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Testing methodologies to evaluate waste-based liners

Méthodologies de test pour évaluer les revêtements à base de déchets

L. Marchiori*
GeoBioTec, Civil Engineering and Architecture Department, University of Beira Interior, Covilhã, Portugal

M.V. Morais, A. Albuquerque, L. Andrade Pais, V. Cavaleiro
GeoBioTec, Civil Engineering and Architecture Department, University of Beira Interior, Covilhã, Portugal

**leonardo.marchiori@ubi.pt*

ABSTRACT: Improper waste disposal and management due to industrial activity may lead to soil and groundwater contamination. Thus, the development of methodologies for mitigating waste generation and its valorisation should be investigated to reduce environmental impacts, create waste-based products, and fulfil sustainable development goals. When malfunctioning, earthworks can negatively impact the environmental, besides clayey soils have mechanical issues, and represent high costs of logistics depending on the region, in addition to geosynthetics being still a costly solution. Therefore, recent investigations are using industrials by-products for construction purpose. This research reviews the literature of the main wastes used as liner materials, and their laboratorial tests program to evaluate their potential for liner. Furthermore, a flowchart was designed to optimize the valorisation process depending on the waste availability, and a table developed within the tests over the literature available.

RÉSUMÉ: Une élimination et une gestion inappropriées des déchets dues à l'activité industrielle peuvent entraîner une contamination des sols et des eaux souterraines. Ainsi, le développement de méthodologies pour atténuer la production de déchets et leur valorisation devrait être étudié pour réduire les impacts environnementaux, créer des produits à base de déchets et atteindre les objectifs de développement durable. En cas de dysfonctionnement, les terrassements peuvent avoir un impact négatif sur l'environnement, de plus les sols argileux présentent des problèmes mécaniques, et représentent des coûts logistiques élevés selon les régions, de plus les géosynthétiques restent une solution coûteuse. Par conséquent, des études récentes utilisent des sous-produits industriels à des fins de construction. Cette recherche passe en revue la littérature sur les principaux déchets utilisés comme matériaux de revêtement, ainsi que leur programme d'essais en laboratoire pour évaluer leur potentiel pour l'imperméabilisation des terrassements. De plus, un organigramme a été conçu pour optimiser le processus de valorisation en fonction de la disponibilité des déchets, et un tableau a été développé pour organiser les tests selon la littérature disponible.

Keywords: Industrial wastes; methodology for liner material; laboratory and in-situ tests; geotechnical applications.

1 INTRODUCTION

Liner materials are usually made of compacted clay liners (CCL) or geosynthetic clay liners (GCL), mainly used as layers of low hydraulic conductivity (k) and environmental protection barriers in landfilling, roads, channels, dams, reservoirs, and wastewater lagoons and ponds (Bouazza, 2002; Kerry Rowe et al., 2022). Suitable liners' properties can be summarized mainly as having low k, less than or equal to 10^{-9} m/s, enough strength to support the weight of the disposed/transported solid/liquid materials, deformation during service without cracking or rupture, self-healing properties, and chemical compatibility with the materials.

Depending on the region, natural clays exploration creates logistics' issues and environmental impacts, besides, geosynthetics still represents a costly solution, justifying the use of alternative materials, for use as waterproofing in earthworks. Furthermore, there are several industrial by-products as mining tailings (Maritsa et al., 2016; Pastore 2003; Marchiori et al., 2022a), furnace slags (Masri et al., 2019; Bennett et al., 2011; Liu et al., 2022; Herrmann et al., 2010), fly ashes (von Maubeuge et al., 2015; Marchiori et al., 2023b), and water treatment sludges (Baghbani et al., 2023, Marchiori et al., 2021, 2022b), which seem to have chemical and mechanical properties for that application. The reuse or valorisation of industrial by-products is within the circular economy directives and United Nations' Agenda for Sustainable Development Goals since it allows reduction of construction costs, helps preserve natural resources, decreases the production of synthetic materials and lead to sustainable new geomaterials design.

In addition, there was identified lack of specific methodologies to classify certain types of waste materials as geomaterials (Kerry Rowe et al., 2022), mainly over geotechnical, chemical, and environmental characterization, long-term behaviour of materials, mechanical properties, chemical and mineralogical composition, and leaching evaluation (Agamuthu, 2013; Devarangadi and Shakar M, 2021; Marchiori et al., 2020). Thus, this paper aims to review the literature, select the main laboratorial and in-situ test programs, and propose a laboratorial program to evaluate industrial by-products as liner geomaterial.

2 METHODOLOGY

A review of the literature was performed gather testing methodologies used for producing and assessing liner alternative materials. The chosen database was Scopus, and the main tests were selected in order to create Figure 1 and Table 1.

3 RESULTS

The process to qualify a waste material as a sustainable barrier should comprise careful sampling, identification, and characterization according to physical, chemical, mechanical, and hydraulic parameters, and the need of additives and/or geosynthetics materials to mitigate environmental impact without performance loss. The following subsections present the main concerns on the mentioned characteristics. Table 1 summarizes testing programs used by different authors. The flowchart in Figure 1 organizes the proposed methodology for waste valorisation as liner material.

3.1 Sampling and identification

The most concern about sampling is due to contamination, all the care with the samples must be done in order to do not contaminate it. It is very important to understand and analyze all the industrial processes that generate the by-products to understand some components in further identification (Kerry Rowe et al, 2022). Sample treatment can be included, like dehydration and sieved, but calcination should be avoided due to gas release.

Chemical compactibility and potential negative environmental impacts are the most important worries when dealing withh waste containment facilities. The composition through X-ray fluorescence (XRF) and mineralogical composition with X-ray diffractures (XRD) should be done to identify the possiblity of contamination in the sample. Besides, microstructure assessment with scanning electron microscopy (SEM), computed tomography (CT) scan and mercury intrusion porosimeter (MIP), in addition to thermogravimetric analysis (TGA) and Fourier transformed infrared (FTIR) linked to leaching potential for chemical detections (Marchiori et al., 2020). Physical identification includes the analysis of particle size distribution by sieve or laser equipment, and material classification, besides specific gravity measurements (Herrmann et al., 2010; Liu et al., 2022). The soil characterization should assess Atterberg limits and compaction characteristics within Proctor tests (Maritsa et al., 2016).

3.2 Geocomposite development

Specific gravity plays an important role in the chosen ratios of soil-waste when is searching for a suitable waste-based liner. Waste incorporation percentage must be defined according to the parameters to reach linked to its density (Marchiori et al., 2023a).

Table 1. Test program for liner material.

Characterization	References
Chemical	
Composition	1,3,5,6,7
Mineralogy	1,3,5,6,7
Leaching	1,2,3
Microstructure	1,3,6,7
Geotechnical	
Particle Size	1,5,6,7
Atterberg Limits	1,5,6,7
Specific Gravity	3,4,5,6,7
Compaction	1,4,5,6,7
Consolidation	6,7
Triaxial CU	6,7
Permeability	1,3,4,5,6,7
In-situ	
Intelligent Compaction	4
Permeability Control	4

1. Maritsa *et al.* (2016); 2. Pastore (2003); 3. Liu *et al.* (2022); 4. Herrmann *et al*. (2010); 5. Marchiori *et al.* (2021); 6. Marchiori *et al.* (2022b); 7. Marchiori *et al.* (2023b).

3.3 Geotechnical assessment

3.3.1 Mechanical performance

With those preliminary physical and chemical identification, and further geocomposite design, the mechanical evaluation can be done, basically understanding deformation over tension application, and the main tests to be develped are one-dimensional oedometric consolidation and consolidated-undrained (CU) triaxial shearing test to simulate liner conditions (Marchiori et al., 2022b, 2023b).

3.3.2 Hydraulic conductivity

The main parameter of liners is the hydraulic conductivity (k), permeability characterization must be comprised due to the required low k, less than or equal to 10^{-9} m/s. Intermediate- to large-scale experiments can be done, and the methodology for experimental liner development should be designed according to hydrogeological and geotechnical aspects of the selected site, besides economical and environmental impact of the area. Intelligent compaction should be addressed and permeability testing must be conducted (Bouazza, 2002).

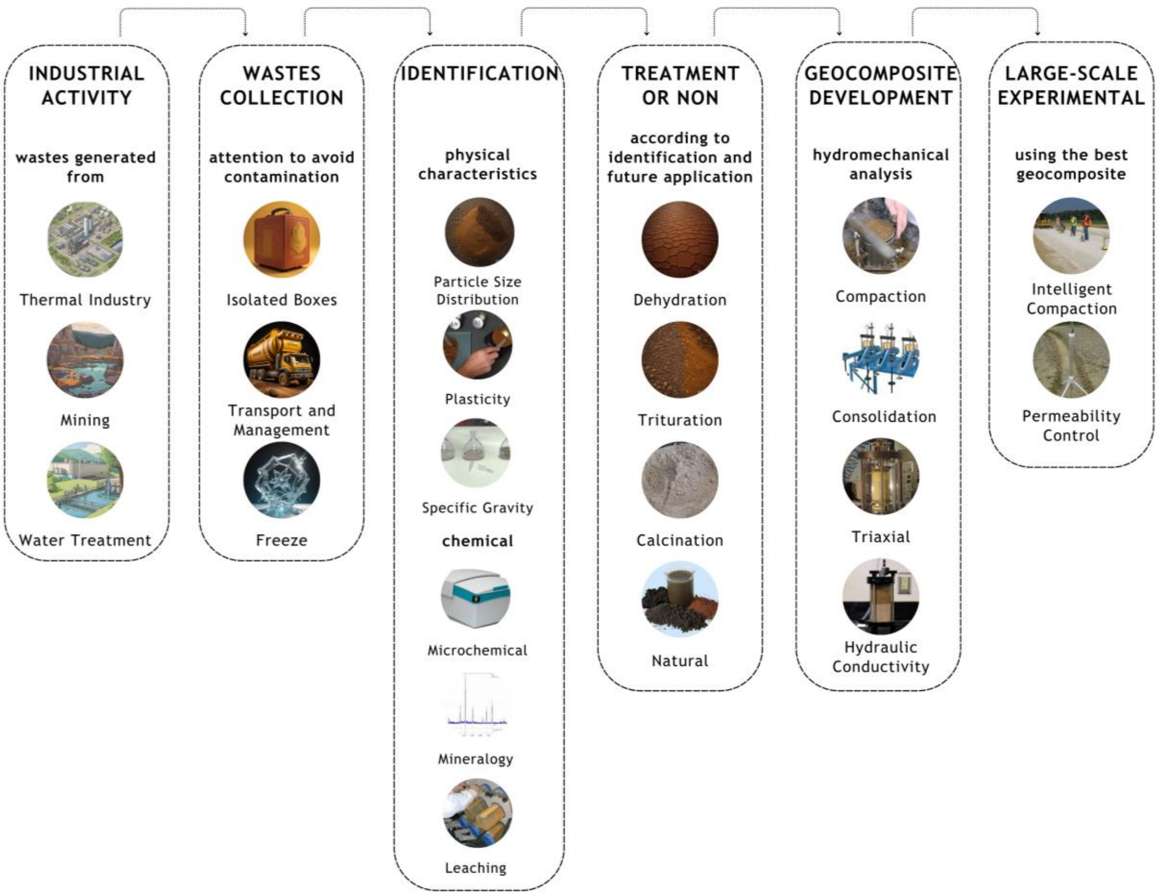

Figure 1. Schematic process for waste-based liner material evaluation.

4 CONCLUSIONS

The flowchart presented here aims to complement rather than invalidate other methods. It focuses on reducing the need for repeated laboratory work and emphasizes key factors and parameters for creating waterproof liners from waste materials. As a result, the information provided in this study, which covers environmental, physicochemical, and geomechanical tests, appears to facilitate the use of wastes with soils for liner production as alternative geomaterials.

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