European Neighbourhood Partnership Instrument (Eastern Region)

Waste Governance – ENPI East

Landfill Operations Guidance Manual

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1 What is ENPI?

The **European Neighbourhood Policy (ENP)** was developed in 2004, with the objective of avoiding the emergence of new dividing lines between the enlarged EU and its neighbours, and instead strengthening the prosperity, stability, and security of all concerned. The ENP goes beyond existing relationships to offer a deeper political relationship and economic integration. The level of ambition of the relationship will depend on the extent to which these values are shared. The ENP remains distinct from the process of enlargement although it does not prejudge, for European neighbours, how their relationship with the EU may develop in future, in accordance with Treaty provisions.

Until 31 December 2006, EC assistance to the countries of the European Neighbourhood Policy was provided under various geographical programmes, including Tacis - for the EU's eastern neighbours and Russia – and MEDA for the EU's southern neighbours. From 1 January 2007 onwards, as part of the reform of EC assistance instruments, MEDA and TACIS have been replaced by a single instrument – the **European Neighbourhood and Partnership Instrument (ENPI)**. This is a much more flexible, policy-driven instrument. It is designed to target sustainable development and approximation to EU policies and standards - supporting the agreed priorities within the Partner Countries. For 2007-2013, approximately €12 billion in EC funding is available to support these partners' reforms.

2 Introduction

The project *"Waste Governance – ENPI East"* includes activities that address waste management priorities at both regional and national level – the latter through the respective development of an up-dated register of waste disposal sites and a 15-year, integrated, waste management strategy for a selected pilot area. The latter will form the basis of an investment project to provide for effective waste management and, in this respect, it is intended that the strategy will become a model for adaptation and replication in other area of the country.

Disposal of waste to landfill is an integral part of any modern, environmentally secure, waste management system, and is likely to form an important part of the strategy to be developed for Armenia's pilot region. In Armenia, and indeed for most other former Soviet Union countries, the landfilling of waste will continue to be the predominant waste management option for the foreseeable future, despite efforts to encourage waste recycling in the country. The majority (indeed practically all) of the country's landfill sites are essentially dump-sites with little, if any, environmental containment measures in place. When badly managed, waste disposal can have significant short- and long-term environmental and health impacts. It is important therefore that waste disposal sites are located, designed, operated, and monitored to ensure that they do not create an unacceptable risk to the environment and human health. Even the best designed and constructed landfill site will have many sanitary and environmental problems if it is operated badly. Conversely, well managed site operations can compensate for weaknesses in site location and design.

In this respect, the Ministry of Nature Protection of RA has identified an immediate need for the development of landfill operational guidelines as a tool for achieving enhanced management at the existing waste disposal sites in the pilot project region (RA Lori marz) in the years until new sanitary landfills can be constructed to serve the region[1].

The objective of this paper is to present guidelines for improving operational practices at waste disposal sites by bringing them into line with international best practice – not least through convergence with many of the practices and principles within the main EC Directives (e.g. Framework Directive on Waste (2008/98/EC), Directive on the Landfill of Waste (99/31/EC), and the Council Decision on the Criteria and Procedures for the Acceptance of Waste at Landfills (2003/33/EC) wherever practically possible to do so. It will not address the design or construction of landfills or waste disposal sites[2].

The documents will, however, be applicable to all landfills without necessary reference to a specific design or to a specific type of landfill. This manual should thus be seen as contributing to the process of improving national waste disposal standards by setting out the requirements for effective day-to-day operations, and covers such matters as waste emplacement, use of cover, cell design, site management, and leachate & gas control. However, effective site management cannot be based solely on how operations on a landfill site are conducted. It is equally important that the interface between the site and its neighbours is considered carefully. Hence this manual also deals with issues such as site appearance, nuisances, and liaison with the general public.

It must be noted that the recommendations provided in the manual may be adopted and implemented only with consideration of, and in line with, the relevant local norms, standards and regulations adopted in Armenia.

Section Three of this report presents a brief overview of the current state of play regarding waste disposal within the country, if only to be able to place the proposed operational best practice into context.

Thereafter the remaining sections are structured as follows:

- Section Four offers guidance on improving the keeping, and management, of site records in line with best practice principles. In this context, it introduces concepts such as environmental

[1] Guidelines may be applied in other regions of the country as well where no modern sanitary landfills exist.

[2] Recommendations on design of landfills are provided in the Manual on Design and Exploitation of Landfills on the Territory of the Republic of Armenia adopted by the Ministry of Urban Development of RA in 2009 (see Section 3).

management planning, the importance of maintaining clear site records, recommendations for site management, staffing, and site inspection;

- Section Five presents guidance on improving a site's appearance and the necessary infrastructure that, ideally, needs to be in place if it is to be operated in line with best practice;
- Section Six recognises the fact that some of the infrastructure outlined in the previous section is unlikely to be achieved for the majority of the country's disposal sites, and thus guidance is given upon moving away from uncontrolled dumping towards more efficient, controlled, waste disposal;
- Section Seven offers guidance on improving waste placement procedures. It sets out the basis for how a waste disposal site should be delineated into cells/phases, if it is to be managed in line with international best practice. It focus on improving waste acceptance procedures, how to deal with non-conforming waste assignments, filling methods, waste compaction, and the disposal of difficult wastes, and how to make best use of cover materials during landfill operations;
- Section Eight presents guidelines on waste co-disposal. It outlines the objectives and benefits of co-disposal, the concept of co-disposal, criteria for accepting toxic industrial wastes at land disposal sites, waste loading rates, disposal operations, management procedures for co-disposal, and specific health and safety precautions;
- Section Nine sets out the basic requirements for the effective control of health and safety at landfill site, in addition to those outlined for the co-disposal of wastes;
- Section Ten presents operational procedures for controlling "nuisance" impacts such as pests, birds, and fires etc;
- Section Eleven sets out best practice for the management and monitoring of a site's environmental impacts, not least control of the leachate and landfill gas generated; and
- Section Twelve sets out some preliminary guidance for the closure and aftercare.

3 Existing Waste Disposal Practices – An Overview

Armenia's existing waste management system in under considerable stress and, indeed, has been recognised as such through a number of recent studies, e.g. the UNDP project *"Strengthening of Integrated Waste Management in Armenia"* (2007), and the recent World Bank Phase I funded *"Advisory Study on the Development of the Solid Waste Management System in the City of Yerevan through Private Sector Participation"* (2009). The main conclusions from these, and other, studies were that:

- Standards of waste disposal throughout the country are below best practice, with the disposal sites (on the whole) lacking the required environmental controls. For example, of the 48 dumpsites operated in the country's 45 towns, only 77% have a permit to operate and, of the 869 rural communities, 565 (65%) have no dumping sites and, of the remainder which do, only 178 (64%) have the required permit to operate;
- Not all powers endowed by existing waste management legislation are implemented in practice to an adequate degree and there is an unclear division of responsibilities. The weakest point for all levels of administration is the general lack of control over the waste management process due to the poor organisation of data registration concerning the operation of waste management companies, uncontrolled waste movement over the country's territory, a general lack of co-ordination and co-operation between the various government agencies involved, and inadequate law enforcement with regard to violators of sanitary and environmental law;
- The lack of adequate staff resources and limited specialist waste management expertise is seriously hindering the resolution of waste management problems;
- An acute lack of finance for solving waste management problems due to their low prioritisation within the disbursement of national and local budget funds;
- An absence of coherent, regional, waste management policy has hindered any significant progress in minimising waste generation and, more importantly, in reducing the number of semi-legal and illegal dumps;
- The market for waste management services is poorly developed, with limited competition and participation of the private sector; and
- The overall administrative system governing municipal solid waste (MSW) management is complicated and inefficient. In particular, the existing arrangements for the control and management of waste disposal activities are largely ineffective.

The issues posed from inappropriate waste landfilling are particularly acute leading, without doubt, to an ever increasing likelihood of adverse impacts on human health and the environment from the leachate generated and the common practice of burning MSW at these sites. These sites cover a considerable area in relation to the size of the overall country. For example, the total area of the dumping sites of the urban communities constitutes 306 Ha (with the total amount of waste amassed estimated to be some 27,824,768 tonnes) and, for the rural communities, waste disposal sites cover some 157.9 Ha with some 36,816 tonnes disposed therein. Plastic wastes (bottles and bags) constitute a large share of the amassed MSW – both at the dumping sites and from that dispersed across roads and settlements. In addition to MSW, poor industrial waste management is also causing a problem. The wastes from about 500 enterprises are believed to be causing environmental pollution – not least because the generated waste cannot be amassed at the enterprise in unrestricted quantities and is therefore dumped at MSW disposal sites or illegally dumped at sites across the country. In addition to industrial wastes, the content of chloro-organic pesticides in the land around landfills also suggests that pesticides, household chemicals, and empty containers were deposited to waste disposal sites for many years.

The dumping sites in the country do not meet existing hygiene and sanitation standards, and are operating haphazardly. Waste disposal sites in the larger towns are in a particularly poor condition – they are not fenced in and scavengers have access to them.

There is neither equipment for washing and disinfecting the vehicles nor utilities for the workers, and waste is neither sorted nor covered by earth. Given that about 700,000 tonnes of waste accumulates annually at the country's 60 organised disposal sites, which contains a large amount of potentially recyclable material such as paper, cardboard, glass, plastic and metal, then there is every incentive for efficient systems for waste sorting, collection and utilization to be created. In addition to construction and household waste, various waste types are dumped there with no regard to the level of harmfulness. Furthermore, there are no monitoring wells in any of the disposal sites to determine the degree of pollution of the groundwater at the disposal sites. Similarly, in most dumps, burning or self-burning of waste occurs has led to pollution of the air, water, and soil – particularly with dioxins whose adverse effects on human health is well known. During natural composition of the organic compounds and their burning in landfill, toxic chemical compounds are released into the environment (air, water, land) which belong to classes 2-5 of hazardousness.

From the above, one can conclude that the majority of waste disposal sites in Armenia do not meet basic hygiene, sanitation, and ecological requirements. There is practically no waste neutralization and treatment, and they are merely used to amass waste. There is no leachate or gas control and treatment, no groundwater or gas monitoring, there is inappropriate machines/equipment at best, and little or none waste accounting is performed. Furthermore: i) There are no special units/organisations for industrial waste neutralisation and no special landfills; ii) Industrial waste is amassed in organisations or end up municipal solid waste disposal sites; iii) There are no household solid waste recycling plants in the country; iv) The operating dumps do not meet hygiene-sanitation and environmental requirements, e.g. protective liners and groundwater monitoring wells do not exist, the biogas is not collected, and the waste quantities are not recorded; iv) Spontaneous combustion is occurring at almost all the disposal sites due to their improper operation; v) Illegal waste dumps are common throughout the country; and vi) Sanitary cleaning and waste collection is done inadequately in urban settlements and is of a haphazard nature in rural communities.

It is within this context that the Government of RA has identified the need to urgently upgrade the standards of waste disposal within the country. In this respect, feasibility studies supported by the international development banks are underway, e.g. EBRD is planning to finance measures aimed for improving Nubarashen landfill and/or the construction of a new sanitary landfill next to the existing one and, in Kotayk Marz, where a feasibility study for a new landfill is being undertaken with international support.

Furthermore, a number of documents have been adopted to facilitate improvements in waste disposal sector. On 6 May 2009, the List of Actions for 2009-2011 to ensure the implementation of European Neighbourhood Policy RA-EU Action Plan was adopted by the Presidential Order N-68A.

In the paragraph 149 of the List the following activities in waste management sector are foreseen to be implemented: (i) to undertake an inventory of managed and accidentally established waste disposal sites in the territory of RA, (ii) to establish a database of the identified waste disposal sites, (iii) to plan, design, and construct waste processing facilities, new waste disposal sites, and to close existing sites, and (iv) to create and run registrars on waste recycling and processing and disposal areas.

On 29 December 2009 the Manual on Design and Exploitation of Landfills on the Territory of the Republic of Armenia was introduced via Order N 321-A of the Ministry of Urban Development of RA (see Annex A). The document does not have an obligatory character. Instead, the manual advises on the design, sanitary and environmental requirements which future landfills should meet. The document also contains recommendations on landfill operation standards. It is strongly recommended that for all environmental and health considerations, future landfills in Armenia should be constructed in accordance with the provisions of the Manual and EU standards.

As part of the Government initiative to strengthen waste disposal practices in the country, detailed guidance has been requested by the Ministry of Nature Protection of RA to provide recommendations on best operational practice at waste disposal sites. This is outlined below.

4 Site Record Keeping and Management

Accurate record keeping and management is an important pre-requisite for ensuring that a waste disposal site is managed in an organised and structured manner. An important upshot of this is that the site's management should not only have a good understanding and control of the site - particularly with respect to its daily operations including the application of manpower, machinery, and materials – but also its environmental management. Consequently, this section outlines the basis for creating an environmental management plan, the need for comprehensive site records (and what these records should encompass), staffing requirements to ensure that efficient day-to-day operations take place, and effective site inspection requirements.

4.1 An Environmental Management Plan

An environmental management plan is essential for managing a disposal site in line with best practice. Such a plan will not only be necessary for competent site management, but it will also provide essential information for dealing with the regulatory authorities. The structure of such a plan is presented below:

Details of Operator	Name and Address of Operator and Site. Included should be contact names in respect of person with managerial responsibility for site operations, including the site manager and site engineer. Relevant telephone numbers should also be given.
Site Description	A description of the site should be provided which covers the following: • Boundaries and topography • Geological and hydrological characteristics of the area • Local meteorology
Types of Waste Accepted	A detailed description of the procedures for acceptance and the types of waste that can be accepted on the site should be given. This should clearly state whether household, commercial, and industrial wastes are to be accepted.
Quantity of Wastes Accepted	Details should be given on the annual quantity of waste taken into the site. This should be sub-divided into major types, e.g. household waste, commercial waste etc.
Site Capacity	An estimate should be provided of the original site capacity and remaining capacity
Engineering Details	Details of all significant site engineering works should be included. Where applicable, the information should cover: • Site preparation and provision of services • Containment details • Leachate drainage, collection, and treatment • Landfill gas abatement method, collection, and flaring • Monitoring points for landfill gas, leachate, surface water, groundwater, etc. • Fencing, gates, and other security • Site access roads and secondary site roads • Offices, fuel stores, etc. • Wheel cleaning infrastructure, site weighbridge etc • Surface water control measures, ditches, road drains, etc.
Operational Matters	These should include: • Description of the operations • Phasing of filling • Water, leachate, and gas control measures • Measures for the control of environmental nuisances • Site opening and operating times • Access control and waste acceptance procedures • Equipment to be utilized • Waste placement procedures • Cover requirements • Site personnel, including duties, qualifications, and responsibilities • Monitoring and maintenance procedures

	• Operational and safety rules (including safety statement) and emergency procedures • Litter abatement methods and procedures • Noise and dust abatement • Measures to deal with vermin and other pests
Closure and aftercare	Closure and aftercare procedures should include: • Final capacity and expected operational period of the facility • Final contours and topography of the site • Restoration Plan • Phases for closure and restoration of completed areas • Aftercare monitoring and other control measures • Maintenance programme for aftercare phase

It is unlikely that any waste disposal site operator will have all necessary information to produce such a plan in its entirety. However, as much information as possible, should be included even if this can only be estimated.

4.2 Site Records

Maintaining accurate and comprehensive records of landfill operations is essential for the management of any waste disposal site to international best practice.

The necessity for an organised system of record keeping should be borne in mind and should be introduced at the earliest possible opportunity. The scope and quantity of these records will grow as the site develops and will not be replaceable if lost. A site's management team is strongly advised to secure these records in a secure location and to maintain a complete duplicate set at a separate location away from the site. Although older sites may have scant data, the introduction of a record keeping system is still necessary and should be considered a high priority for any site operator. Records should be retained throughout the life of the facility, and for the closure and aftercare periods. Documents should be organised, legible, dated and signed by the appropriate personnel.

A full set of drawings of the site and structures on the site should be retained. Any plans should be accompanied by written descriptions of the development works undertaken. Site input records should be maintained for all wastes entering the site, including inert materials for restoration and cover. The results and an interpretation of the results of environmental monitoring should always be included in the site records. It is recommended that, ideally, these records should include:

- Copies of all site appraisal and investigation documents, borehole logs, etc.;
- Information and plans on the landfill design and the design of other structures on the site;
- Copies of site rules for staff, visitors, contractors, etc.;
- Waste acceptance procedures;
- Documentation of inspection records, training and notification procedures;
- A detailed scheme for restoration and aftercare;
- Locations of all landfill gas, ground and surface water and leachate monitoring points, along with sampling protocols;
- Results and interpretation of the results of all environmental monitoring;
- Names, positions and qualifications of all staff involved in site design, management, engineering and environmental monitoring;
- Records kept of quantity, nature and origin of the waste accepted into the facility;
- Site inspection records;
- Details of complaints and remedial actions;
- Procedures and records as required regarding safety and health, accidents and fires; and
- Copies of all official documents relating to the landfill including consents and other certificates.

In order to simplify and consolidate the record keeping process, the establishment of a site manual is strongly recommended. This site manual should comprise a compilation of all relevant documents pertaining to the site and should include, as a minimum, information on:

- Details of the site's design and construction, including specifications, drawings, etc.;
- Planning and waste management licence applications and supporting documentation including changes and modifications;
- Detailed restoration and aftercare scheme;
- Working plan for submission with licence applications, including amendments and modifications;
- Records relating to health and safety, including health and safety plans, accidents, and fires;
- Survey records and plans, including the changing capacity of the dumpsite;
- Waste input details, waste disposal locations, and development of working areas and phases;
- Environmental monitoring programme for leachate, landfill gas, noise, odours, and dust as appropriate;
- Environmental monitoring data; and
- Registers of complaints, etc.

Within the site manual, a register should be maintained of all of the above items to enable search and cross-referencing so that it becomes a useful aid to communication between all parties involved in the operation of a modernised waste disposal site.

4.3 Site Management and Staffing

International best practice entails that all landfill sites should be supervised by a suitably qualified site manager. Other persons should be designated as having responsibility for the site in the absence of that person. Whilst the site manager may not need to be on site all the time, a significant proportion of the site manager's working week should be spent on the landfill site supervising operations. A named engineer should also be assigned to the site, and be educated to degree standard or equivalent and have appropriate experience. The duties of the engineer will include carrying out of routine site visits, inspections/certifications and overall supervision of any development activities.

It is vital that all sites should have personnel capable of undertaking key tasks and acting responsibly on behalf of the operator. Of particular importance is the need for personnel assigned responsibility for waste acceptance to be full time employees of the site operator. Given the fact that many wastes can only be checked at the time of deposit - in other words on the working face - it is crucial that plant operators are aware of the relevant procedures and in a position to effectively implement them. The operation of the working face should be supervised at all times by members of the site's permanent staff. Supervision of the working face and responsibilities for checking materials being deposited should never be delegated to temporarily employed operatives. Furthermore, it is not best practice for one individual, working alone, to be left in charge of an active waste disposal site that is open for the acceptance of waste. It is not possible to adequately check loads in such circumstances, and this arrangement may be undesirable for health and safety reasons.

Professional development and training should be provided so that site staff is familiar with the required standards of operation, statutory requirements and, in particular, the need to verify the appropriateness of incoming wastes. All operatives should be trained to a standard which will satisfy the requirements of national health and safety legislation, particularly in the safe operation of equipment. They should be aware of the contents of the site's Environmental Management Plan, any licence conditions, and the standards of operation required. The nature and types of wastes being handled, and the difficulties involved in ensuring continuous supervision make it essential that staff receive a high standard of training.

If staff are not trained or given clear, well-written, job descriptions, then it is not surprising that they show little interest or competence in operating an organised and well run waste disposal

operation. It is also for site personnel to understand that with training, and defined job descriptions comes the responsibility to perform properly the tasks that they are given.

The minimum level of staffing will vary depending on the quantity of waste received and the standard of disposal operation achieved. The suggested staffing arrangements for a site receiving between 250 and 500 tonnes a day will comprise as a minimum: i) Disposal site manager; ii) Gatekeeper/office clerk; iii) Traffic marshals directing trucks to discharge waste at the working face; iv) Mechanical equipment driver(s); v) Manual labourers; and vi) Maintenance mechanics if it is intended to establish a maintenance facility at the disposal site.

4.4 Site Inspection

During operation, a waste disposal site should receive thorough and regular inspections by the site manager. A written record of each inspection should be kept. This inspection should be carried out at least weekly and should cover the area of current operations, as well as completed areas. This inspection should also include the site perimeter and site security arrangements.

An example of such a site selection report is shown in Table 1 below.

Table 1: A typical site inspection report structure for ensuring best practice

SITE INSPECTION REPORT

Site Name ……..Ref No ……..

Date of Inspection ……..Time in …….. Inspector's Name ……

Reason for Inspection …… Time out …… Weather ……

Site: Open/Closed

Status at Time of Inspection	Unsatisfactory Satisfactory					Not Checked Inapplicable	Comments
Environ. Man. Plan Compliance							
Types of Waste							
Layering/Compaction of Waste							
Covering of Waste							
Crushing Large Objects							
Litter Screens & Litter Control							
Liner/Protective Layer							
Condition of Site Roads							
Condition of Site Entrance							
Highway/ Wheel Cleaning							
Site Tidiness							
Fires							
Insects/Vermin/Birds							
Surface Water Drainage							
Leachate Control (on-site)							
Landfill Gas							
Odour							
Noise							
Dust							
Gate/Fencing/Security							
Office/Site Notice Board							
Manning & Supervision							
Site Record Keeping							
Fuel & Equipment Storage							
Cover Stockpile							
Site Environs	Litter						
	Leachate						
Other Observations/Actions Required:							
IMMEDIATE ACTION IS REQUIRED ON:							
Site Operator's Comments:							
Samples Taken: Yes/No Photographs Taken: Yes/No		Inspector's Signature: ……				Received by: ……	

5 Site Appearance and Infrastructure

If a waste disposal site is to be operated in line with international best practice, then site appearance matters. Litter problems and poor/non-existent landscaping do not engender public confidence that a site is well managed. In order to demonstrate to the public that the landfill is being operated effectively, the site must work and look well. By way of helping this process, certain key elements will have to be addressed to come into line with best practice, not least that an Environmental Management Plan is developed and implemented, and that at least some landscaping takes place which blends the waste disposal site in line with the topography. Figure 1, below, presents the necessary infrastructure to be found on a sanitary landfill site to international best standards.

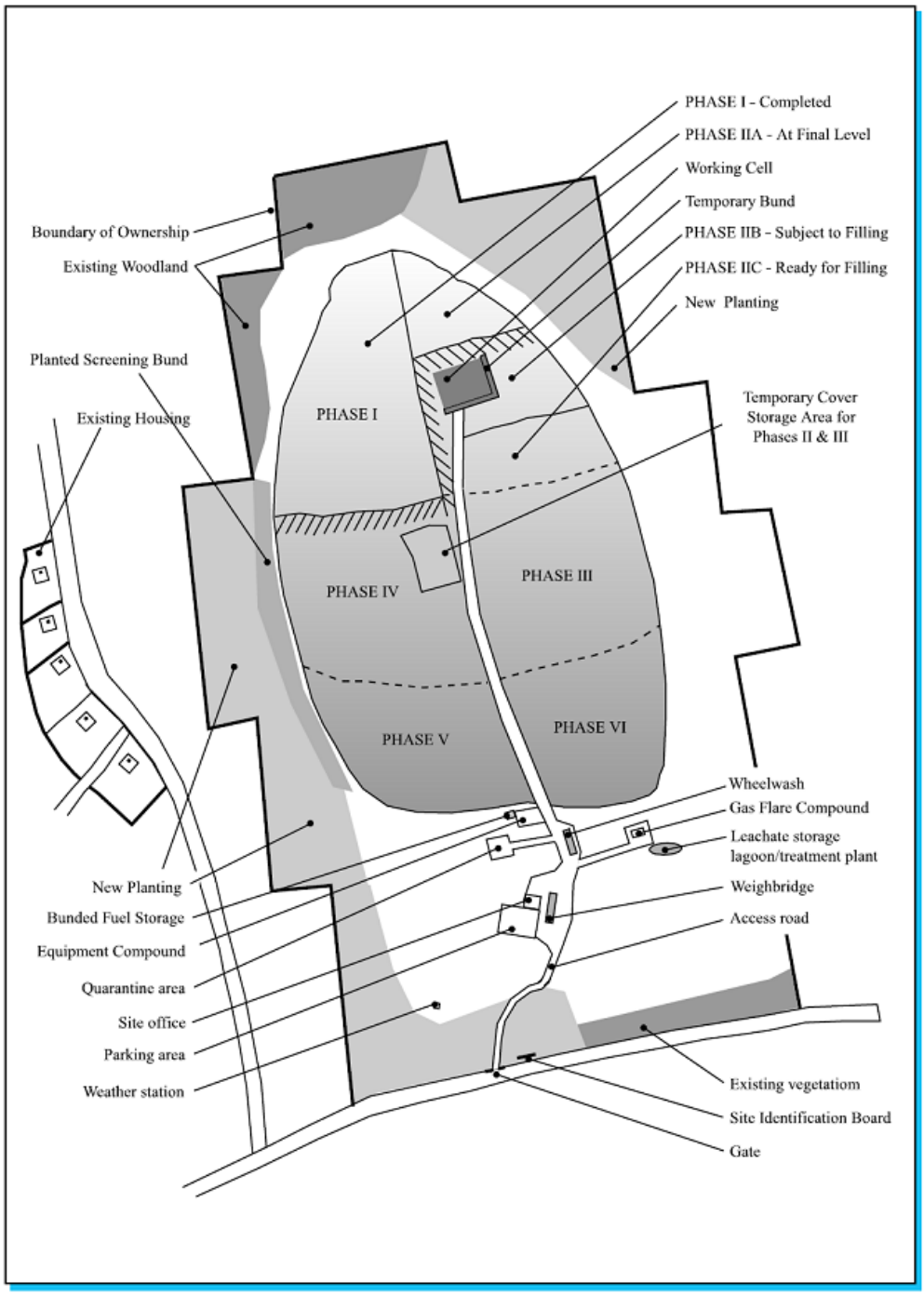


Figure 1: Typical waste disposal site's appearance and infrastructure

This section presents best practice for bring various aspects of a site's appearance and infrastructure into line with that presented in Figure 1 above.

5.1 Screening and Landscaping

One relatively easy way of screening the disposal site's perimeter zone from public view can be provided by constructing earth bunds. Permanent and/or temporary earth bunds provide visual barriers and assist in the restriction of unauthorised access to the site. Temporary earth bunds can provide screening and are a useful way of storing large quantities of materials that can be used for later restoration. Permanent bunds may be desirable to provide long term site screening. In either case, it is important that they are constructed, where possible, in a manner which complements the existing topography. Planting, either in conjunction with bunds or separate to them, can also help prevent undesirable views, restrict litter, dust and noise problems. In terms of site screening activities, priority attention should be paid to areas which have the greatest impact upon members of the public. This applies particularly to the site entrance, boundaries adjacent to the public highway, and at locations in proximity to residential dwellings.

5.2 Site Infrastructure

In any modernised waste disposal site, waste must be moved as effectively and safely as possible to the site's active disposal face. However due account must be taken of all amenity impacts (eg. dust and litter) that may arise during this process, and thus mitigation measures should be adopted to minimise such effects if the site's management is to be brought in line with international best practice. In order to encourage efficient movement of waste, the provision of well maintained, high quality, site roads is necessary to ensure the free flow of traffic and a fast turnaround of vehicles.

5.2.1 Access

The access road between a public highway and the site should be of substantial construction, preferably being surfaced with concrete or tarmac and graded to facilitate drainage towards the sides of the road. If necessary, the main access road should be widened so that two way vehicle traffic can pass along it or, at the very least, have passing areas constructed so that single lane traffic have the opportunity to pass. Site machinery should not be allowed to travel on the main site access road as this is likely to cause damage. It is important that the site's management prevents excessive vehicle speeds on the access road by installing clearly marked road signs, coupled with the vigorous application of site rules.

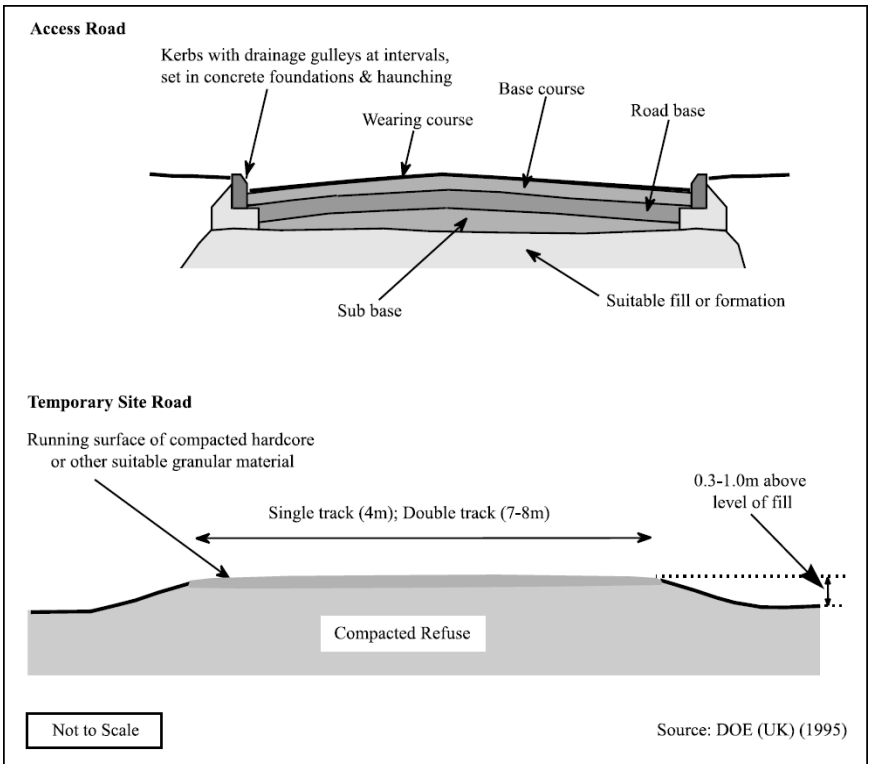


Figure 2: Construction of access and temporary site roads in line with international best practice

5.2.2 Arterial Roads

On a modernised site, arterial roads which lead from the main access road to the tipping area will need to be constructed. Whilst such roads are only semi-permanent, they should be of good quality to cope with heavy usage. Ideally such roads should consist of a running surface placed on hardcore which, in turn, is placed on fill. Secondary roads can be constructed to a lower specification, where they are temporary by nature and due for replacement as filling proceeds. Quarry stone, construction waste or similar materials can be used in these locations. However, should such a road be intended for use over a period of some years, a more substantial surfacing should be installed in order to facilitate road sweeping and improved general maintenance.

5.2.3 Temporary Site Roads

The site's management team need to construct temporary site roads leading from the arterial roads to the disposal face on a cell-by-cell basis. Therefore these will have a short life. The roads should be made of waste construction material, which has been delivered for disposal at the site, and have a running surface of compacted hardcore and/or other suitable granular material. It is recommended that these temporary site roads should be 4m wide for single lane traffic and 7-8m wide for dual lane traffic. The site roads are likely to become heavily compacted and should be taken up or ripped before emplacing more waste at a new disposal face.

For all roads constructed on a landfill, care should be taken to ensure that adequate drainage is provided. All roads should be constructed in a manner which allows the unrestricted discharge of surface water.

5.2.4 Site Security

It is imperative that landfill sites are secure from unauthorised access. The security provided should be based on an assessment of potential risks, taking into account location (particularly proximity to the public highway) and target populations. In areas where unauthorised access is deemed likely, the site should be enclosed by fencing. It may be desirable for reasons of cost, and on the assessment of likelihood of trespassing, to have more than one type of fencing. For example, high specification security fencing may be restricted to the entrance and areas containing weighbridge, employees' amenity building, garage, stores, garage and fuel supplies. Access to the waste disposal site should be restricted to those times when site staff are on duty and the gates should be locked at other times.

Upgrading measures which need to be taken for upgrading the site's security in line with international best practice should encompass the following:

Gates

Gates should be provided which match the fencing specification:

- The gates should span the full width of the access road;
- A suitable locking mechanism should be provided and a register kept of key holders;
- Gate tops may be covered with strands of barbed wire; and
- Gates and fences should be maintained in good repair and inspected by a nominated person at regular intervals.

Fencing

- Perimeter fencing should be provided to prevent unauthorised access;
- Perimeter fencing should be inspected regularly by a nominated person; and
- The fencing should be maintained in good repair at all times.

5.2.5 Site Identification and Information Signs

It is important that adequate information for the operation and regulation is displayed for the benefit of both users and employees. Signs should be used to convey information from the site operators to users, personnel, and visitors to the site. This process is facilitated if signs are well designed, constructed, and maintained. The site notice board should be displayed at the entrance

to the site and should be of a size and located in a position such that it can be easily read. Thus, in order to bring site operations in line with best practice, a site identification board of durable material and finish should be displayed near the site entrance which provides the following information:

- The site name;
- The name, address and telephone number of the operator and/or owner;
- The licence identification number;
- The site opening hours; and
- The contact and emergency telephone numbers.

The site notice board must be maintained and updated as required. Other important signs to be included upon a modernised waste disposal site comprise:

- Direction signs;
- Instruction signs;
- Information signs;
- Safety signs; and
- Warning signs.

On leaving the highway and entering the site, drivers should immediately be made aware of traffic routing, access restrictions, and weighing in procedures by means of clear and well placed signs. The signs should inform drivers carrying different waste streams where they need to go for reception and waste checking and to deposit the waste. Instruction signs are necessary to enable users of the site to carry out their functions in a safe and efficient manner. Examples of instruction signs include the use of weighbridges, use of wheel cleaning facilities, and disposal at the tipping face. Warning signs are extremely important on waste disposal sites as they draw attention to areas of high risk such as deep water and overhead wires. The site's management team should also provide a sign before the exit to warn drivers that it is their responsibility to ensure that their vehicle is free of mud before exiting the site.

5.2.6 Buildings

Buildings and structures for administration of the site and for the checking of incoming loads should be in a convenient location adjacent to the entrance, and provide adequate accommodation for the site workforce. A modernised waste disposal site should have, as a minimum, a water supply and associated cleaning facilities, toilet, telephone and electricity. The site control office should provide secure accommodation to house records relating to the operation. Security against intruders is essential because of the value of the information and equipment stored in the office, such as monitoring devices, and computers etc. The office should have solid doors and lockable shutters or bars on the windows. Lighting will be required whenever the site is in operation during hours of darkness, which is particularly likely during the winter. The site reception area, car park, weighbridge and wheel cleaning facilities, access road, and important signs including all safety signs should be lit whenever the site is operational during hours of darkness or bad visibility.

5.2.7 Waste Inspection Areas

A modernised landfill site should have an area where wastes can be inspected prior to deposit, ideally in close proximity to the site offices so that wastes can be checked when a vehicle driver checks in. At sites equipped with weighing facilities, inspection should be done whilst the vehicle is stationary on the weighbridge. If this is not always possible, then it should be checked when deposited at the landfill face.

5.2.8 Wheel Cleaners

A waste disposal site managed to international best standards must have some provision for the cleaning of vehicles, particularly with a view to preventing mud being deposited on a public highway. Clear instructions must be provided to ensure that all heavy goods vehicles use the

wheel cleaning infrastructure. It is essential that drivers using the site are provided with one or more effective means to remove mud and debris from their vehicles prior to leaving the site. Vehicle cleaning can be via wheel washes or shaker bars - an oversized cattle grid set level with the road, whereby vibration from the vehicle passing over the bars causes the mud and trapped material to drop through the grid bars into a trough or sump (Figure 3).

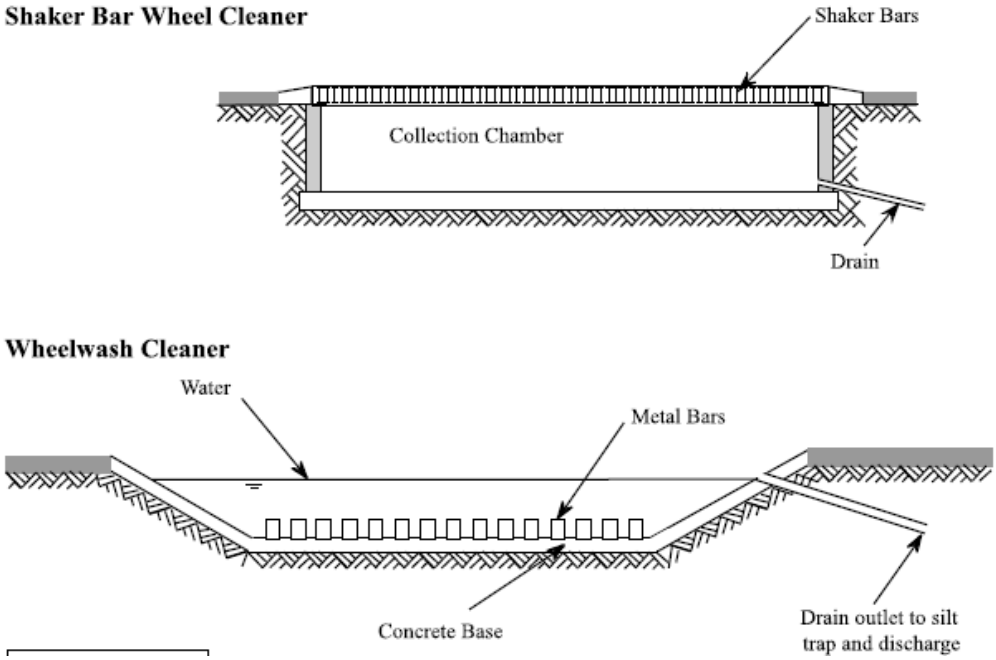


Figure 3: Possible wheel cleaning options for a well managed waste disposal site

5.2.9 Weighbridges

Within any modernised waste disposal site, an accurate record of waste inputs is essential for effective waste management – not least in terms of accurately assessing the rate of fill. The installation of an on-site weighbridge will be the best means of providing such data. It is good practice to weigh both on entry and exit from the site. A weighbridge should be located so that traffic does not back up through the site gates and onto the public highway. A number of different types of weighbridge exist, but platform weighbridges are the most desirable. The weighbridge office will normally be located on the off-side of the weighbridge. It should be positioned so that the weighbridge operator can easily see vehicles approaching, leaving, and using the weighbridge. The office should be elevated so that the weighbridge operator can speak to the vehicle driver. The operator may need to control traffic using the weighbridges by means of traffic lights or lifting barrier. Easy communication between the drivers and the weighbridge office should be provided. The computer based technology to be installed with the weighbridge will help increase the efficiency and the free flow of traffic to and from the site. All of the larger existing landfills should be equipped with weighbridges. As an indication of the appropriate threshold, weighbridges should be installed at all sites with annual inputs of greater than 10,000 tonnes per year and should be considered at other sites where the life expectancy is in excess of five years.

5.2.10 Quarantine Areas

Provision should be made for the temporary storage of rejected loads or other materials which are deemed unsuitable for disposal at the site. This storage area should be secure, bunded and surfaced to deal with any spillages of liquids, e.g. from a damaged drum. This area should be located so that it can be supervised by the occupants of the site office but should not, for obvious reasons, be located immediately adjacent to the office.

5.2.11 Fuel Storage

Other than that contained in the tanks of plant and equipment, all fuel should be stored only in tanks located in bunded areas. The bunds should be constructed to be of a capacity of 110% of the contained tank (or 110% of the combined volumes in the case where more than one tank is present) and no taps, gauges etc should project beyond the internal side of the bund. All bunds should be waterproof. As a properly constructed bund will quickly fill with rainwater, it may be desirable that the bunded area is roofed. Mobile re-fuelling equipment such as fuel bowsers should generally not be left out on the landfill at night. Instead, they should be locked away in a surfaced and bunded area in either a site building or storage compound.

6 Moving from Uncontrolled to Controlled Waste Disposal – Preliminary Measures

The main method of waste disposal throughout the country is uncontrolled dumping. One of the main priority directions for Armenia's waste management system is to move towards sanitary landfilling, albeit step-by-step over a period of many years. For example, waste disposal standards in the EU Member States have increased gradually over a period of about 20 years and, indeed, even today some of the New Member States are still trying to upgrade existing sanitary landfill sites in compliance with the EC Landfill Directive – something that was required by July 2009.

For the purposes of planning, it is convenient to classify land disposal sites into a number of 'principal stages' in the progression from open dumps to fully engineered, environmentally secure, sanitary disposal sites as follows:

- Open Dump;
- Controlled Dump; and
- Sanitary Landfill.

In reality each 'stage' of landfill development is not discrete but a point on a continuum, involving progressively higher and more sophisticated levels of site engineering, operation and management, all of which may be desirable or necessary but not always achievable in the short-term.

Open dumps, which are prevalent in Armenia, are unacceptable but controlled dumps and engineered sanitary landfills can provide effective disposal of MSW in accordance with appropriate local health and environmental standards for low and middle income countries. The highest standards of engineered landfill, with multiple liners and sophisticated leachate and gas treatment systems, are found only in the wealthiest countries in North West Europe and North America.

Developing new landfill sites is almost universally a difficult task, both practically and politically. Experience from elsewhere in the world suggest that, wherever possible, it is better to establish good operations at existing sites before constructing new facilities. This allows operation expertise to develop, decision makers to get used to providing budgets, and allows confidence to grow that good standards of landfilling can be achieved at modest cost.

This section sets out to provide practical and pragmatic guidance on the phased and progressive upgrading of land disposal sites. It identifies a number of stages for the upgrading of sites from open dumps through to highly engineered and controlled sanitary landfilling. The guidance does not discuss in detail the siting, design, engineering, operation and management of waste disposal sites but seeks to identify minimum acceptable standards to safeguard the environment. The guidance has been prepared to assist operators land disposal sites, persons responsible for the regulation and control of such facilities, and those involved in their planning and development.

6.1 Key Characteristics of Different Types of Land Disposal Facility

6.1.1 Open Dumps

Open Dumps have the lowest initial capital investment and operating cost of the three basic types of land disposal site. They are generally sited on vacant plots of land and are sometimes developed on low-lying or marshy lands, often as a means of reclaiming land for subsequent development. They may be located adjacent to existing residential development because of constraints on availability of suitable land or, alternatively, may attract the development of communities involved in recycling activities. As a consequence of the proximity of residential communities, open dumps are often of small size, of limited capacity and pose high potential environmental risks due to the following factors:

- They are unplanned;
- There are no controls over waste inputs (both waste quantities and waste composition); and
- There are no controls over emissions of pollutants released from waste decomposition.

Table 2: Potential environmental impacts of open dumps

Parameter	Potential Impact
Water	Contamination of groundwater and surface water; and Major effect on water resources and water supply (aquifers).
Flooding	Reduction in flood storage capacity and an increased risk of flooding upstream of the site. Need for costly flood control measures.
Ecology	Loss of wetland habitats, including flora and fauna
Pests	Vermin, pests and scavenging animals attracted to fresh and exposed waste
Health	Risks from water-borne diseases and potential for the spread of communicable diseases via pests. Contact with clinical and industrial wastes.
Air Quality	High levels of odour and dust because waste not covered.
Safety	Uncontrolled settlement beneath buildings and structures constructed on old sites. Landfill gas build-up and migration with potential to cause explosions or asphyxiation. Stability of high and steep faces of deposited waste.
Aesthetic	Visual blight from uncovered waste, blown litter, etc.
Socio-economic	Distress to local residents, stigma associated with presence of dump site and loss in property values.

6.1.2 Controlled Dump

A Controlled Dump is a non-engineered disposal site at which MSW is deposited in accordance with minimum prescribed standards of site operation. Typically Controlled Dumps have minimal site infrastructure but are the first stage in the progression from Open Dumps. In upgrading from Open Dump to Controlled Dump there are generally no significant investments required in capital works or equipment purchases, rather, upgrading is concentrated primarily on improvements to operational and management issues. Basic operational controls include:

- Control over size of waste emplacement (working) area, with waste spread and compacted in thin layers in a small working area;
- Waste outside of the area being actively worked is covered with soils and/inert material, working area is covered at the end of each day;
- Covering and seeding/planting of completed areas;
- Supervision of site operations by trained staff;
- No fires permitted on site; and
- Organisation of informal waste picking activities with scavenging controlled by agreeing 'rules' with the waste pickers (e.g. restrictions on location and time allowed following waste deposition, no disturbance of waste after it has been covered).

Where resources permit, capital investment should be channelled into haul road construction, peripheral site drainage and litter fencing, supplemented by mobile plant for spreading and compacting waste and inert cover.

The site of a controlled dump is generally identified on the basis of land availability and convenience; typically a site is not selected on the basis of technical, environmental or financial criteria. Accordingly, there is typically little provision for the management of pollutants released during decomposition of municipal solid waste. Simple and rudimentary control of pollutants may be achieved through good site operational practices and, where feasible, peripheral drainage works.

6.1.3 Sanitary Landfill

The most significant jump in technology, expertise and technical resources required arises at the transition from controlled dump to an engineered sanitary landfill. A sanitary landfill is a disposal site designed, constructed, operated and maintained in a manner that exerts engineering control over significant potential environmental impacts arising from the development and operation of the facility. In particular, engineering of the site is undertaken to contain and regulate the uncontrolled migration of leachate (water contaminated from contact with decomposing waste) and landfill gas.

In siting a sanitary landfill, significant effort is directed into identifying and selecting a favourable location with respect to existing environmental conditions in order that the requirements for landfill engineering are kept to a minimum or the overall potential impacts of site development are considered to be least significant. In practice land availability is often the fundamental factor and most sites for sanitary landfills are selected in far from ideal settings, necessitating that the site is designed and engineered in a manner that minimises environmental impact.

Allied with engineering design is also the fundamental requirement that the sanitary landfill is constructed, operated, managed and maintained to the standards stipulated as the basis of the design. Failure to maintain the specified design standards for all aspects of site engineering, operation and management will inevitably lead to an overall site performance lower than anticipated and, at worst, no better than that of an open dump.

Overall, four basic criteria should be met by both site design and site operations before a waste disposal site may be regarded as a truly sanitary landfill:

- Isolation of the waste from the surrounding environment, unless the site is of low environmental sensitivity or the waste deposited is considered to be inert and non-polluting;
- Containment, collection and treatment of pollutants derived from degradation of waste, on-going throughout the life of the site and following completion of the site, until such time as the waste has degraded biologically, chemically and physically so as to pose no harm to the surrounding environment;
- Managed release of treated pollutants back into the surrounding environment when considered 'safe', supplemented by environmental monitoring to assess the impacts of such releases; and
- Full control over site operations, with well-qualified and adequately trained staff supervising and recording the progress of waste disposal.

The key elements in the progression from open and controlled dump to sanitary landfill focus upon gradual changes to site design and key operational management practices, including:

- Selection of an appropriate location for the site;
- Full or partial geological/hydrogeological isolation of the site;
- Designing the site - the civil engineering, operational methods and restoration/afteruse;
- Site preparation in advance of waste deposition to aid leachate control and collection;
- Phasing of waste deposition to exert maximum operational control;
- Control of groundwater and surface water entering the site;
- Collection and disposal of leachate (may include simple on-site treatment);
- Spreading and compaction of wastes in defined operational areas;
- Installation of landfill gas control or venting measures; and
- Phased and progressive restoration of the site following waste deposition.

6.1.4 Planning and Engineering of Landfills

The degree of site-specific engineering undertaken is dependent upon several factors, including the following:

- Waste composition, particularly the presence of polluting or toxic substances;
- Affordability;
- Available expertise;
- Environmental sensitivity of the site (prevailing conditions);
- Potential impacts and consequences of landfilling; and
- Prevailing legislation.

Notwithstanding the issues of affordability and available expertise, in general the more sensitive the environmental setting or the greater the potential impact of landfill development, the greater the level of engineering that may be required, as illustrated schematically in Table 3.

Table 3: Typical standards of landfill required for different environmental settings

Environmental Sensitivity	Insignificant	Potential Impact Moderate	Severe
Low	Controlled Dump	Controlled Dump	Sanitary Landfill (Level 1)
Medium	Controlled Dump	Sanitary Landfill (Level 1)	Sanitary Landfill (Level 2)
High	Sanitary Landfill (Level 1)	Sanitary Landfill (Level 2)	Sanitary Landfill (Level 2)

At a fundamental level, a sanitary landfill is distinguished from a controlled dump by the basic requirement to plan and design the engineering of the site, regardless of whether:

- The engineering subsequently adopted is simple (for example, sanitary landfill based upon a philosophy of dilute and attenuate or minimum levels of containment engineering); or
- Highly complex (for example, a sanitary landfill operated as a bioreactor landfill, with high standards of containment engineering and sophisticated leachate control and management involving re-circulation and on-site treatment).

Beyond this, the level of engineering is dictated by site-specific conditions and the prevailing environmental legislation and standards. Nevertheless, for planning purposes only, it is possible to recognise at least two fundamental levels of sanitary landfill which may be described briefly as follows:

- Sanitary Landfill (Level 1): Basic level of site engineering undertaken, to minimum prescribed standards, particularly in respect of the standards and methods of containment engineering advocated and in the methods and procedures adopted for site operation and management; and
- Sanitary Landfill (Level 2): Level of site engineering required established by a risk assessment of the environmental impacts of specified design rates of seepage of leachate. Engineering of the site typically encompasses comprehensive containment, treatment and management of leachate and landfill gas, the latter regulated by prescribed minimum standards for active landfill gas control.

The transition towards sanitary landfills (developing more stringent design specifications and encouraging MSW processing systems) can be seen as issues for attention in the medium to long term, once basic environmental controls and operational standards have been put in place and sustained for a number of years. Experience has shown that, in the past, it is often not helpful for a country in transition like Armenia to introduce mandatory engineering standards for all new landfills corresponding to, for example, the EC Landfill Directive (i.e. Step 3) if the current status is dumping. Paradoxically, such standards often have the effect of discouraging efforts to upgrade existing sites or develop new sites, as the costs prove to be prohibitive.

6.1.5 Summary of Key Characteristics

A summary of the key characteristics of each of the principal stages and types of landfill is provided in Table 4.

Table 4: Key characteristics of principal stages / types of landfill

Type	Key Characteristics
	Unplanned, poorly sited and often of small capacity
	No site preparation and waste deposited across large part of the site
	Thin layers of waste – relatively rapid aerobic decomposition
	No leachate or landfill gas management
Open	Contamination of surface water and groundwater
Dump	No or intermittent compaction of waste with no only occasional cover
	Litter blown outside operational area within and beyond site boundary – no fence
	No record keeping and no control over waste inputs
	Uncontrolled presence of vermin, pests and scavenging animals
	Waste picking and trading
	Significant potential for environmental impacts
	May be hydrogeologically sited, but generally not
	Waste not deposited in cells but restricted to small working areas
	Anaerobic and aerobic decomposition
	Peripheral site drainage and surface water control
Controlled	No leachate or landfill gas management
Dump	Regular, but not necessarily daily, inert cover, with compaction in some cases
	Fence, including provision for litter control
	Basic record keeping but no control over waste inputs
	Provision of maintained access road
	Controlled waste picking and trading
	Site covered and replanted following completion of waste deposition
	Site design based on hydrogeological considerations
	Planned capacity with phased development and filling in cells
	Site preparation including surface water control and containment engineering where necessary
	Primarily anaerobic decomposition
Sanitary	Leachate management with leachate abstraction and simple treatment
Landfill	Landfill gas management with passive landfill gas measures
Level 1	Application of cover materials
	Compaction of waste to minimum specified target densities
	Specified operational procedures to protect local amenity, including vector control
	Fence, gate and other site infrastructure with surfaced primary access road
	Full record of waste input volumes, types and source
	Special provisions and procedures for dealing with special wastes
	Fully trained labour force and experienced site management
	Provision for aftercare following site restoration and closure
	No waste picking
	Site design based on environmental risk assessment
	Key factors in site design are often hydrogeological site conditions
	Planned capacity with phased cell development
	Extensive site preparation and containment engineering
	Primarily anaerobic decomposition
	Full leachate management with leachate abstraction and treatment
	Full gas management with active landfill gas abstraction where necessary
Sanitary	Application of daily, intermediate and final cover
Landfill	Compaction of waste to minimum specified target densities

Type	Key Characteristics
Level 2	Specified operational procedures to protect local amenity, including vector control
	Fence, gate and other site infrastructure
	Surfaced primary access road and maintained secondary and tertiary haul roads
	Full record of waste volumes, types and source
	Special provisions and procedures for dealing with special wastes, including on-site
	Laboratory
	Fully trained labour force and experienced site management
	Extended lifetime
	Provision for aftercare following site restoration and closure
	No waste picking

6.2 The Process of Upgrading

As highlighted earlier, focus should be placed on upgrading existing dump sites while developing proposals for future landfill facilities. The former can often be achieved with relatively small levels of investment because the issue is more to improve management practices and operational controls, rather than to invest in expensive engineering features. This is particularly important as developing new landfill sites, from site identification to commissioning, can take long periods of time.

The upgrading of landfill standards inevitably must take place gradually and progressively over time. It is not feasible to instigate radical changes in one go since the proposed changes need to accommodate the following factors:

- Political will on the part of the Armenian Government (and the public at large to higher standards of environmental quality and environmental protection);
- Access to appropriate expertise in the design and construction of more secure landfill disposal sites;
- Access to appropriate expertise to operate and manage disposal sites to higher standards than hitherto;
- The affordability of enhanced standards of landfill disposal; and
- Access to adequate resources (finance, equipment and manpower) to ensure that the sites are constructed and operated to the standards to which they are designed in order to maintain the environmental integrity of the landfill facility.

The last two points are, perhaps, the most critical for Armenia at the moment. The upgrading of waste disposal practices and overall landfill standards will not occur simply through adopting more sophisticated engineering of selected disposal sites because, without appropriate operation and management, sanitary landfills rapidly revert to poorly controlled dumps with the following serious consequences:

- Capital investment in landfill construction is wasted;
- If site engineering is successful, pollutant loadings (volume and concentration) are often greatly elevated in comparison to non-engineered sites, thereby posing a significantly greater threat of contamination to the immediate environment of the site; and
- The public perception of sanitary methods of waste disposal is compromised, thereby jeopardising cost recovery.

6.3 Progressive and Staged Upgrading

Direct upgrading of landfill standards to meet sanitary standards is simply not possible for most towns and cities in the country. It is, therefore, essential to adopt a step-by-step approach in order:

- To improve the overall standards of landfills;
- To phase out existing uncontrolled, open dumps; and
- To rehabilitate existing poorly controlled dump sites to protect the public and the environment.

The emphasis should, in the immediate future, be upon a move from open/uncontrolled dumping to controlled waste disposal by, inter alia, improving operational management practices at final MSW disposal sites, primarily with a view to improving health and safety. The basic operational controls are illustrated in Figure 4 below and can be summarised as follows:

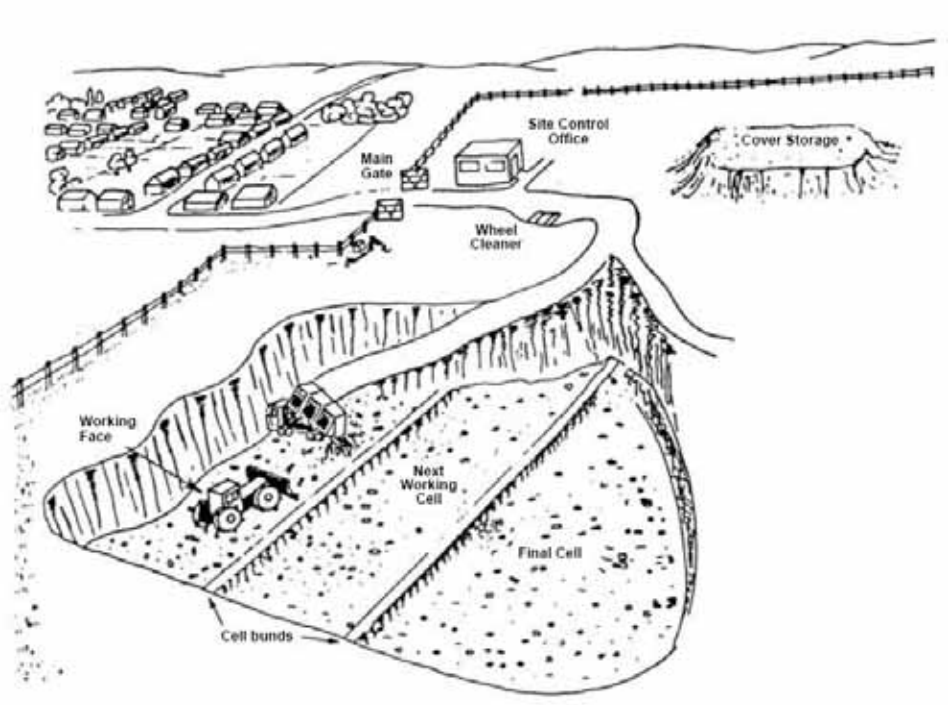


Figure 4: Basic operational controls at a waste disposal site

- *Reducing impacts of the existing dump site* - a perimeter bund wall should be constructed to prevent ingress of surface water inflow and outflow of contaminated surface water from the site. The existing area of fill should be covered with either imported inert material or fully decomposed waste to minimise odours, flies and vermin;
- *Planned MSW emplacement and covering* - wastes should be spread in layers and compacted as far as possible. Cellular bund walls can be constructed of either imported inert material or decomposed waste, and used to enclose the area or 'cell' for waste deposition. The site should be operated in these cells (small working areas) and deposited waste should be covered daily to eliminate burning, minimise pests insects and vermin, reduce visual blight, and reduce nuisances such as windblown litter and odours;
- *Competent and well-planned landfill operations* - professional staff should be based at the MSW landfill to supervise the site operations. The focus should be on improving operational performance and health and safety standards at the site, ensuring vehicular access to the tipping area under all weather conditions, improving control over movement of vehicles around the site, and rationalising waste deposition. A gatehouse and perimeter fence may be provided to control site access;

- *Organising informal waste picking activities* (where in existence), encouraging people to follow basic health and safety procedures such as not moving into tipping area while vehicles are unloading, carrying out waste picking in designated areas (where possible to organise), wearing gloves and shoes, etc.

It should, however, be emphasised that this is not an end in itself and the upgrading of standards is a continuous process. The eventual aim is that all land disposal sites in the country are designed, constructed and operated at a level of environmental and health protection in line with international best practice.

6.4 Moving from Uncontrolled to Controlled Disposal: A Case Study from Russia

Kaliningrad Oblast in Russia has no sanitary landfills but, rather, waste is disposed of to uncontrolled dumpsites which have few, if any, engineering and environmental controls. In order to demonstrate improved operational practice at a typical dumpsite (i.e. by moving from uncontrolled to more controlled disposal), a typical dumpsite was chosen as a case study/pilot project for the region. An authorised MSW dumpsite near the village of Kruglovo was selected accordingly. It occupied a total area of 3 Ha and has been operating since 1977. The open dumpsite is located in an old sand quarry, and is being managed accordingly to standards dating from the 1960s.

The main objective of this pilot project was to upgrade the Kruglovo waste disposal site and improve operational practices by applying appropriate, low cost, and robust techniques in order to mitigate the existing range of public health and environmental nuisances arising from the site. The main activities included:

- Baseline study;
- Liaison and consultation;
- Development and implementation of operational plan; and
- Development and implementation of site upgrading plan

The main outputs included the benchmarking of existing operations at the Kruglova site, a clear understanding and agreement from all key stakeholders on the modernisation of the site, an operational plan which details key procedures and practices, and the development and implementation of a site upgrading plan.

6.4.1 Baseline Review

The dumpsite, like all other dumpsites in the Kaliningrad region, is neither lined nor enclosed by a special protecting structure. The protecting bank along the dumpsite's perimeter consists of separate natural rises in the surrounding relief, located mostly along the eastern and northern sides of the dumpsite. Since the dumpsite is not equipped with a special ramp for rubbish trucks to drive on to and unload the solid waste, their approach has to be regularly "cleaned out" by the bulldozer. As the unloading areas get filled in, the approaches also get covered with rubbish and are also levelled out by the bulldozer. Under such circumstances, the safety level for vehicles entering the dumpsite is compromised because there is a relatively high chance of damaging tyres by protruding, sharp-edged, rubbish fragments. In addition to that, any waste on the roadway sticks to the vehicles' wheels and is carried off the dumpsite territory because, as previously mentioned, there is no disinfecting basin at the dumpsite exit.

6.4.2 Modernising Operational Practices at Kruglova Dumpsite

The first step is to improve operational management practices at the Kruglova dumpsite, primarily with a view to improving health and safety. In general terms, the basic operational controls that the site's management team needed to introduce comprised: i) Planned MSW emplacement and covering; ii) Competent and well planned landfill operations; and iii) Reducing impacts of the existing dumpsite. These have already been described in Section 6.3 above and will not be repeated here.

The above suggestions are consistent with the main recommendations arising from the baseline review, namely the need for:

- Provision of funds for soil covering and purchase of operational equipment;
- Improved site management;
- Better control over waste reception;
- Maintaining access to the tipping face in all weather conditions; and
- Controlling waste movement and tipping

or, in other words, there needs to be a better focus by the site's management team on improving control over MSW flow through the site, reconstructing and rehabilitating site roads, construction of cellular bund walls to act as a tipping face for waste, construction of simple drainage channels, construction of improved worker facilities, and better use of daily cover material etc.

The main purpose of this section is to outline recommendations for strengthening operational practices at the Kruglova Site, i.e. to address issues arising from the first two paragraphs of this introduction. Recommendations and a plan for reducing impacts of the existing dumpsite are described below.

6.4.2.1 Planned MSW Emplacement and Covering

As regards the upgrading of existing MSW emplacement and covering practices, the following procedures for improving site operations are suggested:

- Systematic Waste Acceptance Procedures;
- Procedures for the Control of the Internal Movement of Waste;
- Procedures for waste discharge, emplacement, compaction, and covering of the waste need to be introduced and systematised; and
- Procedures for the disposal of difficult (including hazardous wastes).

Systematic Waste Acceptance Procedures

Waste should not be accepted at the Kruglova dumpsite without prior knowledge of its nature and composition and having determined its acceptability. The waste that is accepted at the Kruglova site must fall within the categories of waste permitted by the site's waste management licence. Permits are required for waste disposal and an environmental activity licence obtained for operation at a land disposal facility. Wastes may not be accepted at the facility unless the waste generator has obtained a waste disposal permit for disposal of the waste at the facility, and that the facility is permitted to accept that waste by the terms of its environmental activity licence.

Procedures for the Control of the Internal Movement of Waste

The Kruglova's site management team must ensure that waste is moved as effectively and safely as possible to the disposal face. However due account must be taken of all amenity impacts (eg. dust and litter) that may arise during this process and thus mitigation measures should be adopted to minimise such effects.

Procedures for waste discharge, emplacement, compaction, and covering

The overall objective is to emplace the waste into its final position within the dumpsite. The particular methods employed by the Kruglova management team will depend on the nature of the waste input and the requirements of the site. Factors which should be taken into account include:

- physical condition of the waste
- weather conditions at the time of emplacement
- special requirements to avoid hazards inherent in the waste
- design objectives.

Emplacement Method

Of the available methods, it is recommended that Kruglova adopts a "face tipping" method for waste discharge and emplacement. This involves the creation of a horizontal or near horizontal platform by tipping over an advancing face with levelling and compacting from above. The maximum height of the face should be no more than 2.5m after compaction. The compaction equipment operates on the flat surface at the top of the face.

Waste Compaction

The site personnel should level and compact the waste as soon as it is discharged at the working area. This will:

- enable the maximum amount of waste to be emplaced within the space available
- reduce the impact from litter, flies, vermin, birds, and fires
- minimise short-term settlement.

The Kruglova site team were recommended to use "tipping cell" working areas by constructing bund walls between which waste is deposited. The main advantage of this approach is that the tipping area is confined and that litter is reduced with the installation of temporary litter fences. The main disadvantages, however, are that there is an increased demand for inert material to create bunds and that such bunds may restrict leachate and gas circulation in the completed landfill unless they are removed. It is up to the site's management team to judge the appropriate balance between using small cells (the lower the fill rate, the smaller the cell), and losing too much of the dumpsite's capacity being taken up by the cell dividing walls. Sufficient material should be stored on site to enable the construction of these cell walls as, and when, necessary.

Use of Intermediate / Daily Cover

The site's management team are strongly encouraged to use intermediate/daily cover for the active cell. This could be a thin layer of non-porous material such as clay or an artificial material to minimise the ingress of water (and therefore the generation of leachate). The use of daily cover will prevent windblow and odours, deter scavengers, birds and vermin, and help to improve the site's visual appearance. In many cases the application of daily cover will improve the visual aspects of the working area. Soil will give a uniform appearance from the site boundary. Whenever possible, daily cover should be obtained from the excavation of material from within the landfill area. If the Kruglova site is deficient in appropriate resources, then it should consider the use of daily cover from construction activities.

Procedures for the Disposal of Difficult Wastes

Difficult wastes are those wastes which, though acceptable for disposal to the Kruglova dumpsite in terms of their overall properties, have some characteristics which require a particular method of handling at the site which is not part of the normal day-to-day procedure. Such difficult wastes could include finely particulate material, empty containers, very large objects, tyres etc. Waste giving rise to dust when tipped or run over by site machinery should be handled and deposited in such a way that dust is not released.

6.4.2.2 Competent and Well Planned Landfill Operations

As previously discussed, professional staff should be employed at Kruglova to supervise operations. The focus should be on improving operational performance and health and safety standards, ensuring vehicular access to the tipping area under all weather conditions, improving control over the movement of vehicles around the site, and rationalising waste deposition. To some extent these issues have already been touched on in the previous section.

- Strengthening the skills and experience of operators;
- Strengthening record keeping;
- Improving general landfill safety, particularly the ability to deal with landfill fires;

- Introducing procedures for performance monitoring;
- Protection of local amenities;
- Strengthening utility services and infrastructure;
- Site closure and aftercare.

6.4.2.3 Reducing Impacts of the Existing Dumpsite

Reducing the impacts of the existing dumpsite calls for the physical upgrading and modernisation of the site. The following steps are envisaged:

Consolidation and Regularisation of the Site's Footprint

The regularisation of the site's footprint involved demonstrating to the site operator how to dome their sites to encourage the runoff of rainfall in a managed fashion. This will help to reduce the amount of rainfall infiltrating into the waste, thus minimising the amount of leachate being generated by it, and hence the site's potential to pollute the local groundwater and surface water (hence leading to immediate environmental improvements). The use of cover material will also help to prevent windblow and odours from the waste, deter scavengers, birds, and vermin on the buried waste body (hence leading to an immediate environment and health/safety impact effect).

Construction of a Perimeter Bund Wall

Closely linked to the regularisation of a dumpsite's footprint, is the use of a perimeter bund wall to screen a dumpsite's operation's from the local inhabitants, to prevent the site encroaching onto adjacent territory, and to help reduce the impact of windblown litter. Particular attention was given to ensuring that the operators fully understood the importance of both the degree of slope that is needed to provide the desired degree of stability, and the removal of bulky waste types which would undermine the bund wall structure during its construction.

Formation of Small Tipping Cells

By introducing tipping cells, the benefits of encouraging, and managing, the disposal of waste into well defined tipping cells was shown, thus demonstrating the environmental advantages from consolidating active waste management into a small, manageable, portion of the site. In addition to this, stakeholders were also be given instruction in the construction of a tipping apron for providing a stable environment for the disposal vehicles which cannot be afforded by the tipping cell itself due to its steep sides.

Reduction of Health and Environmental Problems by Using Daily Cover Material

The working area of the dumpsite (i.e. to where waste vehicles will be actively disposing of their waste) will be the tipping cells – the remainder of the dumpsite will be domed, covered, and hence comparatively isolated from the environment. However the area of waste left exposed by the tipping cells is still substantial, and hence daily cover material needs to be used for reducing potential health and environmental problems.

Prohibition on the Burning of Waste on Site

If the modernisation process proceeds to plan at the pilot site, then the risk of uncontrolled fires (which are commonplace during the summer) should be dramatically reduced. However experience from the EU teaches us that, even in such modernised landfills, fires do occasionally occur. Thus it is important for site operators to be aware of the dangers, how to treat fires and to address the problems associated with them. For example, if the incoming waste is known to be on fire or suspected of being on fire, then an emergency tipping area should be established on site where such waste can be deposited. Thus, under this task, a strategy was developed for minimising the risk of uncontrolled fires and prohibition of burning at the site.

6.4.3 Practical Results of the Modernisation Process

6.4.3.1 Modernising the Kruglovo Dumpsite

The modernisation of the Kruglovo site started in mid-May 2004. In order to facilitate this process, a training seminar was held by the project team on the 21 May, which was attended by representatives from the region's major dumpsites. This training seminar was particularly useful in that it helped to clear up a number of misconceptions relating to the objectives for modernising operations at Kruglovo site. Indeed it became clear to the project team that all stakeholders, particularly the operator of the Kruglovo site, not only had a far greater understanding of the task, and the associated work programme, following this seminar but that agreement was finally reached on the need to grade and compact the waste and construct the tipping cells, plus the operational requirement to apply cover material on a daily basis.

Thereafter the modernisation of the dumpsite proceeded more or less to plan, i.e.:

- Levelling, compacting, and shaping of the waste into a domed landform;
- Covering the domed site to help prevent access of the waste by vermin, littering, and infiltration by rainwater into the waste (hence reducing leachate production);
- Placing a perimeter bund wall around the site, where practical to do so in the constraints of the budget;
- Purchasing sufficient material to be used as daily cover;
- Constructing tipping cells on the site in order to encourage a more managed practice of waste disposal, thus exposing only the working area to the environment.

Photos 1 to 16 below illustrate the main steps of the low cost/high impact modernisation works carried out at the dumpsite to reduce its environmental / health impacts.

Photographic Record Showing the Main Stages of the Kruglova Dumpsite Modernisation Process

Photo 1: A bulk-transporter discharging waste from Kaliningrad within the Kruglovo dump site.

Photo 2: The site tracked-dozer struggling to manage the incoming waste stream at the site.

Photo 3: View of the un-modernised dumpsite (looking south) showing the widespread mismanagement of waste at the site.

Photo 4: View of the un-modernised dump-site. The entire waste body is exposed to the environment thus encouraging health and environmental impacts from the site across a wide area.

Photo 5: Process of compacting, shaping, and doming the site prior to being covered.

Photo 6: Process of forming the bund wall at the western edge of the site in order to regulate and consolidate the site's footprint.

Photographic Record Showing the Main Stages of the Kruglova Dumpsite Modernisation Process

Photo 7: Process of covering the compacted, domed, and shaped portions of the site on a “step by step” basis.

Photo 8: Domed and covered site at Kruglova (looking south). The disposal of waste is now confined to the operational part of the site in the background.

Photo 9: Compacted, domed, and covered north-west portion of the Kruglova site. Note how the doming of the site will encourage rainfall run-off and hence help to prevent leachate perculation.

Photo 10: Completed bund wall at the northern edge of the site. Main purpose of the bund wall is to prevent waste from further migration into the forest.

Photo 11: View of the covered dump-site looking north. Note how the waste disposal operations are now confined only to the active disposal cell on the left of the picture.

Photo 12: Process of constructing the bund wall at the northern edge of the site.

Photographic Record Showing the Main Stages of the Kruglova Dumpsite Modernisation Process

Photo 13: Construction and Tidying-Up of the bund wall on the far SW of the site.

Photo 14: Construction of the bund wall on the NE perimeter of the site.

Photo 15: External bund wall together with central tipping cell bund wall.

Photo 16: Completed bund wall on the NE site.

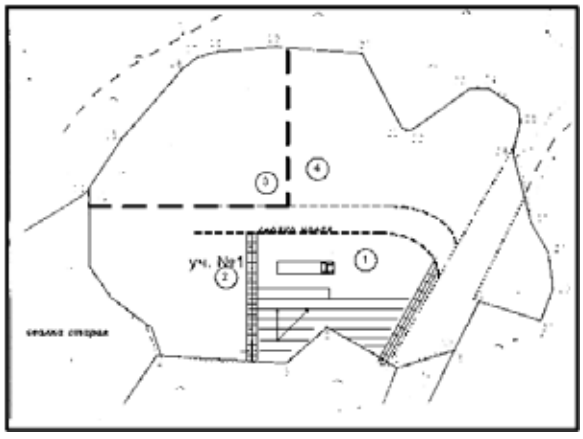


Figure 1: Filling sequence for modernised dumpsite

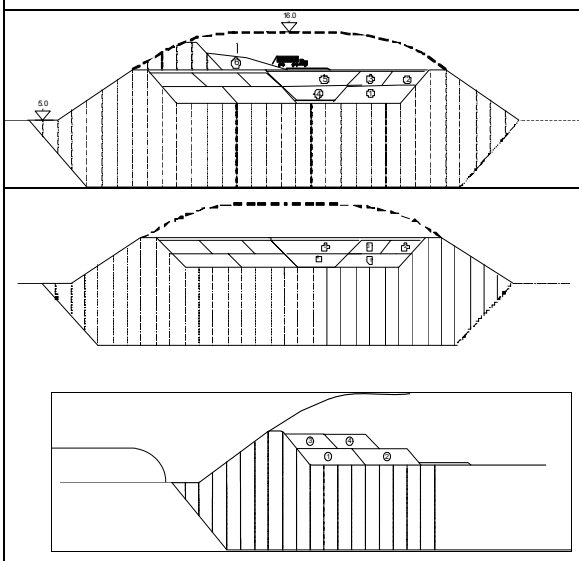


Figure 2: Filling sequence for the site

6.4.3.2 Upgrading Site Operations: Operational Plan

An operational plan was developed for the Kruglovo site which, as described above, focused on the registration of incoming waste at reception through to the disposal of waste, and proper utilisation of the site, in the most rational and safe manner. The operational plan consists of three discrete sections (acceptable waste types, operational guidelines, and filling sequence) which, by the end of August 2004, was being fully implemented by the site operator to the extent possible given the resources available.

6.4.3.3 Rolling out the Capacity Built at Kruglovo: Public Awareness Raising

In order to encourage the replication and uptake of the measures piloted at Kruglovo to the other dumpsites in the region, a number of public awareness raising initiatives were undertaken by the project. These included:

- Development of technical information sheets explaining the process of dumpsite upgrading in practice and what constitutes an operational plan for such dumpsites:
- Production of a leaflet for the general population explaining the benefits of dumpsite modernisation.

7 Waste Emplacement

This section addresses waste emplacement processes and sets out the basis for how a waste disposal site should be delineated into cells/phases if it is to be managed in line with best practice[3].

7.1 Waste Acceptance

Waste should not be accepted at any waste disposal site without prior knowledge of its nature and composition and having determined its acceptability. The waste that is accepted at the site must fall within the categories of waste permitted by its licence/permit conditions. Consequently a site's management team must impose restrictions on the acceptability of certain waste streams, and thus needs to be aware of the nature of the waste being deposited at the site in order to ensure compliance with licence conditions, and health and safety requirements. Thus all waste received at the landfill site must be:

- Covered by the appropriate documentation;
- Weighed in; and
- Checked for conformity.

7.1.1 Documentation and Compliance Testing

On arrival at the facility, vehicles must be stopped at the gatehouse. Paperwork documenting the waste being delivered must be inspected, and the vehicle and contents should be inspected to check that the waste actually being delivered corresponds to the paperwork. All wastes arriving at the site should be covered by the necessary documentation, in accordance with the legal requirements and the requirements specified by the site, and should include an adequate description of the waste.

Some form of waste transfer note must be completed, signed, and kept by both the site operator and the waste deliverer. The transfer note should include a description of the waste and provide information on the premises and process that produced the waste, and its chemical and physical composition. If there is any doubt as to the correctness of the waste, then the waste should be sampled and checked, and the vehicle not allowed to off-load until confirmation is received. Even for loads received regularly, periodic samples of the waste should be taken to ensure that it conforms to the licence conditions. Thus the waste disposal site operator should characterise and, where appropriate, test the waste at three possible levels, namely:

- Level 1: Comprehensive characterisation
- Level 2: Compliance Testing
- Level 3: On-site verification

Level 1

The waste is characterised by the producer to determine the acceptability of the waste for disposal at a particular site. Comprehensive characterisation constitutes a thorough determination of the chemical and physical properties of the waste.

[3] The recommendations regarding waste emplacement may be adopted and implemented with consideration of the respective local norms and regulations. Allocation of landfills, acceptance of waste, allocation of objects for management of consumption waste and structure of waste management objects (facilities) in Armenia must comply with the requirements set in the following documents: i) "Hygienic requirements for ensuring sanitary conditions of the territories of settlements; for collection, storage, transport, processing, recycling, recovery, treatment (disinfection) and disposal; for ensuring safe working conditions for personnel working in sectors of ensuring sanitary conditions of the territories of settlements and management of consumption waste" (Sanitary Norms and Rules N2.1.7.002-09) adopted by the Order N 25-N of the Minister of Healthcare of RA dated on 22.12.2009 (State Register N 10010022); and ii) "Hygienic requirements for management of hazardous chemical waste and for storage and transport of hazardous chemical substances" (Sanitary Norms and Rules N 2.1.7.001-09) adopted by the Order N 20-N of the Minister of Healthcare of RA dated on 29.12.2009 (State Register N 10009463).

Level 2

Waste is re-tested at a specified frequency to look for changes in the basic characteristics of the waste. The frequency should be specified by the regulatory authorities.

Level 3

Waste is subjected to simple checks and tests to ensure that the waste, when it arrives at site, matches the description in the documentation.

7.1.2 Input Control

The checks carried out as part of the modernised site's input control process will depend upon the:

- Type of vehicle carrying the waste;
- Nature of the waste; and
- Method used to contain the waste (for example drums and closed skips).

The checks carried out may involve:

- Visual examination; and
- Sampling and analysis on site (e.g. pH, flashpoint).

Three aspects of input control should be provided for:

- Documentation check;
- On-site verification testing (Level 3); and
- Retention of samples for retrospective (Level 2) testing.

With respect to the documentation check, when waste arrives at the site, the documentation should be checked for compliance by the designated person at the site's reception or weighbridge. If the documentation is in order, the waste should be weighed at the site reception or weighbridge. If not, then the vehicle should be directed to the holding area for further action. In normal circumstances, if a vehicle arrives at the site without proper documentation, or with incorrect waste, then the site personnel should notify the regulatory authorities immediately (hence a modernised waste disposal site should have at least one telephone) or at the earliest opportunity.

On Site Verification

The gatehouse/weighbridge operator should direct the vehicle to either:

- The disposal area;
- An on-site check will be a visual check on the waste following discharge. The most complete visual examination can be made as the waste is spread and compacted;
- A designated waste inspection area; and
- A more detailed on-site verification check may be made prior to disposal.

Representative samples are taken at a specified frequency for Level 2 testing. To minimise delay to vehicles using the site, a schedule of the frequency and type of waste should be established. For loads which cannot be inspected before discharge, a programme of spot checking should be established. A designated area should be provided for this purpose.

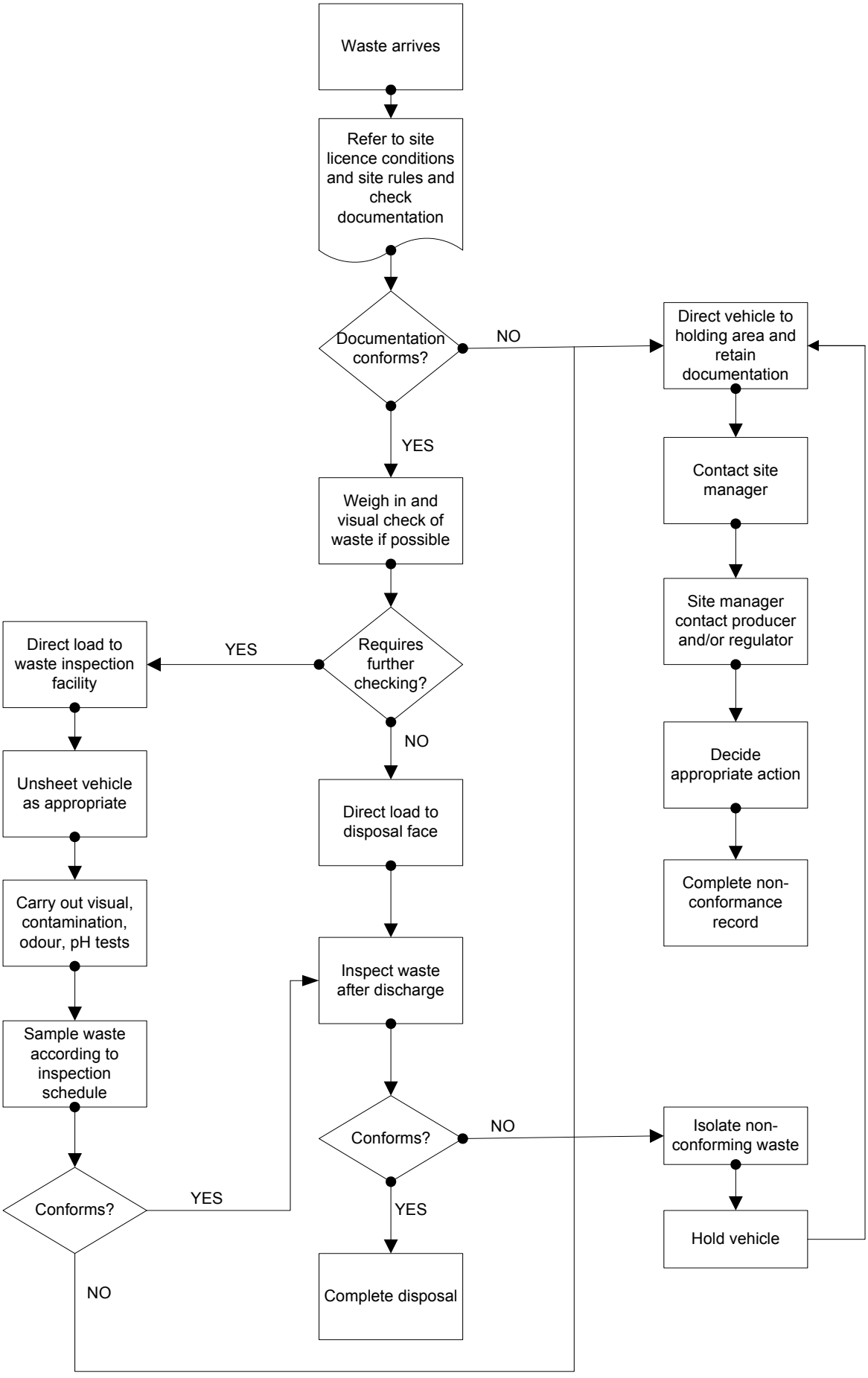


Figure 5: General schematic for waste acceptance procedures

In order to ensure compliance, facilities should be in place to allow the checking of wastes prior to final deposit. The facilities required will depend, to an extent, on the range of wastes which are permitted. There are two areas where waste checking can be carried out:

- The reception area; and
- The tipping face

The weighbridge is usually the first point at which the vehicle will undergo checks to assess the suitability of its load for acceptance at the site. The documentation accompanying the load will be checked at this point. If the load is open-topped, it may be possible to make a visual inspection at the weighbridge office. However, this will not be sufficient for the site personnel to check full compliance of the load because only the surface of the load may be seen. The checking which can be carried out at the reception area is also limited by the type of vehicle delivering the waste. It is impractical to inspect or sample wastes in closed vehicles at the relocation area. The loads of such vehicles are best checked by random waste inspections before the load reaches the tipping area. There will therefore be a need to provide a separate waste inspection area. Where hazardous materials are not involved, a designated hard standing at the reception area with equipment to gain safe access to the load may be sufficient.

Where there is a need to unload for inspection prior to acceptance, a small area on the site should be set aside for this purpose:

- Such an area should have retaining bunds or walls and a hard surface which can be cleaned;
- Drainage water should be regarded as potentially contaminated and should be collected in an interceptor for analysis prior to discharging; and
- The location of the area should be carefully chosen to prevent visual intrusion, odour nuisance, and risk should hazardous materials be encountered.

An area should be set aside for holding vehicles whose loads are found to be non-conforming. In such an event the regulatory body should be contacted to determine the actions to be taken.

7.1.3 Effective Communication

If the documentation is in order, the weighbridge staff should direct the vehicle either to a designated area for inspection or to the disposal area. Effective communication between the weighbridge and the tipping face, and a sound knowledge of the acceptability of waste streams, are required by all personnel involved in the transfer of waste from reception to final disposal, in order to ensure:

- Smooth running of the site;
- Only permitted wastes are accepted;
- Safety of operatives dealing with the waste; and
- Accurate recording of waste inputs and disposal locations.

7.1.4 Competence of Operatives

It is essential that all those responsible for checking the documentation accompanying vehicles and the site operators at the waste disposal face are competent with respect to:

- Understanding the waste acceptance criteria for the site in terms of license requirements;
- Understanding the basic underlying reasons for the acceptance criteria for the site;
- Understanding the information which should be provided on the documentation accompanying loads;
- Having an ability to identify non-conforming wastes;
- Understanding procedures to follow if either the documentation or the load is non-conforming;
- Site safety procedures.

The site operatives at the site reception area, and the waste disposal face, will require training to ensure that they are technically competent in these areas.

7.2 Non-Conforming Waste Consignments

Non-conforming waste consignments arriving at a waste disposal site may be identified at:

- Site reception;
- Weighbridge;
- Waste inspection facility; and
- Disposal face.

Non-conformances may be due to the documentation being incorrect, insufficient, or inaccurate, or due to the waste not conforming with the documentation, the waste management license, or other legal requirements.

The site's management team should compile a written procedure detailing how to deal with non-conforming wastes. All site personnel should be aware of the chain of reporting and the actions to be taken. An area should be set aside for vehicles to be held, pending a decision regarding their future. The regulatory authority should be contacted to provide advice regarding whether the load can be accepted or whether it should be reconsigned to another location. If a waste has been deposited before non-conformance has been established and is contrary to its license, or is an unconsigned special waste, it should be isolated and the vehicle should remain on-site pending a decision as to the necessary actions required to deal with it.

Records of non-conformances should be kept and should include the actions taken to deal with them, who was contacted and the decision which was made for the disposal of the waste, and whether any offence was committed.

7.3 Communications

Effective communication between the site's gatehouse/weighbridge personnel and those responsible for carrying out waste inspections and operatives at the disposal face are extremely important to ensure the following:

- That there is a smooth transfer of wastes through the site;
- Wastes which require to be checked prior to proceeding to the face are directed to the appropriate area;
- Only conforming wastes are allowed to be deposited and are directed to the correct tipping area;
- Appropriate preparations and safety precautions are made for waste streams requiring special handling requirements;
- Plant requirements for handling particular waste streams are provided at the appropriate location; and
- The emergency services and other parties can be contacted.

7.4 Filling Method

Prior to landfilling activities starting at untipped areas of the site, standing surface water, vegetation and other materials should be cleared from the area. A number of landfilling techniques can be distinguished, albeit these tend to be variations on two main techniques, i.e. face tipping and the so-called "onion-skin" method.

Face Tipping

In this method the wastes are tipped out and then compacted into a bench. The bench continues level across the cell or phase for a period of days or weeks until the other side is reached. Generally the height of the bench will be about two metres, with the compactor working down the face, as well as along the surface of the bench. This method tends to find favour with machine drivers, but supervision is needed to ensure that they run the compactor down the face. Otherwise, compaction may be poor in areas other than on the horizontal surface of the bench

itself. Bulky objects which are difficult to bury can be placed at the base of the face and then covered from above. The disadvantages of this method are that waste can become windblown when tipped over the edge, and that the landfill surface becomes heavily compacted by the passage of vehicles – which can lead to the possibility of zones of perched leachate.

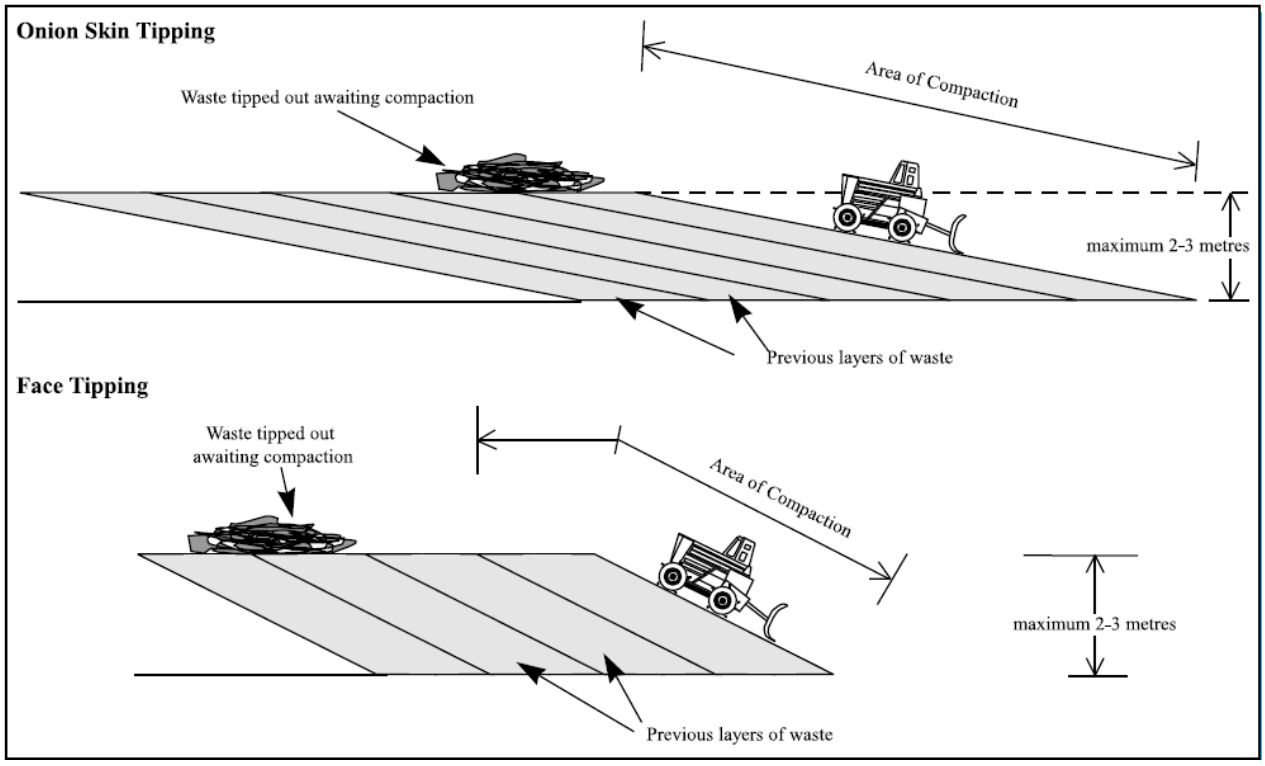


Figure 6: Different tipping methods used at sanitary landfill sites

Onion Skin Method

This has similarities to face tipping, but with the toe of the face extending at a much shallower gradient. The compactor operates solely on the gradient of the more shallow face, pushing thin layers of wastes and applying compaction pressure to them. Whilst it is more difficult to bury bulky objects or other difficult waste, this method has the advantage of having a lower probability of windborne litter.

7.5 Waste Compaction Equipment

Wastes other than cover materials should not be allowed to remain in loose piles on a landfill. There has been a trend towards the use of steel wheeled refuse compactors on many of the larger landfill sites. Whilst these are high capital cost items, they enable the maximum quantity of waste to be placed in available space. Compaction also causes the deposited waste to be pinned down, and hence less likely to become windblown, whilst being less attractive to vermin. Thus mobile wheeled compactors should be used on all waste disposal sites accepting significant quantities of household and other similar wastes.

The main parameters affecting compaction are the nature of the waste material, the weight of the compactor, the number of passes by the compactor, and the depth of each waste layer subject to compaction. The operation of a refuse compactor is a skilled job that should be effectively supervised. If not undertaken correctly, poor compaction can occur. Hence no more that 0.5m in height of uncompacted waste should be compacted at any one time, with the compactor working down to the "toe" of the working face. Besides poor compaction, inefficient operation may result in fuel being wasted, as well as causing the sub-optimal usage of a high capital cost machine. In the minority of cases where tracked machines are used for waste emplacement, the operator should identify measures to deal with uncompacted refuse, particularly in respect of cover, litter, and vermin protection etc. The design of many tracked excavators is such as to be almost a mirror image of a landfill compactor, in the sense that many types of tracks are specifically designed to minimise ground pressure. Consequently, compaction by way of a tracked machine may be less

than desirable. If this option is to be used, the machine should work uphill on a sloping working face as this arrangement maximises the ground pressure.

In all cases, workforce health and safety must be considered. All landfill machines must be fitted with roll-over protected cabs, and there should be protection against falling objects. Audible reversing signals are also essential.

7.6 Disposal of Difficult Wastes

Difficult wastes are those wastes which, though acceptable for disposal to a modernised MSW waste disposal site in terms of their overall properties, have some characteristics which require a particular method of handling at the site which is not normal day-to-day procedure. This usually means that they cannot be placed with other materials on the working face and compacted alongside other refuse. Wastes consisting wholly or mainly of animal or fish waste, condemned food, sewage sludge, and other obnoxious materials all fall within this category. Other examples of difficult waste include light materials such as polystyrene and dusty wastes.

Difficult wastes should not normally be deposited directly with other wastes in the working area. Instead they should be placed in front of the working face and immediately covered with other waste. Any obnoxious material should not be located within one metre of the surface or two metres from the flanks or face. Alternatively, disposal in an area of already filled material may need to be considered. In this case, a disposal trench is dug into deposited waste with the deposited difficult wastes being immediately covered over. Waste giving rise to dust when tipped or run over by site machinery should be handled and deposited in such a way that dust is not released. Whilst the deposit of empty drums may, depending upon their contents, be acceptable, it is increasingly desirable that such materials are recycled. If drums are to be disposed of at a landfill, they should be thoroughly crushed and compacted.

7.7 Waste Emplacement

7.7.1 Procedures for waste discharge, emplacement, compaction, and covering

The *raison d'etre* at any waste disposal site is the emplacement of waste into its final position. The particular methods employed by a site's management team will depend on the nature of the waste input and the requirements of the site. Factors which should be taken into account include:

- Physical condition of the waste;
- Weather conditions at the time of emplacement;
- Special requirements to avoid hazards inherent in the waste; and
- Design objectives.

7.7.1.1 Emplacement Method

Emplacement methods have already been discussed in the previous section. However, in summary, it is recommended that most operators adopt a "face tipping" method for waste discharge and emplacement. This involves the creation of a horizontal or near horizontal platform by tipping over an advancing face with levelling and compacting from above. The maximum height of the face is usually limited by the waste management licence and should typically be no more than 2.5 m after compaction. The compaction equipment operates on the flat surface at the top of the face. The main advantages of this approach are that:

- Machine operators find this method easy;
- It is easy to apply daily cover;
- Temporary access roads can be provided easily;
- Bulky objects are easy to bury; and
- Problem wastes can be tipped at the toe of the face.

Although the site's management team need to be mindful of the disadvantages, which can include:

- The face can be unsightly;
- It is difficult to apply temporary cover to the face;
- Waste easily becomes windblown when tipped over the edge of the face; and
- The surface of the landfill becomes over compacted through the repeated passage of vehicles, encouraging the development of perched water tables within the landfill.

Procedures should be closely controlled as the discharge and emplacement of waste is potentially dangerous. In this respect all drivers using the site must be aware of the site rules regarding the discharge of waste and must obey instructions from the site's personnel. It is up to the site's management team to draft the rules but, as a minimum, they must include provisions for:

- Restrictions on the number of vehicles in the discharge area at any one time;
- Passengers not being allowed to alight in the discharge area;
- Pedestrians on the operational area to wear high visibility clothing, safety boots, and other relevant personal protective clothing;
- Prohibition of smoking on-site;
- Special procedures to unload overloaded vehicles; and
- Special procedures for tipping bulk vehicles in circumstances where they might become unstable when their bodies are raised.

Every discharged load should be visually inspected by a designated operative. Working area personnel should be trained and competent at waste identification in order that they can recognise waste which may be non-conforming. In the event of reasonable doubt as to the waste's acceptability, the operative should inform the waste reception facility and/or the site manager immediately and the consignment isolated pending further inspection. Once the waste has been discharged from the vehicle, it should be consolidated and layered to ensure that the tipping area remains well defined and tipping slopes are maintained at the designed gradients.

7.7.1.2 Waste Compaction

The site personnel should level and compact the waste as soon as it is discharged at the working area. This will:

- Enable the maximum amount of waste to be emplaced within the space available;
- Reduce the impact from litter, flies, vermin, birds, and fires; and
- Minimise short-term settlement.

7.7.1.3 Defining Working Areas

The size of the working area and the way it is defined should be partly controlled by the site's license and must take into account:

- Safe working practices;
- The prevention of nuisance (i.e. odour, flies, birds, visual impact);
- The area required for manoeuvring of discharging vehicles and site plant;
- The size of the discharging vehicles;
- Peak site input rates;
- Configuration of operational cells and phases;
- Minimisation of uncontrolled rainwater ingress;
- Benefits of controlled progressive working; and
- Stability of the waste, particularly in the steep temporary faces and having regard to potential slip planes in the liner system.

By way of modernising site operations, the use of "tipping cell" working areas is recommended. A tipping cell is created by constructing bund walls between which waste is deposited. The main

advantage of this approach is that the tipping area is confined and that litter is reduced with the installation of temporary litter fences facilitated. The main disadvantages, however, are that there is an increased demand for inert material to create bunds and that such bunds may restrict leachate and gas circulation in the completed landfill unless they are removed. The construction of such cells is described more fully elsewhere. However, in summary, these cells should be constructed by building cell walls around the active fill area using low permeability material such as clay etc. It is up to the site's management team to judge the appropriate balance between using small cells (the lower the fill rate, the smaller the cell), and losing too much of the dumpsite's capacity being taken up by the cell dividing walls. Sufficient material should be stored on site to enable the construction of these cell walls as, and when, necessary

7.7.2 Phasing

A waste disposal site should be divided into a series of phases and filled to final levels in succession. Hence a cycle of progressive filling across the site should occur, with one phase being restored, a second filled and a third prepared for filling. The benefits of phasing are that it:

- Allows site disposal operations to become tightly organised;
- Will diminish leachate generation;
- May reduce noise and litter; and
- Provides a positive visual impression and hence encourages public confidence that the site is well controlled and will be subject to adequate restoration

At a relatively shallow site, the phasing plan shown in Figure 7 is appropriate.

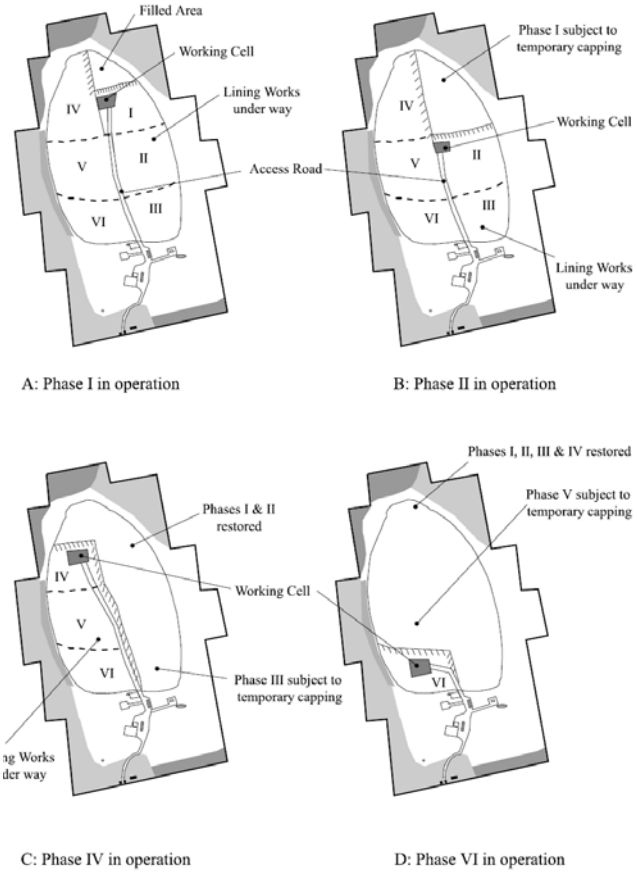


Figure 7: A phasing plan for shallow sites

For deeper sites, this scheme is undesirable because it is not good practice to have high and steep banks between the filled and unfilled parts of the site. These may develop stability problems, could cause unacceptable risks to site users and are likely to result in a very small cell size when near final levels. Accordingly, a series of phases overlaying each other would be normal for deeper sites (Figure 8).

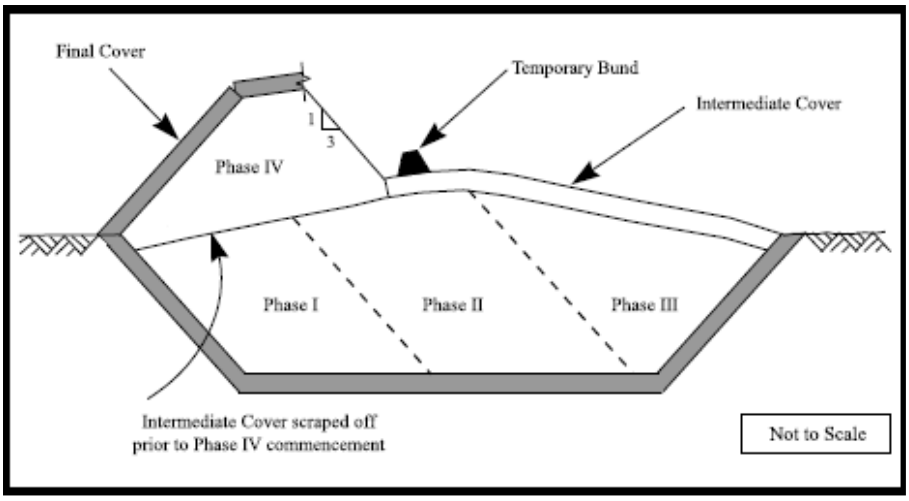


Figure 8: A phasing plan for deeper sanitary landfill sites

Intermediate cover or temporary capping should be used over parts of the landfill surface which will be awaiting further filling activities. New phases are started on top of the lower phases after scraping off as much of the cover as is possible.

7.7.3 Cells and Working Areas

For best practice to be achieved, it is desirable that waste is deposited into cells which are delineated by pre-constructed bund walls. Operating a cellular method of filling enables waste to be deposited in a tidy manner since the bunds serve to both conceal the tipping operation and to act as a windbreak. One potential disadvantage of the cell method, particularly where space is limited, is the amount of void space which may be lost due to building the cell walls. In addition, the delineation of the cell by this method may present barriers to leachate and gas circulation. These drawbacks may be overcome by subsequently excavating the wall and using as much of the reclaimed material for purposes such as cover. For larger sites, there is no reason why the structure of cell walls cannot be made up mainly of deposited waste, with the external faces coated in cover material.

A key area to be addressed for achieving best practice is the size of the cell. In this respect, it is crucial that cell size should be maintained to the minimum practical dimensions. Minimising the cell sizes will:

- Provide the smallest surface area of exposed waste;
- Assist in controlling windblown litter;
- Reduce the requirements for cover material; and
- Will lower contact with rainfall and hence minimise leachate generation.

The major constraint on cell size is, however, created by safety and operational considerations. Incoming vehicles will need room to manoeuvre and to unload. They must kept be well away from uncompacted waste and from any compaction equipment. Overall, the site operator must balance these competing objectives. Hence a busy site would have more emphasis placed upon allowing adequate space for vehicle unloading and for turning. A small rural site, conversely, could have a much smaller cell size.

7.8 Cover Materials

7.8.1 Traditional Cover

A traditional cover material typically comprises subsoils, other excavation wastes, or construction industry wastes such as bricks and crushed broken concrete. The material selected for cover purposes ideally should be free draining and, preferably, of low clay content. Highly impermeable cover materials may encourage the perching of leachate. In the past, subsoils and other construction industry wastes have been used as cover, with a target of 150 mm depth being

applied towards the end of the working day. If soil-based cover materials are to be used, the feasibility of their extraction from the site itself should be considered. This means that the size of the void is not affected by the emplacement of cover materials and that transport costs and associated impacts are limited. Where cover is to be brought in, the quantities of cover material should be calculated and suitable sources located well in advance of the material actually being needed. To ensure that a supply of material is available to meet the requirements of daily cover, a stockpile of cover material should be maintained on site for use. It is generally recommended that a stockpile of between 1-3 months' supply is maintained.

7.8.2 Daily and Intermediate Cover

The site's management team are strongly encouraged to use intermediate/daily cover for the active cell. Daily cover serves an essential function on all landfills accepting municipal and other biodegradable wastes. In particular, daily cover improves the appearance of working areas and decreases the possibility of windblown debris (eg paper, plastics). It also significantly reduces access to the waste by birds, insects and vermin and diminishes odours and fire risk. Soil will give a uniform appearance from the site boundary. To achieve this, a thickness of about 150mm is usually adequate. Whenever possible, daily cover should be obtained from the excavation of material from within the landfill area.

Intermediate cover is used when filled surfaces are likely to be left for a period of weeks or months before additional layers of waste are to be added. This type of cover significantly reduces rainfall infiltration, whilst it binds the deposited wastes down and hence reduces litter. Intermediate cover materials will be subsoils or similar wastes. Intermediate cover is usually spread to a greater thickness than would be the norm with daily cover. Hence a reasonable target should be about 300 mm in depth. The area should be regularly inspected by site staff and any cover materials eroded by rainfall action should be replenished. When the area subject to intermediate cover is to be used for further tipping, the cover should be extensively scraped off.

7.9 Capping

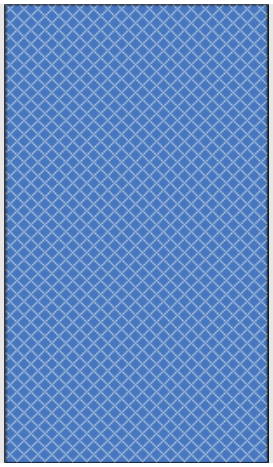
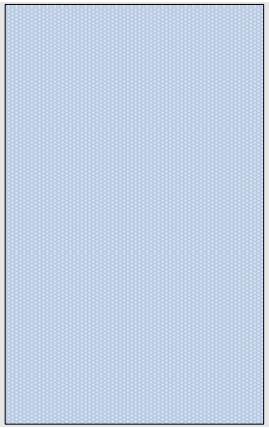
7.9.1 Temporary Capping

Instead of installing a permanent cap early on, it is preferable to place a temporary cap of low permeability material over the filled area. This is because, in the early years of bio-degradation, settlement will be quite rapid due to the weight of the material deposited along as well as biodegradation itself which decomposes a proportion of the landfilled materials into landfill gas and leachate. This rapid rate of settlement is likely to affect the structural integrity of any permanent cap. Hence the installation of permanent capping works should be delayed for this reason.

Once the initial settlement rate has slowed, usually within the first five years after completion of filling, the temporary cap can be removed. To allow for erosion and to provide a consistent depth over other wastes, it is recommended that temporary capping is laid to a minimum depth of about 0.5 m. Unless areas are to be left awaiting final capping for many years, there is no necessity to engineer the installation of the temporary cap. Its main function is to prevent infiltration and to shed rainfall. The result of the effects of settlement is that a permanent capping system should not be installed until significant settlement has ceased. Temporary capping should be undertaken on all of the phases of the site which are at final levels or where landfill activities will not return to a partially filled area of the site for a number of years. The utilisation of temporary capping reduces exposed landfill area and thus diminishes negative visual impacts and reduces leachate generation.

7.9.2 Final Capping

The final landform created by the infilling process should be designed. It should not have slopes sufficient to cause heavy and rapid run-off. Whilst run-off in these circumstances can be mitigated by step profiling and the provision of longitudinal open drains, there remains a danger that it may cause erosion and hence affect the integrity of the cap in the long term. Figure 9 presents the structure of final capping to best international standards.

Profile	Layer	Primary Functions	Usual Materials	General Considerations
	1. Surface layers	Growing and rooting medium for plants depending on end use; may incorporate field drainage as appropriate, prevents erosion	Topsoil and natural subsoils	Surface layer for the control of water is always required.
	2. Protection layers	Protects underlying layers from intrusion by plants, animals, and implements; protects barrier layer from desiccation and freeze thaw; maintains stability	Natural subsoils or screened soil making materials; geological drift deposits.	Some form of protection layer is always required; surface layer and protection layer may be combined into a single cover soil layer depending on afteruse.
	3. Drainage layer/pipework zone	Drains away infiltrating water to minimise barrier layer contact and to dissipate seepage forces; may also incorporate gas suction pipes and leachate delivery mains.	Sands; gravels; geotextiles; geonets; geocomposites.	Drainage/pipework layer is optional: drainage necessary only where excessive water passes through protection layer or seepage forces are excessive; distribution requirements depend on environmental control systems.

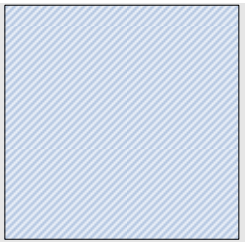
Profile	Layer	Primary Functions	Usual Materials	General Considerations
	4. Barrier layer	Minimises infiltration of water into waste and escape of gas out of waste.	Compacted clay liners; geomembranes; geosynthetic clay liners.	Barrier layer is usually required; protection layers, geomembranes, and/or geotextiles may be required to protect or maintain barrier.
	5. Gas collection layer	Transmits gas to collection points for removal and disposal or utlisation.	Sands; geotextiles; geonets.	Required if waste produces excessive quantities of gas.

Figure 9: A final capping system to international best standards

Although steep gradients should be avoided, slopes should not be of such a shallow gradient as to result in water-logging and ponding. Hence the minimum gradient should be 1:20 and the maximum gradient should not exceed 1:3. Drainage channels constructed in an area of the restored site should also be able to cope with storm water conditions and should be constructed in such a way that they do not cause any gradual leakage into the filled material. The type of capping and restoration materials and their depth of emplacement will be a function of the design requirements of the cap, and the intended after use of the site. The restoration layer above the cap should be at least one metre thickness of soil/subsoil. Otherwise the cap will not receive adequate protection from after uses of the site.

8 Guidelines on Co-disposal of Wastes

At the moment, there are large volumes of industrial wastes being stored in unsatisfactory conditions. The reason that such large volumes are being stored is due to the lack of appropriate and permitted treatment and disposal facilities. Some industrial wastes are disposed of at landfill sites but the sites are operated to variable standards and there appears to be a variety of operational methods employed. In particular, at some sites separate areas or cells are used for the disposal of domestic (household) wastes, commercial and industrial (enterprise) waste and the various types of toxic industrial waste (TIW) whereas at other sites domestic waste and industrial waste is being deposited together.

Current co-disposal practices in the country involve the almost haphazard/unplanned disposal of different waste types. This practice has the potential to turn such sites into large “chemical reactor” which, in extreme cases, could have the potential to create severe human health impacts. Co-disposal of most waste types is not encouraged in most developed countries, and is the exception rather than the norm. In the EU, for example, mono-disposal is the preferred option to landfill sites specifically engineered to deal with the anticipated waste hazard class, e.g. inert, sub-hazardous, or hazardous waste. However, within the FSU, co-disposal of wastes to landfill is likely to continue within the foreseeable future, not least because the resources to support the necessary facilities for mono-disposal are unlikely to be forthcoming until the medium-term at least.

This section thus presents guidance for minimising the risks associated from the co-disposal of toxic industrial wastes (TIW) with municipal solid waste (MSW). It provides practical guidance on the land disposal of hazardous industrial wastes together with MSW, and aims to help raise the overall standards of co-disposal in order to achieve a more uniform standard of operation across different sites. In particular, it outlines the operational procedures and management activities associated with the operation of co-disposal landfill sites and identify operational and management practices which should be applied to existing and new land disposal facilities.

The guidance in this section has been prepared to assist operators of co-disposal landfill sites, persons responsible for the regulation and control of such facilities, and those involved in their planning and development. In addition, it should be useful to those persons responsible for transporting waste to landfill sites, and also to those industries which already consign their wastes to landfill sites and those who generate hazardous industrial wastes which may be disposed of by co-disposal.

8.1 What is Co-disposal?

In the UK and North America, co-disposal is taken to mean the deliberate, controlled and intimate disposal of a range of industrial wastes with municipal (household or similar) wastes in order to utilise the absorptive capacity of the municipal waste together with the chemical and biological reactions associated with the degradation of the organic materials in municipal wastes to achieve ‘treatment’ of the industrial wastes.

Similarly, in most FSU countries, the term ‘co-disposal’ officially appears to mean the disposal of hazardous/toxic wastes with MSW although it does not appear to include the concept of intimate mixing (to utilise the chemical and biochemical reactions occurring within the waste mass as a means of treating the hazardous waste). The term also appears to be used unofficially by some practitioners to mean simply the deposit of MSW and enterprise waste at the same landfill, i.e. not necessarily deposited together.

For the purposes of the guidance presented below, co-disposal will be taken to mean the ‘international’ concept as described above.

8.2 Objectives and Benefits of Co-disposal

As described above, the overall objective of co-disposal is to 'treat' the industrial waste to render it less harmful with the result that the environmental impacts from the landfill site (notably emission of polluting leachate) are no worse than if the site had been filled with just MSW.

Co-disposal may be the best practical environmental option for the disposal of a range of industrial wastes and, where appropriate, its use can avoid the long term storage of wastes when no other treatment facilities are available.

It must be noted that co-disposal is not suitable for all types of industrial/hazardous wastes but, if properly applied, landfill can be used for the safe and economical disposal of a wide range of waste types. In order for co-disposal to be an acceptable means of waste disposal, and to meet the objectives discussed above, good standards of landfill design, construction and operation are required.

8.3 Concept & Scientific Rationale of Co-disposal

Co-disposal involves the controlled intimate mixing of hazardous industrial wastes with municipal (household) or similar, non-hazardous, commercial and industrial wastes. Co-disposal is not appropriate for all types of hazardous wastes but, for a limited range of wastes such as some inorganic solids and aqueous liquid wastes, it provides an environmentally acceptable disposal option.

When municipal solid waste degrades in a landfill site there are a great many physical, chemical and biological (biochemical) processes occurring simultaneously. Many of these processes are similar to those used in chemical waste treatment systems and the objective of co-disposal is to utilise these processes to render the hazardous waste less harmful. This may occur through chemical reaction, immobilisation or degradation of the hazardous components within the waste. Thus, the landfill may be considered as a bioreactor or anaerobic digestor in which there is a strongly reducing, aqueous, chemical environment and near neutral pH which is maintained by the on-going biochemical waste degradation processes.

Examples of the way in which these processes can be utilised for treating hazardous wastes include the following:

- Neutralisation of acids;
- Microbial degradation (metabolism) of organic compounds (such as phenols) to produce, ultimately, methane and carbon dioxide;
- Degradation of cyanides (free and complexed) through a variety of chemical and biological processes; and
- Immobilisation of heavy metals through adsorption and ion exchange as well as precipitation as hydroxides, carbonates and sulphides.

As discussed above, the processes involved in the co-disposal treatment of the various hazardous materials require the ongoing degradation of organic matter within the landfill. It is therefore important that the dominant landfill processes remain those associated with the methanogenic decomposition of municipal and similar solid waste. For co-disposal to work effectively there should be no significant inhibition of these processes which is why the types and loading rates of the various hazardous wastes must be carefully controlled.

Similarly, it is typical to deposit the hazardous wastes into 'mature' refuse because waste which has been deposited for some time is more likely to have reached the more stable methanogenic stage of waste decomposition when the leachate is neutral to alkaline. During the earlier aerobic stages of degradation, the leachate is likely to be acidic greatly reducing the waste's capacity for attenuation of some pollutants such heavy metals.

For a properly managed co-disposal site there should be no significant effect on leachate quality, there should be no unacceptable hazards to the site operators (or others visiting or living near the site) and the restoration and after-care of the site should not be adversely effected.

8.4 Principal Additional Design and Operational Considerations for Co-disposal Landfills

The following design and operational aspects are particularly important for landfill sites used for the co-disposal of hazardous waste types.

8.4.1 Water Balance / Site Water Control

The control of water inputs and management of any leachate generated is important at all landfill sites. In the case of co-disposal sites there is the added consideration of the additional water inputs due to the deposit of any hazardous wastes in liquid or sludge form. In addition to the overall water balance for the landfill, account has to be taken of the absorptive capacity of the waste in different parts of the site and loading rates for liquids and sludges set accordingly based on the relative inputs of municipal and non-hazardous commercial wastes. Operational cell sizes should be adjusted accordingly. Similarly, there must be sufficient municipal or other absorbing type of non-hazardous waste beneath the first deposit of liquid or sludge to ensure that no free liquid drains to the base of the site.

8.4.2 Control over Waste Inputs

The relative inputs of municipal/non-hazardous and the different types of hazardous waste must be carefully controlled to ensure that loading rates for specific waste types are not exceeded and to ensure that the generation of leachate is controlled. This is to ensure that leachate is not generated at those sites without leachate management systems, or so that the volumes generated are within the capacity of the treatment systems of sites with such facilities.

8.4.3 Adequately Trained Staff

In addition to being fully trained in the operation of municipal landfill sites, the staff operating a co-disposal landfill site must be trained in the particular methods of disposal, precautions and safety and emergency procedures related to the particular hazardous wastes which are to be accepted at the site.

8.4.4 Control Over On-Site Operations

There must be a high level of site management to ensure that specific types of incoming wastes are directed to the appropriate disposal area of the site and to ensure that incompatible wastes are kept segregated at all times. Similarly, site security measures must be sufficient to prevent unauthorised access to the site and, in particular, any areas requiring specific precautions to be taken to avoid any potential hazards associated with the receipt and deposit of hazardous wastes.

8.4.5 Monitoring and documentation

Recording the inputs of the different wastes types (quantity and location of deposit) is very important for future reference so that incompatible wastes are not accidentally mixed and to ensure that loading rates (local and for the site as a whole) aren't exceeded.

8.5 Criteria for the Acceptance of TIW at Land Disposal Sites

8.5.1 General Criteria

As discussed above, co-disposal is only appropriate for a limited range of waste types and there are many types of industrial waste which should not be landfilled[4].

Co-disposal is appropriate for those types of waste for which it is physically safe to landfill and which may be treated by the processes occurring within the waste mass. In order to satisfy the

[4] Waste acceptance criteria shall comply with "Hygienic requirements for management of hazardous chemical waste and for storage and transport of hazardous chemical substances" (Sanitary Norms and Rules N 2.1.7.001-09) adopted by the Order N 20-N of the Minister of Healthcare of RA dated on 29.12.2009.

latter requirement, the waste must be of an appropriate chemical nature and the physical form of the waste must be such that it is able to interact with the biomass, either directly or through leaching.

Wastes which are not suitable for co-disposal include the following:

- Flammable and low-flashpoint liquids and sludges;
- Organic liquids;
- Explosive or highly reactive substances;
- Wastes containing high concentrations of heavy metals or high concentrations of cyanides; and
- Polyaromatic hydrocarbons, polyhalogenated biphenols etc

As a general rule, drums of waste should not be disposed of to landfill because they can give rise to stability problems in the waste mass due to voids around and within the drums and because quality control is difficult without sampling all of the drums prior to disposal. Limited quantities of solid waste or sludges in drums may be co-disposed, however, providing that loading rates (see below) are not exceeded and providing that they are dispersed so as to avoid local concentrations of drums.

Specific types of waste which are suitable for co-disposal and those wastes which should not be co-disposed (with concentration limits where appropriate) are listed in Section 8.5.2. Chemical compatibility of different waste types is discussed in Section 8.5.3.

8.5.2 Wastes which may be suitable for co-disposal

Table 5 lists examples of waste types which may be suitable for co-disposal.

Table 5: Examples of waste types which may be suitable for co-disposal

Type of waste
Incineration residues
Products from the solidification of waste
Contaminated soils
Sludges from industrial effluent treatment
Sludges from biological treatment (including sewage sludge)
Animal and food industry wastes
Tannery wastes
Brewery wastes
Adhesive wastes
Detergents, fats and greases in water
Effluent from paint spray booths
Interceptor wastes and tank sludges
Alkaline degreasants
Cutting / cooling oils
Metal finishing wastes
Aqueous effluents containing degradable organic compounds
Acids and alkalis

8.5.3 Chemical compatibility

When more than one type of hazardous waste is deposited at the same landfill site, consideration must be given to the chemical compatibility of the different materials. Undesirable reactions which can occur when incompatible wastes are deposited together including the following:

- Generation of heat by chemical reaction - which, in extreme cases, can result in fires or explosions;
- Generation of toxic gases;

- Generation of flammable gases; and
- Dissolution of toxic compounds.

Thus, it is essential that only those wastes which are chemically compatible are deposited in the same part of the site[5]. Disposal areas for different waste types must be clearly labelled to avoid incompatible wastes being deposited in the same part of the site and there must be adequate supervision of site operations by suitably qualified staff to ensure that wastes are deposited in the correct areas of the site.

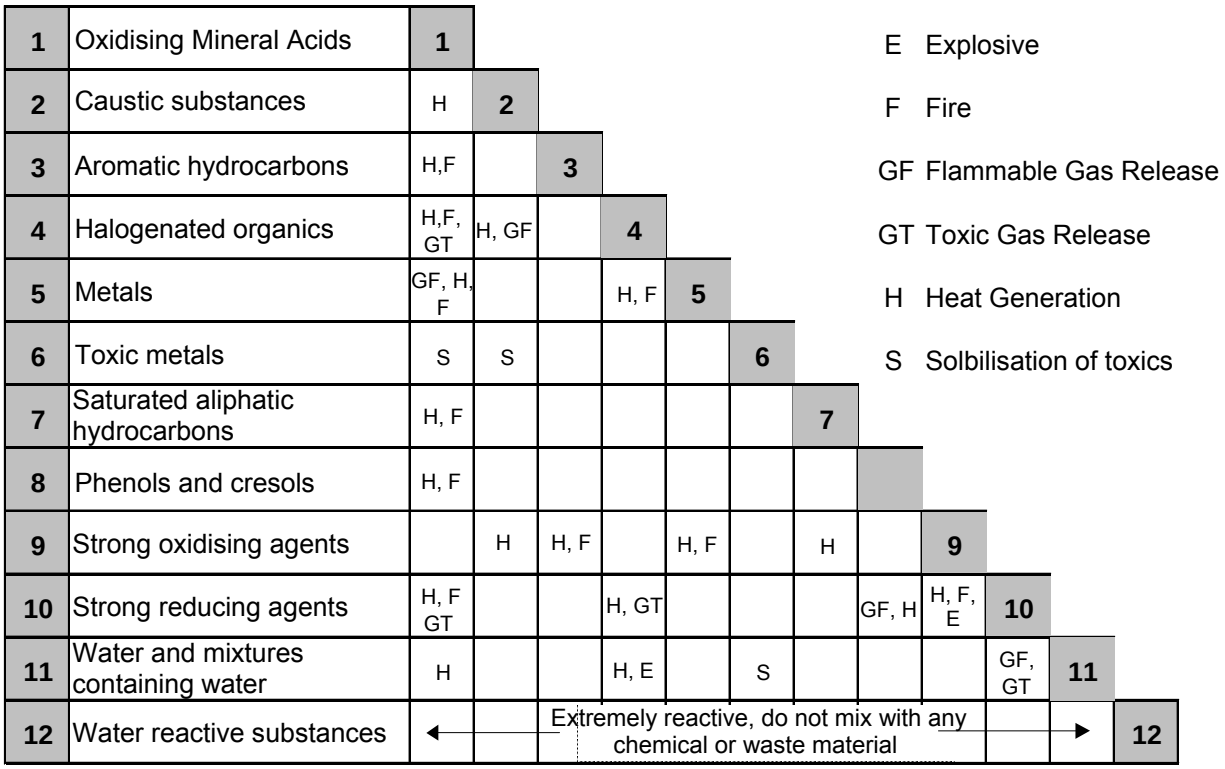


Figure 10: Chemical compatibility

Source: The Safe Disposal of Hazardous Waste: The Special Needs and Problems of Developing Countries, World Bank/WHO/UNEP, 1989.

8.5.4 Wastes which are generally not suitable for co-disposal

Table 6 lists those wastes are not suitable for disposal by co-disposing with MSW or similar wastes.

Table 6: Wastes which should NOT be co-disposed

Generic waste type	Specific conditions
Organic liquids	Any organic liquids
Aqueous waste with:	>100 mg/l strongly complexed heavy metals, or >100 mg/l total cyanide (as CN), or >1% non-miscible organic content, or > 5% total organic content
Solid waste which:	is hydrophobic, or is in a massive, non-leachable, form or contains > 100 mg/kg total cyanide

[5] Types of hazardous chemical wastes that are permitted to be disposed at polygons for household solid waste in Armenia are listed in the Annex 1 of the Sanitary Norms and Rules N 2.1.7.001-09.

Generic waste type	Specific conditions
Any waste containing:	PCBs, PCTs PBBs, PCNs PAH Organometallic compounds
Any waste which:	is explosive is oxidising is reactive to water or air is flammable (capable of burning at 40^0C or less) has a flashpoint < 55^0C

8.6 Loading rates

The ratio of hazardous waste to MSW and non-hazardous solid waste must be controlled for the following reasons:

- To ensure that there is sufficient attenuation capacity to treat the hazardous components in the waste;
- To ensure that excessive leachate is not generated, e.g. that no leachate is generated in the case of sites without leachate treatment systems; and
- To ensure that the waste mass remains physically stable.

8.6.1 Physical Stability

The impact of co-disposal of hazardous wastes on the physical stability of the waste will be site specific and depend on the site's geometry, how it is operated and how the hazardous wastes are deposited as well as the nature of the wastes. In general, for 'below ground' sites (infilled valleys, quarries or other excavations) there should be minimal problems if the hazardous wastes are deposited into trenches excavated into MSW which has already been deposited and compacted. In the case of 'above ground' sites, a competent civil engineer should be employed to advise in specific cases.

Care is also required, for both types of site, if the waste is deposited at the active tipping face. For guidance, work in the UK has demonstrated that 10% is a practical upper limit for the disposal of dewatered sewage sludge.

8.6.2 Leachate Generation

As discussed previously, the co-disposal of aqueous wastes and sludges will increase the input of water to the landfill and, hence consideration will need to be given to the impact on leachate generation. A water balance calculation will need to be undertaken for the particular parts of the site into which aqueous or sludge wastes are to be deposited to ensure that the rate of leachate generation does not exceed the disposal capacity of the leachate treatment system. In the case of sites without leachate treatment facilities, the water balance calculation must be used to determine the maximum inputs of hazardous waste to ensure that leachate is not generated.

A typical water balance equation which may be used for determining the amount of leachate generation is as follows:

$$L = ER + LIW - aW$$

where

L = volume of leachate generated

ER = effective rainfall (for the given period)

LIW = volume of water from liquid industrial wastes

a = unit absorptive capacity of the waste

W = weight of absorptive waste (deposited in given period)

Note: The value of ER must take into account rainfall on active (operational) areas of the site and infiltration through any restored areas.

8.6.3 Chemical Attenuation

The principle of co-disposal is that the landfill acts as a bioreactor and it is therefore important that the loading rate of hazardous wastes does not exceed the capacity of the methanogenic degradation processes within the MSW to treat the hazardous materials.

A lot of research into co-disposal has been undertaken in the United Kingdom from which guidelines have been developed for the maximum quantities of specific types of hazardous waste which can be deposited with a unit mass of MSW in order to ensure the capacity for treatment is not exceeded. These quantities, or 'loading rates', are usually expressed as an amount of hazardous waste per tonne of MSW.

8.6.4 Acidic and Alkaline Wastes

Concentrated acidic and alkali wastes are highly corrosive and should not be directly deposited in landfill. Concentrated acids, in particular, may have the potential to produce toxic gases and may cause fires due to exothermic reactions with other components in the waste. Concentrated acidic and alkali wastes should be neutralised first.

Thus, industry should be encouraged, as a minimum, to install neutralisation and precipitation treatment processes for acid and alkali wastes. Filtration and filtrate treatment for wastewater discharge should also be included. The treated sludge or filter cake may be disposed of at landfill.

Nevertheless, household and similar wastes have a significant capacity to neutralise acids and this capacity is normally maintained until degradation of the waste is almost completed. Dilute acid and alkali wastes have successfully been deposited in landfills in the UK. The technique is generally to excavate a trench in mature refuse (one to five years after deposit), fill the trench with tyres incorporating a pipe through which to inject the waste and then recover the trench with MSW. The liquid waste can then be injected into the covered trench.

When for technical reasons, landfill is the best or only practicable option, the acid should, as a minimum, be diluted prior to deposit.

The criteria discussed in Table 7 must be considered when planning to dispose of acidic or alkaline waste in landfill and, during landfilling of such wastes, operational controls should be introduced to monitor for any adverse effects.

Table 7: Criteria for landfilling of acid and alkali wastes

Criteria	
pH	Leachate migrating from the area of the landfill in which the waste is deposited must remain neutral or slightly alkaline.
Absorptive capacity	The quantity of liquid acid or alkali waste must not exceed the absorptive capacity of the landfill (see Section 5.2).
Heavy metal mobilisation	Acidic waste can dissolve heavy metals present in other wastes. These may be attenuated by absorption, adsorption, neutralisation and precipitation as the leachate moves through the landfill. Care must be taken to ensure that this capability is not exceeded.
Microbial Toxicity	Acids and alkalis may have a local toxic effect on the microbiological organisms in the landfill although recovery is usually rapid.
Generation of ToxicGas	Acids may react with certain chemical constituents in landfills (sulphides for example) to give rise to toxic gases. Monitoring should be taken during and after injection of acidic wastes.

Maximum concentrations and loading rates for the co-disposal of acidic wastes with MSW are recommended below.

Table 8: Maximum concentrations and loading rates for acid wastes

Waste type	Maximum concentration	Maximum initial loading rate
Oxidising acids (eg Cr^{VI}, HNO_3)[1]	5%	2 kg / tonne
Non-oxidising acids (eg HCl, H_2SO_4)	20%	5- 10 kg / tonne
Mixed acids (including oxidising acids)	2%	1 kg /tonne
Mixed acids (non-oxidising)	5%	2 kg / tonne

Note (1): Chromic acids should be neutralised to > pH 4

In the above table, the initial loading rates (expressed as kg of pure acid per tonne of MSW in the area in which the acids are being deposited) are based on UK experience but have been reduced by 50% as a safety margin to allow for the different climatic conditions (potentially lower temperatures slowing chemical and biochemical reactions).

For non-oxidising acids a key criteria will be the potential for solubilisation of heavy metals, HCl is more efficient than H_2SO_4 in this respect (hence the range of initial loading rates).

If monitoring within the site demonstrates that the criteria given in Table 8 are being met easily, then loading rates could be cautiously increased.

After deposit, any heavy metals present in the acidic waste being deposited will be precipitated. This may reduce the absorptive capacity of the waste around the trench due to a "blinding" effect. In an open trench this is easy to monitor but care should be taken when injecting into covered trenches.

Zinc and nickel are typically the first to appear in leachate and may be monitored as good indicators of the level of solubilisation. For very weak non-oxidising acids (<1%), the loading rates are likely to be determined by the capability of the site to accept liquid.

8.6.4.1 Cyanide Bearing Wastes

Industrial hazardous wastes may contain various forms of inorganic or organic cyanides. It is the waste's ability to form free cyanides in the landfill environment which is important when determining acceptable loading rates.

In general terms, it is recommended that only small quantities of cyanide bearing waste should be co-disposed and that they should be deposited at a loading rate of no more than 0.5 g of free cyanide per tonne of refuse.

Under acidic conditions cyanide wastes will give rise to the generation of hydrogen cyanide. As landfill is likely to be slightly acidic during the early aerobic decomposition phase, cyanide wastes should be deposited into mature refuse, in segregated areas of the landfill site, where the pH will not fall below 5 thereby minimising the generation of hydrogen cyanide.

Complexed cyanide wastes, such as contaminated soils, should be deposited at loading rates which take account of the concentration of free cyanide and any other contaminants which are likely to be present. ‘Spent oxide’ from gas works waste, for example, typically contains 10 - 50 mg/kg of free cyanide.

8.6.4.2 Heavy Metal Wastes

Heavy metals have considerable potential for environmental impact. Many hazardous industrial wastes often contain several different heavy metals commonly including iron, cadmium, chromium, copper, lead, nickel and zinc.

Typical wastes containing heavy metals include hydroxide sludges, ashes, slags and some paint pigment wastes. Such wastes generally contain heavy metals in a water insoluble form although waste acids commonly contain dissolved heavy metals. It is recommended that wastes containing heavy metals that may become soluble in dilute acidic conditions are stabilised prior to landfill,

particularly if large quantities are to be deposited. However, it is acceptable for smaller quantities to be disposed of by co-disposal without stabilisation.

The loading rates for heavy metal bearing wastes will depend on their leachability potential and on the capacity of the landfill for sorption/desorption and precipitation. Another factor with respect to co-disposal will be the existing levels of heavy metals in the MSW itself and hence already present in the leachate.

As a general principle, co-disposal of heavy metal bearing wastes should not be carried out if it is likely to increase their concentrations beyond those observed in leachate derived from fresh refuse.

As with acid and alkali disposal, it is better to deposit heavy metal wastes into MSW which is more than 1 year old. This is because the initial phase of decomposition of organic matter in the landfill is aerobic and tends to result in a slightly acidic leachate. If it is difficult to guarantee the age of the waste in any particular part of the landfill, then it is recommended that, where practicable, co-disposal of heavy metal bearing wastes should be undertaken well away from the perimeter of the landfill.

UK experience indicates that an initial loading rate of up to 100 g of soluble chromium, copper, lead or zinc per tonne of mature household waste is unlikely to produce a significant change in leachate concentrations more than 3 metres distance from the heavy metal waste. Monitoring should be undertaken within the site around the area where heavy metal bearing wastes are deposited to check that concentrations of heavy metals in the leachate are not being elevated.

Experience has shown that Nickel is poorly attenuated, other than by dilution and dispersion, and should be avoided other than in very low concentrations.

The co-disposal of heavy metal wastes may inhibit microbial activity within the waste, although resistant populations can, given time, be re-established. It is therefore preferable to monitor microbiological activity at co-disposal sites receiving heavy metal bearing wastes to assess any such impacts.

8.6.4.3 Antimony, Arsenic and Selenium Bearing Wastes

In general, similar criteria as for the heavy metals described above apply for these wastes although it is recommended that significantly lower initial loading rates are permitted (1g per tonne). Rigorous monitoring should be undertaken to ensure that the concentration of arsenic does not exceed 10 mg/litre in leachate away from the area of deposit. Wastes containing soluble arsenic compounds should be pre-treated to render them insoluble.

Generally, wastes should only be accepted if they contain less than 1**%** by weight of arsenic although isolated small quantities of concentrated arsenical waste arisings, containing less than 0.5 kg of total arsenic, may usually be co-disposed without pre-treatment. Such wastes should, however, be covered immediately by at least 2m of refuse and, except for arsenic sulphides, should where practicable be mixed with lime. In a landfill environment is possible for nascent hydrogen to be produced, which can lead to the generation of arsine gas, care must be taken to avoid this when disposing of arsenical wastes.

Selenium and antimony bearing wastes tend to behave in a similar manner and may be managed in a similar manner with similar criteria. As they do not form stable hydrides, there is less likelihood that they will present a problem.

8.6.4.4 Mercury Bearing Wastes

All mercury compounds have the potential to accumulate in human/ animal tissue and it should be borne in mind that organic, and particularly alkyl, mercury compounds are the most toxic.

Where the concentration makes it feasible, non-organic mercury should be recovered from mercury bearing wastes. If recovery is not practicable, mercury bearing wastes should be treated to stabilise them and render the mercury insoluble prior to landfill. The following arrangements are suggested:

- Loading rates for co-disposal of mercury wastes should be set to prevent elevated concentrations of mercury occurring in leachate and consideration should also be given to the possibility of mercury vapour being released.
- It is recommended that the disposal of significant quantities of mercury-bearing wastes should be restricted to sites where there is little or no leachate migration and where there is a high level of operational control.
- Mercury wastes containing more than 20 mg/kg inorganic or elemental mercury or more than 2 mg/kg organic mercury should not be landfilled without prior stabilisation.
- As a general principle, the loading rate for mercury bearing wastes should not exceed twice the average concentration of 2 g/tonne found in household and similar waste. Individual deposits of solid waste containing more than 1 kg of mercury are not permitted, unless distributed through large areas of uncontaminated refuse.

8.6.4.5 Tannery Sludges

Tannery sludges may arise in sludge form or as filter cake. Sludges typically have a solids content of approximately 2% and contain up to 3.5% of Cr^{III} in dry solid form. The recommended initial loading rate should not exceed 1 tonne of sludge per 15 tonne of MSW.

The loading rate for the co-disposal of tannery sludges depends both on the water content of the waste and the chromium content. For a typical sludge solids content of 2% the loading rate should not exceed 65 kg per tonne of refuse. De-watering of the sludge prior to landfill is preferable to minimise impact upon the water balance, the loading rate of the waste being adjusted accordingly.

Whilst leaching of Cr^{III} is generally slow, monitoring for the presence of chromium in leachate is advisable.

8.6.4.6 Oily Wastes

Typically oily wastes include free oils, industrial oil-water emulsions and oily sludges/mousse. The latter wastes are normally semi-solid material such as that derived from tank cleaning activities. Attenuation of oils in landfills is largely through sorption by solid waste, subsequent degradation rates are extremely slow.

Oils should, as far as practicable be recovered for re-use. Oily wastes should only be landfilled when other means of disposal are not practicable. It is recognised, however, that landfill may be necessary for oil removed from beaches after an oil spill at sea.

Some oils cannot be recovered or utilised as low grade fuels because they have become contaminated with unacceptable materials. Loading rates must take into account the exact nature of such contaminants, in addition to the oils.

UK experience has shown that the concentration of mineral oils found in leachate from normal household waste is typically 10 mg/litre. Where oils are deposited at loading rates of not more than 2.5 kg of oil per tonne of well compacted refuse, the concentration of oil in the leachate is unlikely to exceed 10 mg/litre after passage through a few metres of household waste. An initial loading rate of 40 kg of emulsion (or 0.4 kg of oil content) is recommended for oil/water emulsions.

8.6.4.7 Paint Wastes

Where practicable, waste paint and resinous materials should be incinerated at a high-temperature in a plant equipped with an appropriate and approved gas-cleaning system or, alternatively, they should be blended with other high calorific value wastes to produce a waste derived fuel for use in an approved cement kiln.

Where this is not practicable, paint waste and resinous material may be disposed of in an approved landfill site. The waste should preferably be transported in 225 litre steel drums which should have no more than 50% of their volume taken up by liquid paint or resin. The drums must be sealed during transportation to the landfill site.

The drums should be deposited upright at the toe of the tipping face and have their lids removed. The drums should then be filled with and buried by sand, or any other inert fine-grained material, and then covered with further waste deposits as the tipping face is advanced progressively over the drums.

8.6.4.8 Pesticide Wastes

Concentrated pesticide wastes are unsuitable for landfill disposal and should be blended with other wastes and then disposed by high temperature incineration either at cement kilns or dedicated hazardous waste incinerators. Wastes containing low concentrations of pesticides, e.g. tank washings, may be acceptable for co-disposal although such practices should be closely monitored.

It is recommended that loading rates should not exceed maximum concentrations of 5 g/m^3 or 10 mg/kg of pesticide active ingredient in the waste after deposition. These wastes should be deposited only in trenches excavated in mature MSW. In the case of solid wastes, trenches must be immediately back-filled with MSW. Trenches used for liquid wastes may be left open until an acceptable loading rate has been achieved provided that the pesticide waste is being readily absorbed.

8.6.4.9 Phenols and Phenolic Wastes

Phenolic compounds such as phenol, cresol and xylenol are moderately soluble in water and are attenuated by both aerobic and anaerobic degradation, following sorption in co-disposal landfills. However, the rate of attenuation is slow and long residence times in the landfill are required and good contact between the waste and leachate is necessary.

It is therefore recommended that phenol bearing wastes are only co-disposed in landfills on low permeability strata. To maintain the contact between the phenolic waste and the organic fractions of the MSW, and also to delay leaching, the use of low permeability intermediate cover material and small discrete cells is recommended. The ingress of water should also be minimised.

Leachate in the areas surrounding the deposited waste should be monitored and kept within the normal range of total phenol concentrations (1 to 10 mg/litre). The initial loading rate for phenolic wastes should not exceed 2 kg of total phenols per tonne of refuse.

8.6.4.10 Laboratory Chemicals

Small quantities of laboratory chemicals from schools, colleges, hospitals, research and similar organisations may be disposed at landfill.

These wastes should be deposited in a 1m deep hole excavated into the MSW immediately in front of the tipping face. The chemicals should remain in their primary packaging or containers and a slurry of one part cement and six parts sand should be poured into the hole on top of the containers to a minimum depth of 250 mm above the containers. Further deposits of MSW should then be made allowing the tipping face to advance progressively over the chemicals.

8.7 Disposal Operations

The recommendations and guidance for the operation of land disposal facilities outlined in the previous sections are generally applicable to all types of landfill operation including co-disposal landfill sites. A number of additional considerations are required for the operation of co-disposal sites and these are discussed below.

8.7.1 Waste Acceptance Procedures and Documentation

As indicated in Section 7, waste should not be accepted at any waste management facility without prior knowledge of its nature and composition and having determined its acceptability. This is even more important at co-disposal facilities where there needs to be strict control not only on the types of hazardous waste accepted but also on the volumes of such wastes relative to the inputs

of MSW and similar non-hazardous wastes in order to ensure that loading rates are not exceeded and leachate generation is kept within the design limits.

It is essential that the operator of the landfill site assesses the proposed rate of industrial/hazardous waste input relative to the inputs of MSW and other wastes, to ensure that maximum loading rates will not be exceeded, prior to signing a contract to accept hazardous wastes from any particular waste generator.

The operator of the site must retain technically competent staff who can make the necessary assessment of the suitability of proposed inputs of hazardous waste and who are given the authority for making such decisions. In some cases, and particularly for the initial inputs of waste from any particular source, it may be necessary to sample and analyse the waste to determine its acceptability and decide on appropriate loading limits. Again, the type of analyses required must be determined by a technically competent person based on knowledge about the source and nature of the waste and the analyses should be performed by a suitably accredited laboratory.

In the case of regular deliveries of a waste from a standard production process, it will not be necessary to analyse every load although further analyses should be undertaken periodically to determine if there are any changes in the basic characteristics of the waste or in the concentrations of particular components. The frequency of re-testing will depend on the variability of the process generating the waste. The results of all analyses for a particular waste type should be provided to the landfill site operator so that he may check these against documents accompanying future deliveries of the same type of waste.

8.7.2 Waste Reception

All waste delivery vehicles must stop at the gatehouse, or other designated point, on entering the landfill. The site operator must inspect the documents accompanying the waste to ensure that the description matches that pre-notified and must inspect the vehicle contents to verify, as far as practical, that the waste corresponds with the paperwork.

In the case of any doubt about the correctness of the paperwork or the waste itself the vehicle should be moved to a quarantine area and should not be allowed to discharge its load until further investigations are completed. If there is any doubt that the waste matches the description on the paperwork, samples of the waste should be taken and analysed.

If the waste being delivered is acceptable, the vehicle should be directed to the appropriate area of the site, according to the waste type, for discharging. Clear instructions should be given to the driver of the vehicle as to which area of the site he should take the waste together with the route to be taken. For sites with a number of active operational areas or areas for different types of hazardous waste, there should be clear signs indicating the routes/areas to be used for different waste types.

If a vehicle arrives with incorrect documentation or if it is shown that the waste does not match the paperwork, the vehicle should be detained in the quarantine area and the regulatory authorities (SOEPC and Sanitary service) should be contacted as soon as possible (by telephone if possible) and their advice sought as to what further action to take. In such cases, a full record of all actions taken, the results of all checks and analyses carried out and a note of all discussions with the regulatory authorities should be kept and made available to the regulatory authorities as required.

8.7.3 Waste Deposition/Discharging

8.7.3.1 Location

The current practice for the disposal of different types of waste at the same site varies between landfills. At some sites MSW and industrial waste appear to be deposited together whereas at other sites, separate areas appear to be used. As discussed previously, the principle of co-disposal relies on biochemical reactions and the hazardous/industrial wastes should therefore be deposited into the most biodegradable wastes at a landfill, which will usually be MSW.

The hazardous wastes must be deposited a sufficient distance from the base and sides of the site to ensure that there is adequate attenuation of the hazardous components within the waste so

that there is no migration of these compounds off-site, in the case of an unlined landfill site, and no risk of damage to liner in the case of a lined site. Similarly, the hazardous wastes should be deposited at a sufficient distance from the top of the landfill site so that they do not interfere with site capping/restoration.

Although the specific distances will be site specific depending on the waste inputs involved, minimum safe distances are likely to be as follows:

- At least 4 m of MSW or similar biodegradable waste beneath the point at which the hazardous waste is deposited;
- A 10 m lateral distance between the point at which the hazardous waste is deposited and the edge of the site; and
- No hazardous waste to be deposited within 2 m of the capping or restoration layers.

8.7.3.2 Method of Deposition

The method of depositing the hazardous wastes will vary depending on the type and physical form of the waste. In all cases the objective is to achieve a good distribution and intimate mixing of the hazardous waste with the MSW/ non-hazardous commercial wastes to ensure the required attenuation of the hazardous properties. In addition, it is important to avoid any operational problems which might arise due to the physical characteristics of specific hazardous wastes.

Injection of Liquids into Covered Trenches

This technique is generally applicable to most liquid wastes. A trench is excavated in mature refuse (one to five years after deposit), this is filled with tyres and a perforated pipe is installed before the trench is covered with MSW. Liquid wastes can then be injected into the covered trench via the pipe. Typically, the trenches will be 1-2 m wide and approximately 3m deep with their length depending on the rate of liquid input.

Care must be taken when oil/water emulsions are injected into trenches because ‘blinding’ of the sides of the trench can occur. Monitoring should therefore be undertaken to observe how quickly the injected waste is dissipated from the point of injection. This may be achieved by monitoring the rate at which the liquid level in the trench falls following the injection of each load of liquid waste. When the level drops only very slowly, use of the particular trench will need to cease and another injection trench should be used.

Similar problems of blinding may occur, and may be even more acute, when ‘wet’ sludges are injected into such trenches. As an alternative, sludges may be deposited into trenches excavated into waste immediately in front of the working face of the landfill.

Solids/Sludges

Solid hazardous wastes and ‘thick’ sludges are generally deposited at the base of the tipping face and immediately covered in further deposits of municipal and non-hazardous commercial wastes. Spreading the hazardous waste in a thin layer helps to distribute the waste evenly through the landfill ensuring intimate contact with the MSW and avoiding the creation of hydraulic barriers within the fill. It is particularly important to avoid the creation of thick layers of low permeability sludges as these may create perched leachate levels within the waste.

Laboratory Chemicals

As discussed previously, small quantities of laboratory chemicals may be deposited into a 1m deep hole excavated immediately in front of the tipping face. This technique may also be used for other small ‘one-off’ consignments of hazardous wastes. In the case of laboratory chemicals, these should remain in their primary packaging or containers and slurry of one part cement and six parts sand should be poured on top of the containers to a minimum depth of 250 mm.

Drummed waste

As a general rule, drums of waste should not be disposed of to landfill. Limited quantities of solid waste or sludges in drums may be co-disposed, however, providing that the drums are dispersed

so as to avoid local concentrations. The drums should be deposited upright at the toe of the tipping face at a minimum spacing of 0.5 m between adjacent drums. The lids should be removed from the drums and the drums filled with and buried by sand or any other inert fine-grained material. The drums should then be covered with MSW as further deposits are made at the tipping face.

8.7.3.3 Precautions and Health & Safety Measures

As at any landfill site, safe methods of working should be established and clear instructions given to the staff to ensure the health and safety of all people working on or visiting the site. The various safety precautions and methods of operation should be enshrined in a Working Plan which should be followed at all times. There should be adequate management supervision to enforce the methods of working and use of safety precautions.

For co-disposal sites, the methods of operation must take particular account of any potential hazards associated with the handling and deposit of specific wastes. In particular, precautions should be taken to prevent the following:

- Direct contact of site staff or machinery with any hazardous wastes;
- Accidents during the discharge of wastes into trenches or at the tipping face; and
- Mixing of incompatible waste types.

The Working Plan should therefore specify the following:

- Routes to be taken across the site by waste delivery vehicles;
- Marshalling and supervision arrangements for the waste discharge areas;
- Physical safeguards such as fencing, bunds and warning signs;
- Waste deposition procedures; and
- Emergency and health and safety equipment and procedures.

8.8 Management of Co-disposal Landfill Sites

All of the management issues discussed in the previous sections are also applicable to co-disposal landfill sites and reference should be made to this document for general guidance on the management of land disposal facilities. The following sections emphasise those management issues which are of particular importance at co-disposal sites.

8.8.1 Documentation

The documentation of operations at a co-disposal site, including the Working Plan and Emergency Procedures, will inevitably need to be more complex than those for a site accepting just MSW and non-hazardous commercial (enterprise) waste because of the wider range of waste types and potential hazards involved. The procedures for inspection of wastes, for example, will need to include visual checking but will also need to include sampling and chemical analysis. The requirements for Operating Records should, similarly, give specific information about the locations of the areas used for different types of hazardous wastes together with the dates of operation and quantities deposited.

8.8.2 Planning Operations

It is important to ensure loading rates for specific types of hazardous waste are not be exceeded by comparison of input quantities of hazardous wastes against MSW/non-hazardous enterprise waste inputs. The rate of leachate generation should be estimated to ensure that this will not exceed the design criterion. These parameters and information on the types of waste should be carefully checked before a contract is signed to accept a particular type of waste from a waste generator (enterprise).

8.8.3 Supervision of Operations

Experience elsewhere has demonstrated that unless sufficient resources are committed to properly selecting, designing, operating and monitoring co-disposal landfill sites the environmental and financial consequences can be very significant.

The key issues for monitoring of operations at co-disposal sites are:

- Absolutely no scavenging - because of the potential dangers associated with hazardous wastes/ trenches;
- Incoming wastes are monitored;
- Wastes should be deposited in the correct area so that incompatible wastes are segregated at all times;
- Special procedures for specific wastes are followed (e.g. immediate covering); and
- Health and Safety procedures are followed.

8.8.3.1 Monitoring of Incoming Wastes

Inspection and analysis of incoming wastes is necessary to verify the waste producer's description of the waste, to ensure compliance with disposal license requirements, to ensure the health and safety of personnel handling the waste, and to confirm that the disposal method is suitable. Although detailed analysis is not normally necessary, regular monitoring of wastes should be carried out and if necessary samples should be sent for more detailed analysis to an analytical laboratory. Common on-site tests include:

- Appearance;
- Odour;
- pH;
- Flammability; and
- Specific gravity.

The results of this monitoring of incoming wastes can be used to calculate the loading rates described in Section 8.6 above.

8.8.3.2 Manning Levels

The required manning level for a co-disposal site will depend on the scale of the operation and the range of different wastes accepted but the following may be regarded as key personnel:

Site Manager

A landfill site accepting significant quantities of industrial wastes must have a permanent site manager responsible for ensuring that all waste disposal operations are carried out in accordance with the disposal plan and in compliance with regulations. The Site Manager will be the key person on site, making decisions on whether to accept wastes, loading rates, procedures and actions if unplanned events occur. Site Managers should therefore have considerable experience in all aspects of landfill operations.

Foreman / Chargehand

In addition to the Site Manager, a Site Foreman / Chargehand might be required, responsible for running the site in accordance with the Operations Manual.

Tipping Face Supervisor

A Tipping Face Supervisor will be required where the volume of incoming traffic is high. The Tipping Face Supervisor will be responsible for directing vehicles to the appropriate operational area and ensuring that loads are discharged in a satisfactory manner.

Weighbridge Operator / Waste Reception Supervisor

A record of incoming loads is essential. The Weighbridge Operator/Waste Reception Supervisor will be responsible for checking the incoming wastes and recording waste inputs to the site.

Machine Operators

The number of Machine Operators required will depend on the quantity of equipment in use on site.

Site Chemist

A Site Chemist might be required for large sites and/or sites taking a range of different wastes.

All personnel should be trained in the operational procedures for which they are responsible and in Health and Safety procedures.

8.8.4 Environmental Monitoring

Environmental monitoring at landfill sites is required to ensure that the operations do not cause an adverse impact upon the environment and that the site is operating within the constraints imposed by the operating permit or licence.

Environmental monitoring is particularly essential at co-disposal sites. The additional objective of monitoring at co-disposal sites is to build up a picture of the general state of the landfill and the effect of the wastes deposited. This is indicated by monitoring of the distribution of key species in leachate within the site and physical properties such as temperature and water levels.

Initially the wastes deposited should be limited to household and other bioreactive general waste to allow the monitoring network to become established and to ensure sufficient depth of sorptive waste is available before co-disposal is started. The impact of the initial deposits of industrial waste can therefore be monitored, which provides information on appropriate loading rates for the site. Monitoring should continue throughout the lifetime of the site, and the loading rates adjusted as required on the basis of the results of the monitoring.

The following parameters should be monitored:

- Leachate;
- Temperature and water levels within the waste;
- Groundwater quality;
- Effluent discharge quality;
- Air emissions (dust); and
- Air emissions (potential hazardous constituents e.g. asbestos).

8.8.4.1 Leachate

Leachate at co-disposal sites should be monitored regularly to ensure that attenuation mechanisms are not being overloaded and that attenuation is taking place as predicted.

More specifically, leachate monitoring at a co-disposal site should:

- Indicate leachate quality changes over time;
- Indicate water level changes over time;
- Provide data to assist the control of on-site processes (e.g. leachate treatment), and
- Demonstrate compliance with various site licence conditions.

The selection of the exact parameters that should be monitored in the leachate, and the locations of monitoring points, will depend on the type of industrial wastes disposed and on the disposal methods/locations. The parameters that should be measured include TOC, pH, COD, BOD, ammonium concentration, temperature and selected compounds / heavy metals.

8.8.4.2 Temperature and Water Levels within the Waste

Temperature and water levels within the waste are important factors in relation to monitoring and control of the attenuation/reaction processes in the waste. Information on water levels also assists in the monitoring of potential 'blinding' effects in the waste.

8.8.4.3 Groundwater Monitoring

Groundwater quality should be monitored quarterly. Monitoring may be more frequent in areas that have high groundwater flow rate and/or are located near particularly sensitive receivers. Similarly, monitoring could be less frequent if groundwater flow was particularly low and/or the site is located in a particularly non-sensitive area environmentally.

Monitoring parameters should be selected based on the chemical composition of the waste being deposited and the likelihood that these constituents may migrate to groundwater. For co-disposal sites, parameters should include heavy metals, depending on the types of waste disposed.

8.8.4.4 Surface Water and Effluent Monitoring

Surface water grab samples should be taken to determine water quality from run-off water from the site. This enables decisions to be taken as to whether the run-off water needs to be treated or may be discharged untreated. Each batch of effluent discharged should be tested for compliance with performance standards agreed with the relevant regulatory authority prior to discharge.

8.8.5 Air Sampling

Periodic sampling of air quality may be required if the site is handling or disposing of volatile materials or dusty or powdered materials (particularly if these are hazardous e.g. asbestos). Parameters measured may include:

- Total Suspended Particulate (TSP) for one hour, eight hour or twenty four hour period;
- Heavy metal concentrations; and
- Volatile Organic Compounds (VOCs).

Sampling methods would depend upon the parameter being measured.

8.8.6 Health and safety

A major responsibility when operating a landfill site which accepts hazardous wastes is the health and safety of site and delivery personnel. Many hazards which exist at landfill sites are common to other areas of employment (e.g. hazards from use of mobile plant / machinery). The personnel on landfill sites should be trained in dealing with both the normal hazards and those which are unique to landfill operations.

Most hazards can be minimised by adopting appropriate working practices and training personnel in these practices. Training records should always be kept.

The key elements that should be taken into account in the health and safety procedures of a landfill site include:

- Safe working procedures (clear instructions given and enforced);
- Monitoring of working practices;
- Training in health and safety procedures;
- First aid training;
- Provision of protective clothing and equipment; and
- Specific health and safety issues related to hazardous wastes.

Hazardous and toxic wastes received must be identified and their associated hazards documented. Consideration should be given to preparation of Material Safety Data Sheets (MSDSs) for regularly received hazardous wastes and special documented procedures for their handling. Exposure must be assessed and necessary personnel protective equipment supplied,

maintained, **and** used. Facilities receiving particularly hazardous substances for disposal should consider the need for monitoring of health of employees and monitoring personnel exposure.

Mutually incompatible wastes must be kept segregated. Figure 6 (in Section 8.5 above) shows potential incompatibilities and possible consequences.

8.8.7 Emergency Response

Potential emergencies must be identified and procedures developed for their control and management. Staff must be periodically trained in the application of emergency response procedures with practical drills. Procedures must be documented and copies supplied to employees. Records should be kept of staff training for emergency response (as well as practice drills). Practice drills should involve the emergency services where practicable.

The types of emergencies for which response procedures should be developed include:

- Uncontrolled release (to air);
- Uncontrolled release (to water or land);
- Uncontrolled reaction between wastes; and
- Fire.

9 Health & Safety

There are inherent hazards associated with the operation of any waste disposal site, let alone one operated in line with international best practice. Historically, accidents at landfills have resulted from the temporary nature of much of the site's infrastructure – e.g. site roads, sharp bends and steep gradients - and because vehicles and machinery are often operated in confined areas and in close proximity to each other. Reversing vehicles are a significant problem, particularly where staff is required to cross the working area on foot or direct vehicles at the landfill face.

In such circumstances, accidents can be minimized by the implementation of safety and training programmes and by effective site management. These programmes should include the following:

- Identification of potential sources of risk;
- Assessment of the degree of risk from these sources;
- Determination of procedures for addressing the risks;
- Development of procedures to minimise accident/risks when they occur; and
- On-going monitoring to ensure proper implementation of safe working procedures.

In the light of these provisions, the operator should ensure the safety, health and welfare at work of all persons employed on the landfill. This duty should include the following priorities:

- The landfill should be constructed and maintained in a safe condition;
- A safe means of access to the site for staff and vehicles should be provided;
- Plant and machinery should be maintained in a safe condition;
- Risks should be appraised and safe systems of work planned, organised and performed;
- Suitable safety information, instruction, training and supervision should be provided;
- Suitable protective clothing and equipment should be provided and maintained;
- Emergency plans should be prepared and revised as necessary;
- That the presence of any article or substance on the site must not present unacceptable risks to health; and
- Adequate welfare facilities for staff must be provided and maintained.

This section sets out the basic requirements of the effective control of health and safety at landfill sites. It constitutes general guidance which should be considered and enacted by all site operators.

9.1.1 Personnel

One or more persons must be formally designated for site safety issues. Individuals so designated should understand the statutory requirements, be able to act as competent persons under the legislation, and ensure the continued maintenance of a safe system of work. The latter tasks should include matters relating to training and supervision. They should be responsible for the identification of hazards and designated managers should transmit such information by verbal or written instructions to the workforce, contractors, site users and site visitors. Designated persons should undertake regular site safety inspections, with written reports of inspections maintained at the site.

9.1.2 Training

Operators should provide suitable training and instruction to site employees, both full time and part time. The operator should also ensure that any contractor working on site is also informed of the hazards and the necessary precautions. There is also a responsibility for persons employing contractors to ensure that the latter are able to act as competent project supervisors in relation to the safety aspects of the relevant design and construction elements of their work. All site

personnel should be familiar with contingency procedures in the event of accident, injury, fire etc. The locations of emergency equipment should be identified during routine employee training. Phone numbers for local police, fire and ambulance services should be prominently displayed for use in the event of an emergency. Table 9 sets out the format of a possible emergency contact sheet.

9.1.3 Staffing Levels

All staff and users of the site should be effectively supervised. No site open to receive waste should be manned by one member of staff working on their own. Similarly no unloading of vehicles should occur in the absence of site staff or out of their immediate view.

9.1.4 Medical

Good personal hygiene is essential to workers on landfill sites and hence hot and cold washing facilities must be provided. All workers at landfill sites, including those employed temporarily by the operator, or by contractors working on the site, should have adequate protection against tetanus. This protection must be kept up to date, with boosters given at 10 yearly intervals. The onus should be on the employer to ensure that these injections have been received by employees and to require appropriate assurances from contractors working on the site. Workers have to pass mandatory preliminary and periodical medical examination in accordance with the existing requirements[6].

9.1.5 First Aid

A first aid box should be available on site in a clearly marked location. The contents of the box should be monitored for use, so that supplies are checked regularly by a named individual responsible for its upkeep. The operator should arrange for recognised occupational first aid training, with a minimum of one person with a first aid qualification normally present on site. All staff should be familiar with the first aid facilities available on site.

9.1.6 Personal Protection Equipment

High visibility clothing should be provided and worn by all site staff and visitors. Safety boots and/or wellingtons should be issued to all site workers. They should have steel toecaps and have a steel insert in the sole to resist injury from projections of glass, metal, or other items in the deposited wastes. Gloves should be issued as required. The type of glove should be puncture resistant and should be suitable for the relevant task, eg litter collection, vehicle fuelling, cold weather conditions. Safety helmets and eye protection should be available as necessary. Operatives at landfill sites work in all weather conditions and will need to be provided with suitable windproof wet weather clothing.

9.1.7 Landfill Gas

All site staff should be made aware of the possible hazards from landfill gas. Smoking on site should be forbidden except in designated areas. Buildings and other enclosed structures located at the landfill should be designed to prevent the accumulation of flammable gas within them. It is imperative that all cabins, other store rooms and voids such as those below weighbridges and cabins should be regularly monitored for the presence of flammable gas. The flammability, toxicity, and asphyxiate characteristics of landfill gas requires personnel involved in the monitoring, operation, construction or any other aspect of a gas management system to be adequately trained. A written safe system of work with rehearsal emergency procedures should be provided before work on landfill gas management system commences. Stringent safety measures should be incorporated into equipment for landfill gas collection, utilisation, flaring and

[6] Procedure set by Decision N1089-N (dated on 15.06.2004) of the Government of RA on “Approval of the procedures for mandatory preliminary (before accepting for employment) and periodical medical examination of a separate groups of population exposed to harmful and hazardous influence of industrial environment and working conditions; approval of lists of factors, nature of performed works, volume of examination, medical contraindications and approval of hygienic characterization of working conditions“.

venting. If “trigger values” for gas concentrations are exceeded in buildings, then emergency monitoring should be undertaken to identify the point of gas ingress and control measures implemented to prevent further ingress.

Ideally any indoor air testing, soil gas sampling, and ambient air testing are conducted simultaneously to determine if any elevated indoor air concentrations, for example, are from the sub-surface, indoor sources, or the background outdoor air. In terms of monitoring the indoor air for the presence of gas emissions, several technologies can be used which include obtaining grab samples, real-time and near-real-time sampling, and passive sampling. The most common methods for monitoring indoor air are through grab samples – particularly via the use of Summa Canisters. These are small airtight metal containers which fill with air at a fixed flow rate over a preset period of time with the use of a flow controller. Real time and near-time sampling uses analysers which can be used to collect multiple samples that locate problem structures, vapour migration routes into structures, and volatile sources inside the structures. Passive samplers are less commonly used for vapour intrusion assessments, and basically use an adsorbent to capture organic gas concentrations over a set period of time. Irrespective of the method used, the technology must be used to measure levels of contamination at health-based thresholds.

Health and safety issues should have particular priority where any site works involves the disturbance of filled areas.

Table 9: Possible format of an emergency response sheet

Name of Site:	**……..**		
Location:	……	Grid Ref:	……
Operator:	……	Phone: Fax:	…… ……
Safety Officer:	……	Phone: Fax:	…… ……
Licensing Authority:	……	Phone: Fax:	…… ……..
Doctor:	……		……
Ambulance:	……	Phone:	…….
Hospital:	……	Phone:	……..
Police:	……	Phone:	……
Fire Station	…….	Phone:	…….
Location Map: (showing site location)			
OTHER INFORMATION			

9.1.8 Site Infrastructure, Signs, and Barriers

Steep gradients and sharp curves on site access roads should be avoided. If this is not possible warning signs and crash barriers must be provided. Speed limits should be displayed and enforced by the site operator. Vehicles should not travel over unstable areas on a landfill surface, and neither should they travel with their vehicle bodies raised up or being lowered. Sites should be provided with adequate lighting to allow for safe and efficient operation at the tipping area at dawn and dusk in the winter period. Trenches and lagoons used for liquid or sludge disposal

should be fenced, or be clearly marked with poles and bunting and each trench should be labelled to indicate the type of wastes allowed to be deposited. When filled, trenches should be covered immediately. Hazard notices should be utilised on the site in relation to deep water, leachate lagoons or steep faces. Physical barriers should be in place to prevent unauthorised access to culverts and other confined spaces.

9.1.9 Hazardous Substances

The operator should ensure that exposure of persons at a landfill to hazardous substances, is minimised or, where exposure cannot be avoided, adequately controlled. Employees should be trained regarding:

- Potential risks;
- Associated preventative measures and precautions;
- Existence of occupational exposure limits;
- Actions to be taken;
- Hygiene requirements; and
- Personal protective equipment.

Landfills represent working environments where employees could be potentially exposed to a variety of different substances. Operators should assess the types of substances likely to be received at their sites and identify the risks they pose.

9.1.10 Electrical Hazards

The electricity distribution system should be inspected annually by a qualified electrician. Residual current breakers should be fitted to all power outlets. Electrical equipment located in areas where accumulations of flammable gas could occur should be selected, installed, and maintained in accordance with relevant safety requirements. Overhead power lines may cross the site. These should be either diverted or measures should be taken to ensure that the level of waste does not rise above a level agreed with the relevant authority. At no time should vehicles or equipment be able to get within arcing distance of any electrical cables. All power lines should be signposted by protective barriers. Any damage to these barriers should be dealt with immediately.

9.1.11 Scavenging

Scavenging is the separation and removal for re-use of items such as scrap metal. In the past, it provided a means by which materials were recovered and recycled. The practice is dangerous and interferes with the efficient operation of a landfill. Scavenging is perhaps the greatest single cause of accidents and fatalities at landfill sites, due to the partially obstructed view of drivers of vehicles when they are reversing. For these reasons, scavengers should be prohibited by an operator wishing to manage its site in line with international best practice.

10 Nuisances

10.1 Nuisance Control

A key item in the effective management and control of landfill operations is the control of nuisances. Unless an operator effectively addresses nuisance-related matters on a daily basis, a landfill may become detrimental to local amenity. Nuisances which may cause concerns include:

- Vehicle traffic;
- Litter;
- Odours;
- Noise;
- Birds;
- Vermin, insects and other pests;
- Fires; and
- Dust and mud.

These potential impacts should be addressed by clear operating procedures with a view to their minimisation. The following sections set out a range of actions available to mitigate the above nuisances.

10.1.1 Traffic Impacts

Heavy lorry traffic can give rise to nuisance, damage to road surfaces, and verges and routing problems. Traffic is inevitable at all landfills and can become a significant problem at sites served by minor roads. At existing sites only minor changes may be possible to mitigate the impact, but in certain circumstances even small alterations will significantly reduce the impact. Traffic impact is a major factor for consideration and any modernisation should include consideration of:

- Routing vehicles to and from the site via major roads wherever possible;
- Routing to avoid residential areas;
- Using one way routes to avoid traffic conflict in narrow roads;
- Carrying out road improvements;
- Limiting the number of vehicle movements;
- Restrictions on working hours;
- Limiting vehicle size; and
- Alternative means of transporting waste.

10.1.1.1 Litter Control

The negative visual impact from inadequate litter control at landfills can be a major cause of complaints and a significant nuisance to site neighbours. Litter control should therefore be a high priority. A range of abatement techniques is available, with their use depending on site specific factors such as the degree of shelter of active tipping areas, proximity of other land users and types of waste being deposited.

10.1.1.2 Site Management

On windy days the direction of tipping and compaction should be influenced by the need to ensure protection from the prevailing wind direction. At larger sites, an emergency tipping area should be provided, sited in a protected location. If conditions are exceptionally bad, the site should be closed until the wind has abated.
A daily patrol of the site's perimeter, access roadways and adjacent public roadways, should be undertaken. Larger sites may require full time litter pickers. If litter has escaped from a site, a priority should be the clearance of gardens of domestic properties, farmland where livestock are kept, and the public highway. Strict enforcement of the requirement that all vehicles be properly enclosed or covered should prevent litter on access roadways. Vehicle drivers should be issued

with warnings about inadequate covering and should be precluded from using the site if these are unheeded.

10.1.1.3 Site infrastructure

Movable screens or nets should be positioned near the working face to control wind blown litter. Screening bunds, fencing, and buffer zones enclosing the site's perimeter will provide protection for adjacent properties. All types of litter screens should regularly be cleaned of litter. Otherwise, effectiveness may be reduced and/or support structures may be damaged. Further measures for controlling litter include:

- Consideration of prevailing wind direction and strength when planning the filling direction and sequence;
- Provision of an emergency tipping area, for lightweight wastes such as paper, for use when winds are high;
- Strategically placed mobile screens close to the tipping area or on the nearest downwind crest;
- Temporary banks and bunds immediately adjacent to the tipping area;
- Permanent catch fences and netting to trap windblown litter;
- Full enclosure of the tipping area within a mobile litter net system; and
- Closure of the site to specific or all waste types may be appropriate when conditions are particularly adverse.

Restricting incoming vehicles to only those which are sheeted and secured will reduce litter problems on the highways. Another major source of litter along the highways around the site is waste retained in open bodied vehicles after they have tipped. Drivers should ensure that all waste has been removed from the vehicle before leaving the site.

10.2 Odour Control

Offensive odours at landfills can arise from:

- Previously deposited waste disturbed by digging activities;
- Malodorous wastes, such as industrial or agricultural wastes and sewage sludges;
- Leachate treatment systems;
- Stagnant leachate in lagoons or other holding containers; and
- Landfill gas.

Odours from landfills can be reduced by good site management. The principal means of minimising landfill odours include:

- Effective compaction;
- The provision of adequate cover;
- Rapid deposition of malodorous wastes, using covered trenches where necessary;
- Effective landfill gas collection and subsequent efficient combustion;
- Rapid burial of excavated wastes and the closure of such excavations; and
- Prevention of stored leachate becoming anaerobic.

10.3 Noise Control

Site personnel should be aware of the need to minimise noise and of the health hazards of exposure to excessive noise. Special attention should be given to fitting sound reduction equipment to power tools, machines and fixed plant. Speed limits should reduce noise of vehicles accessing the site. High quality road surfacing will have similar effects. In certain cases, bunds, vegetative screens and other noise barriers can dampen the ability for noise to travel. These features should be provided to ensure that adjacent properties are shielded from active

areas of the landfill development. However, they should be carefully sited, designed to fit in with the topography of the site and the surrounding landscape.

10.4 Vermin and Pest Control

The majority of waste disposal sites in the country have a problem with flies and vermin due to the large amount of food waste deposited at the site. If a site's management team moves towards the practice of modern landfilling, including the prompt emplacement, consolidation, and covering of wastes in well defined cells, then this should help prevent infestation by rodents and insects. For example, fly infestations commonly arise from waste which has been awaiting collection for some time. Thus, ideally, the time lapse from the initial collection of waste to final disposal should be kept to a minimum to reduce the risk of infestation. The risk of fly infestation can be reduced by the prompt burial of all biodegradable wastes. Pest control measures should be specified in the working plan and a log kept of measures taken so that compliance with regulations and quality management systems can be demonstrated.

Effective measures to deal with rodent infestation include:

- Effective site management involving well defined, tightly controlled, tipping areas and prompt capping of completed areas;
- Regular visits by pest control contractors or fully trained operatives; and
- Inspection and treatment of areas where rats live, for example, sewers, culverts, and drains.

Regular site inspection will indicate the prevalence of pests. When significant numbers are identified, an experienced pest control specialist should be employed to deal with the problem.

10.5 Bird Control

Scavenger birds such as starlings, crows, blackbirds, and gulls are most commonly associated with active landfills. The most consistently effective measure is the proper covering of all exposed waste as quickly as possible. There is a lot of food waste deposited to such sites, and thus birds are attracted to it in large numbers. They can be a nuisance, transfer pathogens, litter and scraps to neighbouring areas and also be a hazard to aircraft. Landfill operations should all aim to reduce the attractiveness of the deposited wastes to birds. This primarily involves decreasing the potential supply of food by:

- Frequent covering of wastes;
- Baling or bagging waste containing food sources and/or trench disposal; and
- Eliminating the acceptance of wastes that represent food sources for birds.

Many of the methods may have only a short term effect as the birds adapt to the environment in which they find the food. Varying the control techniques may prevent birds becoming accustomed to a single method. Examples include:

- Gas cannons to discourage birds from food scavenging;
- Visual deterrents including realistic models of the bird's natural predators;
- Distress calls of scavenger birds and any sound of its natural predators;
- Use of physical barriers such as nets around the working face; and
- The utilisation of birds of prey such as falcons.

10.6 Fires

Fires in landfills are difficult to extinguish. Proper landfill control methods and operational practices afford the best protection against the risk of fires. The most effective fire prevention programme combines "good housekeeping" with constant vigilance by site personnel. Fire prevention must start with advance identification of potentially hazardous areas and trouble spots.

Fires at any waste disposal site should be treated as a potential emergency and dealt with accordingly. Measures for fire prevention and control include:

- Training of employees in fire prevention and control;
- Prominent posting of emergency response contact numbers (fire service, police, ambulance and other agencies);
- Fire extinguishers and two-way radios on all mobile equipment;
- The provision of on-site water supply and, if necessary, water storage and portable water tanks; and
- The provision of fire fighting equipment in the site office.

An emergency tipping area should be set aside from the immediate working area where incoming loads of materials known to be on fire, or suspected of being so, can be deposited, inspected, and dealt with. Fires within the operational area are either surface fires or deep seated fires. The former usually occur in recently deposited, and as yet uncompacted, materials adjacent to the current working area, whilst the latter are found at depth in material deposited weeks or months earlier. A site's management team must develop a plan to deal with each type of fire and have a code of practice for their operatives stating exactly how to tackle any outbreak. Regardless of circumstances, no individual should ever tackle a landfill fire alone. The following guidance is given for surface and deep seated fires.

Surface Fires

In most cases the best way to tackle any fire is to smother it with large volumes of wet or damp soil/cover material, by working progressively inwards from the edges of the fire to slowly cover and compact the area and then allow it to cool. Such an operation can take some time especially is the fire is a large one and it may be necessary to have the fire brigade attend initially to wet the area and extinguish any flames. Once the area is wetted and cooled, the process of covering should go ahead as quickly as possible.

Deep Seated Fires

Deep seated landfill fires on the site should always be taken very seriously. The existence of a deep seated fire is a major problem, and often only detected by the presence of smoke emanating from some part of the site. In the majority of cases, deep seated fires will be beyond the reach of the equipment available on the site, and thus any attempt to dig them out with the inappropriate plant may exacerbate the situation by admitting air. In such cases, it is better to delineate the area concerned and surcharge the site with large volumes of clay like material. This minimises the number of outlets for gases to escape and reduces the influx of air to the area, thus containing the problem as far as is possible. Daily checks of the area are necessary and immediate remedial action must be taken before any significant fire breakthrough is noted.

If it becomes apparent during any outbreak that it will be necessary to isolate the area in order to stop the fire spreading further, this should be done by excavating deep trenches beyond the burning area and backfilling them immediately with clay material so as to create a cut-off barrier around the fire. No material should be burnt on or close to the boundaries of a landfill. On no account should litter pickers burn collected wastes on the site. Fires in landfills should be regarded as emergencies and dealt with immediately. Site personnel should notify the appropriate agencies and other emergency response contacts should smoke emissions from the filled material be observed.

10.7 Mud and Dust Control

Mud and dust generated by a landfill may be a major local concern, particularly where such materials pass off-site. The deposition of significant quantities of mud on the public highway is unacceptable and should warrant immediate attention and rectification. Mud control should be part of the routine site inspection program. Good quality temporary access roads to the working face, a well designed site access road, wheel cleaning equipment and, where necessary, mud collection and road sweeping all contribute to effective mud abatement.

Dust will be a particular problem during periods of dry weather, and from the tipping of dusty waste, particularly in the following areas:

- The drying out of site roads;
- Site preparation and restoration activities;
- Disposal of waste comprising fine particles; and
- Carriage of dust/mud onto the highway.

The site's management team are advised to affect the following dust suppression measures:

- Limiting vehicle speed;
- Regular mechanical sweeping of the highway and access roads;
- Spraying roads with water;
- Only accepting fine particulate waste in secure bags; and
- Seeding bare earth surfaces as quickly as possible after soil materials have been emplaced.

Mud (and waste) on the roads is one of the most common causes of public complaint regarding waste disposal sites. A site's management team are therefore recommended to provide adequate wheel cleaning facilities to ensure that mud is not carried off-site by vehicles. Wheel cleaning facilities should be installed at strategic places along the main site access road.

11 Environmental Monitoring

There are many potential environmental problems associated with the landfilling of waste. These problems include possible contamination of the groundwater and surface water regimes, the uncontrolled migration of landfill gas and the generation of odour, noise, dust and other nuisances. An environmental monitoring programme is an essential component of the management plan for a modernised waste disposal site. It provides operators with information to assess the effect of the landfill on the surrounding environment and assists in ensuring that the landfill is operated and controlled to the specified standards.

This section provides guidance on the design and implementation of a monitoring programme in order to accurately assess the impact of a landfill on the surrounding environment. It outlines minimum requirements for the location of monitoring points, the frequency of monitoring, the parameters to be analysed and the minimum reporting values of those parameters.

11.1 Objectives and Purposes of an Environmental Monitoring Programme

The three key phases of monitoring at a landfill managed to international best standards can be summarised as presented in the table below.

Table 10: The three key phases of monitoring at a landfill

Phase	Type of monitoring	Reason
Prior to landfill operation	Baseline	Site investigation and environmental impact assessment.
During the operation of the landfill	Compliance/Assessment	Comply with licence conditions
Aftercare and restoration of the landfill	Compliance/Assessment	Comply with licence conditions

Monitoring is required throughout the life of a landfill. It extends from the pre-operational phase (baseline monitoring) through to the operational and aftercare phases (compliance and assessment monitoring) of the landfill. It should include all environmental media likely to be significantly impacted through the operation of the landfill. For a MSW landfill, provision for the monitoring of the following, as a minimum, should be made:

- Surface water;
- Groundwater;
- Leachate; and
- Landfill gas.

The monitoring programme should address the following topics:

11.1.1 Objectives

The objectives for an environmental monitoring programme developed in accordance with international best practice are:

- To establish baseline environmental conditions;
- To detect adverse environmental impacts from the landfilling of waste;
- To demonstrate that the environmental control measures are operating as designed;
- To assist in the evaluation of the processes occurring within the waste body;
- To demonstrate compliance with the licence conditions; and
- To provide data to inform the public.

11.1.2 Selection of suitable monitoring points

The selection of suitable, representative, monitoring points is essential in the collection of valid data. The number and location of monitoring points is site specific and depends on:

- Geological, hydrogeological and hydrological regimes of the area;
- The topography of the site;
- The proximity of people and building developments; and
- The location of sensitive ecological habitats.

Ease of access by sampling personnel and safety issues also need to be taken into account when selecting suitable monitoring locations. Monitoring for parameters such as surface water and groundwater will usually include monitoring points that are not located within the boundary of the facility. The monitoring locations should be located so that they can suitably measure the pollution "source" (i.e. the waste body itself), the "pathway" (i.e. positions in the receiving environment) where the flow and dispersion require monitoring because they affect compliance with ambient limits, and "receptor" positions, i.e. sensitive positions in the receiving environment.

11.1.3 Identification of Monitoring Points

All monitoring locations should be marked on a drawing or map so that they are readily identifiable during subsequent visits. An up-to-date drawing of all monitoring points should also be held at the facility office. The monitoring programme must state clearly the positions (e.g. River A at grid reference 'xxx yyy'), a local description of the monitoring location, how it can be accessed, and where samples and measurements are to be taken. Standardisation of the names of monitoring points is recommended, e.g. surface water - SW, groundwater -GW, etc. All permanent sampling locations should have a marker detailing the location name and type of sample. The location marker should be easily visible from a distance.

11.1.4 Monitoring Parameters and Frequencies

Depending on the baseline monitoring data, the type of waste deposited and the level of containment at the site, it may be necessary to review the monitoring parameters and adapt them to reflect accurately the contaminants most likely to arise and adversely affect the environment. The monitoring frequencies for a landfill may vary according to the age of the site, the type of waste accepted for disposal, and the location of the site. Increased monitoring above minimum requirements (e.g. as laid down by the EC Directive) may be necessary to ensure that sensitive environmental media are adequately monitored. Some factors that would indicate the need for increased monitoring include:

- Evidence of negative impacts or a decrease in environmental quality when compared with baseline conditions or the results of previous monitoring;
- Non-compliance with a licence condition, e.g. if an emission limit value or a trigger level is breached;
- Change in site operations;
- Increased extraction of surface waters or groundwater in the vicinity of the landfill; and
- Change in adjacent land use.

The monitoring programme should detail the sampling and analytical protocols to be employed to ensure that the measurements obtained are valid and reliable. Figure 11 presents a generic outline of a monitoring protocol that should be used for a site being managed to best international practice.

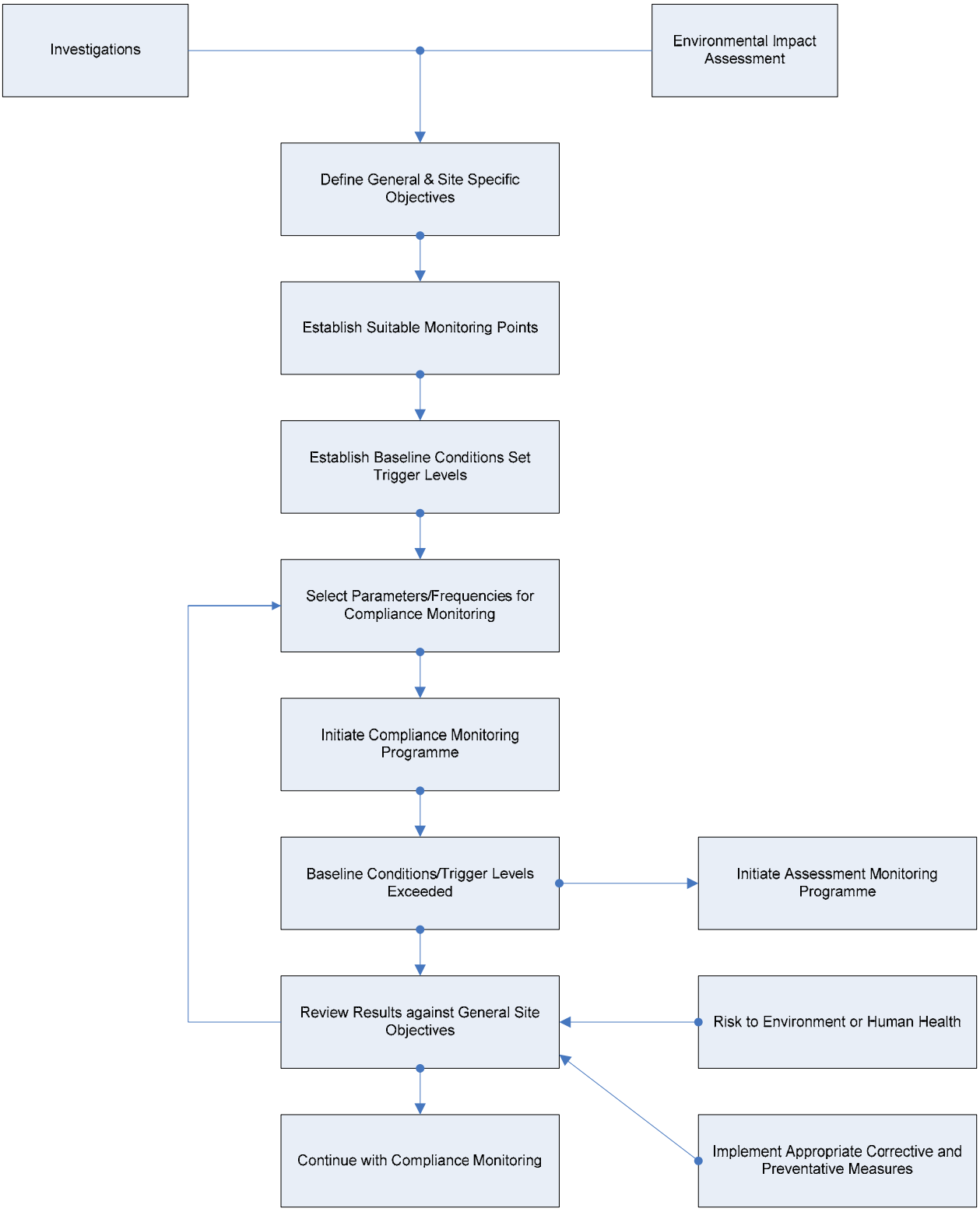


Figure 11: Flowchart demonstrating the main steps for developing a monitoring programme

11.1.5 Review of Programme

The monitoring programme should be reviewed periodically by the operator, assessed against its objectives, and updated as necessary. Such reviews are essential to ensure the quality, effectiveness, and continued suitability of the monitoring programme.

11.1.6 Safety Precautions

Safety must be carefully considered before monitoring begins and appropriate precautions followed. It is recommended that every monitoring programme should include a requirement that a risk assessment based on a safety audit be used to develop a safe working-plan covering the following points:

- Confirmation that the equipment and facilities which will be used are safe and adequate, e.g. electrical and sampling equipment etc;
- Guidance or briefing on how to safely access locations where monitoring is to be done;
- Availability of an appropriate number of qualified personnel; and
- Reminders concerning risks and precautions in relation to physical, chemical and biological dangers;
- Safety training of staff, including training in emergency and evacuation procedures, e.g. by site induction and safety course.

11.2 Surface Water

International best practice (as manifested within the EC's Landfill Directive) requires that surface water, if present, be monitored at representative points. The purpose of a surface water monitoring programme is to verify the quantity and quality of the surface water on a periodic basis and to detect any significantly adverse environmental impacts resulting from landfill activities.

11.2.1 Design of the Monitoring Programme

The design of the surface water monitoring programme should be site specific, and should take into account such factors as the nature of the drainage system, water levels, flow characteristics and the groundwater/surface water inter-relationship. The location of surface water monitoring points will be site specific and will depend on the nature of the drainage system around the landfill site. Table 11 outlines minimum baseline surface water (as well as groundwater and gas) monitoring requirements for a non-hazardous landfill, as specified in the landfill Directive.

Table 11: Minimum baseline surface water, groundwater and gas monitoring requirements for a non-hazardous landfill

Monitoring Medium	Parameters	Monitoring Points	Frequency of Monitoring
Surface Water	Flow/level and composition	At least two monitoring points in each watercourse – one upstream and are downstream of the landfill.	Quarterly intervals over a one year period (pre-operational)
	Biological Assessment	At least two monitoring points in the main watercourse adjacent to the landfill – one upstream and one downstream of the landfill.	At last one between June and September.
Groundwater	Level and Composition	Minimum of three boreholes, one upright and two downgradient of the proposed landfill	Quarterly intervals over a one year period.
Landfill Gas	Gas composition (methane, carbon dioxide, oxygen)	Three perimeter boreholes	Two readings over a year prior to waste deposition to establish landfill gas levels.

The monitoring points should allow information to be collected on the quantity and quality of the water both upstream and downstream of the landfill and should be representative of site conditions.

When assessing suitable locations for monitoring points for flowing water bodies (e.g. rivers and streams), monitoring should be undertaken at not less than two locations, i.e. one upstream and one downstream of the landfill. For static freshwater bodies (e.g. lakes), a minimum of two monitoring points should be located radiating away from the landfill site and should be in an area

that is representative of the water body as a whole. In addition, surface water draining from the landfill site should be monitored before discharge to the receiving surface waters.

11.2.2 Monitoring Frequency and Parameters for Analysis

For baseline monitoring, each monitoring point should be monitored quarterly for a minimum of one year prior to the commencement of activities at the site. The frequency of compliance monitoring during the operational and aftercare phase is site specific and should be governed by the licence. It should take into consideration the characteristics of the surface water regime and its vulnerability to contamination. For baseline monitoring, the parameters listed in the following table should be included in the determination of the surface water quantity and quality (Table 12).

Table 12: Monitoring parameters for surface water, groundwater and leachate

	Surface Water	Groundwater	Leachate
Monitoring Parameter	Baseline (pre-operational)	Baseline (pre-operational)	Characterisation (when site is operational)
Fluid level	√	√	√
Flow rate	√		
Temperature	√	√	√
Dissolved oxygen	√		
pH	√	√	√
Electrical conductivity	√	√	√
Total suspended solids	√		
Total dissolved solids		√	
Ammonia (N)	√	√	√
Total oxidised nitrogen (N)	√	√	√
Total organic carbon		√	
Biochemical oxygen demand	√		
Chemical oxygen demand	√		√
Metals	√	√	√
Total alkalinity (as $CaCO_3$)	√	√	√
Sulphate	√	√	
Chloride	√	√	√
Molybdate Reactive Phosphorous	√	√	√
Cyanide (total)	√	√	√
Flouride	√	√	√
Trace organic substances	√	√	√

11.2.3 Sampling Guidelines

The monitoring of surface waters may involve obtaining samples for physical, chemical or biological analysis. The principal purpose behind a sampling programme is to collect samples that accurately reflect the quality of the medium being investigated. There is a variety of sampling equipment available for these purposes, but its suitability will depend on the nature of the investigation and the intended use of the sample. All staff involved in the taking of samples should receive appropriate training and be familiar with the sampling procedure and equipment to be used. Appropriate protective clothing should be worn which may include the use of high visibility vests, hard hats, eye protection, gloves and protective footwear. All equipment should be checked to ensure that it is in working order and, if necessary, calibrated. All samples should be put into

appropriately labelled containers and detailed fieldsheets should be used (e.g. site, time, date, sample code, personnel, weather etc). Samples should be stored in a cool box or similar environment, out of direct sunlight and delivered to the laboratory with minimum delay, ideally on the same day and preferably within 24 hours of sampling.

11.3 Groundwater

The fundamental objectives of a groundwater monitoring programme are to assess groundwater quality/quantity, and to determine the effectiveness of any environmental control systems in place in order to ensure the continued integrity of groundwater quality/quantity. These objectives are achieved through the collection and analysis of representative groundwater samples.

11.3.1 Monitoring Locations

The efficiency of a monitoring programme is dependent on a thorough understanding of the hydrogeological conditions of the site, coupled with the appropriate location and construction of monitoring boreholes Monitoring boreholes should be installed at appropriate locations and depths to:

- Provide samples representative of the quality of groundwater upgradient of the site;
- Provide samples representative of the quality of groundwater downgradient of the site;
- Permit an accurate water level or pressure (piezometric) level of groundwater to be measured and
  recorded to an elevation expressed as metres above ordnance datum; and
- Provide data to show the direction of groundwater flow (minimum of three monitoring boreholes
  necessary).

For groundwater monitoring at a landfill, the EC Landfill Directive specifies a minimum of one upgradient and two downgradient boreholes. In reality, a number of site specific factors will determine the actual number and locations of the boreholes required. Such factors may include:

- The area of the landfill,
- Heterogeneity of the aquifer(s),
- Permeability of the aquifer(s),
- Groundwater abstraction,
- Groundwater flow velocities,
- Anticipated composition of leachate (based on expected wastes types),
- Baseline water quality,
- Proposed containment system,
- Licence requirements,
- Ease of access to the borehole by sampling personnel; and
- Safety issues.

Monitoring locations may include existing groundwater discharges and abstractions (e.g. springs, water supply boreholes or wells), existing monitoring points (e.g. those installed for other monitoring purposes by adjacent landowners or for site investigations), and/or the construction of new boreholes. This allows the monitoring points to be located and designed specifically to meet monitoring objectives. The groundwater monitoring programme at a landfill site should contain the following information:

- Number and location of boreholes - the precise location of the boreholes should be recorded on the logs using a grid reference and marked on a drawing or a map;
- Depth of boreholes;
- Screen area/level;
- Pump tests, yield information etc;

- Information on soils;
- Borehole construction material;
- Nested borehole configurations;
- Direction of groundwater flow;
- Groundwater recharge and discharge areas; and
- Groundwater abstraction points in the vicinity of the landfill.

Most groundwater monitoring boreholes will require periodic maintenance. Any boreholes that become damaged should be repaired or replaced as soon as possible. Table 12 above outlines minimum baseline groundwater monitoring requirements for a non-hazardous landfill.

11.3.2 Monitoring Frequency

Baseline data are those that are characteristic of conditions in the absence of any impacts arising from landfill operations. For the determination of baseline water quality, each monitoring location should be monitored at quarterly intervals for a minimum of one year prior to the operation of the site. A groundwater contour plan with flow direction should also be produced to provide baseline information. The frequency of compliance monitoring during the operational and aftercare phase is site specific and will be governed by the licence and should take into consideration the hydrogeology of the site and the landfill design. Throughout the life of the landfill the baseline monitoring parameters chosen should be re-analysed at intervals not exceeding twelve months. Monitoring of groundwater levels will be required on a more frequent basis. The EC Landfill Directive requires level monitoring to be undertaken every six months as a minimum during the operational and aftercare phases of the landfill.

It is recommended that groundwater sampling commences with up-gradient boreholes. In order to obtain a representative sample of groundwater, stagnant water must be removed from the borehole. A purging trial should be undertaken to observe the behaviour of field parameters (e.g. conductivity, pH, temperature) continuously or at intervals during purging. A sufficient volume (normally at least 3 borehole volumes) should be pumped during the trial to demonstrate genuine stabilisation of the pumped water chemistry. Generally, purging of three times the borehole volume is sufficient to allow a representative sample to be taken.

11.4 Leachate

Leachate may be defined as any liquid percolating through the deposited waste and emitted from, or contained within, a landfill. If this leachate is allowed to migrate from the site it may pose a severe threat to the surrounding environment and in particular to the groundwater and surface water regimes. Effective environmental protection requires an understanding of the composition and volumes of leachate being generated and the implementation of control measures.
The purposes of a leachate monitoring programme are:

- To confirm that the leachate management systems are operating as designed;
- To provide information on the progress of decomposition of the waste; and
- To provide information for the potential revision of groundwater and surface water monitoring parameters.

11.4.1 Monitoring Locations

The EC's Landfill Directive requires that sampling and measurement of leachate (both volume and composition) must be performed separately at each point at which leachate is being discharged from the site. The precise location of these monitoring points will be site specific, but they should be located taking into account the likely flow-paths of the leachate so as to provide samples representative of the leachate composition. The frequency of leachate monitoring at a landfill site should be reviewed on a regular basis to reflect changes in:

- Quantity and types of waste deposited;
- Operational practice;

- Size of operational cell; and
- The effectiveness of the leachate drainage and collection system.

The EC Landfill Directive specifies minimum monitoring frequencies for leachate volume and composition during the operational and aftercare phases of a landfill. Monitoring of leachate levels within the waste body is important to ensure that the leachate head is successfully controlled. The volume of leachate discharged or transported from a landfill should be recorded on an ongoing basis. A representative sample of leachate from each monitoring location should be taken for analysis.

Table 13: Frequency and location of sampling points for monitoring leachate

Parameter	Monitoring Points	Monitoring Frequency (operational and aftercare)
Leachate levels	• lined landfills, at the leachate collection points and at two other points per cell; • For unlined landfills, three points per five hectares of filled area; • Leachate lagoon	As required by waste licence
Leachate composition	• Sampling point representative of the landfill body; • Leachate lagoon • Treated leachate before discharge	As required by waste licence
Leachate discharge volume	• Treated leachate discharge point	As required by waste licence

11.5 Landfill Gas

Landfill gas is generated by the decomposition of organic materials in waste deposited at the landfill. Typically, the gas is a mixture of methane (up to 65% by volume) and carbon dioxide (up to 35% by volume). The rate of gas generation at a landfill site varies throughout the life of a landfill and is dependent on several factors such as waste types, depths, moisture content, degree of compaction, landfill pH, temperature and the length of time since the waste was deposited. The EC Landfill Directive requires the following with respect to landfill gas management:

- That appropriate measures are taken in order to control the accumulation and migration of landfill gas;
- That landfill gas should be collected from all landfills receiving biodegradable waste and the landfill gas should be treated and used. If the gas collected cannot be used to produce energy, then it should be flared; and
- That the collection, treatment and use of landfill gas should be carried on in a manner which minimises damage to or deterioration of the environment and risk to human health.

Landfill gas poses various risks including: flammability and explosion risks; potential health impacts due to many minor constituents present at low concentrations. It is important therefore that landfill gas is properly monitored and controlled.

11.5.1 Gas Monitoring Locations

Monitoring should take place both within the waste to identify both the quantity and quality of gas generated, and outside of the waste to assess whether gas is escaping in an uncontrolled manner. The methane content of landfill gas is flammable, forming potentially explosive mixtures in certain conditions, resulting in concern about its uncontrolled migration and release. Landfill

gas can move in any direction within the waste body and may migrate from a site. The potential for gas migration will depend on the gas quality and volume, the site engineering works, geological characteristics of the surrounding strata, and any man-made pathways such as sewers, drains etc. The monitoring programme should commence prior to waste disposal and should continue until the biodegradation process within the waste has ceased. It is important in the case of new sites to get naturally occurring background levels of methane and carbon dioxide which may vary depending on local geology. These levels should be established prior to the commencement of landfilling at the site.

11.5.1.1 Within the Waste Body

The EC Landfill Directive requires that gas monitoring be representative for each section of the landfill. It is recommended that the locations for gas monitoring within the waste body should be at a density of at least one monitoring point per cell in lined landfills, and one monitoring point per hectare of filled area in unlined landfills.

Monitoring wells constructed within the waste body are for the purpose of monitoring landfill gas concentrations and fluxes within the waste. These wells should be independent of the gas collection and extraction system, and used as dedicated monitoring points for the purpose of ascertaining the state of degradation within the waste body and how it responds to environmental conditions.

11.5.1.2 Outside the Waste Body

The monitoring of boreholes outside the waste body is essential to detect any gas migrating from the waste body and to demonstrate the efficient management of gas within the site. Boreholes for monitoring gas outside the waste body may be located both on-site and off-site. The spacing and location of gas monitoring points outside the deposited waste should be determined on a site specific basis. Factors which need to be taken into account when selecting such monitoring locations include:

- Quality and volume of gas being generated;
- Geology of the site;
- Type of waste;
- Containment measures adopted, e.g. landfill lining or capping;
- Proximity of buildings and developments to the site; and
- Permeability of the waste.

The spacing of the monitoring locations is unlikely to be uniform around the site. It is probable that more monitoring points will be needed near building developments, where there are changes in the site geology and where there is no containment. It is recommended that monitoring boreholes are located a minimum of 20 m from the waste body and should be installed at least to the depth of the maximum depth of waste within the waste body. Where appropriate, groundwater monitoring boreholes may also be used for gas monitoring.

11.5.2 Monitoring Frequency

The frequency of monitoring required is site specific and will depend on a number of factors, such as the:

- Age of the site;
- Type and mix of waste;
- Possible hazard or nuisance from gas escaping from the site;
- Results of previous monitoring;
- Control measures that have been installed;
- Development surrounding the site; and
- Geology of the site and its environs.

Table 14 summarises typical landfill gas monitoring requirements for a MSW landfill in line with the EC landfill directive.

Table 14: Landfill gas monitoring requirements under the EC Landfill Directive

Monitoring Points	Parameter	Monitoring Frequency (operation and Aftercare)
Perimeter boreholes (outside the waste body), site office/buildings	Methane, carbon dioxide, oxygen, atmosphere pressure, temperature	As required by licence
Boreholes/Vents/Wells (within the waste mass)	Methane, carbon dioxide, oxygen, atmosphere pressure, temperature	As required by waste license
Collection wells and associated manifolds	Bulk gas concentration, flow rate	As required by waste license
Surface emissions	Methane, flow-rate	As required by waste licence

Monitoring should be increased above this schedule when:

- Increases in gas quantity or changes in gas quality are observed during monitoring;
- Control systems are altered by landfill operations;
- Capping of part, or all, of the site takes place;

Table 15 presents an example of a typical gas monitoring form used for recording the relevant data.

Table 15: An example of a typical landfill gas monitoring form

Landfill Gas Monitoring Form						
Facility Name: **Waste License No:**			**Facility Address:**			
Licensee:						
Date of Licensing:			**Date of Sampling:**		**Time of Sampling:**	
Instrument Used:			**Date Next Full Calibration:** **Last Field Calibration:**			
Monitoring Personnel:			**Weather:**		**Barometric pressure:** **Mean Temperature:**	
Results						
Sample Station Number	CH_4 (%v/v)	CO_2 (% v/v)	O_2 (% v/v)	CO ppm	H_2S ppm	**Comments**

General Comments

12 Site Closure and Aftercare

Restoration and aftercare are both essential steps in the process of waste disposal, and must be considered at all stages of the life of the site if landfilling is to be managed in a way that minimises environmental impacts. Restoration includes design, initial landscaping works, soil spreading and aftercare. Aftercare is the work that is carried out after replacement of the soil and includes all operations necessary to establish and maintain the afteruse of a restored site. Aftercare includes cultivations, vegetation establishment, maintenance and an ongoing long term commitment to the restored land.

The proposed afteruse should be realistically achievable in terms of site topography, geology, soil types and particularly the quantity of soils available for restoration. The long term requirement of the environmental pollution control systems on the landfill and the need to provide access for use and monitoring purposes must be built into the chosen afteruse. The financial costs involved in restoration need to be considered and provision needs to be made during the lifetime of the landfill to ensure adequate funding is available for restoration, aftercare and post closure management.

The range of afteruse options include:

- Amenity afteruses ranging from nature conservation to informal recreation and formal sports, both water and land based;
- Woodland afteruses include the planting of hedgerows, shelterbelts, amenity and commercial woodland;
- Agriculture afteruses; and
- Hard end uses e.g. roadways, buildings, car parks, yards etc.

Once the land disposal site is full it must be properly closed in such a way as to continue to minimise the impact upon the environment. Site operators are required to continue to maintain the site and monitor for impacts long after the site has closed. This “aftercare” may need to cover a period of up to thirty years.

Final Cover

Leading up to completion of fill operations sufficient material must be accumulated to cover the site with a low permeability cap.

The cap must be designed to:

- Encourage the controlled run-off of surface water;
- Prevent release of landfill gas if generated;
- Facilitate appropriate after-use;
- Have final cover which facilitates growth of vegetation;
- Be resistant to soil and wind erosion; and
- Minimise surface water “ponding”.

Final cover generally consists of 0.3 to 1 m of topsoil, which must be planted to prevent erosion. Slopes should generally not exceed 5% although this may be exceeded slightly for landfills in dry climatic conditions provided that they are well planted. Following closure, the site operator must periodically inspect the landfill cap / final cover to ensure that there is no erosion / degradation of the final cover, and that there is no settlement or subsidence affecting the security of the cap or final cover. If any significant degradation is observed, the site should be re-graded as necessary.

Decommission Site Infrastructure

Site infrastructure, which is surplus to requirement, should be decommissioned, including temporary storage areas (for waste and/or raw materials). This may include temporary storage

facilities that may have been used for storage of hazardous wastes. Such facilities must be decontaminated and properly decommissioned. This activity may itself give rise to wastes, which must be treated and/or disposed of at a suitable waste management facility.

Leachate Collection and Treatment

After final cover, operational activities continue for a while with periodic leachate extraction from the completed cells and treatment of leachate collected. Leachate collection and treatment must continue until no further leachate is being generated.

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Annex A – Manual on Design and Exploitation of Landfills on the Territory of the Republic of Armenia

Unofficial translation

Endorsed by the Minister of Urban Development of RA
Order # 321-A, 29 December 2009

LANFILL DESIGN AND EXPLOITATION MANUAL

I. Landfill Design

I.1 General Provisions

1. Landfills are organized for placing, neutralizing and stocking household solid waste, garbage emerging from sanitary cleaning of inhabitations, non-hazardous wastes of production and consumption, which ensure protection of atmosphere, soil, surface and underground waters from pollution, preventing or decreasing adverse effect of wastes on human health and environment.

Town-planning, sanitary and environmental legislation of Republic of Armenia is considered as basis for landfill design.

2. Landfills can be community, inter-community and regional. Based on daily garbage stock capacity, landfills can conditionally be small, up to 50t/day; medium, 50-100 t/day; large, more than 100 t/day. From the perspective of applied technologies, landfills can conditionally be divided into two main groups:

1) Landfills for placing, neutralizing and stocking household solid waste, garbage emerging from sanitary cleaning of inhabitations, non-hazardous wastes of production and consumption with application of environment protection measures. If necessary, systems for sorting, composting garbage, utilization of occurring gases and collection and neutralization of after-extracted liquids can be foreseen;
2) Specialized polygons are foreseen for processing, utilization, neutralization, burying all types of hazardous and non-hazardous wastes applying modern technologies. Specialized polygons are complex facilities with environmental infrastructure and environmental assessment monitoring systems.

3. Establishment of landfills is implemented according to measures ensuring implementation of RA-EU Action Plan approved by RA President Order # NK 68-A, May 6, 2009 and according to planned project on landfills, specialized polygons, establishment of garbage loading stations and processing plants, foreseen in the frames of RA Environment Protection Second National Program endorsed by RA Government decision # 33, August 14, 2008.

Before actual implementation of above-mentioned project temporary landfills are established for placing and neutralizing the garbage in small inhabitations, by application of environment protection measures. These temporary landfills can in future be reconstructed to reloading stations.

4. Current manual contains advisable indications for landfill design and exploitation regarding town-planning, sanitary and environmental legislation requirements.

Landfill design is carried out according to requirements of Government of RA order N 812 dated on 21.12.1998 and by disposition indicated in the legislation is submitted for town-planning and environmental impact expertise. Normative references are given in the Annex 1.

I.2 Content of design (document)

5. Following sections are included in the content of design:

1) General description;

2) Hydro-geological conclusion;
3) Main plan, including transport and sanitary preservation zone;
4) Technological section, estimation of capacity, technological scheme, taking into account sequence of construction, longitudinal and transverse technological section, regime of exploitation, estimate of demand for exploitation staff, vehicles and mechanisms, indications for rehabilitation (re-cultivation) of land after closure of landfill;
5) Architectural-construction section;
6) Engineering equipment, networks and systems;
7) Organization of construction;
8) Environment protection;
9) Cost estimate documents;
10) Summary of main construction materials, constructions;
11) Other sections according to design task.

6. Corresponding sections of the design are developed in accordance with rules defined by Minister of Urban Development order N 273-N dated on 29.11.2006.

I.3 Selection of plot

7. Landfills are located out of towns and inhabitations, not less than 500 m away from residential buildings. Width of landfill sanitary protection zone is set according to construction rules requirements of SNiP (construction norms and regulations) 2.07.01-89 “Town-planning: Planning and construction of urban and rural inhabitations”. According to RA Law on Land landfill lands based on purpose (category) are considered communal lands.

8. Installation of landfills is planned in town-planning documents of inhabitations and in accordance with project indicated in bullet 3. For installation of new landfill selected plot has to be agreed with town-planning, environmental, health and territorial administration bodies.

9. Landfills can be installed in those areas, where engineering solutions and measures excluding development of environmental pollutions and hazardous geological and other negative occurrences can be implemented, particularly:
1) Useless for agricultural purposes, as well as areas not occupied by tree planting;
2) In zones situated out of sanitary areas of water springs, surface waters, nature reserves, sanitariums and other similar objects;
3) In areas with natural protection excluding pollution of underground waters;
4) In coulees and exploited mines.

Best places from hydro-geological perspective are considered those with clay and heavy sand-clay soil, and level of underground waters is more than 2 m deep.

Landfills are placed on the opposite side of main wind streams towards residential constructions, resort areas and other public places

10. Landfills cannot be installed:
1) In the areas of spring water, mineral water, river watercourse;
2) In the areas of seismic activity, landslides, snow slides, areas affected by seasonal floats and swamp areas;
3) Green areas with protective function;
4) Special protection zones;
5) Less than 15 km remoteness from airports.

In exceptional cases, while designing landfills in swamp or permanently surrounded by water areas, fill composed of neutral materials should be foreseen – not less than 1m above underground and surface waters, as well as water-transparent protective layer.

11. Based on location and possible impact on environment the landfills can be divided into following categories:

1) Valley – up to 5% incline towards flat surface
2) Slope – more than 5% incline towards flat surface
3) Gulch – situated in natural pits and gulches
4) Mine – situated in exploited mines.

12. As a rule exploitation of plot for the landfill is not less than 25 years. Based on local conditions and specificities the indicated deadline can be less. According to SNiP 2.07.01-89 construction rules the surface of polygons (landfills) is calculated 0.02-0.05 ha for 1 thousand tons of garbage annually. Extent of area for the landfill has to be justified in landfill design through volume calculation.

13. Economically vise it is better to use exploited mine or a plot with square shape, where it is possible to reach higher level of garbage stocking (taking into account incline 1:4).

14. After selection of the plot for landfill topographical extraction, geological and hydro-geological surveys are carried out. For the design of the landfill the plan is drafted in 1:1000 scale with 1m drop of horizontals. Plan for economic trench is drafted in 1:500 scale with 0,5m drop of horizontals (in case when external networks are long, can be drafted in 1:1000 scale).

15. Geological study is carried out at least 10m deep. In case of occurrence of different soils the study should be carried out till reaching waterproof layer and dig into it for 1-1,5m.

16. In result of hydro-geological study the horizon of ground waters (HGW) and flow direction is identified.

17. In result of hydro-geological and geological studies plans for pits and geological sections are drafted as well as hydro-geological conclusion is prepared, on appropriateness of the plot for installation of a landfill and recommended environmental protection measures.

I.4 Calculation of landfill capacity

18. Calculation of capacity is carried out for designed landfill to justify required necessary surface of plot. Annual average of accumulated garbage per capita (including garbage accumulated in enterprises), number of population served, exploitation time of the landfill and level of garbage concentration in landfill is taken into account during calculation.

19. Necessary surface of plot for landfill is determined as follows:

$$S=V/H \qquad (1)$$

Where:

S - is the surface in m^2
V - is volume in m^3
H - is height of garbage stock in m

Garbage stock volume is calculated using following scheme

$$V=Nx1.3xT/R\ conc. \qquad (2)$$

Where:

N - is the number of served population
1.3 - is annual average of accumulated garbage per capita in m^3
T - is landfill exploitation time in years
R - is garbage concentration rate; average magnitude is 3, in case when no concentration occurs in landfill the rate equals 1.

Landfill surface calculation example using conditional data:

Number of population served is 30 000
Time of exploitation is 30 years

Garbage concentration rate R conc.=3

Garbage stock height is 10 m

Calculation of landfill plot surface using following data will make:

S= (1/10)x30000x1.3x30/3=39000m^2=3.9 ha.

I.5 Landfill scheme

20. Main elements of landfill are: entrance road, waste stock section, economic zone, engineering structures and trenches (example schemes are given in annex 2).

21. Entrance road connects the landfill with the main highway; it is planned for two-way movement. Entrance road category and main indicators are determined based on average frequency of vehicles – car/day.

22. Main structure of landfills is stocking section, which occupies up to 85-95% of landfill area. Depending on annual garbage volume the stocking section is divided to exploitation zones by order, taking into account that each of zones should have capacity to receive garbage for the period of 3-5 years. Garbage stocking in first, second and third turns is implemented in 2-3 levels, each of levels 2.0-2.5m height.

23. Next turn of exploitation is carried out through delivery of wastes till the threshold indicated in design.

24. Marking storage zones according to the order is done taking into account the relief of the plot.

25. Landfill storing zone has to be protected from surface waters flowing in. For this purpose water removing rill is planned at the border of the plot, its indent is planned based on atmosphere downfalls and water absorbing surface data.

26. Water shuttering fence (wire, net etc.) is placed 1-2m distance from the water removing rill.

27. Within 5-8m diameter from the fence tree planting, water-sewage networks, lighting posts, as well as soil storage for covering (isolation) wastes are planned.

28. Economic zone is planned on the crossroads of entrance road and landfill. Industrial and common use facilities are placed in the economic zone. The economic zone can occupy 5-15% of total area.

29. Zones for sorting wastes which have raw material value and separation of hazardous wastes, as well as composting organic wastes and storing compost from diverse garbage on the landfill can be organized in case of corresponding justification. Zones for delivery, processing, utilization, neutralization and burying hazardous wastes can be planned on the landfill.

30. For the facilities indicated in point 29 separate sections are drafted in the design of the landfill according to the scheme given in point 6.

I.6 Storing zone

Construction of pit is planned at storing zone, in result of which occurring soil is stored for intermediate and final isolation of wastes. Average depth of the pit for the landfill is calculated based on balance requirements of land works and level of underground waters. The bottom of the pit should be not less than 1m above level of underground waters.

32. From the pits of first shift soil is moved to storages planned throughout the perimeter of landfill, and soil removed from the pits of second and third shift is used for isolation of wastes in the zones of first and second shifts.

33. As a rule, the basis of the pit is planned horizontal ensuring equal spread of extracted liquids through the basis of the landfill. Taking into account the relief of the plot and the shifts of waste storing the landfill can be divided into a number of pits, in case when the plot has more than 5 incline pits can be planned in a scale format (annex 3). The bottom levels of neighboring pits should not exceed 1m, otherwise dam sustainability has to be estimated. If necessary, temporary

road can be planned for the garbage removing vehicles, at the upper part of intermediate dam of the pit.

34. The basement of pits should have ground basis not less than 0.5m deep and not more than 10^5sm/sec (0.0086 m/day) water bypass rate (clay soils in the natural state). In case when the rate of water bypass at the basement of the pit exceeds 10^5sm/sec artificial water-penetrating layers (screen) should be planned from membrane or clammy water isolating materials (annex 4).

35. In those climate zones, where humidity of garbage does not exceed 52% and annual atmosphere downfalls is less than 100mm water-penetrating layer does not to be placed.

36. In case of planning landfills in gorges and coulees their upper areas are selected to carry out rain water and snow melt water removal in a more accessible way. Construction of the landfill starts from the upper part of the coulee moving down gradually. Bottom part of each constructed layer is reinforced with soil stronghold to prevent landslides. Each stronghold is planned for emergency (extreme) situations, taking into account necessity to insure static stability of waste mass saturated with water.

37. In case when landfill is planned at exploited mines (quarry) roads providing entrance and unloading on the lowest level (unloading plot), as well as plot for formulating soil to isolate wastes are foreseen.

38. When designing landfill through trench method trenches are planned 3-6m deep and 6-12m width in the upper part. Tranches are planned vertical to prevailing wind directions. Soil extracted from tranches is used for isolation of waste layers.

39. Incline of tranche slopes in condition of natural humidity of soils are calculated as in table 1 according to SNiP III-4-80* "Security in technical construction" construction rules. Tranche landfills can be designed with 2-3 layers.

Table 1

Soil type	Tranche depth up to 3m		Tranche depth up to 6 m	
	Angle made up with horizontal and incline direction, degree	Slope incline	Angle made up with horizontal and incline direction, degree	Slope incline
Sandy	45	1:1	45	1:1
Clay-sandy	56	1:0.67	50	1:0.85
Sand-clayey	63	1:0.5	63	1:0.75
Clayey	76	1:0.25	63	1:0.5

40. In medium and large landfills extraction and utilization, of gas occurring in solid garbage mass, as well as systems for refined liquids should be foreseen.

I.7 Economic zone and engineering structures

41. Administrative and common use facilities, control points, scales, garbage sorting and processing plants, close and open parking, vehicle and machinery renovation workshops, storages, electricity, water supply and water removal and other facilities can be planned in the economic zone.

42. The economic zone has to have hard cover, lighting, entrance road and fence.

43. Large landfills receiving 100 thousand tons of garbage annually and with more than 30 years exploitation period should have permanent water supply. In case of small and medium landfills water supply can be carried out through water delivery.

44. Water removal can be carried out:

1) Through sewage system of inhabitation, in case of economic justification to connect to highway sewage line;
2) Through vaporizing basin (artificial lake) the surface and capacity of which is determined through estimation of atmosphere downfalls at the landfill;

3) Through septic (dirt water sediment) from where the accumulated dirt waters are pumped to humidify and vaporize the waste mass. Special road is planned for removal and cleaning of dirt sediments.

45. Control and disinfection zone – a 3 m width, 8 m length and 0.3 m depth reinforced concrete pit filled with bran and 3% Lysol liquid is planned at the entrance of economic zone to wash the tires and carcasses of vehicles driving out.

46. Water expenditure for putting off fires is estimated 10 l/sec for which lake or watershed of 50 m^3 capacity can be planned.

47. Fence is planned throughout the perimeter of landfill, which is not obligatory to place if 2.0 m deep tranche or 3.9 high dam is planned. Gate or barrier is planned at the entrance of the landfill.

48. Water removing rills are foreseen for removing waters which are higher the landfill area, and their shape and bypass capacity are estimated based on local conditions.

49. Permanent lighting is planned at the economic zone of the landfill, and at garbage storing zones lighting is provided on temporary basis.

50. Temporary roads are planned at waste storage zones. These roads are made of construction and other neutral solid wastes.

I.8 Sanitary protection zone and monitoring

51. Sizes of sanitary protection zone are determined according to construction rules indicated in "Sanitary rules for design of industrial enterprises" SN (sanitary norms) N245-71 and "Town-planning: Planning and construction of urban and rural inhabitations" SNiP 2.07.01-89.

52. Construction of residential or social buildings, water supply facilities, as well as other facilities forbidden by town-planning and sanitary regulations at the sanitary protection zones is forbidden.

Soil storages can be placed at sanitary protection zones to function as covering isolating layer when landfill is closed.

Preservation and control of sanitary protection zone is implemented based on acting sanitary regulations.

53. Special monitoring section can be drafted in the design of the landfill, which includes control and prevention of hazardous impact over surface and underground waters, atmosphere air, soil and plants. Monitoring plan can be drafted based on clients' technical assignment with approval of supervising bodies.

54. For control over the state of underground waters control pits can be designed in the direction of underground waters – one control pit at the upper part of the landfill, and 1-2 control pits in the lower part of the landfill within 50-100 m distance. Pits should have access for taking water samples.

55. For control over surface waters sample collection points can be established at upper part of the landfill for surface waters, and lower part of the landfill for water removing rills.

56. For control over quality of underground and surface waters roads and water removing possibilities are foreseen.

57. To control the state of atmosphere air places to collect air samples at sanitary protection, landfill working and economic zones are planned.

58. Volume of estimated rates and frequency of sample collection are justified in design.

II Landfill exploitation

II.1 Work arrangement

59. Exploitation of landfills is implemented according to the design following sanitary, town-planning, environmental legislation requirements.

60. Following main arrangements are implemented at the landfill: receipt, storing and isolation of wastes, as well as other activities connected with other use of wastes, in case of availability of zones mentioned in point 29.

61. Wastes are accepted at the landfill by volume or weight if scales are available, and notes are made in the “Waste receipt book” on volume of wastes as given bellow:

Template

Date/time	Waste Importer (organization, individual, businessman, etc.)	License plate and mark of the vehicle	Rout number or other similar data	Volume of received waste	
				m^3	tone
1	2	3	4	5	6

62. Storage of wastes is implemented in two main ways: moving or pushing (annex 5).

63. Vehicles at the landfill are unloaded at special zone (card). In large and medium landfills unloading plot can be divided into two parts – in one place vehicles are unloaded, in the other one unloaded wastes are trampled with bulldozers.

64. Wastes are trampled (consolidated) by layers; each of layers should be 0.5 m. When trampled waste reaches 2m height, upper layer is being isolated with 0.25-0.3 m soil. Waste trample is done by bulldozer or trampling machine for 2-4 times throughout the length of the layer.

65. Measuring posts (bench marks) can be placed at consolidated waste plots to ensure required 2 m height and check solidity. Bench marks can be wooden or metallic with 0.25 or 0.3 m marks.

66. Before covering the wastes with soil, trampled waste should be humidified – 1litres of water per $1m^3$ of waste.

II.2 Requirement of necessary mechanisms

67. Garbage trampling (consolidation) and special mechanisms for isolation layer are planned in design based on daily accumulated volume of garbage at the landfill.
Approximate requirement of necessary mechanisms is given in table 2.

Table 2

Daily volume of stored garbage in tons	Required mechanisms	Capacity in kilowatt	Number	Comments
0-50	Bulldozer	50-60	1	
50-100	Bulldozer Ties Water spraying machine	60-70	2 1 1	Excavator can be used instead of ties or elevator and unloading vehicles
100-300	Bulldozer Ties Water spraying machine	90-120	3 1 1	Excavator can be used instead of ties or elevator and unloading vehicles
300-1000	Bulldozer Ties Water spraying machine	90-120	5 2 2	Excavator can be used instead of ties or elevator and unloading vehicles

II.3 Conditions for placing other wastes

68. Garbage accumulated from sanitary cleaning of inhabitations, garbage included in the list of industrial and consumption wastes accumulated on the territory of Republic of Armenia, under lines 910-920 approved by order of Minister of Nature Protection of Republic of Armenia 26 N 342-N as well as other non hazardous wastes can be placed in the landfill.

69. Besides the wastes indicated in point 68, placing other wastes in the landfill can be implemented according to legislation of Republic of Armenia, preserving main sanitary conditions – in case of diverse placement of last toxicity of waste mass shouldn't exceed toxicity degree of solid household garbage.

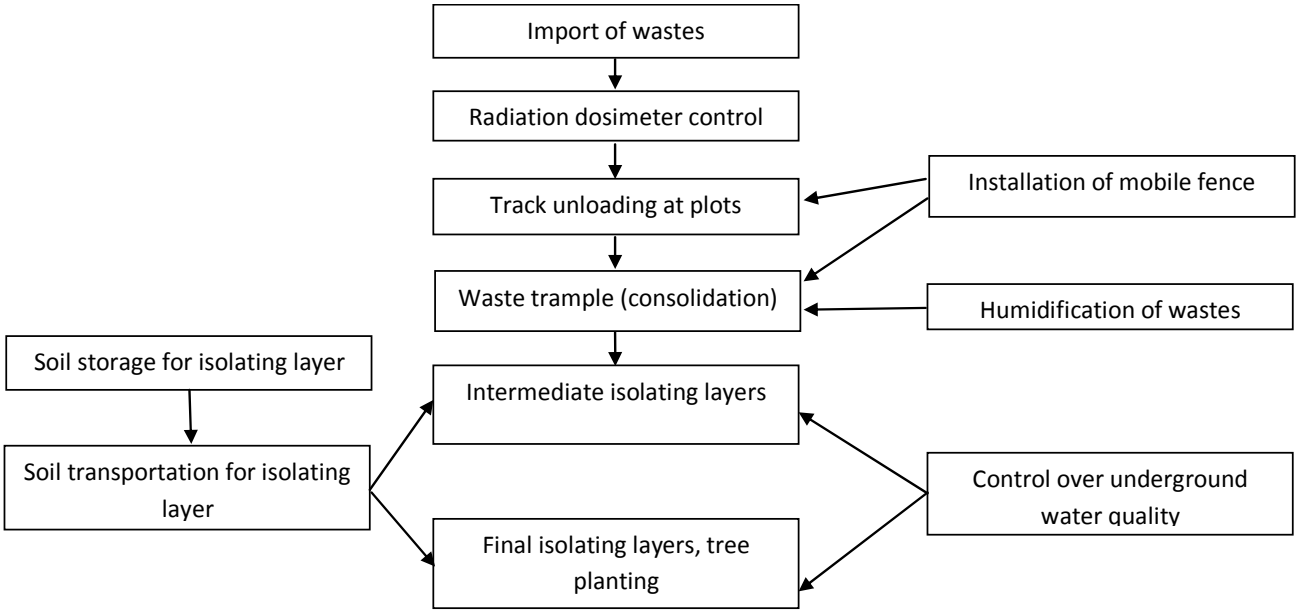
70. Radioactive, toxic and hazardous garbage is forbidden to be placed at the landfill.

71. Humidity of diverse industrial garbage placed together with household garbage at the landfill should not exceed 85% and it shouldn't be explosive or self-burning.

72. For isolation of wastes and coverage of temporary roads construction and other neutral solid wastes can be used.

II.4 Environmental protection

73. To ensure provision of environmental protection requirements sequence and interconnection of technological processes given in scheme bellow should be implemented at the landfill.



74. Control over pollution of underground and surface waters is implemented through examination of samples collected from control pits and rills.

75. Water removing rills are permanently cleaned.

76. Visual inspection of sanitary protection zone is carried out at least once in a month, and measures are undertaken to eliminate identified violations and failings.

77. With regularity and in areas indicated in the design samples of atmosphere air are collected to control air pollution.

78. To exclude placing wastes containing radionuclide x-ray dosimeter control is carried out at waste delivery point.

79. To exclude self-burning of wastes humidification of wastes is carried out in seasons of fire risk.

II.5 Closure of landfill, rehabilitation of soils

80. Closure of landfill is implemented when placed waste reaches bench mark determined in the design and/or after the deadline for landfill exploitation. Exploitation of landfill can continue in case that possibility is justified in result of appropriate research.

81. Before closure of the landfill last layer of wastes is covered with soil, type and width of which is determined based on land rehabilitation and further use purposes set down in the assignment.

82. During closure of medium and large landfills installation of occurring gas extraction and utilization systems can be implemented.

83. Reinforcement of external slope at the beginning of landfill exploitation is carried out simultaneously with waste storage height and soil removed and stored during the construction of landfill can be used for that purpose. Terraces can be placed on the slopes and trees and bushes planted.

84. Rehabilitation (re-cultivation) of soils at closed landfills is carried out for the purpose of soil efficiency rehabilitation and environment improvement in accordance with requirements of Republic of Armenia Government 26.05.2006 N750-N decision.

85. Lands at closed landfills can mainly be used for forestry, tree planting and town-planning purposes. In case of justification of appropriate research results lands of closed landfills can be used for agricultural purposes.

86. In case of using for town-planning purposes only industrial or common use facilities (without cellars) can be planned in those areas.

87. Landfills exploited with violation of town-planning, environmental or sanitary regulations and spontaneously organized landfills are subject to closure. Closure of similar landfills and soil rehabilitation can be implemented through development and implementation of an appropriate program of measures based on inventory and registration.

Annex 2

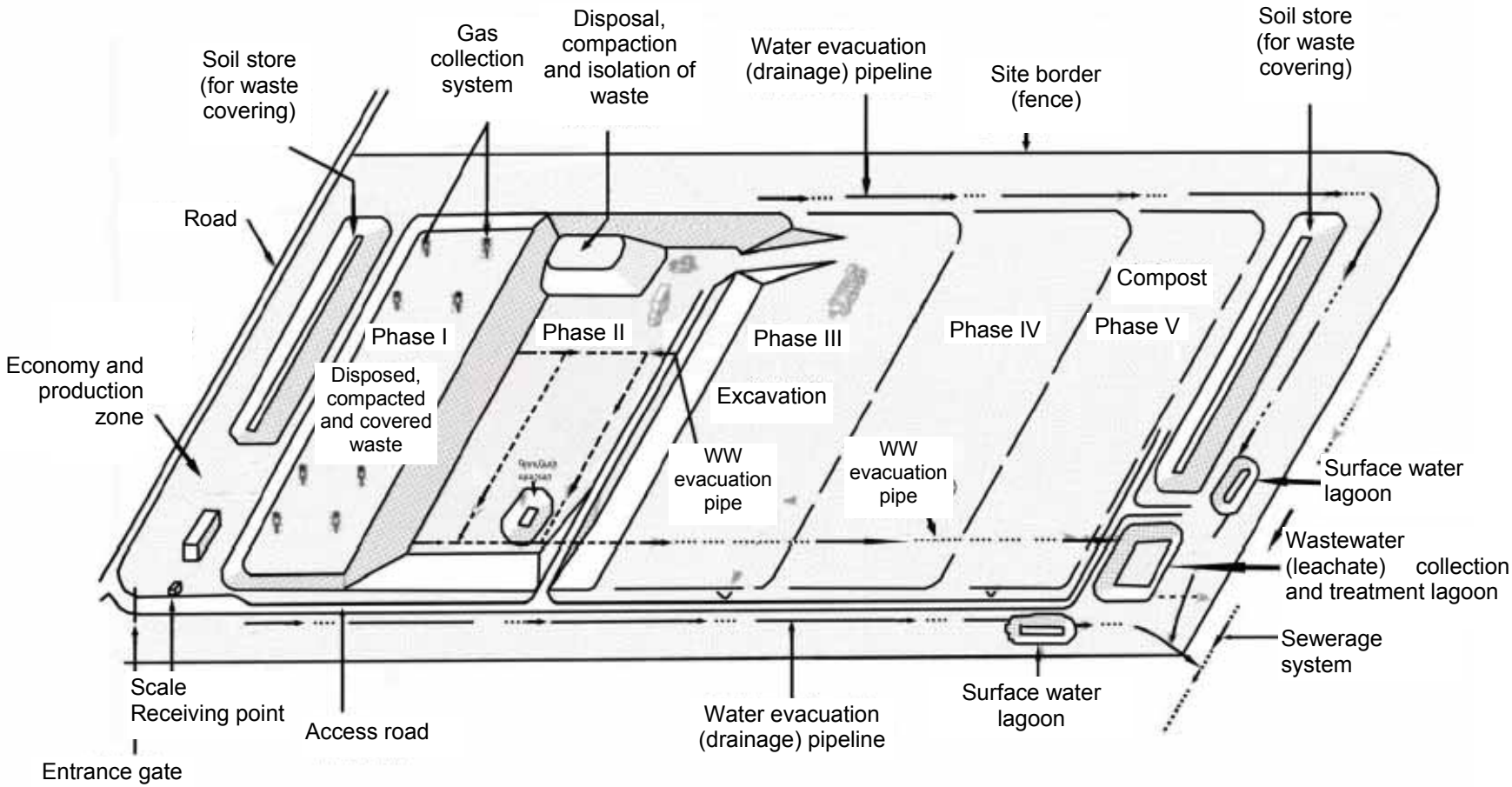


Figure 1: Landfill scheme

Annex 2 (continuation)

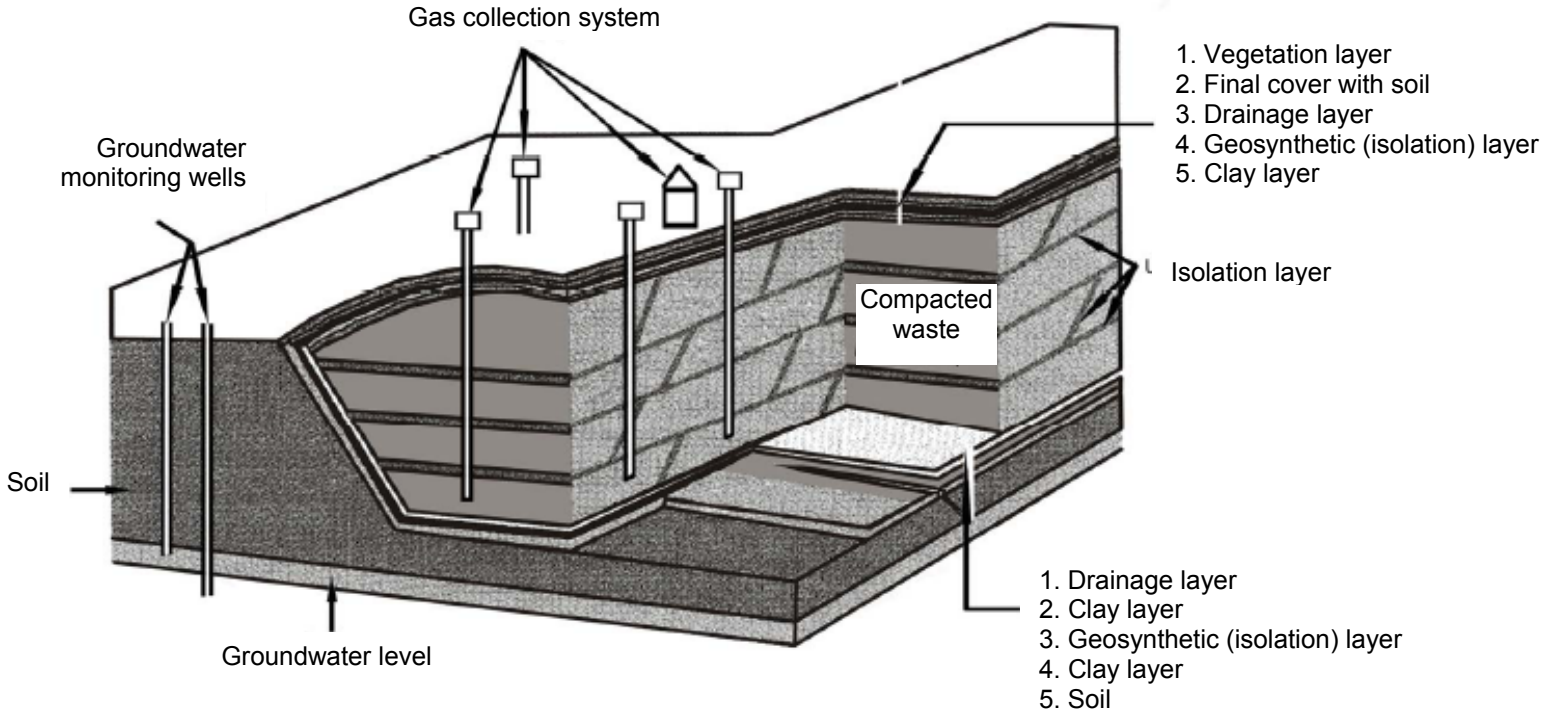


Figure 2. Profile of landfill

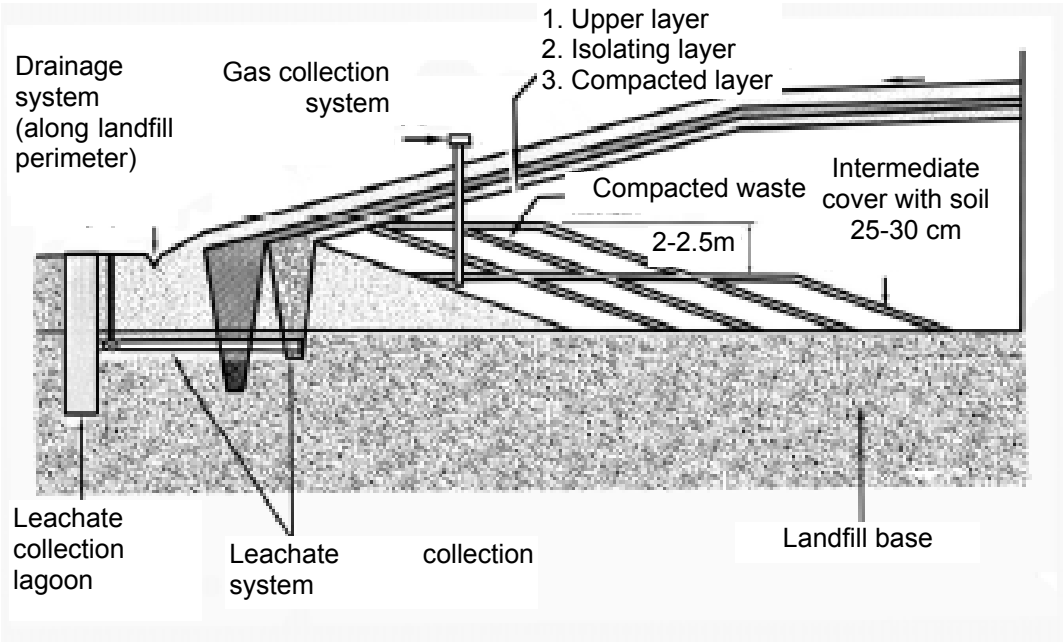


Figure 3. Sample of landfill profile

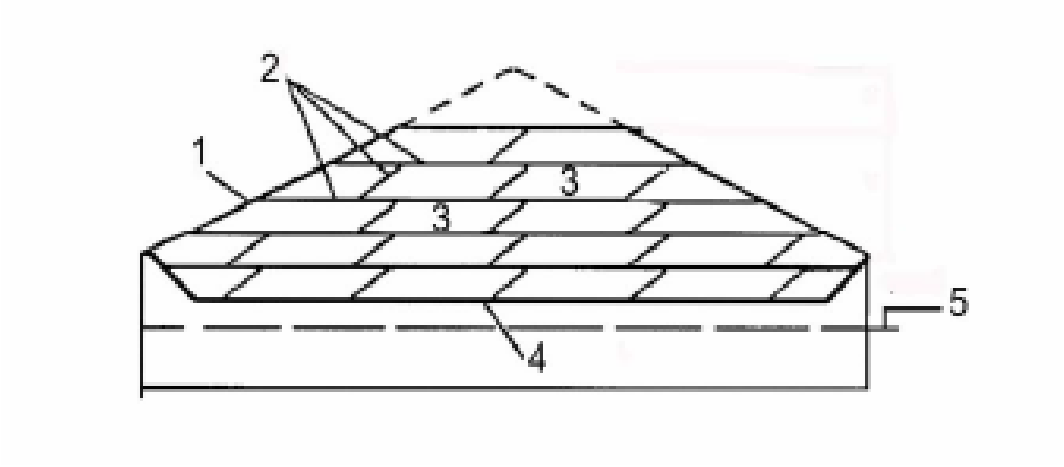
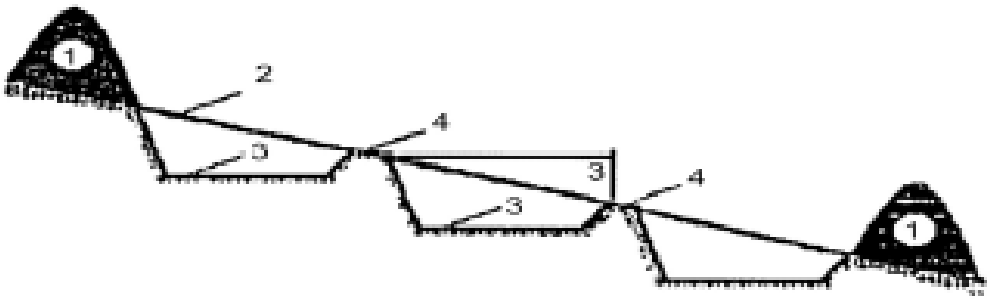


Figure 4. Profile of a simple landfill

1. External isolation layer
2. Intermediate isolation layer
3. Waste
4. Waterproofed base
5. Groundwater horizon

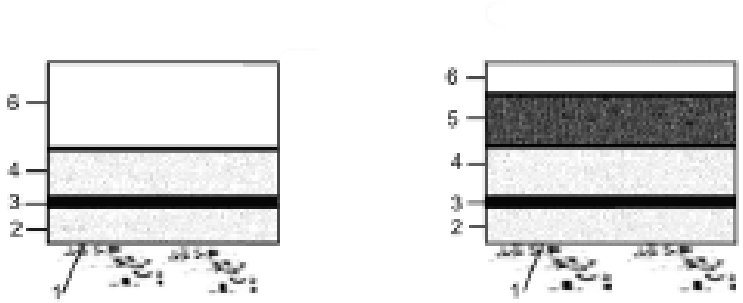
Annex 4



Schematic profile of staircase type landfill sells

1 – Storage of excavated soil to be used for waste covering
2 – Natural surface of the area before soil excavation
3 – Horizontal base of sells (pits)
4 – Intermediate separating soil bands

Annex 4



Option A **Option B**

Samples of artificial isolation of landfill base

Option A: without drainage layer, Option B: with drainage layer
1 – Soil
2 – Compacted main layer of clay (20-30 cm)
3 – Artificial isolating layer (membrane or resilient substance)
4 – Protecting layer of compacted clay soil (30-50 cm)
5 – Leachate collection drainage layer (crushed rock, 30-50 cm)
6 – Waste

Annex 5

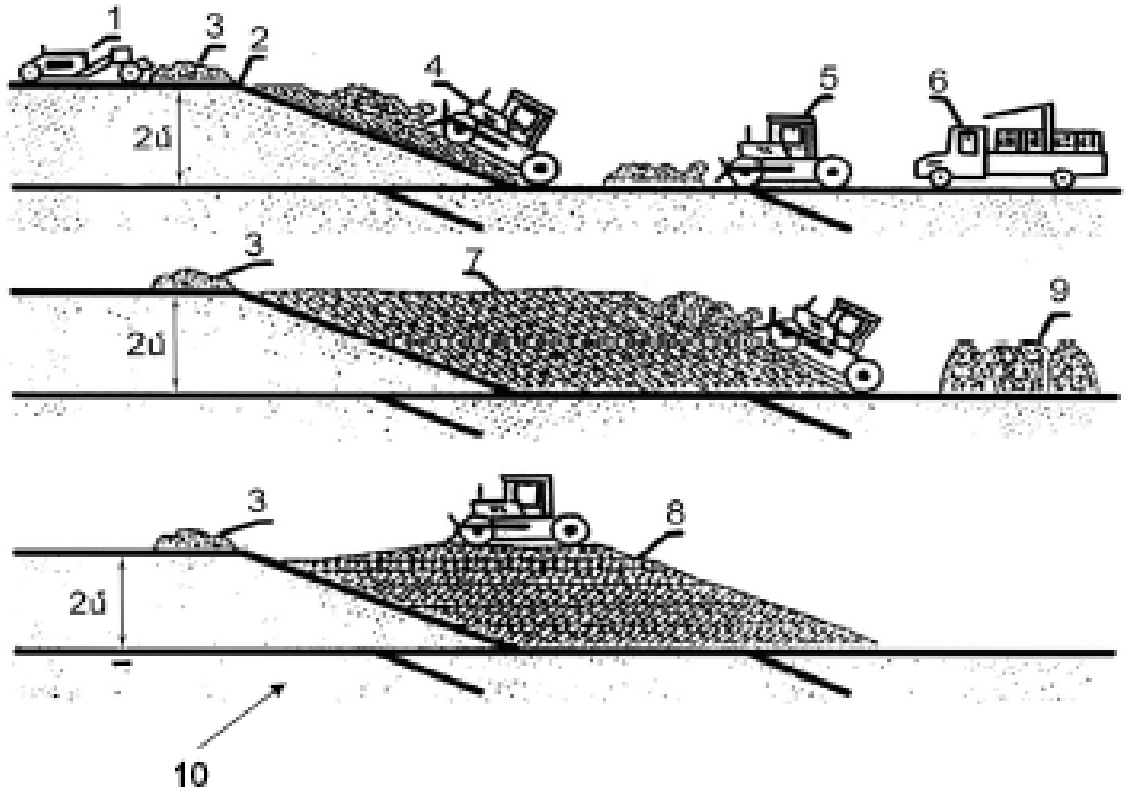


Figure 4. Bottom-up method of waste disposal

1 - Dump-body machine for transportation of soil
2 – Isolating layer
3 – Soil for isolation purposes
4 – Waste compacting machine or bulldozer
5 – Bulldozer for transportation of waste from discharge point to working site
6 – Waste discharge point
7 – Compacted waste layer (2 m)
8 – Intermediate layer of compacted waste (0.5 m)
9 – Discharged waste
10 – Previously disposed waste layer

Annex 5 (continuation)

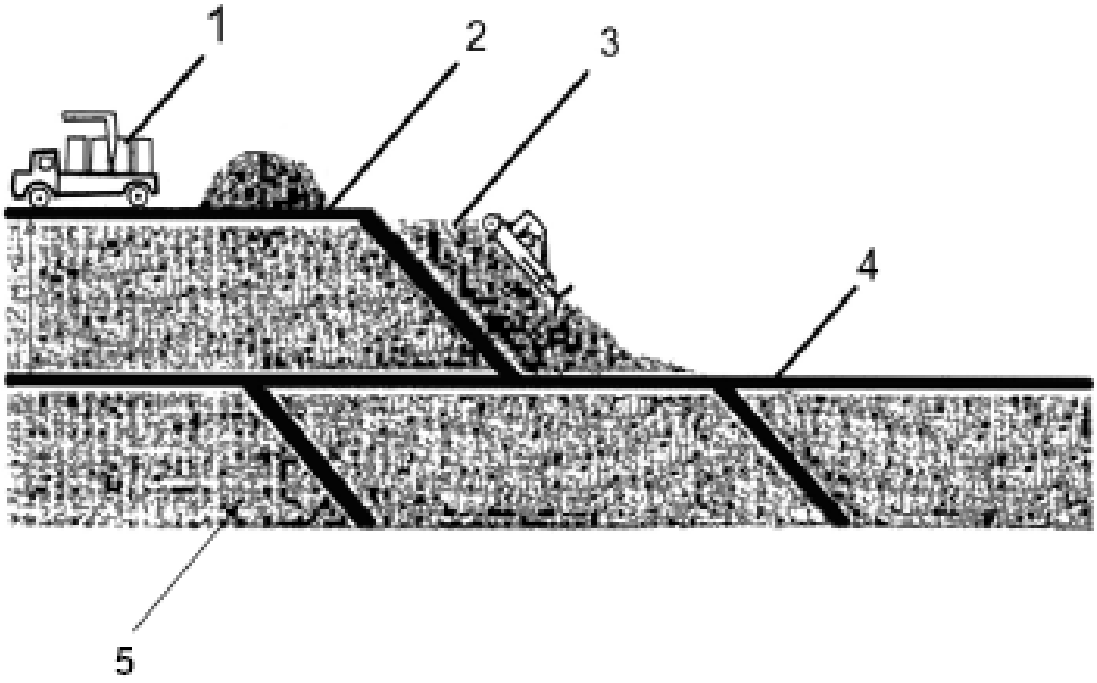


Figure 5. Top-down method of waste disposal

1 – Waste discharge point
2 – New isolating layer
3 – Compaction of waste at working site
4 – Isolation (layer) of the previously disposed waste
5 – Previously disposed waste layer

Appendix 1
Normative References

1. Law RA “On wastes”(ՀՕ-159-Ն,2004)
2. Law RA “On RA population sanitary-epidemic security provision”(ՀՕ-43, 1992)
3. “RA terrestrial code”(ՀՕ-185, 2001)
4. Law RA “On town-planning”(ՀՕ-217, 1998)
5. RA President N ՆԳ-68-A order approving “List of measures for the years 2009-2011 ensuring implementation of RA-EU action plan in the frames of European Neighborhood Policy”
6. RA Government decision N 1204-N, 01.08.2002 “National action plan on environment hygiene.”
7. RA Government decision N 1840-N, 02.12.2004 “On confirmation list of measures, concerning number of international environmental conventions.”
8. RA Government decision N 812, 21.12.1998 “On residential, social and industrial buildings and constructions planning, examination, concordance, affirmation and changing order establishment”
9. RA Government decision N 997-N, 08.08.2003 “On territorial design planning and project elaboration, examination, concordance, affirmation and changing order establishment.”
10. RA Government decree N 96, 02.02.2002 “On town-planning documents expertise order establishment.”
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12. RA Government decision N 500-N, 20.04.2006 “On roll management establishing of wastes origin, processing and using objects.”
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14. RA Government decision N 750-N, 26.05.2006 “On approving of technical regulations of undergoing reclamation degraded soils and requirements to soils reclamation.”
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16. RA Government minute decision N 30, 23.07.2009 “On construction and demolishing wastes safely utilization conditions approval.”
17. RA Government minute decision N 48, 19.11.2009 “On Approving the list of wastes occurring from different technological processes and specific rate of industrial and consumption wastes”
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21. CN&R 2.07.01-89. ”Town-planning: planning and construction city and village built-up areas”
22. CN&R III-4-80 “Safety appliances in building construction.”
23. RACN I-1.01-95 “System of rationing and standardizing in building construction.”
24. “Strategic policy consultancy on creation of solid waste management integrated projects in Ararat and Vajots Dzor marzes.”, RA Town-planning ministry and EU TACIS project, 2004
25. “Waste comprehensive management system enhancement in Armenia” RA Nature protection ministry and UNDP joint project, 2006
26. “Consultative research on solid waste management by collaboration of Yerevan city social and private sectors.”, RA ministry of Economy and German “Fechner” company.
27. “Proving ground technologies”, by V.Hogland, “Ecoteckprom”, 1997 (in Russian, translated from English).