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A cradle-to-gate based life cycle impact assessment comparing the KBF_w EFB hybrid reinforced poly hydroxybutyrate biocomposite and common petroleum-based composites as building materials

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ABSTRACT

Aligning the sustainability in construction process can be achieved through material selection process with low impact on environment and human health. Today, biocomposite materials are investigated and developed to replace with none, and less eco-friendly materials used in the construction industry leading to emergence of next generation of sustainable and green building materials. This paper aims to develop a model of fully hybrid bio-based biocomposite based on Life Cycle Assessment (LCA), and comparing it with fully petroleum-based composite, which are common conventional building materials. The methodology framework of this research is determined based on ISO 14040 and 14044. Also, the ReCiPe as the common method in SimaPro software is chosen for appraising and comparing LC impact assessment (LCIA). This research highlights the negative effect of these kinds of building materials with providing single scores coming from three gauges including Human Health, Ecosystems and resources. It is observed that substituting the biocomposite with the fully petroleum-based composite has led to a decline of about 30% in single score outcome. The significance of this research is related to important judgement information to policy makers and the prospective manufacturers in the commercialization phase of this new biocomposites as sustainable and green building materials.

1. Introduction

The construction industry consumes the astonishing amount of materials, most of which derive from non-renewable resources or resources that require considerable time to be renewed (Pheng Low et al., 2009). On the other hand, the use of materials during the life cycle of a building would be associated with various environmental effects like: harmful emissions (CO_2), burdening weight initiated by excavating, extraction and waste dumping. The volume of construction and demolition material debris has been dramatically increased, which is composed of 30–50% wood, drywall and plastic (Environmental Protection Agency (EPA), 2003; Sandler, 2003). These materials are generally recalcitrant in land-fills being potential to substitute by biocomposite materials that can be more quickly biodegraded. In 2015, Cordelia Sealy in Materials Today published an article “How green are cellulose-reinforced composites?”. This article emphasized the use of cellulose fibres as reinforcement in biocomposites to provide a sustainable and renewable alternative to petroleum-based plastics (Sealy, 2015). Biocomposite materials being studied for use in construction submissions with the aim of mitigating the negative environmental and human health impacts of construction materials (Christian and Billington, 2009). Biocomposites and other green materials eliminate non-renewable waste, reduce raw material usage, and cut fossil-fuel consumption (Sandler, 2003).

In compare to biocomposites, polymeric composite products as conventional building materials are important sources of indoor chemical emissions (Ayrilmis et al., 2016) which would influence the environment and health of users. The current paper deal to improve the understanding of the hazardous of petroleum-based composites which are pose to public health and the environment. Life cycle assessment (LCA) considered as pragmatic decision making in progress sustainability in the construction industry to adjust nowadays the growing worry of environment and resource exhaustion as well as public health (Bond et al., 2013; Morrison-Saunders et al., 2015). The LCA is a

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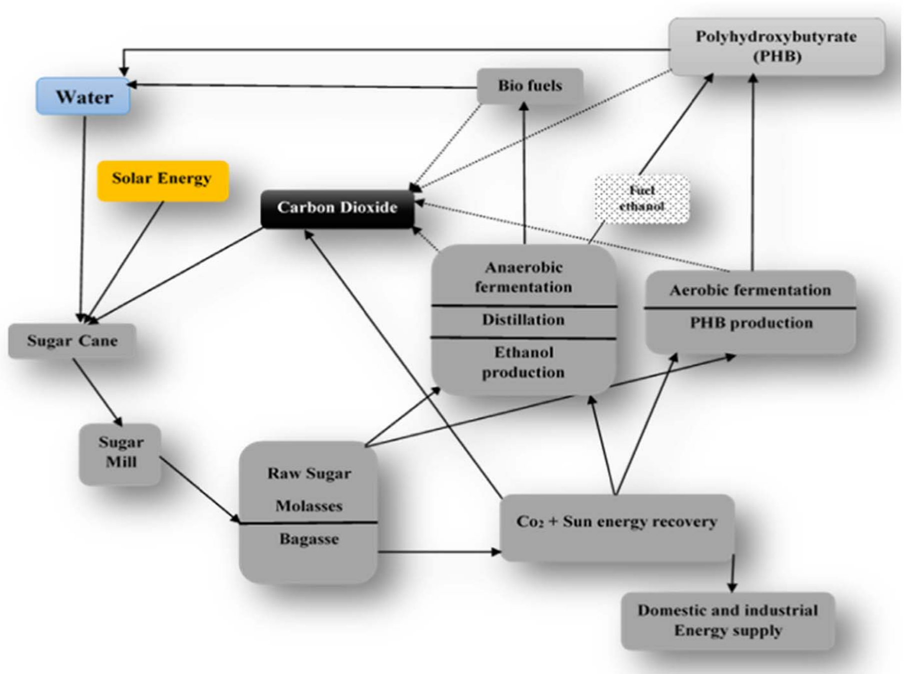

Fig. 1. carbon cycle of PHB production (Koller et al., 2009b).

technique of assessing the environmental load of procedures and products (things and services) throughout their life cycle from the cradle to grave. Based on LCA, the aim of the current research is to appraise the environmental effects associated to the production of a biocomposite and LCA providing information in two parts:

1. A wide-ranging life-cycle inventory with appropriate energy and material inputs for biocomposite production and environmental discharges during its structure,
2. Approximations of the subsequent impacts from biocomposite life cycle for a widespread assortment of impact types, as well as global climate change, natural resource exhaustion, ozone depletion, acidification, eutrophication, human health, and ecotoxicity

2. Role of Life Cycle Assessment (LCA) and its software's in construction industry

The Life Cycle Assessment is considered as the suitable method capable of assessment of environmental impacts related to building materials from the cradle to grave (Cole, 1998; Junnila et al., 2006; Horne et al., 2009; Kiliç et al., 2011). The LCA methodology was formerly established by the Society of Environmental Toxicology and Chemistry (Setac, 1993) to reduce resource consumption and environmental burdens related to product, packaging and production process (Upadhyayula et al., 2012; Weir and Muneer, 1998; Korol et al., 2016). In addition, it empowers the identification and quantification of materials and energy usage, and surpluses free to the environment over the whole life cycle (Klöpffer, 2006). Since 1990, the LCA has been applied in building industry and is considered as significant evaluating device (Taborianski and Prado, 2004; Fava, 2006). In recent years, LCA has received increasing attention as a tool with a range of uses such as product environmental improvement, eco-design and policy evaluation. Although, LCA is a complex and expensive methodology, progression of LCA software leads to resolving the complexity of this method in material science. Totally, LCA Software Reduces cost and risk in material selection, and also increases energy and resource efficiency in buildings. Although the methodology framework of this research is determined based on ISO 14040 and 14,044, the role of SimaPro software is highlighted based on their outcome for presenting environmental burdening of biocomposite. The SimaPro is the most widely used LCA software that offers standardization as well as the ultimate flexibility (http://www.simapro.co.uk, n.d.), and is considered as the main software used for analyzing LCA in this research.

3. Biocomposite as building materials

Biocomposites are structural materials made from renewable resources that are biodegradable and affected by bacteria turning them into small substances without any harm to environment (Sealy, 2015; Wool and Sun, 2005). The biocomposites consists of two components named NFs functioning as reinforcement and Biopolymers serving as matrixes, which are derived from plants (Netravali and Chabba, 2003a). Behaviours of biocomposites depend on certain factors including kinds of fibres, matrix and distribution of fibres on matrix, etc. This study addresses the NFs hybrid biocomposite and briefly elucidates biocomposite components.

Biopolymers are polymers that are derived from living organisms, such as plants and microbes. The primary sources of biopolymers are renewable, which is in contrary to petroleum (Fowler et al., 2006). Polyhydroxybutyrate (PHB) is the most common polymer that is considered as matrices for biocomposite in this research. The PHB is an organic and biodegradable polymer (Ramsay et al., 1990), a source of carbon and energy which formed by different microorganisms. Its combination by environmental tensions like nitrogen, phosphate or oxygen restraint (Steinbüchel, 1991; Steinbüchel and Lütke-Eversloh, 2003). There are a lot of inexpensive carbon sources and high productivity as basic feedstocks for PHB production (Zhang et al., 1994; Kim, 2000; Koller et al., 2005; Koller et al., 2009a; Silva et al., 2004; Fukui and Doi, 1998). The Fig. 1 shows closed carbon cycle in combined sugar mill with ethanol PHB production (Koller et al., 2009b). The major benefit of PHB is include: biodegradable, made from a low-cost renewable carbon source, less expensive to produce from sugar or corn starch, produced with lower energy inputs and release lower greenhouse gas emissions over their life-cycle compared to petrochemical plastic materials, and the key to a true cradle-to-cradle carbon cycle.