CHAPTER

6

FINANCIAL ASPECTS OF REHABILITATION

6.1. Introduction

There is a strong relationship between the environment and the economy. The mutual interaction of economy and environment is seen in the economic systems created by consumption and production as resource depletion, waste discharge into environmental areas, a change in aesthetic function, and global life taking on a new shape. In this interaction, the management process and form of the economy change the environment, and environmental characteristics play a key role in the success of the economy (Erturk, 1998; Marangoz et al., 2015). The relationship between the environment and the economy has become even more important today. Discussions generally focus on the careful use of resources and the compensation for the damage caused and the cost. In this context, the relation basically takes shape at two points. The first are expenditures made for environmental protection and environmental values, while the second are expenditures that the economy must undertake and suffer in order to eliminate environmental damage (Marangoz et al., 2015; Keleş et al., 2005).

Sanitary landfill is the most common and environmentally safe disposal method for the fractions of municipal solid waste (MSW) that cannot be reduced, recycled, composted, incinerated, or processed. Open dumping of MSW, practiced by approximately three quarters of the world's countries and regions, is a primitive stage of landfill development (Rushbrook, 2001; Joshi et al., 2007). Open dumps and unsanitary landfills cause environmental degradation as they are susceptible to open burning and exposed to scavengers and disease vectors. Many times, dumps are poorly located and operated by technically inexperienced personnel (Kurian et al. 2005).

Open dumps have a number of significant risks and impacts on the environment. The leachate generated as a result of the decomposition of waste pollutes surface and underground water resources. Air pollution from open burning, fire hazards, and explosions not only poses public health risks, but also increases emissions of greenhouse gases (methane and carbon dioxide). The scattering of waste by the wind and scavenging by birds, animals, and garbage pickers creates aesthetic discomfort. The bad odor generated by the degradation of the waste in the dumpsite restricts the development of land use as it reduces economic and social values in the environment. The landfill's lack of regular cover attracts animals as well as individuals who enter and collect waste without permission.

The process of rehabilitating a dump site into a sustainable landfill can be done incrementally, depending on the risk posed by the landfill and its financial aspects. The key to making such a change possible is the introduction of gradual improvements in disposal standards in accordance with current scientific knowledge and available financial resources (Rushbrook, 2001; Rushbrook, 1999). The following sections of this chapter present the financial aspect of open dumps and its rehabilitation with engineering applications.

6.2. Slope stability and embankment construction

Slope stability and embankment construction are one of the important financial parameters for open dump rehabilitation. Landfill stability factors include the global stability of the landfill mass (i.e), the landfill's ability to retain itself), pavement stability of the cover soil system, and placement. Landfill stability is affected by the type of waste, compaction applications, depth of backfill and steepness of side slopes. Steeply sloping disposal of solid waste and high humidity conditions in the waste mass cause instability in the waste deposited area. Pavement instability is affected by the types of materials used to form the pavement system, the interface friction, the drainage properties of these materials, and the applied loads.

The grounding rate and slope of a dump site can significantly affect cover design, stormwater management, landfill gas management, and other facility improvements in an enclosed landfill (Perl, 1998). The waste settles due to the loads caused by the weight of the waste mass and the decomposition of the waste. Over 20 years, the weight of gas and leachate discharged from the waste disposal site can reach up to 22% of the initial dry weight of the waste. Eventually, after stabilization, the storage mound loses about 10-25% of its original height (Frantzis, 1991). Successful site rehabilitation efforts must carefully consider stability as well as the management of biogas and leachate (Ayalon et al., 2006).

The slope of the dumpsite is of primary concern, as sufficient slope is required to encourage the flow of surface water without ponding, or puddling, or erosion of the final cover. The grade and length of the land affect slope erosion. The final slopes of the filled parts of the site should be 2-

8% slope and should not exceed the upper limit. A slope process and embankment construction in an open dump site is given Fig 6.1.

(a)

(b)

Figure 6.1. Slope process of garbage

Slope stability and embankment construction in the rehabilitation process get a share between 14% and 16% of the total budget. Excavation, transport, laying, and compressing of waste, land excavation and filling in open dump sites, and finally road construction for the rehabilitation area are all part of slope stability and embankment construction.

The cost of excavation, transport, laying and compressing of waste is approximately 1,5 € per m^3 of solid waste. The cost of excavation and filling processes in open dump site is approximately 7

€ per m^3 of solid waste. The cost of road construction for the rehabilitation area is approximately 5 € per m^2 (Balıkesir Metropolitan Municipality, 2017).

6.3. Leachate drainage system

Landfill leachate is defined a high strength wastewater which has high pollutant and toxic content (Bodzek et. al., 2006). Leachate is extremely harmful to the environment. The one of the most important effects of landfill leachate are that it mixes with aquatic ecosystems such as lakes and streams, causing an increase in algae and plankton. The amount of oxygen in the water body decreases and the life of the aquatic ecosystem is endangered over time (Lavrova et al., 2010). Due to its high toxicity, garbage leachate is a major threat to ground and surface waters. The content of landfill leachate depends on the composition of the waste, climatic conditions and the age and degradation rate of the solid waste (Bulc, 2006).

The leachate pipes to be installed for the treatment of leachate depend on various factors, such as the depth of the waste, the topography of the area, the underlying soil, and the age of the accumulated waste. Installation is required if economically and engineeringly feasible. Leakage water sources that may occur in the rehabilitation area should be determined before the final cover process. Constructing channels and ditches can be applied to collect leachate.

The collected leachate should then be diverted to the leachate holding pool/pond located downstream of the site. Below the slope of the disposal site, a containment ditch, shear wall, and collection pipes can be constructed to prevent underground leachate movement. However, these measures do not ensure that the ground or surface waters around the site are not polluted. These are simple and inexpensive corrective measures aimed at reducing possible contamination as much as possible. Biological or chemical methods can be used to treat leachate. Biological methods involve allowing wastewater to pass through a series of stabilization ponds or using vegetation to absorb or digest pollutants. Chemical methods, on the other hand, are based on treating leachate with chemicals.

Leachate drainage system includes the construction of leachate collection pool, clay layer placement process and geomembrane laying and welding processes. Leachate drainage system in rehabilitation process get a share between 5% and 7% of the total rehabilitation budget. The cost of leachate collection pool is approximately 7 € for m^3. The cost of clay layer placement process is approximately 17 €/m^3 for leachate pool and finally the cost of geomembrane laying and welding processes are approximately 7.5 € for m^2 (Balıkesir Metropolitan Municipality, 2017). Leachate treatment cost is out of the scope of this chapter.

6.4. Surface water drainage system

The purpose of installing a drainage facility is to reduce the amount of surface water entering the open dump. Depending on the topography of the open dump and its surroundings, rain accumulates on the surface and may damage the landfill. The amount of precipitation and the surface water generated are usually much higher than the amount of leachate produced at the open dump. If large volumes of surface water enter the waste disposal area, the amount of leachate will increase significantly and thus exceed the facilities' collection, holding and treatment capacity. Preventing surface water from entering the waste disposal area and separating it is necessary to avoid such situations. Embankments or perimeter drains are constructed away from disposal areas, and the water is directed to the uphill side of the storage area. Erosion is an important parameter when conducting water diversion studies. Care should be taken to prevent erosion. Surface water drainage plants can be divided into the following categories (https://www.sprep.org 2022).

6.4.1. Perimeter drainage

The purpose of the perimeter drainage system is to collect rain and surface water and prevent it from flowing into the waste disposal area. Perimeter drainage diverts surface water to the storm-water reservoir. After the site is filled and the final soil cover is established, the perimeter drainage should also collect surface water inside the disposal site. Environmental drains not only divert surface water from the fill, but also have the function of preventing animals and people who trespass in the site for collecting the materials. (https://www.sprep.org 2022).

6.4.2. Landfill surface drain

After the final cover soil is applied, stored area surface drains are installed to discharge runoff from the open dump surface. The surface drains are excavated on the fully compacted final pavement layer to the required slope (usually 2% to 3%). The surface drains are dug to the required gradient (commonly 2 to 3%) on the fully compacted final pavement layer.

The rate of ground settlement is high at the early stage after the site is filled up. Therefore, it is recommended that simple drains such as an open ditch be installed temporarily until the settlement of the ground (final soil cover) comes to an end. Once the settlement is nearly complete, a concrete-based ditch may be constructed as permanent structure.

6.4.3. Upstream diversion channel

Upstream diversion channels are required in cases where the catchment areas of both the open dump site and the outer areas are too large, and the capacity of perimeter drains is considered insufficient for the surface water from the surrounding areas.

Surface water drainage system in rehabilitation process get a share between 5% and 7% of the total rehabilitation budget. The cost of the surface water drainage system is approximately 123 € per meter (Balıkesir Metropolitan Municipality, 2017).

6.5. Gas drainage system

The main function of a gas venting facility is to release the gases generated from the landfill layers as soon as possible before they create environmental impacts on surrounding areas. It also accelerates the stabilization process of the landfill under the semi-aerobic system. The gas venting facility needs to be planned and designed to suit these purposes.

Typically, a gas venting facility for a semi-aerobic landfill system consists of horizontal and vertical/inclined gas venting pipes. A vertical gas venting pipe is installed on top of a connection pit. A connection pit is used to connect the main leachate collection pipes and branch pipes. In this case, the connection pit is made of concrete that is placed in-situ using formwork. Since the function of the connection pit is to connect pipes and secure space for air to move in and out freely, you can form a connection pit using other materials such as cement blocks, bricks, wood, used drums, used tyres, mounds of gravel/rock material, etc. It does not have to be square or walled (Swarbrick et al., 2011). A typical gas drainage and its system is given in Figure 6.2.

(a)

(b)

(c)

(d)

Figure 6.2. Examples of installation of gas drainage system

In the rehabilitation of the open dumps, gas chimneys are set up as shown in Figure 6. to discharge landfill gas from the waste mass. Gas drainage system includes gas wells, biofilter constructions, and observation well. Gas drainage system in rehabilitation process get a share between 4% and 6% of the total budget. The cost of gas well and biofilter construction is approximately 1350 € for one piece. The cost of an observation well is approximately 4250 € for one piece (Balıkesir Metropolitan Municipality, 2017).

6.6. Final cover

Leachate formation continues in the open dump site as in the sanitary landfill areas. The sanitary landfill and open dumps should be covered with a final top-cover to prevent the increase in the amount of leachate due to precipitation on the site. This cover should be a sufficiently impermeable material and have a suitable slope. This cover should be placed on the site after the storage process is finished (and after the largest depression has occurred in the landfill). The final top cover prevents the water from precipitation from leaking into the storage area. The final cover should consist of 4 layers;

- Base layer
- Impermeable insulation layer
- Drainage layer
- Topsoil cover

The schematic illustration of the final cover is given in Figure 6.3 (Republic of Turkey Ministry of Environment, Urbanization and Climate Change, 2014).

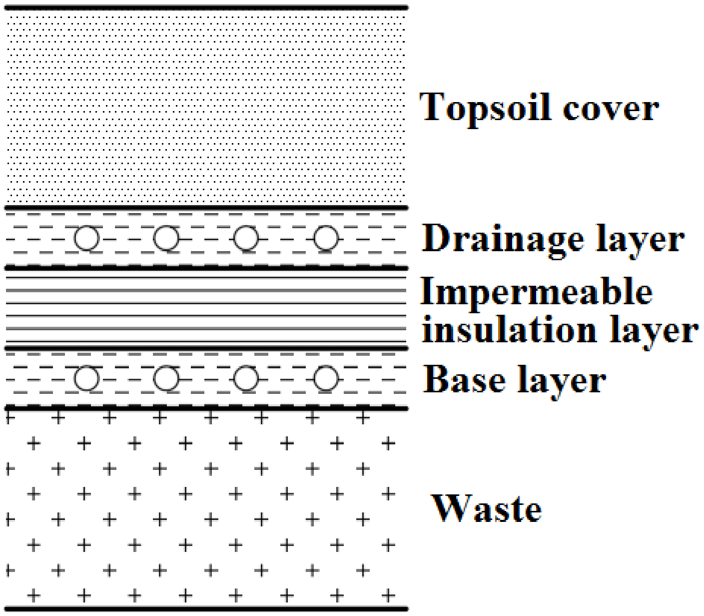

Figure 6.3. Schematic illustration of final cover

6.6.1. Base layer

The quality of the final cover system built is largely dependent on the strength of the base layer placed on it. A layer of soil should be placed on top of the last layer of waste placed (its thickness should be about 30 cm, depending on the size of the waste stored).

The purpose of this is to prevent the upper insulation from being damaged. This cover may be made of a natural sandy material that allows the evacuation of the formed landfill gas, or from coarse materials from construction sites or from brick industry scraps. With the help of the gas transport system located in this layer, the storage gas gathered in the bottom layer is released into the air.

6.6.2. Impermeable insulation layer

The impermeable insulation layer has to be placed on top of the foundation layer. This layer should be made of a flexible material or combination of materials that are impermeable to gas and water.

In principle, an insulating layer made of plastic sheeting is completely impermeable to water. However, the possibility of local leakage due to an error during assembly and overloading should be considered. If a plastic sealing cover is to be used as an impermeable layer, it must be checked at regular intervals and protected against leakage. In general, replacement of these covers every 30 or 40 years should be considered to ensure optimum conditions.

6.6.3. Drainage layer

To remove surplus water from the higher soil layer and protect this layer from heavy precipitation, a drainage layer must be built on top of the impermeable insulating layer.

The drainage layer should be constructed of sand with low humus content and high permeability. A drainage substructure should be placed inside the drainage layer. At least a small slope should be given to the layer so that excess water entering the layer can flow by gravity and reach the main collection pipes at the edges. Collector pipes perform the task of removing excess water from the storage area.

6.6.4. Topsoil cover

The final cover system of the storage area is completed by laying the topsoil. The task of this layer is to protect the underlying layers from mechanical damage, drying and cracking (with plant growth), penetration of plant roots and erosion.

The thickness and quality of this layer will vary based on the amount of water required, the planned cultivation, and the closed storage area's intended purpose. In any case, this layer must be at least 1 m thickness. If wood is to be used in landscaping, a thicker layer will be needed. It is not recommended to plant deep rooted trees above the storage area.

Trenches and barricades should be built around these areas to prevent rain and flood waters from outside to landfill. The impermeable top cover layer also prevents the uncontrolled emission of landfill gas. However, a gas collection, treatment, or utilization system may also be required. In general, if the ground is impermeable in open dumps, the application of the final cover system will be sufficient since the waste will not have a connection with the groundwater (Turan et al. 2009).

The final cover process in open dump rehabilitation gets a share between 70% and 74% of the total budget. Final cover process includes balancing layer construction, natural clay supply and formation, gravel supply and laying, supply and laying of geotextile for separation.

The cost of balancing layer construction is approximately 4,5 € per m^3.
The cost of natural clay supply and formation is approximately 17 € per m^3.
The cost of gravel supply and laying is approximately 8 € per m^3.
The cost of supply and laying of geotextile for separation is approximately 1,2 € per m^2.

The approximate cost schedule for the rehabilitation of open dump is given in Table 6.1 and unit price of engineering applications is given Table 6.2 (Balıkesir Metropolitan Municipality, 2017).

Table 6.1. Financial aspect of open dump rehabilitation.

	ENGINEERING APPLICATIONS	Percentage of Payment (%)		TOTAL COST EURO (€)	
Waste Excavation, Transport, Laying and Compaction	Slope Stability and Embankment Construction	6,1452	15,125	39.631,6	97.547,4
Land Excavations and Fillings		6,3260		40.797,7	
Wire Fence Construction		0,5698		3.674,68	
Road Construction		2,0845		13.443,3	
Leachate Drainage System, Leachate Collection Pool and Leachate Collection Pool Impermeability	Leachate Drainage System	6,2063	6,2063	40.025,5	40.025,5
Surface Water Drainage System	Surface Water Drainage System	1,4790	1,4790	9.538,05	9.538,05
Gas Wells and Biofilter Construction	Gas Drainage System	3,1623	5,1533	20.394,5	33.234,3
Observation Well		1,9909		12.839,7	
Final Cover	Final Cover	72,036	72,036	464.574	464.574
		100,00	**100,00**	**644.920**	**644.920**

Table 6.2 Unit price of engineering applications for open dump rehabilitation.

Application	Unit	Unite Price (Euro)
Machinery Excavation, Transport, Laying and Compaction of Waste	m^3	1,49
Excavation and Transportation (transportation to filled areas)	m^3	1,68
Filling Works (from excess excavation material)	m^3	1,18
Filling Works (with material to be procured from outside)	m^3	4,15
Road Construction	m^2	5,01
Wire Fence Construction	m	36,75
Final Cover System: Balancing Layer Construction	m^3	4,64
Final Cover System: Natural Clay Material Supply and Formation	m^3	17,27
Final Cover System: Gravel Material Supply and Laying	m^3	7,86
Final Cover System: Supply and Laying of Geotextile for Separation, 300 gr/m2	m^2	1,13
Final Cover System: Top Cover Soil Construction	m^3	4,64
0.3x0.3x0.9 Surface Water Drainage Channel	m	9,61
Supply and Laying of Ø500 Surface Water Pipe	m	114,86
Ø 300 mm Perforated SS Pipe Formation	m	87,57
Ø 300 mm Closed SS Pipe Formation	m	59,83
H=2.25 m Ø 1000 mm HDPE Chimney Formation	piece	538,55
For Leachate Pool: Excavation and Transportation (transport to filled areas)	m^3	1,68
For Leachate Pool: Filling Works (from excavated material)	m^3	1,18
For Leachate Pool: Filling Works (with material to be procured from outside)	m^3	4,15
Leachate Pool: Natural Clay Material Supply and Formation	m^3	17,27
Leachate Pool HDPE Geomembrane Supply and Laying	m^2	7,40
Gas Wells and Biofilter Formation	piece	1.359,64
Observation Well	piece	4.279,93
Sowing Grass Seed	da	182,46
Irrigation of park areas	ha	1,01

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