Engineering Geology 154 (2013) 20–35

Contents lists available at SciVerse ScienceDirect

Engineering Geology

journal homepage: www.elsevier.com/locate/enggeo

Landfill site requirements on the rock environment: A case study

Hakan Ersoy [a,*], Fikri Bulut [a], Mehmet Berkün [b]

[a] Karadeniz Technical University, Department of Geological Engineering, 61080, Trabzon, Turkey
[b] Karadeniz Technical University, Department of Civil Engineering, 61080, Trabzon, Turkey

ARTICLE INFO

Article history:
Received 3 August 2012
Received in revised form 21 December 2012
Accepted 23 December 2012
Available online 30 December 2012

Keywords:
Geological barrier
Geotechnical
Landfill
Site selection
Solid waste
Rock

ABSTRACT

The objectives of the study are to improve the standard of waste disposal and to provide guidelines for an environmentally acceptable waste disposal strategy in the biggest city of the eastern Black Sea region (NE Turkey). The requirements for waste disposal by landfill were investigated in three important stages: site selection (SS), engineering geological investigation (EGI) and finally site evaluation (SE). Because one of the serious and increasing potential problems in the growing urban regions is the shortage of land for waste disposal, the candidate sites for an appropriate landfill area in the major city of the region were determined by using the integration of spatial and multi-criteria decision analysis based methodology. Due to the fact that the main issue in this investigation is description of engineering suitability of the rock masses exposed at the proposed landfill site, the rock properties to be required for landfill construction and design were identified as a priority, and finally drainage and filtration materials, leachate collector system, covering and gas venting system were proposed. For these purposes, the borehole applications, in-situ and laboratory tests, scan-line and seismic surveys were conducted to characterize the engineering properties of the rock masses exposed at the proposed landfill site, and the Lugeon tests were applied to determine bedrock permeability. The methodology defined in the study proves to be an appropriate method for site selection, design and construction process in sustainable solid waste management program for other growing urban regions in the country.

1. Introduction

Integrated solid waste management is a complex process involving the incorporation of much information from different disciplines with many parties either responsible or affected by the results (Yesinacar et al., 2011). For the disposal process to be responsive to public attitudes, the disciplines must include administrative, financial, legal, architectural, planning, and engineering functions. The US Environmental Protection Agency (EPA) has identified four basic strategies for integrated solid waste management (EPA, 2009): (1) source reduction, (2) recycling and composting, (3) combustion (waste-to-energy facilities), and (4) landfills. Even in countries that incinerate or recycle much of the waste, disposal of solid waste in landfills is still inevitable because sanitary landfilling is necessary for the storage of ashes from burning and the remnants of recycling practices (Proske et al., 2005). However, some of the serious and growing potential problems in large urban areas is the shortage of land for waste disposal and the availability of suitable barrier rocks and/or soils (Ersoy and Bulut, 2009). In the stage of landfill construction, a site specific evaluation of geological barriers is required for landfills and waste repositories. The waste-repository-rock system has to be taken into consideration for this evaluation (Langer, 1995). Since the geotechnical barrier in conjunction with geological barriers contributes considerably to long-term isolation of the harmful substances from the biosphere, it is absolutely necessary to use engineering geology and hydrogeology methods for a quantitative assessment of the barrier effect of the host rock and the geological environment.

A scientific and technically appropriate approach is needed to analyze data and to make proposals to manage waste. This is called the site searching process for waste disposal sites. Dörthöfer and Siebert (1997) have outlined the details of the site searching process for industrialized countries. The first phase of the site searching process is to locate and delineate areas with sediments or rocks that have potential barrier properties. These properties which hinder water and contaminant infiltration to the groundwater (Dorn and Tantiwanit, 2001) can be considered a geological barrier. It is quite clear that particularly high standards must be required for the long-term functioning of the geological barrier (Dörthöfer and Siebert, 1997). Barriers in a landfill are divided into three main categories: engineered barriers, geological barriers and the waste itself. Engineered barriers are constructed to control horizontal migration of leachate within groundwater and used to isolate wastes from soil, surface water, and groundwater. The design of subsurface barriers should be based on more complete hydrogeological and geotechnical investigations. In addition, designs should be more prescriptive in terms of contaminant diffusion and compatibility that could affect long-term performance (Dörthöfer and Siebert, 1997). Considering the failure scenario for engineered barriers in landfills, it is quite clear that particularly high standards must be required for the long-term functioning of the geological barrier (Dörthöfer and Siebert, 1997). The main

* Corresponding author. Tel.: +90 462 377 35 06; fax: +90 462 325 74 05.
E-mail addresses: blavetirraa@hotmail.com (H. Ersoy), bulut@ktu.edu.tr (F. Bulut), berkun@ktu.edu.tr (M. Berkün).

0013-7952/$ – see front matter © 2012 Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.enggeo.2012.12.005

Table 1
Barriers in landfill and their requirements for waste management procedure.

The waste itself	Requirements for waste management ➢ Analysis of the • expected waste amount • waste composition ➢ Analysis of the possibilities for • alternative disposal • avoidance of waste production • preliminary treatment and sorting ➢ Determination of environmental pollution size • water pollution • soil pollution • air pollution
Liner and drainage system	Requirements for the liner and drainage system ➢ Planning of the liner system ➢ Prediction of the water balance of the landfill ➢ Prediction of leachate formation ➢ Planning of the leachate treatment facilities Planning of the gasses collection systems
Barrier rocks	Requirements for the geological barrier ➢ Determination of • lithology • permeability at different depths • thickness • homogeneity • groundwater flow rate • rock mass strength • slope stability • rock excavatability • intact rock properties • discontinuity surveying

requirements are: (1) low permeability, (2) low (effective) porosity, (3) large thickness, and (4) high natural retention capacity for hazardous substances. If these conditions are met, little groundwater will flow through the barrier and if the technical barriers fail, groundwater contamination can be kept to a minimum. Of the rocks that might be suitable as a geological barrier, only cohesive, argillaceous rocks have these favorable properties (Dörhöfer, 1988). On the other hand, for a waste disposal mine, the load-bearing capacity of the rock, the protective properties of the surrounding rock formations and the geological stability of the area are important factors in safety analysis. The analysis comprises an engineering geological study of the site, laboratory and in situ experiments, long-term monitoring, and special geological and geochemical investigations. All requirements for waste management procedure are illustrated in Table 1 considering the waste itself, liner and drainage system and geological barrier.

Although highly-developed countries have designed regulatory programs for disposal of solid wastes, developing and under-developed countries have generally continued to use unsophisticated and inadequate methods such as open dumps (Berkün et al., 2005; Ersoy et al., 2008a,b). In spite of efforts to turn open dumps into sanitary landfills and build modern recycling and composting facilities, there are still over 2000 open-air dumps in Turkey (Nemlioğlu et al., 2002; Ersoy et al., 2008b). The quantities of solid wastes produced with rising population in Turkey are large and increasing along with growing affluence and improved standard of living. In the year 2010, disposed municipal solid wastes reached 30 million tons with 60% disposed in open dumps, on land, and in the sea and the rivers (Ersoy et al., 2008a). Due to the lack of modern landfills and treatment plants, the solid wastes originating from human activities have caused serious environmental problems such as sea pollution especially in coastal municipalities, and air and soil pollution in inland centers.

In the eastern Black Sea Region (NE Turkey) (Figure 1), although collection and transport stages of waste management have been well organized by municipalities, various problems occur in recycling and disposal of municipal, industrial and agricultural wastes (Ersoy et al., 2008a). For

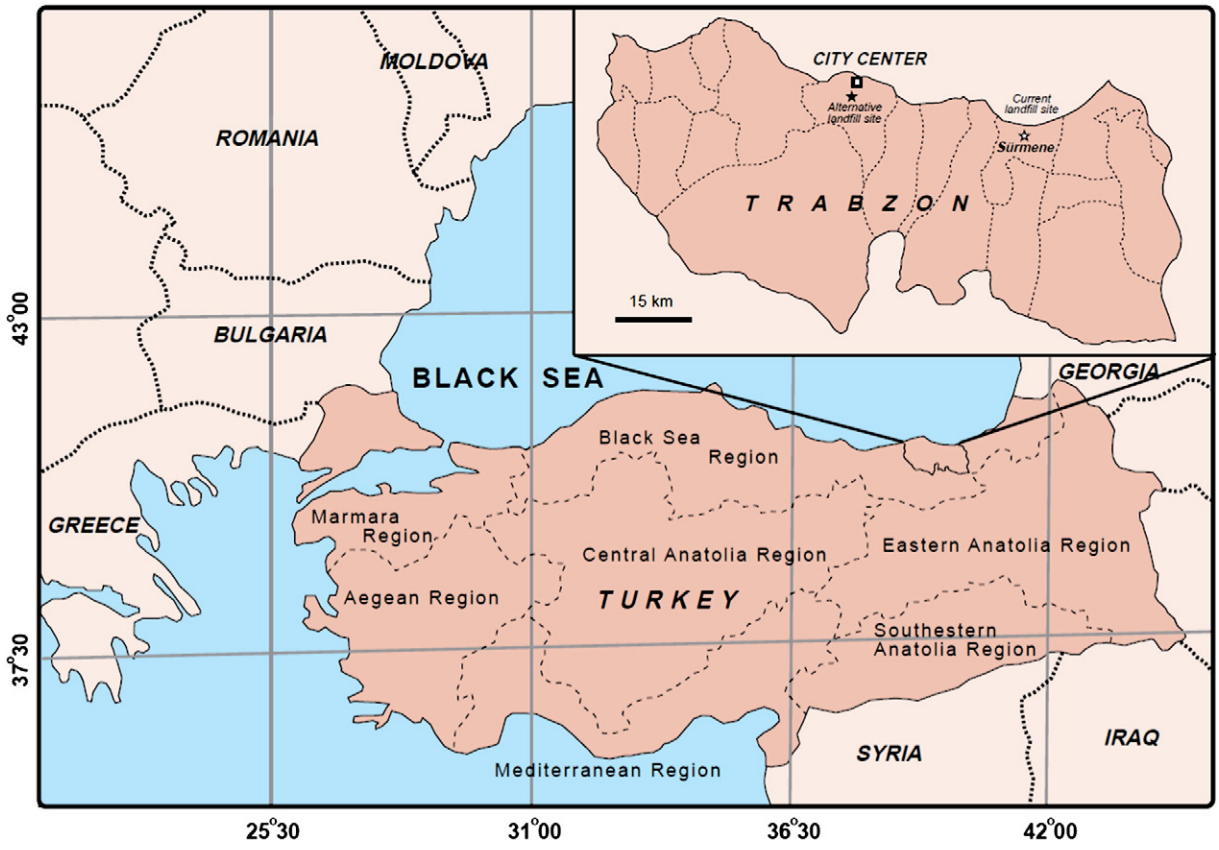

Fig. 1. The location map of the studied area.