CHAPTER

3

REHABILITATION METHODS AND ENGINEERING APPLICATIONS

3.1. Introduction

The term solid waste management (SWM) comprises all processes from occurring of solid waste up to the disposal of it. Integrated solid waste management (ISWM) is a more comprehensive concept than SWM due to containing a lot of components, for example, public health, economics, aesthetics, etc. Open dump site rehabilitation can be analyzed within the scope of the ISWM. As a result, ISWM can be explained as all techniques and applications to minimize the environmentally harmful effects of solid waste and to convert it to a useful product.

The open dump site method has been used by municipalities for the removal of municipal solid waste (MSW) because of easiness, effortlessness, economic reasons, technical deficiencies, and environmental irresponsibility. The open dump site method is an inappropriate solid waste removal method on account of engineering design and operation deficiency.

Organic and biodegradable waste originating from MSW is the main responsible issues related to the negative effects of open dump sites. These types of solid waste after being deposited in an open dump site start to decompose firstly aerobically and then anaerobically. High carbonaceous matter content in biodegradable waste increase chemical oxygen demand (COD) concentration in leachate and landfill gas volume in the dumping area. Leachate sources primarily are the water content of organic solid waste and precipitation. As mentioned above, COD concentration of leachate is high because of the high organic content of MSW. In addition, leachate is generally characterized by high volatile fatty acids (VFA) heavy metals, ammonium nitrogen and low pH. Therefore, it is described as high-strength wastewater in terms of characterization and treatability. If leachate reaches underground water, this will cause irreversible effects. As known, open dump sites don’t have a leachate collection pipe system. The other main problem of open dump sites is landfill gas, especially methane. Methane gas causes explosions and fires on the site and around open dump sites. Moreover, methane is a more dangerous gas than carbon dioxide in terms of the greenhouse effect and climate change. Methane gas is released into the atmosphere, due to the absence of a landfill gas collection system in open dump sites. Odour is the other problem that arises from open dump sites. In particular, the suburbs are influenced by the type of negative effects of open dump sites. Open dump sites must be rehabilitated due to their harmful and unhealthy effects.

While developed countries use modern solid waste disposal systems such as incineration, composting, and landfill, uncontrolled dumps have been still used in undeveloped and developing countries, unfortunately. Open dump site rehabilitation is an important issue that needs to be on the agenda. Even though the open dump site is no longer used, it must be rehabilitated because of its ongoing damages.

Different methods have been used for the rehabilitation of open dump sites. In-situ rehabilitation, rehabilitation after mechanical separation, and rehabilitation via solid waste transfer to the landfill are the most commonly used rehabilitation methods. Which method to use is decided according to the situation of the uncontrolled dump sites and needs. In addition, rehabilitation cost is also an important parameter. Effective parameters related to method selection are location, size of the area, disposed solid waste quantity in the open dump sites, and nearness to the underground and surface waters. Topographic and geologic factors are also important in deciding whether or not to carry out in-situ rehabilitation. Waste characterization can be investigated by taking samples from different points of an open dump site. As a result of the characterization study, rehabilitation can be applied after mechanic separation. For example, if recyclable waste quantity is high and the rate of under sieve material is low, mechanic separation will be an extremely useful procedure. But economic factors and cost analysis must be taken into consideration. Engineering applications consist of these types of assessments and applications.

Engineering applications can be examined under two headings as evaluation of current state and planning of rehabilitation. Evaluation of the current state includes assessment of area situation before disposal, ultimate area planning, geological and hydro-geological survey, and types and quantity of deposited waste. After this stage comes rehabilitation planning and implementation issues. These stages consist of slope stability and embankment construction, surface water drainage system, gas drainage system, final cover, vent construction, road and chimney establishment, landscape planning, monitoring well, and control planning, respectively. Although these stages differ within different rehabilitation methods, they are the main process.

The purpose of this chapter is to introduce the reader to rehabilitation methods and engineering applications of open dump sites. In this direction, in-situ rehabilitation, rehabilitation after mechanic separation, and rehabilitation via solid waste transfer to the landfill as rehabilitation methods will be discussed in the next titles. In addition, engineering applications will be explained.

3.1. Rehabilitation methods

There are no definite rules set by regulations in European countries for the rehabilitation of open dump sites. The European Union's directive on the storage of waste (No: 1999/31/EC) defines the procedure to be performed to completely prevent or minimize the effects of waste storage activities on the environment. Waste storage areas closed before this regulation enters into force do not have to comply with the "dump site closure criteria" specified in the regulation. However, member states have to make arrangements in line with the European Union Landfill Directive for the landfills they currently operate (including open dump sites). Rehabilitation of open dump sites is one of the priority issues among environmental problems and is usually left to the initiative of local governments. The open dump site rehabilitation process is a multi-factor system that includes condition assessment, planning, and implementation steps. In the rehabilitation process, surface water and leachate control and gas drainage systems can be listed as the processes that should be applied during rehabilitation. Different rehabilitation methods may include different steps as well as the processes mentioned. Other rehabilitation procedures may incorporate different steps and processes in addition to the ones listed. Rehabilitation approaches will be reviewed under three key areas in this section.

3.1.1. In situ rehabilitation

In-situ rehabilitation, as the name suggests, can be defined as the rehabilitation of open dump sites in the area where they are located, without moving them to another place. This rehabilitation method provides for the rehabilitation of dump sites that have been abandoned or are still in use. The priorities of this rehabilitation method are to prevent problems such as odor, insect formation and the spread of disease-causing microorganisms and to make the closed dump area a safe habitat for nature and living things. The purposes for which the closed area after the rehabilitation process can be used will be mentioned in Chapter 7.

In the in-situ rehabilitation method, the procedures given in Figure 3.1 are performed sequentially. The current situation is evaluated primarily for the dump site area to be rehabilitated. As a result of this evaluation, the final state of the area, its geological and hydro-geological structure, the type and amount of stored waste are determined and how the closing process will be applied is planned. After the planning, slope stability and filling works, surface water drainage system, leachate drainage system, gas drainage system, a final cover layer, culvert and road details, landscape plan, and observation wells and control plan processes are carried out respectively. These stages will be explained in detail in the engineering applications section.

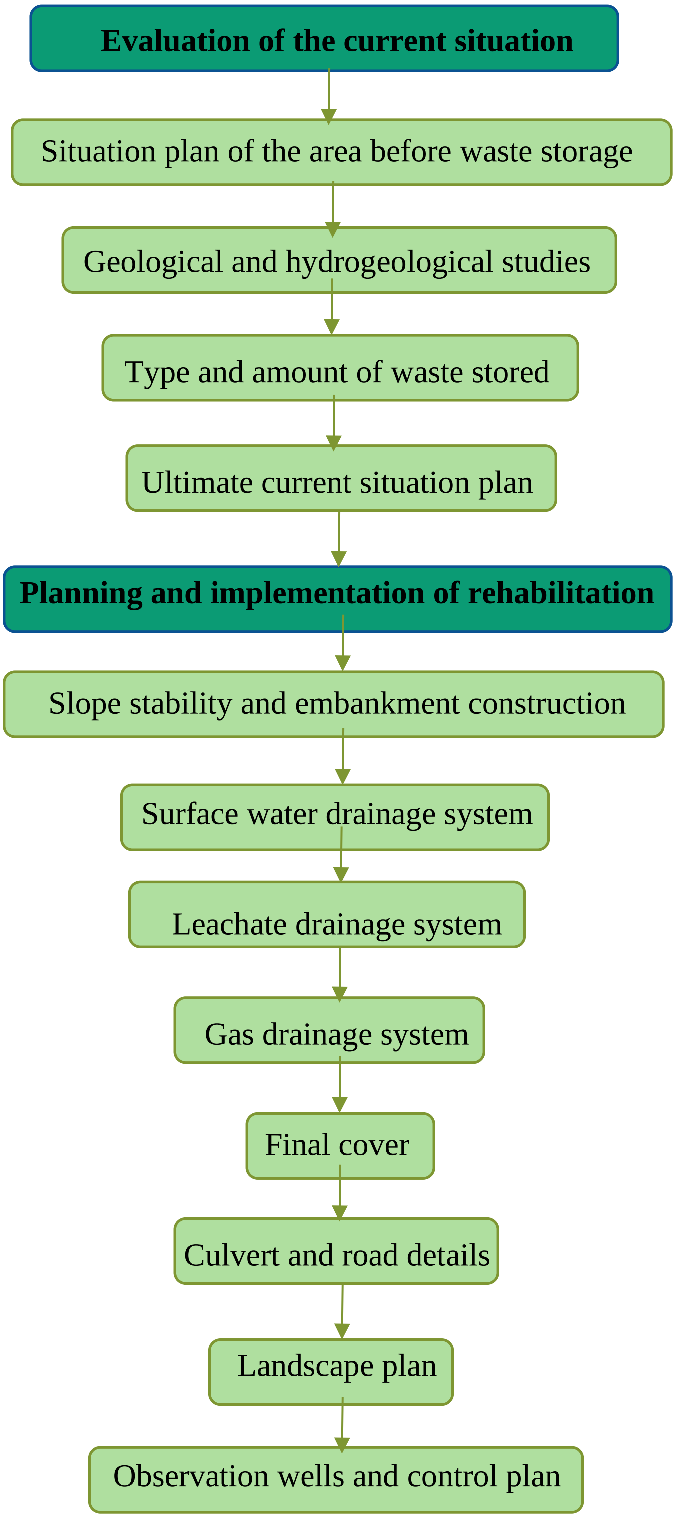


Figure 3.1. In-situ rehabilitation flow chart.

During determination of the slope stability and the boundaries of the area, the waste placed on the surface is somewhat displaced. Along with the laying and compaction of the cover layers, the waste in the open dump site is compacted a little more. In the in-situ rehabilitation process, no other improvement is applied to the waste. Organic wastes in the storage area continue to biodegradation for years after the rehabilitation process is completed. During this decomposition process, water and landfill gases (LFG) are released. For this reason, the presence of leachate and gas drainage systems in closed open dump site is important in order not to pollute groundwater and to avoid the risk of fire and explosion.

Since the open dump sites around the world have been operated uncontrollably for many years, the amount of waste in the area and the size of the stored area cannot be estimated. For this reason, the rehabilitation of most of the open dump sites is carried out with an in-situ rehabilitation method.

3.1.2. Rehabilitation by waste transportation

In some cases, in-situ rehabilitation of open dump sites is not possible. In such cases, the rehabilitation of open dump sites is carried out by transporting the waste from their existing places to the sanitary landfills. Especially if the amount of waste is low in the open dump sites, the waste transportation method can be easily applied. Apart from this, reasons such as the open dump site’s being an environmentally sensitive area (for example, a special environmental protection zone), high groundwater level, and the presence of a sanitary landfill nearby are effective in choosing the rehabilitation method through the transportation of wastes. In this method, the first step is also to evaluate the current situation. Afterward, the waste is transferred to the landfill. During the transfer, the recyclable waste in the area can also be separated. After the waste is completely emptied, depending on the condition of the area, a fill or cover layer is applied over the existing area. The rehabilitated area can be used for various purposes. The flow chart for this method is shown in Figure 3.2.

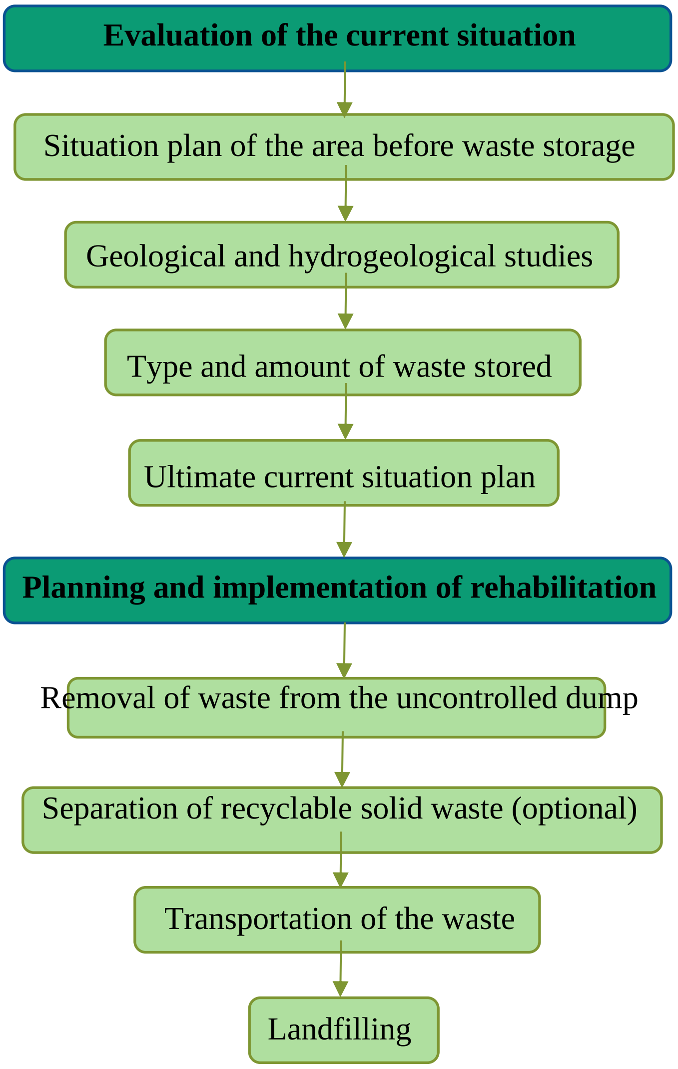


Figure 3.2. Rehabilitation flow chart by the waste transportation method

As stated above, application of this method in cases where the open dump site is small, the amount of waste is low, or the area to be transferred is nearby to open dump site may be cost-effective method. If the area where the open dump site is established is close to any surface or underground water source, the leachate or surface water drainage system must be planned very well. In this case, transportation of waste would be a more convenient solution to avoid spending more money. It may be appropriate to use transportation method for open dump site that is still in use, since the degradation of organic wastes in a young storage area is largely incomplete. After the rehabilitation and closure of this type of open dump, the organic wastes in the area continue to biodegrade. As a result of decomposition, there is a decrease in the volume of the wastes and collapses occur in the stored area. Settlement in the area can affect the final cover layer and damage the surface water and gas drainage systems. For these reasons, if it is economically viable, rehabilitation by waste transportation from the open dump site to an operating sanitary dump site may be a suitable option.

3.1.3. Rehabilitation after mechanical separation

The rehabilitation of the open dump site using after mechanical separation method can be defined as the rehabilitation performed by separating the recyclable waste such as metal, plastic, glass, and combustible organic waste in the open dump site from the soil and fine particles. Since there is a material recovery here, it is possible to come across the term "landfill mining" in the literature instead of the term "rehabilitation after mechanical separation of recyclable wastes". In this method, as in the above-mentioned method, after the current situation is evaluated, the wastes are excavated and divided into certain classes (Figure 3.3). The elements extracted as a result of excavation can be classified mainly as soil layer, recoverable wastes, metal wastes, and fine particles. Evaluation of recyclable waste is generally done in two ways. In the first method, metal, plastic, and glass wastes that do not have much degradation and pollution are subjected to the recycling process. In the other method, all combustible parts are used in energy production after the metal wastes are separated.

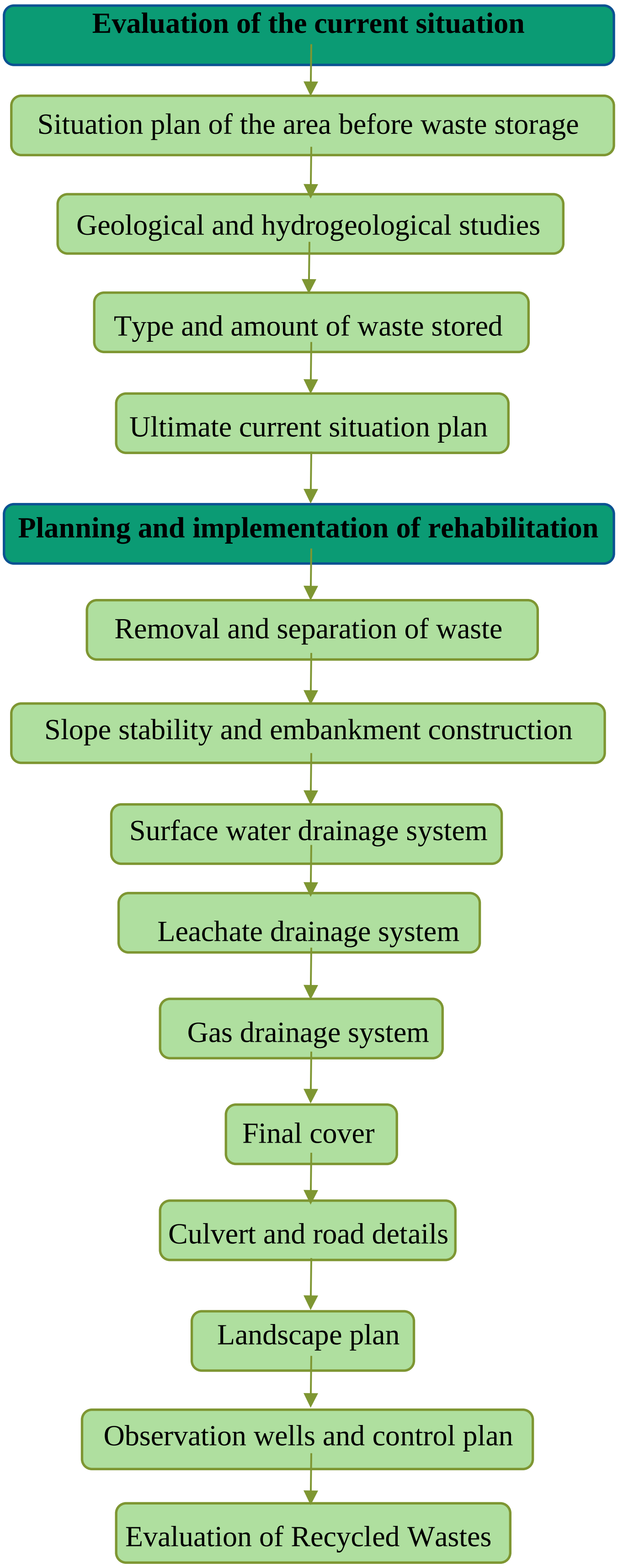


Figure 3.3. Rehabilitation flow chart after mechanical separation of recyclable wastes

Since the cost of applying this method is high, the feasibility of making a profit from the field should be established by conducting pilot studies. Such a feasibility study was realized in the rehabilitation study of the Florida open dump site (Jain et al., 2013). In this article, firstly, a pilot-scale study was carried out on 1 hectare of approximately 18.2 hectares of land, and then full-scale rehabilitation studies were carried out on 6.8 hectares. In another study, two different scenarios were studied for the utilization of recyclable wastes as fuel by the waste mining method in an open dump site in Sri Lanka. However, it has been concluded that waste mining is not suitable for that area because the transportation costs are more than the electricity generation gain (Maheshi et al., 2015).

3.3. Engineering applications

3.3.1. Evaluation of the current situation

Before starting the rehabilitation works, the current situation of the open dump site, which is planned to be rehabilitated, should be stated. It is important for the rehabilitation planning to have information about the situation plan of the area before the filling, geological-hydrogeological studies, the type and amount of the stored waste, and the final situation plan. This information can be useful in many issues, from the selection of the rehabilitation method to the determination of the techniques to be used in rehabilitation applications.

3.3.1.1. State of the area before filling

Before beginning work on rehabilitating an open dump site, information on the status of the land before it is filled is required. Furthermore, before the land is utilized as a dump site, it is vital to acquire information about the purpose for which it is used, as well as the criteria used to select this location.

There are certain criteria for the selection of the location of the landfill in the disposal of wastes with the landfill method. The first of these criteria is that the area to be used as a landfill is large enough to store waste for 25-30 years. Another important criterion is the distance between the area and the residential areas where the solid waste is collected. The selected area should not be so close to the residential areas as to adversely affect the environmental health, and not so far away that the solid waste collection vehicles should excessively increase the fuel and depreciation costs. Apart from this, attention should also be paid to the special conditions of the selected area, such as its distance from agricultural lands, forest areas, and special protection zones, its closeness to underground and surface water resources, its topographic, geological, and hydrogeological conditions, the risk of floods, landslides, and avalanches, and the prevailing wind direction and precipitation. However, as stated above, these criteria are valid in the selection of the landfill site. But, in the open dump site method, which means the indiscriminate storage of waste, most of these criteria are not applied at the site selection stage. Generally, a pit area where wastes can be discharged easily is chosen as a storage site. No special situation is required in the selection of the open dumpsite, and random dumping is done on land not far from the settlement to facilitate the transfer of wastes. The proximity of the area to the residential areas brings with it environmental and human health problems. Open dumps may be close to agricultural areas (Figure 3.4.a), forests (Figure 3.4.b), and riverbeds. Unfortunately, even fault lines can be used as an open dump site(Figure 3.4.c).

a. open dump site near an agricultural area (vineyard next to the field)

b. open dump site in forest area

c. open dump site within the fault line

Figure 3.4. Some adversely effects of open dumps.

Knowing the state of the open dump site before it is filled is a factor that will contribute to each step applied during the rehabilitation of the open dump site and will help for what purposes the area should be used after rehabilitation. For this reason, rehabilitation work should be started by determining the state of the area before it is filled.

3.3.1.2. Geological and hydrogeological studies

The information about the soil components and water resources under and around the open dump site, which is revealed as a result of geological and hydrogeological studies, is important for calculating the pollution risk of the landfill for groundwater or soil.

Thanks to the geological studies carried out in the open dump site, the soil and rock types in the area have been determined. The type of soil layers under the site indicates how deep the leachate can go and mix with groundwater. Therefore, the type of subsoil affects the transport of both water and pollutants. Since the permeability of sandy soil is high, the risk of leachate mixing with groundwater will be higher. However, clayey soil has a lower permeability and a higher pollution-capturing capacity. Subsoil type also affects the amount of settlement. For example, settlement is not high in sandy soils, while settlement is more in clay and peat soils. If the subsoil layer of the open dump site is composed of clay or peat soil, it should also be considered that some collapse may occur when the final cover layer is applied (Mcbean et al., 1995). For these reasons, it is important to determine the soil structure before starting the rehabilitation works.

In geological studies, in addition to soil structure, information about general tectonic formations, folds, strikes, and dips, fold axes, flexures, anticlines, and synclines and their axes, closed structures and their open or closed directions, faults and their types, strike and dip of fault planes, fault slips are also accessible (DSI 2019). After the geological surveys, this data should be shown on the map, explained, and reported. In the light of this information, predictions can be made on the issues of landfill gas compression, gas leaks, and changes in the direction of leachate due to ruptures that may occur in the open dump site as a result of an earthquake that may occur.

When examining the hydrogeological structure of a region, the climate of the region and the determination of the water resources in its vicinity are important issues to be considered. Precipitation, temperature, and evaporation data for the region can be accessed from the meteorology stations located near the open dump site. By evaluating these data, monthly and annual precipitation amounts should be calculated. With these data, the amount of precipitation water that can mix with the groundwater from the landfill surface can also be calculated. As seen in Figure 3.5, open dump sites may be close to water sources. Another profit of hydrogeological studies is the identification of rivers, lakes and marshes, dams and ponds, and underground water resources in the vicinity. Hydrogeological study reports may include the size, flow directions, flow rates, and usage purposes of these water sources. As a result of evaluating these data by blending it with climate information, monthly and annual changes in water resources are revealed.

Figure 3.5. Example of an open dump site near a water source

Determining the groundwater level is an important process to define the contamination levels that may occur in groundwater originating from the open dump. In cases where the groundwater level is close to the bottom of the storage area, it is inevitable that the pollutants carried by the leachate in the storage area mix with the groundwater and pollute it. The permeability of the soil layer at the bottom of the storage area is also effective in determining the level of this contamination. The concentrations of the pollution parameters measured by sampling from the groundwater should also be added to the hydrogeological study report.

3.3.1.3. Type and amount of waste stored

One of the necessary information at the stage of determining the status of the open dump site is the data on the waste stored in the area. These data include how long the dump site is used, the volume, density, and mass of the waste in the storage area, and the types of waste. Knowing the amount of recyclable and organic waste in the stored waste is one of the important parameters that can be used in determining the rehabilitation method. For example, if the amount of recyclable waste in the area is high, the rehabilitation of the open dump site can be done with the method of mechanical separation before rehabilitation.

If the open dump site is operated by a municipal corporation, any information about the waste can be obtained from the relevant unit in the municipal corporation. In a waste storage area where the municipal corporation does not keep records, or illegal dumps, the amount and types of stored waste are determined in two ways. The first method is based on estimation. In this method, residential areas that bring waste to the open dump site are determined. A waste characterization study is carried out by determining the households from these settlements, and the amount of waste production per person is calculated. In characterization studies, the presence of scavengers should also be considered. The amount of waste in the storage area is estimated from the amount of waste generation per person and how long the open dump site has been used. In the other method, after calculating the volume, mass, and density of the waste by taking samples from certain points of the open dump site, a characterization study can be conducted. The reason for taking samples from different points in that the waste has various compression ratios in different regions, and the amount of degradation rate of organic waste in the open dump site is variable according to the years. If the open dump site to be rehabilitated is an area that has not been used for a long time, it can be said that this area may be a more suitable open dump site for mechanical separation method since most of the organic wastes will have decomposed over time.

3.3.1.4. Final situation plan

Before the rehabilitation of the open dump site, a situation plan containing the information that is considered useful in the planning and execution of the rehabilitation should be prepared. In the situation plan, first, the geographical location information and surface measurement of the area should be included. This information can be supported by maps of the area, photographs showing the current state of the area, and information about the residential areas in its vicinity. Apart from this, the depth and volume of the waste should also be calculated and added to the site plan. Another important factor is how long the open dump site has been used and when the waste storage process ends. Thanks to this information, the amount of landfill gas that may be released as a result of the decomposition of organic wastes in the area, the gas output time and the amount of leachate can also be determined. These will be essential information in the gas and leachate collection system design in the next step.

Current situation plans may also include environmental problems. Including issues affecting environmental health such as odour and fly problem in the storage area in the plan allows necessary precautions to be taken during rehabilitation. In addition, when deemed necessary, samples from the surface or underground waters can be taken and the presence of fecal coliforms can be added to the plan. Information on disasters such as earthquakes, landslides, explosions, and fires in the region can also be added to the current situation plan. During rehabilitation, attention should be paid to gas entrapments that may spread from the open to the environment thus creating the risk of explosion and fire.

Since current situation plans are the documents for which the first information is accessed before starting a job, any information identified should be included in the open dump site situation plan. After the situation plan is created, rehabilitation work can be started with more confidence.

3.3.2. Planning and implementation of rehabilitation

After the observations and the compilation of information about the open dump site, rehabilitation is planned, and studies are started. The planned rehabilitation work includes many steps. These steps are important issues to be taken to make open dump site safe, and the work done at each step directly or indirectly affects the other. In this chapter, slope stability and embankment construction work, surface water drainage system, leachate drainage system, gas drainage system, a final cover layer, culvert and road details, landscape plan and observation wells, and control plan sub-headings will be mentioned.

3.3.2.1. Slope stability and embankment construction

Since the open dump is not a suitable solid waste storage method, the shape and dimensions of the waste pile are not clear. In some cases, the waste hill height is very high, and sometimes the open dump site is spread over a large area. For this reason, first, it is necessary to determine the edges of the waste in the open dump site. As seen in Figure 3.6, borders are drawn and the region where the wastes should remain within these limits is determined. Afterward, the wastes outside these limits are transported into the planned area.

Figure 3.6. Determine the waste border

After this stage, the storage area must be reinforced for shear strength. A 3:1 slope should be given to the heap to keep the waste stable and to prevent the final cover layer to be applied to it from slipping (Blight, 2008). An example of this situation is given in Figure 3.7. The top of the heap should be made flat in order not to cause ponding. The upper part of the pile, which will be made in the form of a trapezoid, can be slightly inclined (at most 1-3 %) to allow the rainwater to run off.

Figure 3.7. Transporting waste inside the border and sloping the area.

In some cases, it may be necessary to terrace the pile rather than have a single trapezoidal shape. This is applicable in case of the height of the waste exceeds 1.5 m or there is a settlement near the site that may be affected by slippage, since it is difficult to supply the slope of 3:1 at once. An example of this was implemented after the collapse of the Meethotamulla open dump site in Sri Lanka (Jayaweera et al., 2019). To prevent additional slippage, the areas of the open dump site that were quite close to the residences were terraced. The same method was applied after the slipping problem in the Payatas open dump site in Quezon city in the Philippines (Jafari et al., 2013). In both examples, the intervention was carried out after the collapse and slipping problems were experienced in the uncontrolled dumps. Rehabilitation of open dump sites is of great importance to avoid such disasters.

3.3.2.2. Surface water drainage system

Water is one of the important parameters that should be evaluated in the disposal of wastes by storage method, as it is in many areas of life. For this reason, it is necessary to keep the water balance under control in the rehabilitation of open dump sites. There are many inputs and outputs that will affect the water balance in the open dumps (Figure 3.8). These inputs and outputs determine the amount and quality of leachate. The moisture content of the solid wastes in the storage area and the small amount of water produced during the anaerobic decomposition of the wastes increase the amount of leachate. Apart from these, the sources that increase the amount of leachate from outside the storage area are the infiltration of rainwater falling on the waste body and the water inputs leaking from the groundwater to the waste body. The part of the precipitation that evaporates from the surface and the part that passes into the surface flow constitute the outputs. By evaluating such sources together, the water balance in the area can be calculated. The water mass balance in a landfill is shown in equation 3.1 (Worrell et al. 2011). As a result of compiling this data, the infrastructure is created for the selection of materials to be used in the final cover layer, the surface water collection system, and the leachate collection system.

$$C = P\,(1 - R) - S - E \tag{3.1}$$

C : total percolation into the top soil layer, mm/yr
P : precipitation, mm/yr
R : runoff coefficient
S : storage within the soil or waste, mm/yr
E : evapotranspiration, mm/yr

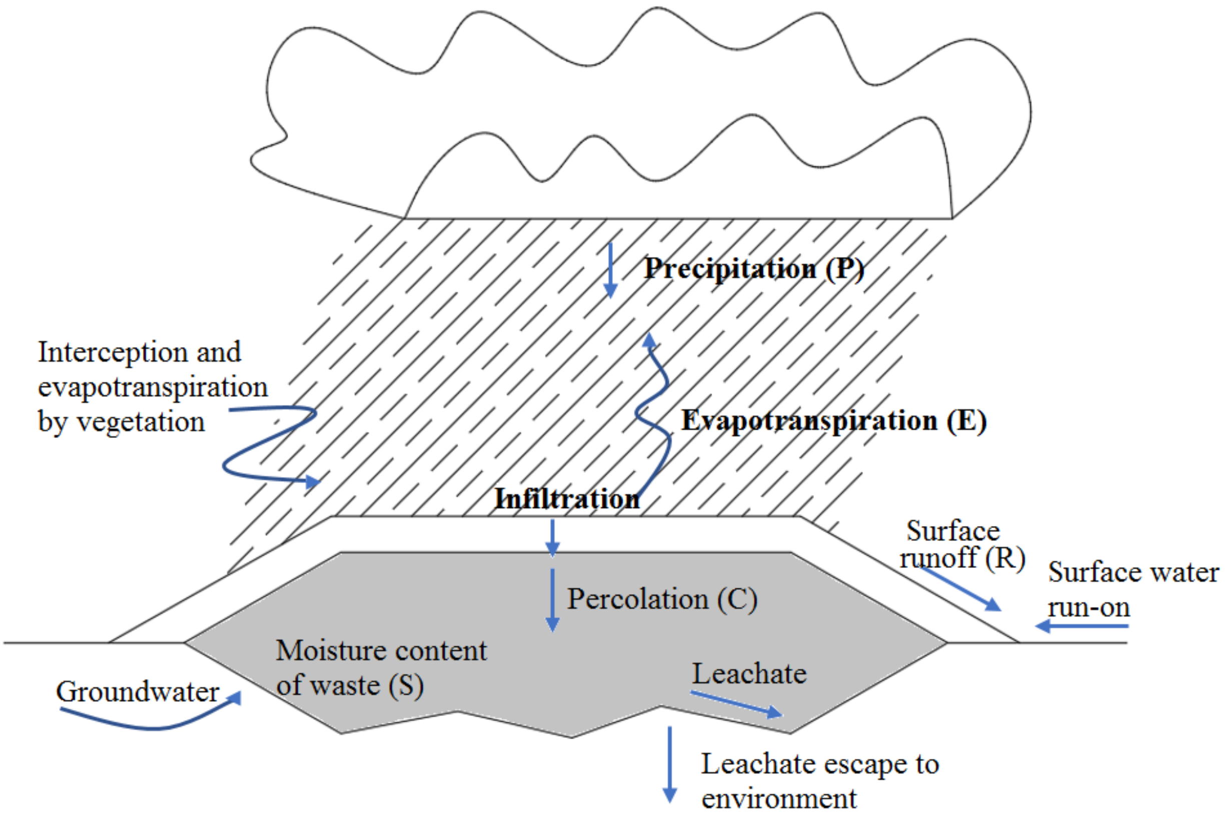


Figure 3.8. Schematic representation of the water balance in the storage area

Some measures are taken to reduce the amount of leachate caused by rainwater in waste storage areas. These can be listed as allowing surface flow by increasing the surface slope, reducing the amount of water leaking from the waste body by creating an impermeable final cover layer, blocking water leaks from the surface by preventing collapses and cracks in the storage body.

One of the most important factors preventing the mixing of surface water in the landfill with the waste body is the drainage layer in the final cover layer. It is necessary to construct a drainage layer to remove excess water from the topmost soil layer and to reduce the water load on the impermeable insulation layer. After the upper soil layer reaches saturation with precipitation, the waters pass into this layer. Thanks to this drainage layer consisting of sand with low humus content and high permeability, the water coming from the surface leave the area quickly without entering the waste body. If the economic situation is suitable, rainwater is allowed to flow from the pipes made of HDPE material placed in this layer to the main pipes located on the side edges by attraction. Collector pipes ensure that excess water is carried out of the storage area. The water coming into the drainage layer can be collected by inclining the surface without pipes. Channels are formed on the side edges to collect the rainwater passing over the surface flow (Figure 3.9).

Figure 3.9. Surface water collection channel

3.3.2.3. Leachate drainage system

Leachate management in the open dump site is carried out with the help of geological and hydrogeological studies done before planning. If economically and technically viable, pipes can be utilized to collect leachate in landfills. Factors such as the depth of the waste, the age of the waste, the topography of the area, and the underlying soil layer are effective in the creation of leachate drainage systems. In addition to this information, different applications are determined for leachate drainage depending on the height of the groundwater. It is possible to prevent the leachate from mixing with the groundwater by some methods such as a cut-off wall, collection pipes, or prevention ditches formed according to the direction of the leachate. The leachate collected in the waste body is transferred to leachate collection ponds built at the bottom of the field by pipes. With these arrangements, the pollution of the surface and underground waters near the open dump site is prevented. The collected leachate can be treated by biological and chemical methods. However, there is no need to establish a treatment plant since leachate formation will not be excessive after rehabilitation in the uncontrolled dumps. Leachate drainage systems will be explained in detail in Chapter 4.

3.3.2.4. Gas drainage system

One of the problems in open dump sites is the gases that form and accumulate in the storage area. Biogas, which is formed as a result of the decomposition of organic wastes under anaerobic conditions in open dump sites, is called Landfill Gas (LFG). This gas contains approximately 50-60% methane, 35-40% carbon dioxide, and 3-10% nitrogen. When these gases leak out of the area in an uncontrolled manner, they cause various environmental problems, especially global warming. There is a risk of explosion and fire, as a result of the accumulation and compression of gases and mixing with the air at different rates in the storage area. Landfill gases cause an explosion when mixed with air at a rate of 5-15%, and fire when mixed at a higher rate. As mentioned as chapter 1, the explosion in the Ümraniye-Hekimbaşı (İstanbul, Turkey) open dump site in 1993 can be given as an example of this situation (Kocasoy & Curi, 2000). To avoid such issues, gas drainage systems must be installed in open dump sites.

The amount of LFG varies depending on the amount of organic waste in the storage area and the storage period. The gas drainage system, which includes the gas collection and transport systems, is contained within the impermeable layer. Collection pipes are placed in the impermeable layer to ensure a controlled collection of gas. In cases where the amount of gas expected to occur in the current and future years is high, this system is supported by vertical gas collection chimneys. The collected gas, depending on the situation, is burned with an automatic torch system, or transported to a facility to generate energy. Gas drainage systems will be explained in detail in Chapter 4.

3.3.2.5. Final top cover

Information about the source of leachate in the storage areas was given in the section "Leachate drainage system". The final top cover layer, designed to prevent leakage of rainwater through infiltration, will be explained in this section. The design of the final top layer plays a major role in changing the water balance of the open dump site.

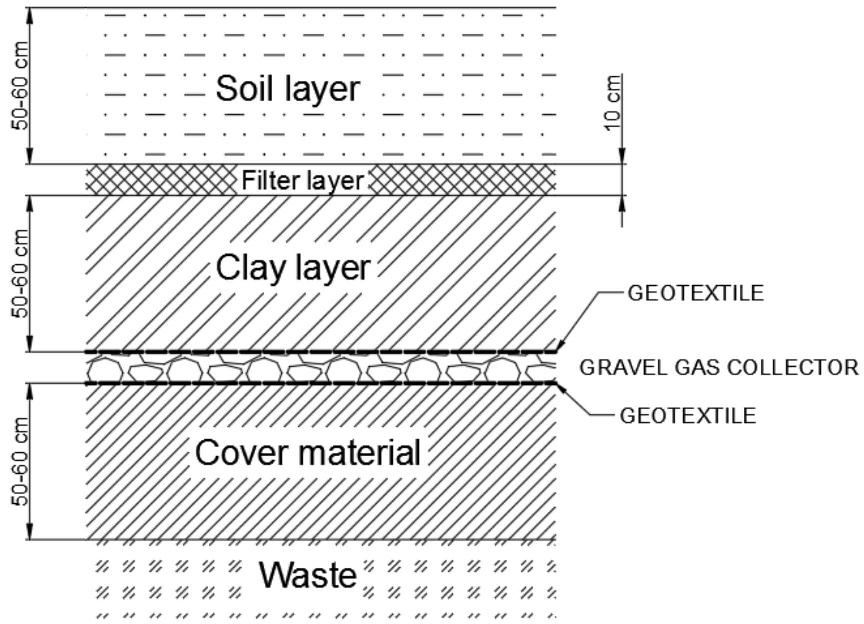
The use of the final top cover layer allows the design of leachate drainage and treatment systems to be adjusted for lower flow rates by reducing the amount of leachate and allows the system to be operated sustainably for many years without deterioration. Some factors need to be considered while creating the final top cover layer. Designs made without paying attention to these factors, prevent the use of the cover for many years and cause loss of money and time. In the rehabilitation of uncontrolled dumps, a poor final top layer also means unsuccessful rehabilitation. For this reason, it is necessary to consider the factors affecting the strength of the final top cover layer. The material to be used in the final cover, the slope, the amount of material to be utilized, and the layer thicknesses are all factors that influence the final cover layer. Another important component is to ensure proper stability so that it does not cause erosion. Furthermore, the amount of precipitation that will fall on the area in future times should be assessed, and it should be established whether the places where the water traveling through the surface flow will be directed are appropriate. While designing the cover layer, necessary controls should be made so that it can be used for many years without requiring any other process. In addition, a cost analysis should be used to determine the most appropriate ultimate top cover layer.

It would be more acceptable to augment the final top cover layer with layers that serve certain objectives rather than applying it as a single layer. The surface layer ideal for growing plants and the hydraulic barrier layer are two types of these layers. The hydraulic barrier layer, on the other hand, can be made up of layers like the filter, drainage, and impermeable layers. Table 3.1 lists the purposes for which these layers are used.

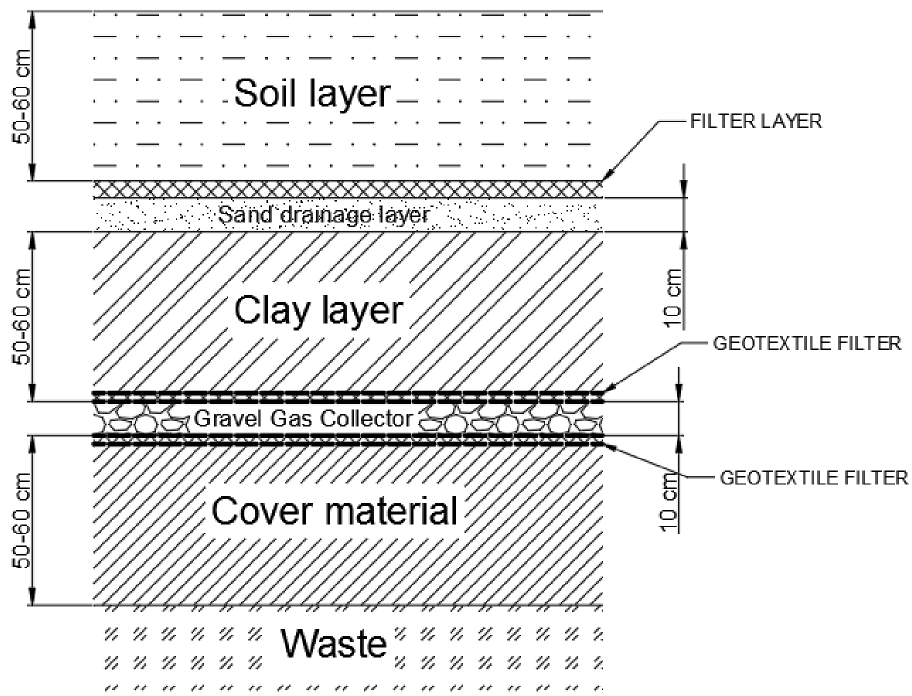
Table 3.1. The primary role of various layers within a landfill cover

Layer Type	Layer Component	Primary Roles
Surface layer	Soil layer	Since it is suitable for growing plants on it, it increases root development and water holding capacity, reduces infiltration and wind erosion.
	Filter layer	It prevents the soil layer and pesticides coming from the surface from mixing with the drainage layer.
Hydraulic barrier layer	Drainage layer	It allows the water coming from the surface to leave the system quickly.
	Impermeable layer	By forming an impermeable layer, the leakage of water into the waste body is prevented and it also hosts the gas collection system.

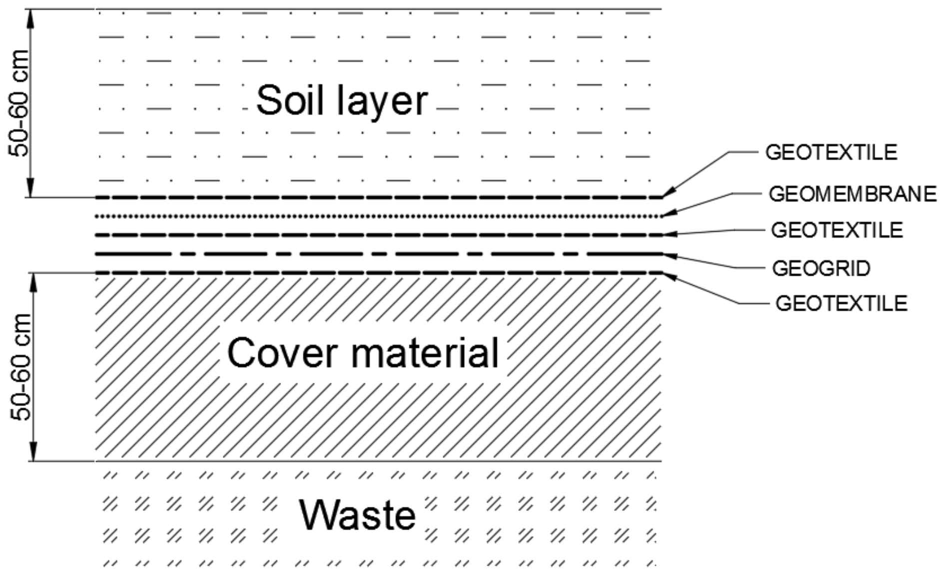
For the purposes mentioned in Table 3.1, there are no specific standards for the selection, thickness, and amount of material to be used in the layers, and the combination is left entirely to the discretion of the designer. Different combinations of these layers are given as examples in Figures 3.10. As can be seen from the figures, the soil suitable for growing plants should always be used in the top layer. Plants planted in the ground release their roots, making the ground stronger and protecting it from disasters such as erosion. However, very deep-rooted plants should not be used. Figure 3.10.a shows a simple design of the final cover. Here, the drainage and filter layers are used as a single layer. A layer of geotextile and gravel can be used as a drainage layer under the clay layer. The impermeable layer is often used as a suitable layer for gas collection. Figure 3.10.b is a slightly more detailed version of Figure 3.10.a, where the drainage and filter layers are separated, and the impermeability layer is strengthened. In Figure 3.10.c, impermeability was provided with a geomembrane, filtering was provided with geotextile and an environment suitable for the gas collection was created with geogrid (Republic of Turkey Ministry of Environment, Urbanization and Climate Change, 2014).


50-60 cm
Soil layer
10 cm
Filter layer
50-60 cm
Clay layer
GEOTEXTILE
GRAVEL GAS COLLECTOR
GEOTEXTILE
50-60 cm
Cover material
Waste

(a)


50-60 cm
Soil layer
FILTER LAYER
Sand drainage layer
50-60 cm
Clay layer
10 cm
GEOTEXTILE FILTER
Gravel Gas Collector
GEOTEXTILE FILTER
10 cm
50-60 cm
Cover material
Waste

(b)



(c)

Figure 3.10. Final cover layers' examples

3.3.2.6. Culvert and road details

Drawings of any technical operations to be carried out in the field should be recorded during rehabilitation planning. To avoid confusion in the implementation phase, it is important to determine all kinds of transactions in the planning phase. The plans for the culverts to be used to remove the leachate and surface water from the area should also be made before the work begins. Since the layers to be used in the final cover layer will also affect the amount of water to be formed, the dimensions of the culverts should be adjusted accordingly. The culvert to be used to remove leachate from the area should be sized according to the estimated amount of leachate and should be sufficient size and capacity. If a leachate collection pool is to be built, the culverts are connected to the rehabilitated dump site. In cases where there is no pool in the plan, the culverts allow the water to be connected to the nearest sewer network.

It is important that the road to be used for access to the open dump site is arranged before the work starts, so that the work machines to be used in the process can easily come to the site and carry out the activities in the area. The surface of the road should be strong so that it will not be easily damaged by heavy machinery passing over it. Compacted soil or asphalt can be used, depending on economic situation. The road to be built must be large enough to allow the mutual passage of at least two vehicles. Because the region will be visited for control purposes and used in the event of a potential threat after the works are completed, this road should be planned in such a way that intervention is made as simple as possible.

3.3.2.7. Landscape plan

Open dump sites can be used as green areas, recreation areas, or construction areas after rehabilitation. The purpose for which the area will be used should be clearly determined at the stage of rehabilitation planning. For example, if a structure is planned to be built on the site, it would not be appropriate to use membrane structures in the final cover layer. The most profitable and appropriate evaluation methods for rehabilitated storage areas are green areas or recreational use. The area needs to be planted for both uses. Plant selection is an important criterion at this stage. While the planting of this area with grass or meadow-type plants does not pose a problem, it is necessary to be careful in choosing the trees to be planted in this area. Plants with deep roots should not be preferred because their roots can puncture the insulating layer and cause surface water to be carried into the storage body. Plants suitable for the flora of the region, whose roots can remain in the last cover layer suitable for plant growth, are the most suitable plants for greening studies.

3.3.2.8. Observation wells and control plan

The maintenance, monitoring, and control of the open dump site, whose rehabilitation has been completed, should be carried out by the necessary authorities for a certain period. Some factors for these maintenance, monitoring, and control activities vary according to the condition of the storage area. These factors are given below:

-The gas collection system and the combustion installation, if any, should be maintained.
-If landfill gas is processed after collection, these systems need to be maintained.
-The quality of the collected gas must also be continuously monitored.
-The maintenance of the leachate drainage system should be done regularly.
-Leachate quality controls should be carried out by taking samples from the pool in the area at regular intervals.
-If there is a leachate treatment plant or transfer system, it should be ensured that they are regularly checked and maintained.
-Water quality should be checked by taking samples from the surface waters around the landfill.

-Observation wells for groundwater should be established to monitor whether there is a contamination from the area.

-Finally, problems that may arise in the final cover layers on the area's surface, as well as slips and collapses in the heap, should be monitored.

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