Enhancing sustainable infrastructure through life cycle assessment and Type III environmental product declarations for a wicking geosynthetic composite

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Abstract. Geosynthetics play a critical role in sustainable infrastructure. Accurate assessment and communication of their environmental impacts have become increasingly important. Although Type III Environmental Product Declarations (EPDs) provide transparent environmental impact information, their adoption of geosynthetics in North America remains limited compared with Europe, resulting in a lack of verified, region-specific data for these products. This research aims to address this gap by developing Type III EPDs for a novel wicking geosynthetic composite (WGC) product through systematic data collection, rigorous life cycle assessment (LCA), and third-party verification following international standards (ISO 14025, ISO 21930:2017). The (WGC) investigated is a novel composite product combining a high-stiffness, open-aperture polymeric geogrid with a unique nonwoven geotextile possessing wicking properties in multiple directions, specifically engineered to transport water even under zero hydraulic gradient due to its proprietary microstructure and specialized treatment. The research includes goal and scope definition for the composite EPDs, detailed mapping of manufacturing and transportation processes, collection of inventory data on materials, energy use, emissions, and waste for the composite production. OpenLCA software with ecoinvent database will be used for LCA modeling to ensure the accuracy of the environmental impact assessment in these EPDs. The study will extend product-specific EPD data in representative infrastructure projects scenarios to support project-scale environmental-impact analysis and comparison with conventional alternatives. This research highlight sustainability assessments in civil, geotechnical, and environmental engineering by providing accurate, product-specific benchmarks. If verified and applied within functionally equivalent project scenarios, the EPD can support more informed material selection and help identify opportunities to reduce embodied carbon and other environmental impacts.

1 Introduction

Geosynthetics are increasingly used in transportation and geotechnical infrastructure because they can improve mechanical performance, extend service life, and reduce the need for conventional construction materials. Despite these advantages, environmental evaluation of geosynthetic products remains challenging in North America because verified, product-specific environmental datasets are still limited. In practice, this often leads to the use of generic assumptions, which reduces the reliability of sustainability comparisons and weakens the basis for transparent material selection.

Environmental Product Declarations (EPDs) provide a standardized mechanism for reporting product-level environmental impacts. For construction products, Type III Environmental Product Declarations are typically based on life cycle assessment and third-party verification in accordance with international standards [1]. Expanding their use for geosynthetics can improve data transparency and support more robust environmental decision-making across civil and geotechnical engineering applications. Unlike normal geosynthetic, wicking geosynthetic posses' unique behavior of draining water even under zero hydraulic gradient due to its proprietary microstructure and specialized treatment. This behaviour is useful in draining water from the structure which reduces maintenance and increases the service life of infrastructure. The major challenge in developing EPD of this novel geosynthetic is incorporating its use phase benefits in its LCA modelling. This study aims to fulfill this challenge based on project data, reduction in maintenance frequency and service life of infrastructure on using this product in real world project.

2 Objective and methodology

The objective of this research is to develop verified Type III Environmental Product Declarations for a novel non-woven wicking geosynthetic composite intended for infrastructure applications. The study follows a life cycle

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assessment framework consistent with ISO 14025 and ISO 21930:2017, with emphasis on methodological transparency, representative primary data, and documentation suitable for verification.

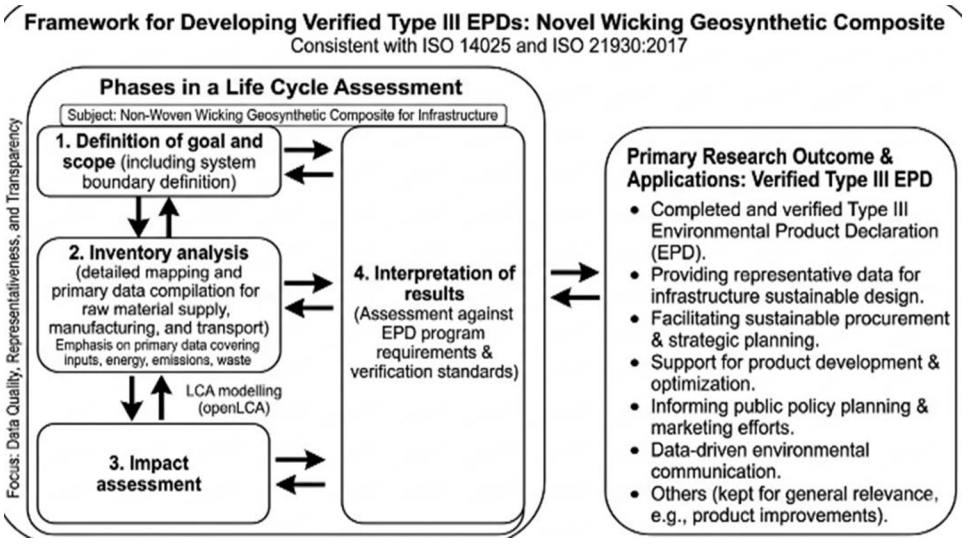


Fig. 1. Phases of LCA for wicking geosynthetic composites

The methodological scope includes goal and scope definition, identification of system boundaries, detailed mapping of raw material supply, manufacturing operations, and transportation activities, and compilation of primary inventory data covering material inputs, energy consumption, emissions, and waste generation [2]. Life cycle assessment modelling is performed in openLCA using background datasets selected to represent upstream processes. Cradle to gate with use phase is the proposed system boundary to incorporate the benefits of reduced maintenance of infrastructure because of the wicking behaviour of the concerned product. Attention is given to data quality, representativeness, and consistency with Environmental Product Declaration program requirements, since these factors strongly influence the credibility of the results.

3 Relevance to infrastructure assessment

Beyond product-level disclosure, the developed Environmental Product Declaration data are intended to support infrastructure-scale environmental assessment. Product-specific datasets can improve comparison between the wicking geosynthetic composite and conventional alternatives by replacing generalized assumptions with verified environmental information. This is especially important in project-level evaluations because the environmental implications of a material depend on its manufacturing profile, design context, substitution effects, and application-specific assumptions.

By establishing verified benchmarks for an emerging geosynthetic product, this research contributes to improved sustainability assessment in civil, geotechnical, and environmental engineering. The work provides a pathway for integrating product-level environmental data into infrastructure design frameworks, helping practitioners make more informed choices about embodied impacts and material selection.

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