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Utilization of spilitic mining wastes in the construction of landfill bottom liners

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ABSTRACT

In the present research work the possibility of spilite valorization, a mining waste produced during the exploitation of nickeliferous laterites from LARCO Mining and Metallurgical Company, as an alternative material for the construction of compacted landfill liners was examined. For that purpose, different types of mixtures were tested with bentonite content up to 3 wt%. Particle size distribution, chemical analysis, mineralogical analysis by X-ray diffraction (XRD), thermogravimetric analysis (TG-DTG) and microstructure examination by scanning (SEM) and transmission (TEM) electron microscopy were used for the spilitic sand characterization. The evaluation of the produced spilitic sand-bentonite mixtures was carried out by determining the liquid limit (WL), the plasticity index (PI), the organic matter content, the Proctor compaction and the hydraulic conductivity. According to the results, the hydraulic conductivity coefficient of the mixture with 3 wt% bentonite addition was less than 10^{-9} m/s, satisfying the requirement for landfill liner materials.

1. Introduction

The disposal of solid waste on the ground and in the aquatic environment coincides with the beginnings of civilization. Although the risks of this practice on the environment and health of living beings have been known for many years, in Europe the concept of Municipal Solid Waste (MSW) sanitary landfilling was firstly adopted in the late 60s. Before that, the MSW deposition had been taken place in non-sealed areas (refused open dumps), or in places with simple natural clay layer. Technical landfill bottom sealing action had not been taken and the protection of subsoil was based only on physical degradation mechanisms of the pollution load, during the infiltration of contaminants through the soil. As a result, a large number of hazardous compounds, even in low quantities, such as aromatics, halogenated compounds, phenols, pesticides, heavy metals etc, often caused more harmful effects especially because of their synergistic action [1–3].

Today, landfilling is the least preferable option and according to the waste management hierarchy should be limited. However, in many countries the most common treatment method for Municipal Solid Waste (MSW) is still landfilling and in many cases difficulties have been generated due to improper disposal or/and insufficient collection system, resulting in environmental and public health problems. The main reasons of insisting in the above choice as a treatment method are the simplicity and its cost effectiveness, although in many cases landfilling has been readily connected with the groundwater pollution, due to waste-derived leachates [4,5]. In Europe, in cases where the MSW landfilling is still an option, the requirements of Directive 1999/31/EC and thus of the Council Decision 2003/33/CE should be implemented, as their main objective is to minimize the negative effects on the environment (surface water, groundwater, soil, air) [6,7]. According to the above European Union (EU) legislation, geological barrier of minimum thickness of 1 m is required, presenting a minimum hydraulic conductivity of 10^{-9} m/s. An artificial geological barrier of minimum thickness of 0.5 m should be established, in cases that the existing geological barrier does not naturally meet the above conditions [8].

In order to prevent pollution of the subsoil due to the leachates migration, the EU environmental regulations applied for landfills for MSW disposal, except the construction of a protective and low

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permeability sealing layer of the landfill floor and sides, require and the installation of a collecting and removing of polluting leachates system. The construction of this barrier layer can be carried out by using either physical earthy materials (usually compacted clays), or by artificial liners (high-density polyethylene), or with a combination of natural and artificial insulation. The thickness of the composite liners can be varied between few decimeters to greater than one meter [9–11].

Except low hydraulic conductivity and the ability to minimize leachates migration, the final barrier that will separate the buried waste from the groundwater should also present sufficient engineering properties such as high flexibility, high tensile and compressive strength, chemical compatibility and workability [12–14]. In most cases compacted natural clays satisfy the above requirements, presenting very low permeability, mainly because of their complex porous structure [15–17]. One of the major considerations for the selection of a suitable material, for economical reasons, is local availability and as a result many different types of earthen materials could be used as liners. In most cases clay minerals present relatively high availability and low cost [9,18]. However, if it is not possible to find impervious natural soils readily available at the disposal site that satisfy the technical regulations, or because of the high costs of synthetic liners, the natural soil amendment is required. In this context compacted mixtures of bentonite, an absorbent granular clay formed from volcanic ash, with natural earthen material could be used in the constructions of landfill bottom liners [19]. Alternative materials have been examined as liners in MSW landfills, such as mixtures of bentonite with foundry sand, fly ash or zeolite materials, thus replacing the natural clay soils [20–23].

The main objective of the present research work is to present an alternative landfill liner material composed of spilitic sand and bentonite. Spilite (albite diabase), is a byproduct of LARCO Mining and Metallurgical Company, which is generated during the exploitation of nickeliferous laterites. It is a fine-grained igneous rock, product of basalt transformation, which has become altered, either magmatically or post magmatically, due to hydrothermal metamorphism and it is characterized by the presence of greenschist mineralogical phases, such as albite and chlorite [24,25].

2. Experimental

2.1. Spilitic sand characterization

Spilite was supplied from G.M.M.S.A. LARCO, a Hellenic Mining and Metallurgical company, the only Ferronickel producer today in EU, which utilizes local nickel deposits, covering the 5% of the European annual demand in nickel, with an annual ore mining that exceeds two million tones and a nickel annual production of about 19.000 tones. Spilitic sand was used in construction of compacted landfill liners, as the results of preliminary TCLP tests revealed that the concentrations of leached heavy metals were substantially below the regulatory thresholds [26]. The original sample presented a size of −5 mm. Its particle size distribution (fractions of 0.5 mm – 5 mm) was determined by sieve analysis, while for the −0.5 mm fractions, a CILAS (Model 1064) laser scattering particle size distribution analyzer was used. Chemical analyses were carried out with X-ray Fluorescence (Spectro–Xepos), Atomic Absorption, Spectrophotometry (PerkinElmer 4100) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS X Series II, Thermo Scientific). Its mineralogical phases were determined by XRD analysis, using a Bruker D8-Focus diffractometer with nickel-filtered CuKa radiation (λ = 1.5406 Å), at 40 kV and 40 mA. Semi-quantitative phases analysis was determined by TOPAS software (Bruker-AXS), based on Rietveld algorithm. Thermal Gravimetric analysis was also conducted using a Mettler Toledo 851 thermal analyzer from room temperature to 1000 °C, at a heating rate of

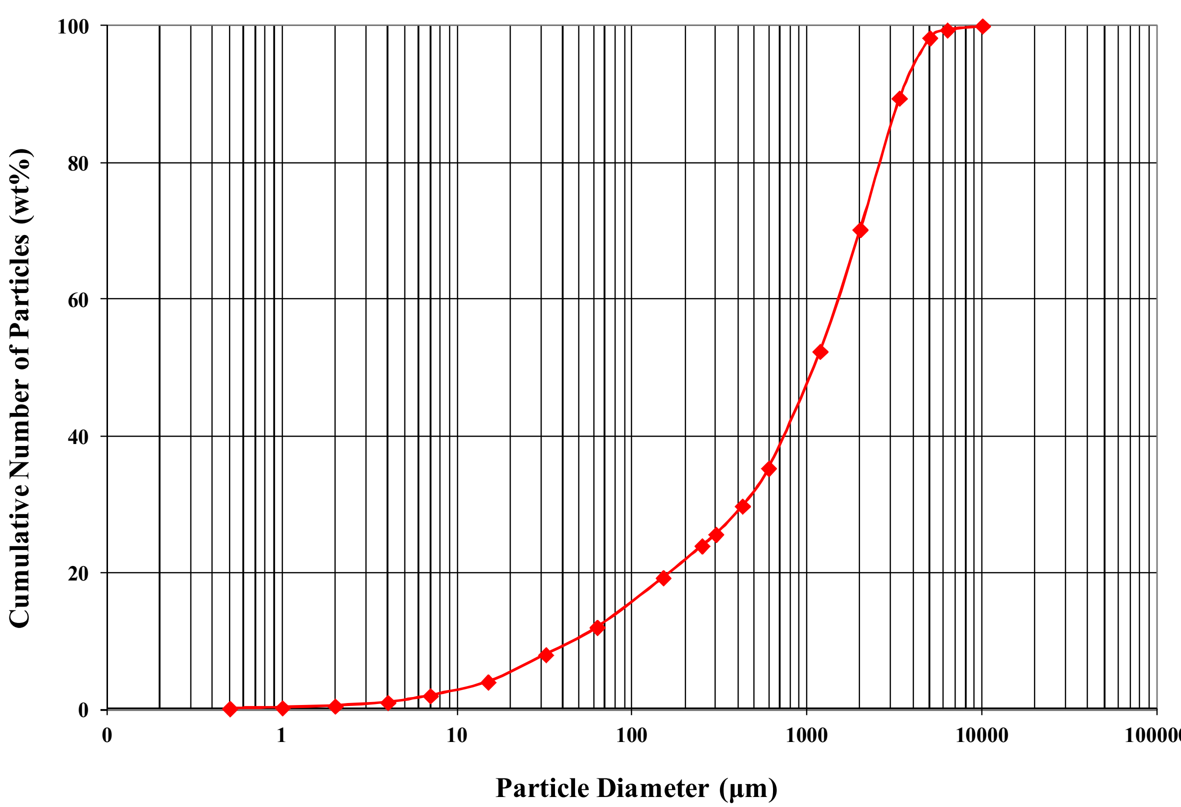

Fig. 1. Particle size distribution of the as-received spilitic sand.