of waste e.g. households, industry, shops and institutions

- **What is its general composition?**

- **How might the amount or general composition of wastes change in the future?**

LANDFILL SITE IDENTIFICATION

Selecting a site on which to develop a landfill is one of the most important decisions to be made by a municipality in developing and implementing its waste management plan.

Making the wrong decision will be expensive and may also cause long-term problems resulting from public opposition. Unnecessary transport costs, as well as higher than necessary expenditures on site development, operations and environmental protection measures may be incurred.

To ensure that an appropriate site is chosen, a systematic site selection process should be followed. Selection criteria should be prioritised according to local circumstances, including climate, political and cultural conditions.

To enable choices between possible sites, desk and field studies must be made. After these preliminary studies, more detailed site investigations need to be carried out on the preferred site, or short-listed sites, to confirm a site's characteristics, develop designs and establish likely costs. Public participation in the siting procedure should be encouraged and facilitated.

Priority should be given to areas where leachate would be likely to have little or no impact on the environment, so that measures to collect and treat leachate which are often expensive can be reduced.

Since the principal environmental concern associated with waste disposal to land is the generation and control of leachate, it is beneficial to choose a site whose geology will naturally contain or limit releases of leachate to the wider environment.

The distances and impacts of transport to and from the site should also be considered, as this will affect collection services and modes of transport as well as travel times.

MAIN POINTS

- Sound site selection is a key factor
- A systematic process for site selection is needed
- Preliminary studies will identify possible sites and eliminate unsuitable ones
- Detailed studies can confirm preferred sites
- Site selection criteria include land use, geology, site capacity, transport distances
- Groundwater protection is a main concern

INVOLVING OTHER GROUPS

Once the decision has been taken to seek a suitable site for developing a landfill, the municipality should actively encourage participation in the process by communities and organisations with an interest in the choice of site.

The geographical area served, and type of waste to be handled in a new landfill site, together with the capacities of potential sites, will determine their probable lifetimes. Large regional sites will require co-operation between municipalities.

Site selection criteria may be grouped into headings including transport, geology and conditions relating to land use, public acceptability and safety.

These site selection criteria have the effect of excluding whole areas of land from further consideration. Mapping those excluded areas can focus attention on the remaining areas where landfill sites *may* be located.

The amount of land required, which can be calculated from the amount of waste expected to be generated and the desired operating life of the site, can then be used as a guide in the search. The land should preferably be in single ownership, and in a state of neglect or non-use.

A range of *positive* selection criteria can also be identified to help find potential sites.

One such positive factor would be areas where controlled or accidental release of leachate will have little or no impact on the local environment. Abandoned clay workings may be an example of a suitable location.

The municipality should aim to draw up a list of up to five possible sites, whose positive features may include:

- easy access to the road system
- proximity to the urban area and waste source
- ease of land acquisition
- lack of use for any other purpose

This shortlist of sites could also include the open dump which is to be replaced, providing it meets some of the criteria above and it would have a lifetime of several years more as a sanitary landfill. Conversion of an existing open dump site may offer financial advantages over the development of a new site since the cost of closing down the open dump will be in addition to the cost of developing a new site.

The first steps identified will not need first-hand knowledge of the possible sites, but any further elimination of

THE NEXT STEP

Conceptual designs for each remaining site will need to be developed, and taken to the point that rough estimates can be made, for comparison, of:

- the site capacity
- the volume of daily cover which would be needed
- the resources needed for leachate control
- the extent of surface water diversion works
- the amount of work required to provide all-weather access
- the costs - a cost per cubic metre of waste can be calculated to enable comparisons between sites
- the impact on the waste collection service of using each site

sites will depend on formal inspections and studies.

A number of factors, both favourable and unfavourable, will quickly be identified by visiting the possible sites. The objective of these site visits should be to reduce the number of sites for detailed consideration to a maximum of three.

PREFERRED SITE

Once one preferred site has been identified, further site investigations should be undertaken to confirm assumptions made in the conceptual design.

Waste management staff of the municipality, or consultants, should then prepare a feasibility report on the viability of developing the preferred site as a landfill.

ENVIRONMENTAL IMPACT ASSESSMENT

Assessing the possible environmental impacts of the site can help identify which activities, if any, are likely to give rise to significant adverse impacts. These impacts may then be reduced by amending the design. Alternatively, if the impacts are sufficiently serious, it may have to be acknowledged that the potential for harm is unavoidable and the site abandoned.

FINAL STEP

Before the project can be implemented, approval must be given by the appropriate committee of the municipality, regulatory authorities and/or by the provider of the funds as well as meeting the requirements of any licensing authority.

In order to obtain that final approval, it may be necessary to promote the scheme by demonstrating an urgent need to improve waste disposal practices.

The feasibility report should show that the site chosen is the best available in the area, and that the new site will be operated to satisfactory environmental standards.

It should also be shown that the impact of the new site on the waste collection system has been fully accounted for, and that the cost of the changes to the waste management system as a whole are reasonable and affordable.

KEY POINTS FOR DECISION-MAKERS

- **What area should the site serve?**
- **What site selection criteria should be used?**

  There are positive as well as negative indicators
- **What are the views of the community and of organisations with an interest in the site development?**

SITE DESIGN AND PREPARATION

Paying careful attention to the detail when designing a landfill can avoid - or at least reduce significantly - future operational problems.

In order to design properly and plan the landfill, it is essential to understand the practical and logistical problems of waste delivery and discharge, waste compaction and covering.

There are three general ways of forming a landfill. These are the 'trench', 'ramp' or 'area' methods. Which one is appropriate depends on local topography and landscape.

A trench landfill is usually located in an area of flat land where the soil has been excavated and waste is deposited into the void. The stockpiled soil is then used to cover the waste.

A ramp landfill is usually where a low bank is present, or has been created, and waste is deposited along one side. Soil excavated from the front of the face of the ramp is used to cover the waste.

The most common type of landfill is *the area landfill*. It may be constructed in a natural depression, in excavated mineral workings or built above the ground into a hill.

The first two methods are usually confined to smaller centres of population as the amount of soil excavation needed to prepare the sites would be excessive for larger quantities of waste. Also it is difficult to control water movement through such sites, and to construct effective drainage control systems.

The third method allows more wastes to be placed on the same surface area than the other two methods.

MAIN POINTS

- Attention to detail at design stage can simplify future management
- Control of water in and out of site is crucial
- Wastes can be manually or mechanically placed

Controlling the movement of water into and out of a landfill is essential in good landfill design. The site design can either control leachate by completely sealing the site, only permitting leachate to be discharged after treatment, or alternatively, by allowing the leachate to attenuate by gradually seeping through the soil. The decision is largely based on the geology of the site, as well as hydrogeological factors, the groundwater flow and the vulnerability of water sources. Where the option to seal the site is taken, significantly more cost is incurred and more management control needed, both during site preparation and operation, and after closure.

Developing the site in phases allows some of the costs to be deferred and

minimises environmental impacts. In this case, a sequential tipping plan must form part of the initial design.

The design must include access to and around the site, as well as the construction of waste reception facilities.

Sanitary landfilling can be compared with a highway or civil engineering construction project, as many of the same skills are required.

The purpose of having a detailed design for a sanitary landfill is to communicate (by means of drawings and specifications) how the designer intends the site to be developed. The design should be detailed enough to show how and when the site is to be prepared for accepting wastes; the wastes are to be landfilled; the site is to be restored; and monitoring is to be carried out.

Before having identified the site for the development of a sanitary landfill, the municipality will have considered whether it has the technical resources to design and operate the landfill itself. It will also have made a decision at to what standards of design and operation are to be adopted.

A wide range of professional skills will be needed for the landfill project. A project team, managed by an experienced civil engineer, should be formed, either from within the municipality or brought in from other organisations.

Part or all of the project may have to be carried out by outside agencies, such as consultants or waste management contractors.

SCAVENGING

Scavenging is disruptive to good landfill operation. It presents safety hazards to both the scavengers themselves and the landfill employees. It reduces productivity by delaying waste compaction and soil cover, and scavengers sometimes cause fires.

Ideally, it should not be allowed to take place. However, in many places it is inevitable, and in such cases it should be controlled. Ways of enabling scavengers to sort through the waste without interfering with the landfill operation need to be devised. These should include improving their health, safety and welfare.

(The Guide which accompanies this Summary provides practical information on this subject in Appendix 4D)

Questions of operational policy have to be addressed: will waste emplacement be manual or mechanical, and will scavengers (also known as waste pickers, or informal recyclers) be permitted to operate at the site.

Mechanical equipment, such as a bulldozer, makes it easier to control the placement of waste. It is not essential for small sites, though, and if there are no machines, the waste placement can still be properly managed at sites receiving less than 50 tonnes a day. A combination of mechanical and manual methods can also be considered.

GROUNDWATER PROTECTION

Sanitary landfilling enables waste disposal to land to be handled in a way which reduces *to an acceptable level* adverse environmental impacts. Part of the design brief is to identify that 'acceptable level' and ensure that it is met.

Minimising contamination of groundwater by leachate is one of the primary objectives of landfill design. (However, it should be noted that in arid climates the potential for producing leachate is greatly reduced.)

The approach depends on whether the groundwater is a drinking water resource. It also depends on other downstream water users, on the depth of the groundwater table below the waste, and the type of the soils below the site. If untreated leachate would have an unacceptable impact on the groundwater, then a containment design is needed. Otherwise an 'attenuate and disperse' approach may be followed, allowing the leachate to seep gradually through the soils.

If it is necessary to construct a containment site, a natural barrier (eg clay) or a synthetic barrier system will inhibit the release of leachate into surrounding soils.

No barrier can be 100% watertight, but the barrier in combination with a leachate removal system (which treats leachate before discharging it into a water course) can be effective.

If the site is close to a municipal sewage works, leachate may be treated there. Otherwise a leachate treatment plant will need to be established on site. In many climates, the simplest form of treatment could be a series of lagoons or flow through wetlands.

Barriers made of synthetic liners are expensive to install and require a high level of quality control in site preparation, installation and protection.

LEACHATE REDUCTION

Limiting the amount of water which gets in to the waste will reduce the amount of leachate produced, though this will also slow the degradation of wastes and the final stabilisation of the landfill. There are a number of simple design and operational measures which reduce leachate generation.

Managing the surface water is important not only to reduce leachate but also to reduce flooding which could destabilise slopes and cause slips.

GAS CONTROL SYSTEMS

As wastes decom-pose in a sanitary landfill, landfill gas will be generated.

Gas will start to be given off within a few weeks of wastes being deposited, and may be generated for many decades after the site is closed. Landfill gas can migrate considerable distances from the landfill site.

Landfill gas contains methane which is both potentially explosive and flammable. Carbon dioxide, the second predominant constituent of landfill gas, can cause asphyxiation.

Landfills can be designed to collect and vent, or burn, the landfill gas, as well as preventing off-site migration.

COVER

Soil or similar inert material should be used throughout the lifetime of the landfill site, to cover the wastes on a daily basis. Extra thickness of "final cover" material should also be used, once the site has reached completion.

The simple spreading of daily cover is a very effective way to:

- reduce the attraction of wastes to birds
- suppress odours
- prevent fly infestations
- discourage rats and other vermin
- reduce exposure to atmospheric conditions
- reduce wind blown litter

Ideally, cover material should be taken from within the site, increasing the available space for waste disposal and reducing the need to bring material from elsewhere.

If not all of the material needed can be found on site, alternatives such as construction and demolition materials and ash from power stations may be used.

ENVIRONMENTAL MONITORING

Not only should upgraded landfills be designed and constructed to provide an acceptable level of environmental protection, they should also include systems for monitoring that protection.

Boreholes and sampling points to monitor the quality of groundwater should be installed at site preparation stage.

COMPLETION

Settlement will continue for several years after filling as organic wastes decay. This must be taken into account and the site 'over filled' so that when settlement is complete, the intended final landform is achieved.

Slopes should be designed to be stable and final contours designed to be sympathetic with surrounding landforms. Flat surface areas should be avoided as, with uneven settlement, low areas may be created which allow surface water to collect.

The design needs to take into account one or more possible end uses for the site once it is completed.

End uses which are compatible with a completed landfill are generally limited to agriculture and open space recreation. Development for housing, or commercial or industrial use, should not normally be considered due to the problems of settlement and methane hazards.

DISPOSAL PLAN

A key part of the design for an upgraded landfill is a planned sequence of filling to achieve the final landform. The purpose of a disposal plan is to minimise the environmental impact of the landfill while at the same time reducing the amount of construction work needed.

KEY POINTS FOR DECISION-MAKERS

- **Does the municipality's waste division have the skills to design the site?**

  If not, skills may be brought in from other parts of the municipality, or from the private sector

- **What standards are to be adopted?**

- **What will the policy be on scavenging?**

LANDFILL SITE OPERATION

Upgraded landfilling uses modern civil engineering techniques to control the way in which wastes are deposited and to ensure that products from decomposing wastes do not pollute the environment or threaten public health.

A successful landfill is one where it could be considered that the filled site has been improved by the waste filling process, and not degraded by it.

Safe, well-organised waste placement is what distinguishes a controlled landfill from an open dump. The best-designed site will have problems if it is not operated properly. Conversely, well-managed sites can make up for some weaknesses in site design and location.

A competent landfill manager should be based full-time at the site to direct activities. Good operation of the site will require an improvement in the engineering and management skills of the staff. The on-site manager should be given the authority, and the resources, to manage the site properly.

ACHIEVABLE STANDARDS

Two basic requirements of sanitary landfill operation are that:

- *wastes should be deposited in thin bands of around 0.5m, building up into layers not greater than about 2 metres in depth; and*

- *the surface of the newly deposited waste should be covered at the end of each day with approximately 15cm of soil or similar material.*

These two requirements should be achievable by most municipalities.

MAIN POINTS

- Fires should be eliminated on a site
- Waste should be covered daily with soil
- Waste tipping should be restricted into small areas
- The disposal plan must be followed

The disposal plan is the operational guide for the site, and will be used by the landfill manager for organising and running the site. The disposal plan has to be prepared before any waste is delivered to the site, and will specify in detail where waste is to be placed, what site preparations and engineering are required, and how environmental nuisances (for example birds, vermin, litter, fires, gas, leachate) are to be dealt with.

It will also provide details of equipment, materials and staff needed to operate the site, what documentation and administration is required, what monitoring will be undertaken and when and how each part of the site will be completed and restored.

The operational stage of a landfill spans many years. Organisational changes may be needed within the municipality in order to operate waste management to higher standards. One of the key decisions is whether the site should be run by existing staff. It might be possible to identify skilled civil engineering or waste engineering staff within a different part of the public sector.

Alternatively, it may be preferable to hand the operation of the new landfill site over to a private sector waste contractor, with municipal staff over-

ROUTINE OPERATIONAL PROCEDURES REQUIRED AT A WELL-MANAGED LANDFILL SITE INCLUDE THE FOLLOWING:

- Waste should be compacted in thin bands up to 0.5m which should be built up into a layer about 2m deep. This reduces the likelihood of instability and settlement problems in the future
- Compacted waste should be covered daily with 15cm of soil to deter flies and other insects from breeding in waste, as well as reducing wind-blown waste and improving the surface for waste vehicles
- No biodegradable waste should be deposited in water
- Open burning should not be permitted. Fires can cause hollows in the waste, encouraging instability, and they could ignite pockets of landfill gas, causing explosions. If not quickly extinguished, fires can become deep seated and smoulder for many years.
- Frequent inspections for vermin (rodents, other animals, birds and flies) should be made and measures taken to prevent infestations in order to reduce health risks.
- Frequent collection of litter from the site helps convey an impression of a well-managed site.
- Drainage ditches should be kept clear to avoid problems during wet weather
- Site access roads should be kept in good condition to allow vehicles to deposit their waste loads quickly and efficiently. Broken fences should be repaired and maintained to prevent animals coming onto the site.
- The general public should be excluded from the site for their own safety.
- Records of waste deliveries to the site should be kept, showing who delivered the waste, of what type, how much and when. These records are particularly important if the municipality decides to charge waste generators for their waste service.
- Environmental monitoring (which may be simple visual inspections, or more complex sampling and chemical analysis) must be carried out to a regular schedule, and records kept.

seeing the work to ensure that standards are met.

The landfill site manager should report directly to the chief officer responsible for all waste management.

COSTS

The operation of a better managed landfill site will, in almost all circumstances, cost more than open dumping.

It will, however, avoid money being spent at a later date to remediate harm caused by the open dump.

It may be possible to meet some of these costs with savings resulting from improved efficiency within the municipality or within the waste management organisation.

Costs can also be met by charging commercial waste producers, such as shops, hotels and industry, for providing them with a waste disposal service, and indirectly by charging residents through property taxes or utility charges.

STAFFING

There is a minimum staffing requirement for a well-managed site where either manual spreading or mechanical waste placement and compaction is undertaken.

If machines are used, the minimum staffing is:

- a landfill manager based at the site
- a gate man/office clerk
- a security guard or night watchman
- a traffic controller, for organising vehicles at large busy sites
- landfill equipment drivers
- a maintenance fitter (if equipment is maintained at the site)
- manual labourers

It is crucial that sufficient funds are identified to enable the site operation to be correctly managed.

A well-managed landfill site can minimise operational problems.

KEY POINTS FOR DECISION-MAKERS

- **Who should operate the new landfill site?**

  Are there enough suitably skilled personnel within the municipality, in the waste or other sections? Alternatively, should the operation be contracted out to the private sector?

- **Is there enough money allocated to the project for it to be done properly?**

  Funds can be raised by cost-cutting elsewhere, or by charging waste producers for the waste service.

HAZARDOUS WASTES

Many kinds of industrial wastes can be safely landfilled. There are advantages to the landfilling of industrial waste in middle- and lower-income countries, since landfill represents a widely available, long term disposal method which offers a low cost disposal route.

Disposing of *hazardous* industrial wastes in landfill sites can also be done in some circumstances, but it requires special procedures to be undertaken, and careful management and operation. Where sanitary landfill site management principles are in use, disposal of hazardous, or special, wastes can usually be undertaken.

Where such principles are not yet being applied, hazardous industrial waste should not be landfilled.

There are three basic approaches to landfilling hazardous industrial wastes: separate disposal in a site which takes only this type of waste (a mono-fill); disposal together with municipal wastes in a co-disposal site; or pre-treatment of wastes before either mono- or co-disposal landfill.

MONO-FILL

Wastes which have the same overall physical and chemical characteristics and which are stable can be disposed of together, but separately from other wastes.

CO-DISPOSAL

Planned mixing of hazardous industrial wastes with municipal wastes relies on the processes which the municipal waste undergoes to stabilise the industrial waste. It is important that co-disposal is carefully managed to ensure that the rate of input of hazardous industrial waste does not overwhelm the municipal waste.

MAIN POINTS

- Landfill is a widely available disposal method and a safe disposal option for many industrial wastes
- Separation from other wastes, or some form of pre-treatment, may be necessary for the hazardous components

Direct disposal of *liquid* industrial hazardous wastes is sometimes possible in modest quantities and providing the site is well-managed. At a co-disposal site it is inevitable that different types of hazardous industrial wastes will come into contact. It is therefore important to ensure that incompatible wastes are not disposed of together, to avoid unwanted chemical reactions.

PRE-TREATMENT

Pre-treatment of hazardous industrial waste reduces the bulk or the hazards associated with handling, transporting and landfilling the waste.

Some industrial hazardous wastes are completely unacceptable in a co-disposal landfill because of their highly reactive chemical nature or their solubility.

The costs of treatment technologies may be too high in many middle- and lower-income countries, and co-disposal may be the compromise necessary to improve crude dumping or stockpiling of hazardous industrial wastes. There may also be too few industrial operations to justify investment in treatment technologies.

Providing there is already a good standard of design and operation, a decision must be made on which types of waste will be allowed in the landfill, and how they are to be handled. Deciding which wastes are acceptable must be done on a site-by-site basis, as landfills vary in their suitability for co-disposal.

Some wastes should definitely be landfilled, as no other option exists. An example of this is asbestos.

Other wastes which are readily biodegradable without pretreatment could be accepted, such as food processing wastes and oily sludges.

CO-DISPOSAL LANDFILLING REQUIRES:

- *a well-designed and managed* municipal waste landfill
- *a continuing supply of municipal* waste properly placed
- *a trained landfill manager and* operational staff
- *sufficient mobile equipment* to prepare the site
- *no scavenging directly on the landfill* if hazardous waste is accepted
- *no burning of waste directly on the* landfill
- *a means of ensuring that only* suitable types of industrial wastes are deposited
- *regular inspection to check that* industrial wastes are not leaching

In addition, a check must be made at the landfill entrance of the composition of industrial waste being received, and a record kept of that waste and its location in the site.

KEY POINTS FOR DECISION-MAKERS

- Landfill may be the only or best disposal option in a locality for industrial wastes
- In this case, which wastes will be accepted?
- How will they be handled?

SITE CLOSURE AND AFTERCARE

Once the filling of a landfill is complete, the waste is covered with a thicker layer of soil, and other surface capping systems are installed, in readiness for the site's after-use. On large sites, the final cover may be placed in stages, with areas of land restored for use while other areas continue to be filled with waste. This helps to reduce the amount of rainfall entering the site, and reduces leachate.

Although the site may be filled and capped, there may still be many decades before all of the waste has decomposed and stabilised. Monitoring and control systems should be maintained during this aftercare period.

The final cover of the waste has several functions to perform while the waste completes its decomposition and settlement processes:

- reducing rainfall infiltration
- reducing surface erosion
- providing surface drainage systems
- controlling migration of gas and leachate
- preparing the site for its planned after-use

Unfortunately, landfills cannot be relied upon to behave exactly as they were designed. Unpredicted settlement, weaknesses in construction and nature itself will inevitably compromise - to a greater or lesser extent - the environmental protection systems incorporated in the design. Inspection and monitoring programmes can help identify any necessary maintenance or repair of systems.

MAIN POINTS

- Correct covering of completed site is vital
- Acceptable uses for a former landfill can be found, once restored
- Need for continued environmental protection
- Settlement will disrupt the final cover and repairs will be necessary
- Need to check if closure plan still applicable

Leachate will continue to be generated, so in sites where leachate is contained it will continue to be necessary to collect and treat it as long as it poses a threat to the ground and surface water.

Although a site closure plan will have been part of the original design, it will be necessary to check its continued relevance, after so many years. In the intervening period, stricter environmental legislation may be in place, land use plans may have changed and the intended after-use of the site may no longer be appropriate.

It may also be necessary to examine the cost implications of the closure since the preparation of the replacement sanitary landfill should be well under way by this time, which may be competing for financial resources.

Budgetary constraints may force the waste manager to choose between, for example, maintaining the integrity of the cap or doing groundwater monitoring. Should priority be given to filling low spots or to repairing storm drainage?

A primary aim of the final cap is to minimise leachate generation by excluding rainwater and other surface water.

The best caps are constructed from around one metre of natural soil materials, such as clay. A cap is usually domed or contoured into a slope to further encourage the run-off of surface water.

A well-compacted and drained clay cap that is protected from soil erosion by vegetation will inhibit surface water entering the waste.

Synthetic materials, similar to those which can be used as liners for landfill sites, can be used in the final cap, but these are more expensive and are also at risk of damage from settlement of the waste.

Final cover from natural materials is often better at self-sealing if disrupted by waste settlement.

Whatever the intended after-use, the early establishment of grass or other vegetation will help protect the cap from erosion.

AFTER-USES

Recreation may, in many cases, be a beneficial after-use of a completed landfill. Only small, light constructions, such as equipment storage sheds, are needed.

If the site's after-use is grassland, then a light topsoil dressing over the cap will promote the rapid growth of grass. If it is planned for arable uses, a total soil depth of up to 1m over the clay cap may be needed to prevent ploughing from damaging the cap.

The use of completed sites for construction or urban development should be discouraged because of a number of constraints including:

- low load-bearing capacity
- extensive and uneven settling

POTENTIAL AFTER-USES

Amenity: open space, buffer zones, airport runways
Recreation: parks, playing fields, tracks and golf courses
Agriculture: arable land, grazing
Forestation: woodland, tree screens, nature reserves
Habitation: gardens, play areas
Industry: open storage areas, parking, open fabrication areas, open air markets

- presence of combustible and potentially explosive gases
- corrosive character of waste decomposition products and of the internal landfill environment in general

These constraints continue long after the filling has been completed.

However, there is a growing land shortage in some cities, especially in lower- and middle- income countries where rural to urban migration has exacerbated the situation.

If pressures on land availability force the use of a completed site for building development, extensive precautionary measures must be included to control associated hazards.

ENVIRONMENTAL CONTROL AND MONITORING

Leachate will continue to be generated after closure, although in decreasing quantities providing the final cap remains effective. Leachate collection and treatment systems will need to be maintained after closure.

Landfill gas will also continue to be generated. Landfill gas could have disastrous consequences for local residents or squatter communities if allowed to migrate off-site. Even if the gas is contained within the boundaries of the site, there are still significant risks and environmental impacts. Gas venting trenches in and around the final cover can allow landfill gas migration to atmosphere if there is no pumped gas flaring or utilisation on site. Where there is a pumped gas management system in place, it will need to be maintained, and probably continuously staffed, during the aftercare period. Failure of a pumped system will lead to gas migration off-site.

AFTERCARE

To maintain the effectiveness of the environmental protection measures built into the landfill after closure, regular checking of the site is necessary. This is termed 'after-care' and involves erosion control, observation of settlement, groundwater monitoring, leachate and gas control, observation of the condition of vegetation and presence of vermin and odours. Funds should be set aside for these procedures.

There may still be several decades before all of the waste has decomposed. As a result, even though the site has been capped, settlement will continue. To maintain the domed cap profile, it may be necessary to backfill areas of settlement (which appear as depressions in the top surface) with cap material and soil. Settlement will be less at a site which has been operated as a sanitary landfill, since the waste will have been well compacted when originally deposited.

KEY POINTS FOR DECISION-MAKERS

- Is the closure plan, which was written some years ago, still appropriate?
- For how long should an aftercare programme be maintained?
- A regular programme of monitoring will continue to be necessary for some time

CLOSURE AND CONVERSION OF OPEN DUMPS

In order to abandon the practice of open dumping, the municipality may either close its open dumps when a replacement upgraded landfill site is ready to accept wastes, or alternatively it may convert its open dumps to operate as upgraded landfills.

This latter option will only be possible if:

- the dump is in an area where groundwater pollution is not critical
- there is sufficient remaining void space to justify the cost and effort of conversion

If the dump is to be converted to a landfill, operational practices should be the same as those for a new sanitary landfill site. However, the ability to protect the groundwater beneath the site will be limited.

CLOSING A DUMP DOES NOT MEAN ABANDONING IT.

Standards to be adopted in remediating a closed site should be comparable to those for completion of a sanitary landfill. One option for the remediation of a closed site is to remove all dumped material to a replacement sanitary landfill. This is likely to be an expensive approach unless only a small volume of waste is involved. It will also use space in the new landfill. It may also be possible to use bio-remediation techniques.

It is important to ensure that illegal dumping does not continue at any closed dump site. A public awareness programme should be initiated to encourage the use of the new landfill.

It is assumed that, in deciding to develop an upgraded landfill, the municipality will be committing itself to moving away from the practice of open dumping.

MAIN POINTS

- Dumps should only be converted if environmental protection needs can be met
- There is no point in costly conversions for dumps with only a little space left
- Closing a dump does not end the responsibility for it

The municipality must decide whether the dump will be closed or converted, and if it is to be closed, whether it is to be remediated in any way.

The decision to move towards sanitary landfilling will have been based on a recognition that open dumping was having an unacceptable impact on the environment and on human health and safety. Consequently, to simply abandon the dump would not address the local hazards associated with the dump. Something needs to be done to improve its condition.

Where an open dump does, or might, contaminate a useful groundwater resource, it is not recommended to attempt to convert it to an upgraded landfill.

It would be better to limit the impact on the groundwater by controlling the infiltration through the site by means of a low-permeability cap.

The Guide suggests the minimum standards that should be applied when undertaking a dump conversion to an upgraded landfill.

REMEDIATION

The objective of remediating an open dump is to minimise the environmental health and safety problems created by the dump.

Extinguishing fires, eliminating vermin and reducing groundwater and surface water pollution will achieve this objective.

At those open dumps in ravines, where waste has been tipped over a steep cliff into a valley below, the main problem may be to stabilise the loose and dangerously steep slopes of waste.

COUNTERING ILLEGAL DUMPING

The open dump was probably located where it is because of convenience and proximity to urban areas. Consequently, closing this convenient site may require that access to the dump be restricted. Otherwise, unwanted dumping will continue.

SURVEYING THE DUMP

The first step towards rehabilitating an open dump is to assess the condition of the site and its geographical setting.

A desk study can gather a wide range of information about the site, including maps and photographs, and information about the geology of the site. Any known pollution or contamination of soil, water and air at or near the site, and details of the waste types and amounts dumped can also be obtained.

The site investigation survey will, where physically and safely possible, confirm the depths of dumped wastes. Boreholes will detect any pollution by leachate.

A topographical survey will provide a 1:500 scale map of the site on which to prepare remediation plans.

Extreme care should be taken in carrying out these surveys since open dumps can present a range of health and safety hazards to humans. These include unstable slopes, hidden voids, sharp objects, hazardous chemicals, attack from rodents or mosquitoes, hidden bodies of water and risk of injury from falling waste.

These investigations will need to be undertaken before the choice can be made on whether to close or convert a site, since the findings will guide the decision.

To counter this, the municipality can either take steps to prevent illegal dumping at the same time as informing the public about the new facility, or provide a waste reception area at the closed site for a short period, with transfer of the wastes to the new landfill undertaken by the municipality itself.

The first option requires public cooperation as well as enforcement measures such as fencing and a watchman.

The second option requires the provision of a waste transfer facility, with associated costs. Such facilities are commonly provided on a permanent basis in some countries as a free service to the local community, where other disposal facilities are remote. The service is not made available to commercial and industrial waste generators who should pay transport costs of their wastes.

The municipality's aim should be to provide waste transfer facilities for a short period after closure, at the same time conducting a public awareness campaign to encourage direct use of the new landfill site.

KEY POINTS FOR DECISION-MAKERS

- **Should the dump be closed or converted?**
- **If closed, is the site to be remediated?**
- **What standards are achievable at the dump site?**
- **Should a waste transfer facility be offered permanently or temporarily?**

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