6th EURASIA WASTE MANAGEMENT SYMPOSIUM
www.eurasiasymposium.com

Rehabilitation Methods for Open Dumps and Its Global Applications: SMARTEnvi Eu Project

O. N. Agdag [1], R. G. Yilmaz Cincin [2], S. Toprak [3], Y. Kaplan [1], R. Degirmenci [4], F. Agdag [4], S. Gebes [4], B. Cetin [3], E. De Angelis [5], K. Pikon [6], A. Kujumdzieva [7], V. Petrova [8], C. Panaitescu [9], D. Frulla [10], O. Dal [3], C. Balcik [3], K. De Angelis [5], F. Dinu [9], T. Nedeva [8], M. Bogacka [6]

Abstract

A European Union project called 'Smart Decision Tools for Reducing Hazards to Our Environment and Water Resources by Rehabilitating Open Dumps (SMARTEnvi)' is underway related to the rehabilitation of MSW open dumps. This project aims to develop pilot, and test innovative digital tools for reducing hazards to the environment and water resources by rehabilitating open dumps via training methods and materials using competence tool, multilingual e-learning-platform, learning modules, and smart guidance manual. The topic of one of the learning modules is about rehabilitation methods and engineering applications. The rehabilitation methods for open dumps and its global applications, which will be discussed in this study, will be an output of the mentioned learning module of SMARTEnvi project.

Different methods have been used for the rehabilitation of open dump sites. In situ rehabilitation, rehabilitation after mechanical separation, and rehabilitation by waste transportation are mainly rehabilitation methods. The open dump rehabilitation process mainly includes condition assessment, planning, and implementation steps, regardless of which method is used. In the rehabilitation process, surface water and leachate control system and gas drainage systems can be listed as processes that should be applied during rehabilitation. During the rehabilitation method, the state and the needs of the open dump and the surrounding settlements should be considered. The effective parameters related to method selection are location, size of the area, amount of solid waste disposed at open dump sites, and nearness to

[1]Pamukkale University, Denizli, Turkey

[2] Corresponding author: Pamukkale University, Denizli, Turkey, rgokcey@pau.edu.tr

[3]Gebze Technical University, Kocaeli, Turkey

[4]Denizli Municipality, Denizli, Turkey

[5]Training 2000, Mondavio, Italy

[6]Silesian University of Technology, Gliwice, Poland

[7]Research and Development Biointech, Sofia, Bulgaria

[8]Sofia University St. Kliment Ohridski, Sofia, Bulgaria

[9]Petroleum-Gas University of Ploiesti, Ploieşti, Romania

[10]Fano Municipality, Fano, Italy

underground and surface waters. In addition, rehabilitation cost is also an important parameter. In this study, different rehabilitation methods and some common global applications of these methods will be explained.

Keywords: Municipal Solid Waste, Open Dumps, Rehabilitation Methods

1. INTRODUCTION

Today, for the disposal of municipal solid waste (MSW), the sanitary landfill method is the most widely used method in many countries. Before the use of landfills, solid waste was randomly dumped in any area outside of the city which method is called an open dump [1] . The open dump method has been used by waste for the removal of municipal solid waste (MSW) for ease, economic reasons, technical deficiencies, and environmental irresponsibility. In many countries, abandoned and still used open dumps cause environmental and health problems. Problems such as erosion caused by irregular storage of waste [2], explosion caused by compressed methane gas [3], polluting natural water resources, and soil by toxic leachate are only the main problems. Therefore, open dumps have to be rehabilitated due to their harmful and unhealthy effects.

Although there have not many studies on the rehabilitation of open dumps, it has become a topic that has begun to attract worldwide attention [4]. The member states of the European Union are required to act in accordance with the directive 1999/31/EC, which covers a number of rules to be applied in waste storage activities [5]. In this directive, there are no specific rules to be followed in stages for the rehabilitation of open dump areas. However, in the closing and rehabilitation processes of sanitary and unsanitary landfills used after the directive entered into force, they must comply with the 'storage site closure and post-closure maintenance criteria' in this directive.

Rehabilitating open dump is a multidisciplinary issue that requires engineering planning. Before open dump rehabilitation, the economic feasibility of the rehabilitation method needs to be evaluated [6]. However, sometimes rehabilitations were carried out urgently as a result of an accident, and they were applied regardless of their economic viability [2], [7], [8]. A wide variety of methods have been used for the rehabilitation of open dumps. Some of these methods also involve energy and material recovery. Regardless of the rehabilitation method, both the environmental damage of the open dump is prevented and new areas are introduced into the society.

In this study, the rehabilitation methods of open dumps are mentioned. Rehabilitation methods are examined under three headings in this study. These; in situ rehabilitation, rehabilitation by waste transportation, and rehabilitation after mechanical separation. These rehabilitation methods have been reinforced with global applications.

2. REHABILITATION METHODS

The landfill rehabilitation process is a multifactor system that includes condition assessment, planning, and implementation steps. Factors such as the evaluation of the situation plan of the area before filling, the final situation plan, geological and hydrogeological studies, and the type and amount of stored waste can be counted, which will be illuminated in the determination of the rehabilitation method during the situation assessment phase. As the planning and implementation stages, slope stability and filling works, surface water drainage system, leachate drainage system, gas drainage system, final cover layer, culvert, road and chimney type details, landscape plan, observation wells and control plan can be counted.

There are different methods for landfill rehabilitation, but the most common are; in situ rehabilitation, rehabilitation by waste transportation, and rehabilitation after mechanical separation[9]. In the selection of these methods, technical and economic factors are taken into consideration of open dump. Factors such as the location of the landfill, the size of the area, the amount and type of waste stored, and its state to underground and surface water resources can be effective parameters in the selection of the method. These factors play an important role in deciding whether landfill rehabilitation can be done primarily on site. Furthermore, knowing geological features such as soil structure in in situ rehabilitation will be of great benefit during leachate collection. Apart from that, samples can be taken from different points to investigate waste characterization in the open dump. For example, mechanical separation may be beneficial if the amount of waste under the sieve is not much at the end of the characterization process and the amount of waste that can be recovered is much[6]. However, since this method may require cost, it may be necessary to consider economic considerations in its selection.

2.1. In situ rehabilitation

This method can be defined as the rehabilitation of open dumps on the area, without moving them to another area or a sanitary landfill. It can be applied in the rehabilitation of abandoned or currently used open dumps. The purpose of the implementation of this rehabilitation method is to prevent the damage they cause to the environment by closing the open dump area where no measures are taken for leakage, surface water and gas drainage[2].

In the rehabilitation method, the first thing to do is evaluation the current situation. In this evaluation process, information about the prestorage and final state of the area is obtained, its geological and hydrogeological characteristics are examined, and the amount and characterization of the stored waste are determined. After planning, slope stability and filling works, surface water drainage system, leachate drainage system, gas drainage system, final cover layer, culvert, road and chimney type details, landscape plan, observation wells, and control plans are created respectively.

2.2. Rehabilitation by waste transportation

It is a preferred rehabilitation method in cases where in situ rehabilitation of open dumps is not possible. In this method, wastes are transported from the area to a current sanitary landfill or newly established sanitary landfill located nearby. The reasons such as the area's location within the special environmental protection zone, the area's being within the residential area, the high groundwater level, and the low amount of stored waste play a role in the selection of the rehabilitation method by waste transportation. For these reasons, if it is economically viable, rehabilitation of the area by transporting the waste from the open dump to an operating sanitary landfill may be a suitable option.

The first step in this method, as in the other method, is to evaluate the current situation. After the necessary examinations, the wastes are excavated and transferred to the nearby sanitary landfill. During this process, recyclable wastes can also be separated by investigating the degradation and characterization of the wastes. After the wastes are completely emptied, depending on the condition of the area, a fill or cover layer can be applied. If a construction is to be made, it can be left after the necessary controls. In these controls, the presence of pollutants and pathological microorganisms in soil and groundwater that will adversely affect the environment and human health can be checked. After the rehabilitation, this area can be used for various purposes, such as a recreation area.

2.3. Rehabilitation after Mechanical Separation

Rehabilitation after mechanical separation can be defined as the rehabilitation performed by separating the metal, plastic, glass and combustible organic wastes from soil and fine particles that can be recovered by excavating the waste stored in the open dump [9]. Since there is a material recovery here, it is often possible to come across the term "landfill mining" in the literature instead of the term "rehabilitation after mechanical separation of recyclable wastes". This method was mentioned in 1993 in ref [10]. From the past to today, landfill mining has been divided into branches within itself [4], [11]. In this method, after the current situation is evaluated, the wastes are excavated and separated into certain classes. The elements extracted as a result of excavation can be classified mainly as soil layer, recoverable wastes, metal wastes and fine particles. It can be used as a filling material in cases where there are no precious metals in the excavated soil layer. Evaluation of recyclable waste is generally 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 waste is separated. Thus, this method has an economic advantage.

3. GLOBAL APPLICATIONS

There are 9 partners in the Smartenvi project from Turkey, Poland, Italy, Bulgaria and Romania. Partners: the applicant Gebze Technical University, Pamukkale University, and Denizli Metropolitan Municipality, from Turkey; Training 2000 and Municipality of Fano from Italy; Silesian University of Technology from Poland; Sofia University St. Kliment Ohridski and Research and Development Biointech from Bulgaria; and Universitatea Petrol-Gaze din Ploiesti from Romania. The partners studied on regional applications of open dump rehabilitation studies in their countries on part of the project.

In all application cases, the open dump is operated without the construction of a bottom insulation screen, drainage system for filtration water, or other measures limiting the spread of waste or hazardous substances released from the processes of decomposition of waste. The waste is dumped directly on the ground in the used spaces of two quarries for facing materials. The open dump has been operated without any measures for the protection of soils, groundwater, and earth's bowels from pollution due to the disposal of waste on the site, no security ditches have been built, etc. So, they were rehabilitated to provide healthier conditions.

First application is rehabilitation of Buldan open dump in Turkey. Buldan is located 42 km away from the center of Denizli. Buldan open dump was operated between 2007-2020. It has 2.6 ha waste storage area. Until

2020, an average of 31.2 tons/day of waste was dumped into the open dump. After this time, waste colleted by the Buldan Municipality and transferred Solid Waste Transfer Station established in Bozalan town and then transported to the Kumkısık Landfill located in Denizli. There are some observations on the open dump area before rehabilitation. There are no activities related to landfill gas management were carried out in the open dump prior to rehabilitation. Landfill gas formed in the open dump can neither be completely removed from the garbage mass, nor be completely isolated within the mass. Due to the location of the disposal site, it causes visual pollution and odor on the Denizli-Salihli road. The dense smoke from active and passive combustion in the open dump affects the residential areas and the highway. After the observations waste amount was calculated from waste generation per person daily. Approximately 227.257 m^3 of house of wastes belong to Buldan were stored in the open dump has 9 m depth and 2.6 ha area. Slope arrangement and embankment formation, top cover system set up, surface water drainage and gas management system were carried out in this area. It was given 3% of slope on the top of the area to ensure surface drainage. The drainage channel, which will provide the surface water drainage of the waste mass and the whole side, was built on the outside of the embankment. 12 vertical gas chimneys as shown figure 1 were used to collect landfill gas. For top cover, 50 cm leveling layer, 50 cm clay layer, 30 cm drainage layer, 50 cm vegetative soil were chosen. Maintenance and monitoring activities after closure were planned.

Figure 1. Installation of gas chimney

Sarayköy open dump is second application from Turkey. Sarayköy is 20 km away from the center of Denizli. The use of the open dump area, which was started in 2007, was terminated in 2014. Average of 33.5 tons/day of waste was dumped into the open dump site until 2014. Observations before rehabilitation showed that approximately 162.946 m^3 of house of wastes belong to Sarayköy were stored in the open dump has 6.5 m depth and 2.5 ha area. Before rehabilitation there were so many problems such as odor, smoke and flies (Figure 2). Slope arrangement and embankment formation, top cover system set up, surface water drainage and gas management system were carried out in this area. The steep slopes, especially in the northern part of the open dump, where active solid waste dumping is made, have been moderated to 1/3 rate by filling approximately 10.000 m^3. Gas drainage wells as shown in figure 3 were used to collect landfill gas. Also top cover layers applied for prevent rain drainage.

Figure 2. Fires on Sarayköy rehabilitation area before rehabilitation

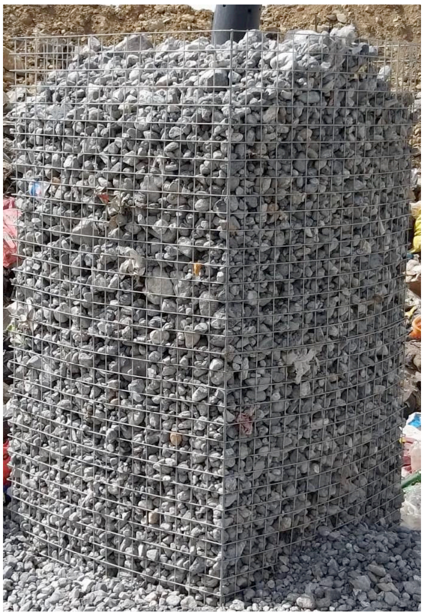

Figure 3: Gas drainage well.

The open dump in Gliwice is one of the largest open dump in Silesia, Poland. The current state is 4 open quarters, and the closed part of the open dumps discussed in this case study. The open dump was put into operation in 1989 and the recultivation process started in January 2001. The mass of waste deposited on the closed section may amount to about 390 thousand tons of deposited municipal waste. As a standard, land reclamation was performed after the liquidation of the open dumps headquarters, and consisted of backfilling the excavations with clean, properly compacted soil. To protect the open dumps and uncontrolled leakage of leachate into the environment, a double protection was used in the form of drainage surrounding the open dumps and a ditch on the surface led over the drainage, which also covers the open dumps. The leachate from both safeguards is collected into a retention tank, where it can be redirected further in a controlled manner. The gas discharged through vertical pipelines was used in a power generator and partially burned in a flare. The process started in 2001. Appropriate openings and an installation for degassing the open dumps gas have been made. This stage was completed in 2005, when the amount of biogas was so low that it was not justified to continue the degassing process. The top layer was covered with soil and greened in order to improve the aesthetics of the area and to prevent wind erosion.

The other application is closure and reclamation of an existing old open dump for solid waste in the land of Aleko Konstantinovo village in Bulgaria. Its implementation includes the reclamation of an old open dump (92 000 m^2), which contained 100 000 m^3 solid wastes, accumulated for the period from 1962 to November 2017. In 2019, activities are carried out mainly for the re-disposal of waste and the construction of a system for polluted water (Figure 4). In 2020 the activities for pre-disposal and shaping of the open dump body were completed and the gas system, the insulation screen, and the technical reclamation were built. The biological reclamation was performed at the end of 2020 - soil preparation of the areas for reclamation and sowing with seeds. Mainly finishing works were carried out during the winter of 2020-2021 - drainage ditches and connection of the gas system. The reclamation process and restoration of the terrains continue until the third year with planned care. The biological reclamation will be implemented during 2021, 2022, and 2023.

Figure 4. Aleko Konstantinovo open dump rehabilitation studies

The existing municipal open dump for non-hazardous waste of Elena municipality, Bulgaria is located 450 m northwest of the construction boundaries of the city. Waste is deposited in an area of 24,221 m^2. The open dump neighbored in its northwest (about 150 m) a gully with a variable runoff after rain. In addition, no surface water and infiltrates were drained from it and there were no gears for collecting and treating the rainwater. There was neither a system for biogas collection/control. The general view of Elena open dump before rehabilitation shown in figure 5. Total of 1460 m3 waste was re-deposited outside the boundaries of the open dump and 57 716 m^3 were re-deposited for re-shaping the slopes of the open dump. Shaping a slope 1:2.5 without a deviation from the slope angle. Drainage channels were constructed for surface water collection. For top layers 0.75 m soil and 0.25 m humus were used. The rehabilitated open dump will be used as a green area.

Figure 5. General view of Elena open dump before rehabilitation

The open dump of Rasnov has an area of 2.29 hectares and has not been used since 2009, when landfilling was stopped. There are several sources of pollution in the area, including garbage storage that resulted in biogas production, emissions, water vapor, leachate, odors, and microbial pollution. The lithology of the soil allows leachate to infiltrate into the groundwater due to the thin topsoil layer of around 0.15 m, which is followed by sandy and clayey soil. Technologies for waste management were nonexistent, unable to be used, and unsafe for disposal. There are no rainwater collection channels or waterproofing on the artificially constructed slopes. This results in more leachate building up. There is no leachate treatment facility because there is no drainage and collecting system. The nearest water source, about 50 meters from the ramp (Figure 6). The closure strategy calls for totally or partially filling potholes and unevenness, rearranging waste into a cap with a cap slope between 1:20 and 1:3, and closing the road. All plastic foil, which is regarded as light waste, has been disposed of by being diverted to a landfill. By covering the waste with a layer of at least 30 cm of clay soil that is evenly spread throughout the dump, the area is considered to have been systematized. The compacted clay layer is also covered with at least 10 cm of topsoil. The upkeep of this green cover and ongoing study of the amount of leachate constitute post-closure monitoring.

Figure 6. Rasnov open dump located about 50 m to water source.

This case study presented the steps behind the rehabilitation of an urban waste landfill located in the municipality of Fano (Italy) which operated from 1978 to 1986. The Landfill of Monteschiantello was built in an old quarry traditionally used for the extraction of clay. Historical sources confirmed that the site, at the beginning of its life cycle, can be now classified as an open dump, as the waste collected wasn't monitored nor controlled in any way. The landfill site is currently formed by two adjacent basins. The first one is called "Basin 1" and is situated in the North-eastern part of the area where the old municipal dumpsite was operating from 1978 to 1996. Now, Basin 1 is completely rehabilitated. For rehabilitation the surface is curved. Soil layer, clay layer, geocomposite drainage layer and vegetative soil were used as top cover layers. A rainwater collection pit was created around the area. The biogas extraction system was adapted to Basin 1 needs considering that its biogas production of was gradually decreasing. New extraction wells were gradually built on the area, along the landfill expansion process. The planting of different species of native tree and shrubs also allowed to reinforce the local environment in terms of quantity and quality creating a good habitat for birds. This is due to the vastness of the area (8 hectares) which is fenced from farming, people and wild animals (Figure 7).

Figure7: Basin 1- Final stage of the Environmental restoration plan. Source: ASET Spa, 2011.

4. CONCLUSIONS

Open dumps, which have been used for many years due to being economical and easy to operate, have started to pose a problem today. In many reports, disasters such as explosions, fires, groundwater contamination, and erosion have been reported in these landfill areas, even while they are still operating in most applications. The still-operated open dump areas and the closed open dump areas are considered to be rehabilitated as a priority.

In this study, some examples of rehabilitation studies carried out in open dumps are given. As a result of the rehabilitation studies, the negative environmental effects of open dump areas were minimized. The risk of gas compression and explosion has been eliminated, the strength of the field has been ensured, and the formation of leachate that may occur due to rain water has been minimized in the scope of our EU project .

ACKNOWLEDGMENT

This work is derived from the European Union Project 'Smart Decision Tools for Reducing Hazards to Our Environment and Water Resources by Rehabilitating Open Dumps (SMARTEnvi)' and code KA226-6DB764B5.

REFERENCES

[1]. P. A. Vesilind, W. A. Worrell, and D. R. Reinhart, *Solid Waste Engineering*. Brooks/Cole, 2002.

[2]. M. Jayaweera *et al.*, “Management of municipal solid waste open dumps immediately after the collapse: An integrated approach from Meethotamulla open dump, Sri Lanka,” *Waste Manag.*, vol. 95, pp. 227–240, 2019.

[3]. G. Kocasoy and K. Curi, “The Umraniye-Hekimbası Open Dump Accident,” no. April 1994, pp. 305–314, 2000.

[4]. P. T. Jones *et al.*, “Enhanced Landfill Mining in view of multiple resource recovery: A critical review,” *J. Clean. Prod.*, vol. 55, pp. 45–55, 2013.

[5]. European Union, “Council Directive 1999/31/EC on the landfill,” *Off. J. Eur. Communities*, no. 10, p. L182/1-19, 1999.

[6]. P. Jain, T. G. Townsend, and P. Johnson, “Case study of landfill reclamation at a Florida landfill site,” *Waste Manag.*, vol. 33, no. 1, pp. 109–116, 2013.

[7]. H. Yang, J. Xia, J. R. Thompson, and R. J. Flower, “Urban construction and demolition waste and landfill failure in Shenzhen, China,” *Waste Manag.*, vol. 63, pp. 393–396, 2017.

[8]. G. Blight, “Slope failures in municipal solid waste dumps and landfills: a review,” *Waste Manag. Res.*, vol. 26, pp. 448–463, 2008.

[9]. J. Morelli, “Landfill reuse strategies,” *BioCycle*, vol. 31, no. 4, pp. 60–61, 1990.

[10]. G. M. Savage, C. G. Golueke, and E. L. von Stein, “Landfill mining. Past and present,” *BioCycle*, vol. 34, no. 5, pp. 58–61, 1993.

[11]. J. Krook, N. Svensson, and M. Eklund, “Landfill mining: A critical review of two decades of research,” *Waste Manag.*, vol. 32, no. 3, pp. 513–520, 2012.