CHAPTER 5
IMPROVING LANDFILL OPERATION

You have learned in the previous chapters how to improve your landfill facility. Upgrading an existing landfill facility may be a difficult task for you, but a real challenge is whether or not you can sustain the proper operation and maintenance after the landfill facility is upgraded. In this respect, physical upgrading work is relatively easy, compared to proper daily operation. You can improve the facility overnight. However, you have to continue the operation at the landfill for many years in a sound and controlled manner.

Landfilling work includes the methods of landfilling, spreading and compaction, cover requirements and access roads. These items must be considered carefully before undertaking landfilling work as there is a close relationship among them.

In order to sustain proper operation and maintenance of the landfill, it is required to develop an operation & maintenance plan. In the majority of landfill sites across the Pacific, either the national or municipal government will be responsible for the management and operation of the landfill. Due to this, the relevant government agency should take ownership of the operation and maintenance plan at an early stage and be very familiar with its contents. It will be more beneficial if most, if not all, of the operating and management practices are developed by the responsible body.

Photo- 35: Improved Operation (right) as Compared to Previous Operation (left)

5.1 Landfill Method

Appropriate numbers and quality of staff need to be employed to supervise dumping in the disposal area. The staff at the tipping face should ensure that users are not dumping in other areas across the site and only in the designated disposal area. On small dumpsites the responsibility for site access at the entrance, and supervision of dumping, may be more practically undertaken by the same staff member. This is only feasible if the entrance and the tipping face are within a short walking distance.

The disposal area should be kept as small as possible and clearly defined. The area can be defined with the use of soil bunds or excavated trenches.

5.2 Cell Construction

A cell is a unit of landfilled space or area including cover material that is developed during one operating period. Ideally one operating period is one day, but in reality in the Pacific islands, it varies from several days, a week, or even a month, depending on the availability of landfill equipment and cover materials.

Sandwich Method - Waste is placed horizontally in layers for the sandwich method and is useful for filling in narrow valleys.

Cell Method - An amount of solid waste is covered with soil in cells. This method is the most popular method of filling. The amount of solid waste deposited during one operating period (usually one day) determines the size of each cell. As each cell is an independent filling area covered with soil, each cell acts as a firewall to minimize the spread of any underground landfill fires.

Dumping Method - This method involves rubbish trucks simply dumping solid waste into the landfill site. As the solid waste is not compacted, the landfill base is weak and negative impacts such as bad odour and harmful vectors may develop. Due to these problems it is not recommended for a method of landfilling.

5.3 Order of Landfilling

Landfilling on a waste site can be either of two ways: towards a downstream direction, or, toward upstream direction.

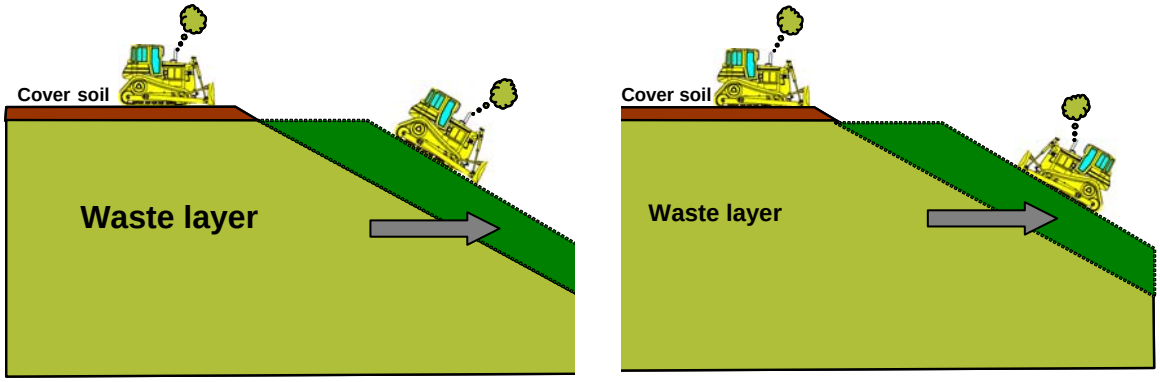
Landfilling from uphill downwards allows easy access to the tipping face via the already landfilled area. However, sliding of the landfilled layer may occur if the landfilled slope is steep, and especially during periods of heavy rain. In contrast, landfilling from downhill upwards gives reduced access to the tipping face but reduced risks of slippage.

5.4 Spreading and Compaction

Method - Spreading and compaction can be performed two ways, pushing down or pushing up the slope by the compaction equipment (bulldozer, loader, and landfill compactor). It is easier to push solid waste into a uniform thickness if spreading uphill and better compaction is achieved. If pushing solid waste down the slope, the waste at the base of the slope tends to be thicker.

The spreading and compaction of the waste has a direct influence over the capacity and stabilisation of the landfill. If low compaction is achieved the landfill site will last a shorter period of time than that if high compaction is attained.

When pushing solid waste, waste should be spread thinly out in layers of about 30 to 50cm. The layer should be made as uniform as possible. Between each layer, the compacting equipment needs to make regular passes over the waste layer. The layers should make a lift of about 2 metres with a maximum of 3 metres. A slope gradient of 3:1 (about 20 degrees) is recommended for pushing up (compacting) the slope.



Push-down Method Push-up Method

Figure- 15: Method of Spreading and Compaction
(In both cases, the direction of landfilling is from left to right as shown.)

Landfill Equipment - Landfill equipment should be carefully selected to suit the conditions for your landfill. A number of factors need to be considered. Such factors include type of waste, amount of daily incoming waste, site characteristics, weather conditions throughout the year, etc.

Landfill Compactor Bulldozer Excavator/backhoe Wheel-mounted Loader

Photo- 36: Typical Equipment used for Landfills

Typical problems with landfill equipment include breakdown from wear and tear, entanglement of wires or metal pieces caught in moving parts, loss of hydraulic pressure, or clogging of the radiator mesh due to dust and dirt. Therefore it is important that a regular service schedule for preventive maintenance for the equipment be followed.

The activities that require the use of heavy equipment include:

1. grading and maintaining site access roads,
2. excavation of disposal areas,
3. excavation and loading of soil for cover, and,
4. spreading, compacting and covering the deposited waste.

The equipment that can be used to undertake these activities includes bulldozers, multipurpose utility loaders, wheel-mounted loaders, landfill compactors, graders, backhoes etc. Refer to Table 4 for details of how landfill equipment can be used.

Table- 4: Features of Landfill Equipment

Equipment	Advantages	Disadvantages
Landfill compactor	- very effective in compacting and crushing rubbish - good mobility	- ineffective in soft ground - very expensive - limited availability
Bulldozer	- effective in spreading and transporting waste in a short distance - suitable for compaction - effective in covering of waste with soil - available in most countries	- ineffective for excavating soil
Backhoe	- effective in excavation and loading of waste/soil - available in most countries - can be utilised for multi-purpose	- ineffective for compacting waste/soil
Wheel-tractor-mounted loader (Front-end Loader)	- effective in loading rubbish and soil - high mobility	- ineffective for: o excavation o compacting waste/soil o maintaining access roads
Multipurpose Loader/Excavator (Backhoe Loader)	- can undertake most tasks (excavation, soil application, waste handling) - high mobility	- ineffective in compaction - unsuitable for excavating some soils (i.e. hard clay)
Grader	- effective in grading and maintaining site access roads - high mobility	- unsuitable for waste spreading, transporting waste

It is necessary, when selecting equipment, to ensure that:

1. maintenance parts and servicing are available
2. operators can effectively use the equipment
3. compaction efficiency is considered (which will affect the landfill life)

Taking into account conditions such as the amount of incoming waste, type of waste and availability of equipment, then landfill equipment with small capacities will be sufficient in most landfills in PICTs. For instance, a small bulldozer, say 7~10 ton, is enough for handling 200 tons of waste per day. It should be also considered to share (or borrow) the equipment as much as possible with other government departments to reduce the number of machinery, if exclusive use at the landfill is not possible. A storage shed should also be included so that maintenance for the equipment can be located on site.

In PICTs in the past, donors provided many different types of equipment without any specific regard for standardisation or consideration for what could easily be maintained in country. Since standardisation of equipment is very important for the ease of operation and maintenance, the recipient country should discuss the type of equipment to be provided in advance of any agreement with donor agencies.

5.5 Working (Tipping) Face

The working face of a landfill should be kept as small as possible. The advantages of maintaining a small face include less litter as there is less waste exposed to the wind, better control of scavengers, less leachate generation as there is less rainwater entry and, covering and compacting waste can be undertaken more efficiently. Amount of soil cover is also minimised. A large landfill should not extend its tipping face any greater than 30m by 50m, whilst smaller operations should aim for a 20m by 20m area.

During the wet season, efforts should be taken to minimise the tipping face size as much as possible as this will help to reduce the amount of surface water penetrating the waste to produce leachate. The working face can be increased during the dry season to a wider area.

Photo- 37: Working Face
Left: waste is compacted in a relatively small area
Right: waste is spread over wide area without boundary

5.6 Cover Material and Disposal Operation

Necessity of Cover Material - To maintain sanitary conditions the waste needs to be covered on a regular basis. The frequency of covering will be dependant on a number of factors, such as weather conditions, type of waste being landfilled, or availability of landfill equipment and cover materials. Covering at small landfill sites can be done manually, but at larger sites, equipment will need to be obtained to undertake spreading, compaction and covering of the deposited waste.

Cover material needs to be identified and sourced, preferably on-site, or else from a borrow pit nearby. Cover material ideally should consist of inert, non-combustible, dry and dense material. Once the material has been spread and compacted over the waste, then it should prevent pests and vermin from accessing the waste, minimise rainwater infiltration, prevent litter migration and provide a stable platform for tipping vehicles. The placement of soil over solid waste also reduces the fire risk and the covered waste becomes an effective firewall.

Suitable cover material could include soil, sand, crushed rock, crushed coral rock, ash, decomposed waste from another part of the site, demolition waste, sawdust and garden

waste. When covering, the thickness of the cover material should be approximately 20cm on the waste, since using too much cover material takes up a lot of space that should be filled with garbage instead.

Photo- 38: Covering Soil
Left: Covering soil using a backhoe
Right: Using a bulldozer

Type of Cover Soil - There are three purposes of cover soil: daily, intermediate or final cover soil. Daily cover soil, as the name suggests, is laid each day after waste has been dumped and compacted. The best quality soil should be reserved for intermediate and final cover soil requirements. Intermediate cover soil is laid for the base for roads or over daily cover areas where landfilling will not be occurring for an extended period of time and it is important that rainfall infiltration is prevented. Final cover soil is the soil placed on the top of the landfill when the final waste is placed in the landfill unit. Final cover soil should be of good quality and preferably clay to form an effective barrier against rainfall.

Selection of Cover Soil - Cover soil can be classified as sand, silt or clay and the permeability differs depending on the soil type. Permeable and porous sand types should be used for daily and intermediate cover for ease of spreading and compaction and to assist with waste decomposition at semi-aerobic landfills.

The final cover soil needs to resist erosion by rainfall, be low permeability and suitable for sustaining plant growth. The final cover is usually clay topped for these reasons.

Thickness of Cover Soil - The type of waste will determine the amount of daily cover soil that should be used. General municipal waste should be covered with about 20cm of soil, whilst very odorous waste (i.e. dead animals) should be covered with a thicker layer. When impermeable soils such as clay are used, the daily cover should be as thin as possible. Thicker requirements, approximately 50cm, are needed for intermediate cover.

When completing the landfill, it is recommended that a minimum thickness of 50cm be placed for the final cover, if small plants and bushes are being planted afterwards. When larger trees are planned for landscaping, more than one metre will be required.

Maintenance of Final Cover - The cover soil must be compacted uniformly to form a low permeability barrier across the top and slopes of the landfill. Care must be taken to prevent

the cover being eroded by rain water. The top of the cover should have a slope of 2-3% so that rainfall does not pond, and the side slopes should have a gradient of 20-30 degrees.

Waste decomposes over time, causing settlement of the landfill and subsidence. This subsidence can cause cracking and sinking of the cover, as well as the formation of potholes. This can result in leachate volume increases, gas leakage, erosion of the cover soil and landslides. During the following years after installation of the final cover, it should be inspected regularly for defects. Any areas of settlement should be filled in and repaired. At large and deep landfills, settlement can occur for up to 30 years after closure.

5.7 Leachate Management

Leachate management includes avoidance, collection, removal, treatment, disposal and monitoring of leachate generated in the landfill. A programme to regularly inspect and monitor leachate management needs to be developed and implemented.

Leachate should be treated to the extent that it does not pose a health hazard, before it is discharged to public water such as streams, rivers, wetlands or the ocean. Normally, leachate treatment is a very costly exercise employing sophisticated systems in the industrialised countries since leachate contains various chemicals and heavy metals in those countries. Generally speaking, leachate from landfills in the PICTs, however, does not contain hazardous chemicals or heavy metals and is basically derived from organic waste. Therefore simple and economical treatment methods indicated in chapter 4 will work well.

The quality of leachate should be tested periodically to see if there is any significant change in quality over time. Monitoring leachate quality also keeps you informed of the effectiveness of the treatment operation.

The water level at the leachate retention pond needs to be monitored to ensure it is kept below the outlet of the collection pipe so that fresh air is naturally provided into the pipe at all times. Through the leachate re-circulation process, as shown in chapter 4 (6), the amount of leachate in the retention pond can be significantly reduce by evaporation.

Some examples of failure in controlling the water level of leachate are shown in the Photo below.

Photo- 39: Submerged leachate pipe outlet (example of bad practice)
(Adapted from Reference No. 4)

5.8 Maintenance of Facilities

In order to maintain proper operations, landfill facilities must be regularly inspected and kept in a good condition. Facilities to be maintained include access roads, landfill slopes, drainage, and leachate collection and the gas venting facility.

Access Roads - Access roads at landfills usually have a short lifespan. There are two types of roads which should be considered, trunk roads and branch access roads. The trunk roads are those roads that exist on site for a number of years, while the branch access roads to the tipping face will usually only be used for a matter of months.

The road should be designed according to the size of vehicle and their speed, and geography of the land. Other considerations include safety measures such as guard rails to prevent traffic from falling down steep slopes that inevitably exist at many landfill sites and also reinforcements to prevent slippage from slope failure. Diversion of water should be considered carefully across the whole site and drainage around the road network is also important.

Photo- 40: Example of Site Access Road (Bouffa Landfill, Vanuatu)

Construction of Slope - The landfill slope is formed from the deposited waste and the exterior soil placed around the outside. It is the slope which the final form of the landfill will take and should be carefully considered as it may restrict the final usage of the site if not chosen wisely. The slope should fit in with the terrain in the area and soil characteristics of the landfill site.

The earth bund is the final soil cover on a landfilled slope. Progressively building the bund as the landfill progresses is the ideal method of construction. Therefore as each layer of the landfill is placed (approximately 2 to 3 metres high), the next layer of the bund should be constructed. When the new bund is built on the underlaying landfill layers, a minimum setback of 1~2 m is recommended for every lift of 2~3 m. Even at a large landfill site, one lift should not exceed 5 m.

As the landfill slope is usually built on a landfill layer, the stability of the slope is greatly dependent on the compaction and stability of the underlying landfill layers. Consult with engineers if you plan to install more than 3 lifts or 6 m high.

Photo- 41: Construction of Slope (M-dock Landfill, Palau)
Left: before rehabilitation
Middle: Slope formation and soil cover
Right: after rehabilitation with vegetation

Erosion and Drainage – Since the landfill slope is easily eroded, it is important that preventive measures be taken. Preventive measures against rainfall erosion include planting of the slope with plants and grasses.

The installation of a drainage system is the most effective method of preventing erosion. Rainwater should be collected and diverted from steep areas and not allowed to pond and seep into the landfill to form leachate. Sometimes springs can form on the side of a landfill slope. These leakages of liquid must also be collected as leachate. Crushed stones can be laid on the inside of a landfill slope to act as a drainage layer and keep the liquid within the landfill for collection by the leachate collection system. This drainage layer is most suited if a leachate collection system has been installed in the landfill.

Leachate Collection and Gas venting Pipes **-** As the landfilling operation progresses, the leachate collection facility and gas venting facility need to be extended. Any damage or defects experienced during landfill operation should be repaired so that the designed functions will be restored. Special care must be taken not to damage these facilities during landfilling operation.

As seen in Figure-16, leachate collection pipes are easily damaged at the initial stage of landfill operation by either direct hit or excessive load of the landfill equipment. The height of waste layer on the leachate collection pile should exceed 1.5 meters for protection.

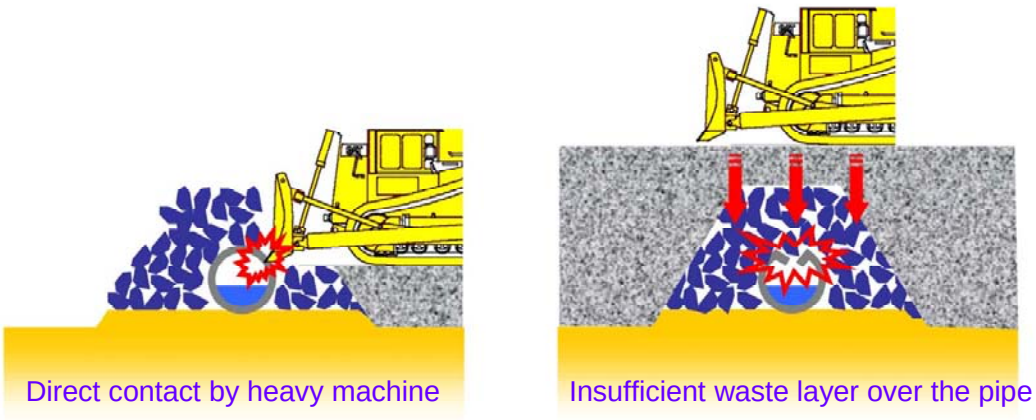


Figure- 16: Causes of Damage by Landfill Equipment
(Adapted from Reference No. 4)

Photo- 42: Damaged Leachate Collection Pipes

Photo- 43 Clogged Leachate Collection Pipes
Left: Normal condition Right: Clogged with plastic waste

Photo- 44: Clogged Vertical Gas Venting Pipes
(The protective filter materials around the gas venting pipe are buried with waste and cover soil, thus soil and waste penetrated into the gas venting pipe and clogged it.)

Photos 42, 43 and 44 illustrate the damage or malfunction of leachate collection pipes and gas venting pipes. Because the leachate collection pipes are laid on the bottom, it will be

extremely difficult to repair them after waste is deposited and piled up high. Therefore careful operation must be carried out especially at the initial stage of landfilling and at the point where leachate collection pipes and gas venting pipes are installed.

When you observe or discover damage to the leachate collection facility or the gas venting facility, it is better to fix it as quickly as possible before the waste layer is further piled up. The following photos explain how to repair damaged pipes.

Photo- 45: Sequence of Remediation of Damaged Gas Venting Facility on the Connection Pit

1. Excavate around the damaged gas venting facility.
2. Remove the gas venting pipe and the support (previously iron rods were used) on the connection pit.
3. Clean inside the connection pit.
4. Install a strong support on the pit and place stones around. A big used tire with steel rim (yellow circle) reinforced by 2 inches steel pipes underneath (on the connection pit) is used as the support in this case since the previous support was collapsed due to the heavy load of the facility.

5 & 6. Install a new gas venting pipe and used drums on the support and fill the drums with stones.

7. Backfill around the gas venting facility with fresh waste and compact it.
8. Install another set of drums with stones around the pipe to extend the gas venting facility.
9. Continue the processes 7 and 8 up to the designated height.

As the waste layer becomes deeper (higher), additional gas venting facility as well as leachate collection facility should be installed in the waste layer if the final depth (height) of the waste layer will exceed more than 20m. (See Figures 17 and 18)

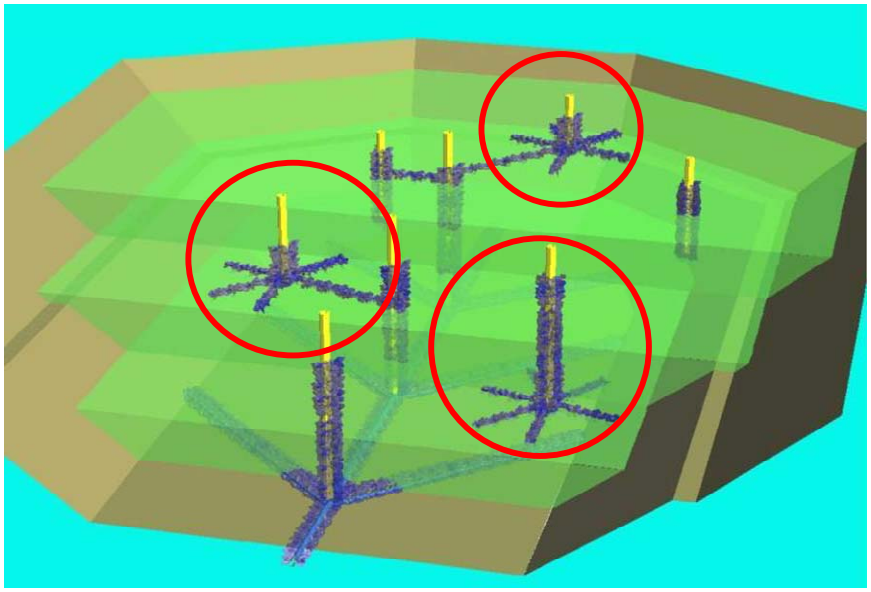


Figure- 17: Installation of Additional Gas Venting Facility in Deep Waste Layer
(Adapted from Reference No. 4)

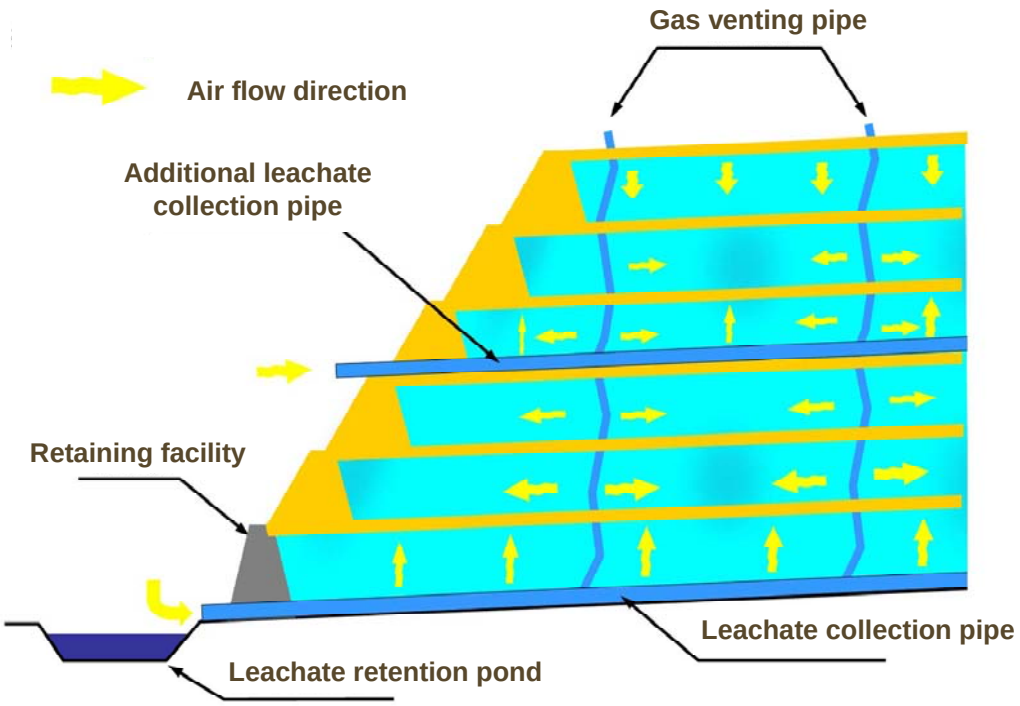


Figure- 18: Installation of Additional Leachate Collection Pipes in Deep Waste Layer
(Adapted from Reference No. 4)
(Additional horizontal leachate collection pipes can also provide fresh air into the waste layers.)

5.9 Environmental Management

Landfills are sometimes referred to as a typical NIMBY facility. The reason for this is that people suffer many nuisances caused by the landfills. Appropriate measures can minimise the nuisances as illustrated below (also refer to Tables 1 & 2, Section 4.1 Review and Assessment of Existing Conditions).

Odour - Odour is sometimes very difficult to manage at a landfill site. All sites will generate odour to some extent and it will generally be worse in wet, hot weather. Some measures which can be taken include:

- immediate covering of highly odorous waste
- regular covering of waste
- ensure the tipping face does not pond water
- encourage residents to store waste in a dry condition (so that when waste reaches the landfill it is not as odorous),
- maintain buffer zones around the landfill site (to minimise impacts on neighbouring sites)

Dust - Dust control measures at a landfill site typically include wetting down of dirt roads with a water truck. Regular rounds of the roads will need to be made by the water truck, particularly in periods of very dry weather. Water can be sourced from on-site surface-water ponds or basins.

Fire and Smoke - Fires should be minimised at landfill sites as burning rubbish can generate poisonous gases and be an environmental and health risk. The type of control measures typically considered includes:

- regular soil cover to minimise risk of fires
- developing a fire management plan including maintenance of an effective fire break around the perimeter of the site, and,
- developing emergency procedures for minor and major fires, including soil cover, water spray, excavation of trench, etc.

Photo- 46: Examples of Fire Incident at Landfills
Left: M-dock Landfill, Palau (2004)
Right: Lami Landfill, Fiji (2006)

It is therefore important to have good compaction of waste in daily operation in order to prevent the fire from spreading.

For chronic smouldering in the waste layer, additional installation of a number of independent-type gas venting facility with proper cover soil will be very effective as shown in Photo-47.

Photo- 47: Installation of additional independent gas venting facility
Left: Excavation of trench (1.5 m deep)
Middle: Installation of additional gas venting facility
Right: Compaction and soil cover

The following figures explain the mechanism of fire and how it is put out by installing additional independent gas venting facilities.

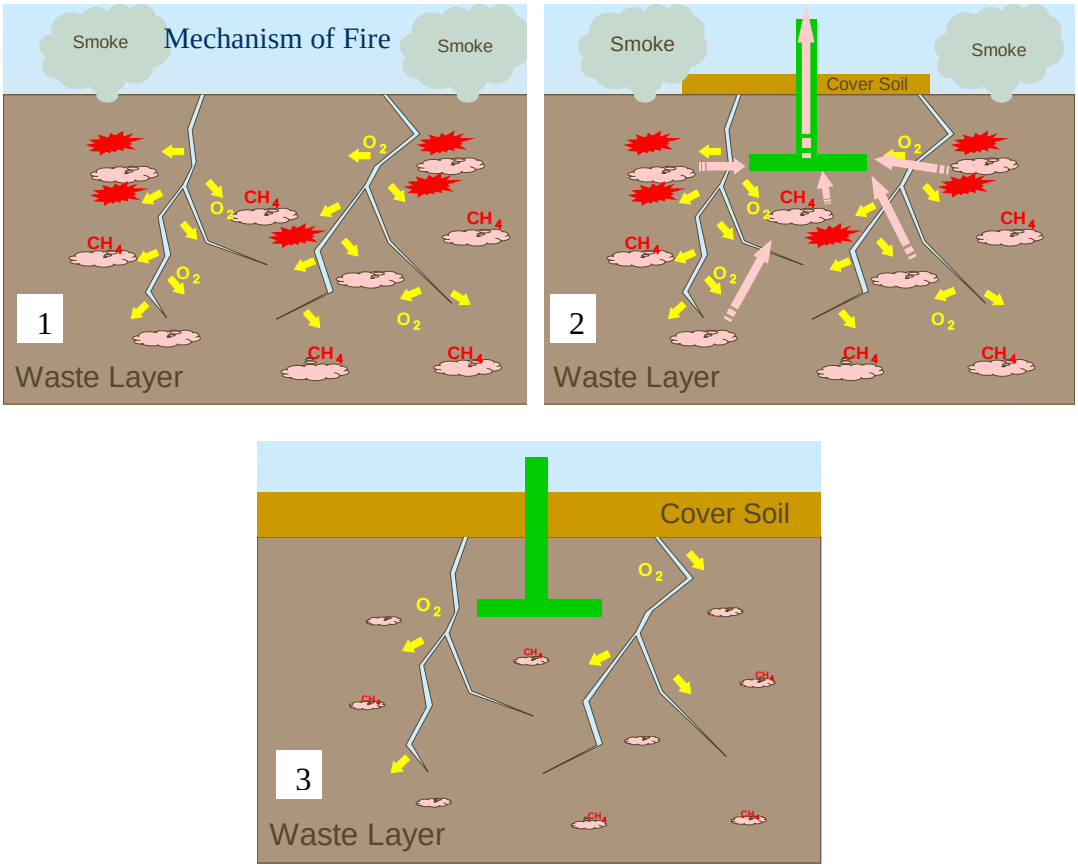


Figure- 19: Fire Fighting Measure for Chronic Smoulders

Where the waste layer is in an anaerobic condition (absence of oxygen), methane is generated and contained in the waste layer. When oxygen penetrates into the waste layer from the ground, the concentration of methane enters a certain range (5–15 %) and catches

fire naturally by chance or by deliberate ignition. In an anaerobic landfill, the fire continues consuming flammable materials (buried waste) in the waste layer. (See No. 1 of Figure-19)

By installing a number of additional gas venting facility with soil cover, quick discharge of methane is promoted and supply of oxygen from the ground is minimised. (See No.2 of Figure-19)

When much methane has been released in the air, the fire (smoulder) gradually becomes suppressed. (See No. 3 of Figure19)

Noise - Noise control can include the restriction of opening hours to certain times. Noise barriers can be constructed, either soil berms or maintaining a buffer zone with trees.

Surface Water Quality - Landfill sites typically have a lot of exposed surfaces in which stormwater can become a significant source of sedimentation. A sedimentation basin or other soil erosion and sediment control measures may be useful so that water can be collected and sediments be allowed to settle from the water prior to discharge from the site. Any measures constructed will need regular maintenance, particular after heavy rainfalls.

Stormwater that has travelled across the site may become contaminated. If surface waters are contaminated, they may need to be directed for treatment along with the leachate (if a leachate treatment process is in place).

Visual Impact - Improvement of a landfill site can contribute to reducing the NIMBY syndrome against rubbish dumps. Effort should be made to try to keep waste from view of the public employing such measures as building a buffer zone with trees, constructing bunds, installing wooden or galvanised walls or fences, etc. This can reduce some of the potential impacts of landfill operations such as noise, dust and odour. Even simple regular covering of soil over rubbish can significantly reduce the eyesore potential.

Photo- 48: Waste Dumps vicinity of Residential Area

Public Health and Environmental Monitoring - Public health and environmental monitoring can provide an indication of the severity of impacts at the waste disposal site and how effective control measures are in reducing the impacts.

Monitoring the aquifer(s) below a landfill site will provide an indication of how effective the leachate collection system is operating. Groundwater wells should be installed upstream and downstream of the landfill so that regional concentrations (background values) can be monitored and compared to downstream values. Groundwater monitoring is quite expensive so the wells should be chosen with care and for optimum benefit.

Groundwater and surface water quality should be monitored on a quarterly (every 3 months) or bi-annual (every 6 months) frequency. It is important to account for seasonal variations in the groundwater monitoring program. In addition, the water level at the leachate retention pond needs to be monitored so that any overflow of leachate or plugging of the outlet of leachate collection pipe is avoided.

Gas monitoring needs to be conducted where there is potential of gases to accumulate in high concentrations, such as the outlets of gas venting pipes. Regular monitoring of landfill gases will enable you to see if the semi-aerobic system is functioning. It must be emphasised that measuring gases is utmost important when entering a deep pit or excavated place in order to avoid any accident caused by deficiency of oxygen.

There also needs to be a mechanism for reporting and responding to complaints and problem monitoring results. Results should be reported on a regular basis to the responsible body so that decisions can be made to minimise and manage any outstanding issues.

5.10 Social Considerations

At a landfill you will often see unauthorised people roaming around the tipping face. Those people are called waste-pickers who collect recyclables or valuable materials. They sometimes disrupt the landfill operation and vandalise landfill facility, if you try to remove them from the landfill area without their consent.

It has become more and more important to give consideration to social aspect of solid waste management. Indeed, waste-pickers are a diligent workforce from the stand point of recycling waste. It is not quite a good solution to remove them from the circle of solid waste management. Rather, you will be better off if you can come up with an idea to keep them in the system of waste management. Such an idea may be employing them as registered landfill workers, setting up a separate waste segregation point, or providing training for other skills, etc.

Photo- 49: Waste-pickers at landfill

5.11 Occupational Health and Safety

Occupational health and safety with landfill operation generally consists of the aspects such as site traffic, landfill operation, and landfill staff/workers including visitors from outside.

Site Traffic – In general, no official traffic regulations are enforced in the landfill area in PICTs. It is however necessary to establish site specific rules and training program so that safety of both traffic and site workers is ensured and efficiency of site operation is improved. Traffic rules and regulations should include travelling routes, speed limits, traffic signboards, information boards, etc. Both English and local language should be used in the signboards to avoid misunderstanding.

Landfill Operation – Special care must be taken at the tipping face, on the access road and possibly in other areas since heavy landfill equipment and collection trucks are moving around. Site workers need to provide guidance to truck drivers and equipment operators to avoid any direct contact or falling into a gap. When working in a deep pit or excavated location, prepare for deficiency of oxygen or existence of hazardous/inflammable gases. Establishment of a health and safety plan and on-site training for landfill operation is essential in order to avoid accidents and damage of facilities.

Because the landfill operation is to backfill the space with waste (and soil cover) from the bottom, the most important facilities, such as leachate collection pipes and gas venting pipes, will be buried under waste when the first layer is filled up. Therefore, in-house and on-site training is essential for new site staff as well as operators to let them understand functions of various facilities and proper landfill operation in order to prevent any damage caused by operational carelessness.

Photo- 50: On-site Training

Staff, Workers and Visitors – Proper safety gear can prevent site workers from injuries on site. Such safety gear includes hard hat, goggle, gloves, safety shoes/boots, safety vest, etc. In the landfill area, at least proper shoes must be worn on-site at all time. All visitors to the landfill site must register themselves at the gate and those who are not familiar with the site should be escorted by site staff.