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A sustainable and resilient approach through biochar addition in wood polymer composites☆

Oisik Das [a], Ajit K. Sarmah [a,*], Debes Bhattacharyya [b]

[a] Department of Civil and Environmental Engineering, University of Auckland, Auckland 1142, New Zealand
[b] Department of Mechanical Engineering, Center for Advanced Composite Materials, University of Auckland, Auckland 1142, New Zealand

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ABSTRACT

Biocomposites have been used for sustainability for a few years now and considerable advancements have been made to perfect the physical and mechanical properties. However, there still remain some considerable disadvantages (such as inferior mechanical strength, thickness swell, and rotting) which restrict their proper utilization in wider markets. Attempts have been made to remedy these drawbacks but still further investigation is required to address all the issues and alleviate as many shortcomings as possible. Additionally, concerns related to landfill gas emission prompted the necessity for effective utilization of organic wastes. Lignocellulosic wastes can be valorized by thermo-chemical conversion to form a carbonaceous and renewable material called biochar. Keeping these two problems in mind, a relatively novel idea is recommended for the manufacture of biocomposites where biochar made from pyrolysis of waste could be added with wood and plastic. It is expected to mitigate the general disadvantages of conventional wood plastic composites (WPCs) and at the same time manage landfill wastes giving rise to a potential new breed of improved next generation biocomposites. Furthermore, a 'resilient' perspective is conferred where the long term viability of the state-of-the-art product could be ensured.

1. Introduction

The need for energy is manifold and extends to transportation, food production, irrigation, industries etc. (Asadullah et al., 2007). Population growth, technological advancement and commercialization are responsible for the increase in demand for fossil fuels. The utilization of fossil fuel has contributed to pollution and greenhouse gases and their presence has a detrimental effect on the environment (Klass, 1998). Fossil fuels are non-renewable resources and it takes millions of years to form, and with the continued dependency of human beings on these resources worldwide reserves are being depleted much faster than new ones are being found (Folland et al., 2001). This over usage of fossil fuels has created a disparity between demand and supply in a continuously expanding economy (MacCracken, 2008), which in turn is going to escalate the price of fossil fuel derived products in the near future.

The lavish use of fossil fuel derived products has created a problem which is twofold in nature: diminution of petroleum based materials and gridlocking of synthetic products in the environment and food chain (John and Thomas, 2008). These synthetic materials, mainly of polymeric nature, form one of the spearheading factors in environmental deterioration given their production, application and disposal, all lead to pollution by adding non-degradable materials to soils and toxic gases to the atmosphere. It goes without saying that the dependency on fossil fuels for materials, products and processes is crippling the development of a sustainable future.

Stimulated by the deteriorating environment, the policy makers and governmental agencies are focussing their attention on the adverse effects of landfilled organic wastes which include but are not limited to greenhouse gas production, water contamination and toxin production (Emberton and Parker, 1987). Methods are being investigated to recycle, reuse and reduce these wastes which could curb pollution, preserve resources and conserve energy (http://www.epa.gov/epaoswer/non-hw/organics/index.htm). Biochar is a carbonaceous and renewable material which can be produced by the thermo-chemical conversion of these organic wastes (Sohi et al., 2010). Until now, biochar has only been used in soil amendment and contaminant removal (Kookana et al., 2011; Srinivasan and Sarmah, 2014). Owing to its very high surface area, high carbon content, and hydrophobic nature, biochar can also be potentially used as a filler in wood and polymer composites. This application of biochar in biocomposites can widen its usability and produce improved composites while managing wastes in a sustainable way. However, to date, no studies have been conducted which involved biochar in wood/polymer biocomposites. Hence, this commentary could inspire researchers to delve into the matter of biochar application in biocomposites.

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* Corresponding author at: Department of Civil and Environmental Engineering, Faculty of Engineering, University of Auckland, Auckland 1142, New Zealand.
E-mail address: a.sarmah@auckland.ac.nz (A.K. Sarmah).

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From the above discussion it becomes clear that economic competency, ecological efficiency, green chemistry and sustainable manufacturing should be the cornerstones for guiding the present situation towards a habitable next generation. It is critical to develop methods and materials that a) offset the use of fossil fuels, b) utilize wastes and, c) are innocuous to the environment as well.

This article points out the necessity and rationale for delving into more renewable and sustainable practices when composite materials and waste utilization are concerned. A brief background in the development of the biocomposite industry is given with a focus on their drawbacks and recommendations to improve them. The article concentrates on wood plastic composites and other new biocomposites made with biochar (procured from pyrolysis of organic wastes) as fillers. The article illustrates the shortcomings of the present WPC products and critically analyses the researches done involving biochar in biocomposites. Finally, the authors propose a novel idea of minimising the disadvantages of current biocomposites and incorporating biochar to create improved biocomposites. Furthermore, recognising the importance of having a steady supply of resources to develop biocomposites, the article encourages a 'resilient' thinking while planning to incorporate the new product in a system. Concepts are presented where the state-of-the-art product system could be made more resistant to unforeseen hindrances and more efficient by incorporating certain perspectives of economic, environment and technological scales.

2. Roles of biocomposites, bioplastics, and biofibres to improve environmental quality

In the light of the problems associated with the application of petroleum based products, it becomes absolutely vital to resort to techniques and processes that encourage the development of bio-based materials. These materials would primarily be able to reduce the ubiquitous dependency on fossil fuels and minimise wastes simultaneously. Furthermore, the bio-based materials would promote the concept of sustainability, and would be capable of being resilient, diverse, efficient, adaptable and finally competing in the present petroleum dominated markets (Fiksel, 2003).

The inception of biocomposites (for the purpose of this article, by biocomposites we mean composites having natural fibre reinforcement and the polymer matrix which may or may not be derived from biological sources) as a technology goes beyond the boundary of mitigating the prevalence of synthetic composites. This suite of technologies has the potential to overcome the disadvantages of synthetic composites by being eco-friendly, biodegradable, renewable and flexible in design. Biocomposites are typically made by combining two or more constituents (natural fibres and natural/synthetic polymers) which have different physical and chemical properties, and which stay distinct macroscopically in the final product while exhibiting synergistic material properties (John and Thomas, 2008). The bio-based materials include but are not limited to forestry and agricultural wastes which are generally lignocellulosic in nature. Furthermore, the ideology of attaining a sustainable society is driven by the fact that the biocomposites would be a) insipid in environment and b) pecuniary in markets. The development, disposition and disposal of these biocomposites can be viewed as carbon neutral/negative (Thomas et al., 2014). Fig. 1 describes the mechanism by which the process involving biocomposites delivers back the CO_2 to the plant from which the raw materials were procured in the first place. When biocomposites are made from petroleum based products, the CO_2 produced upon their disposal and subsequent degradation adds to the existing pool of CO_2 in the air. This is due to the fact that the plants which were responsible for the production of the fossil fuels are non-existent in the present day (Folland et al., 2001). On the contrary, when biocomposites are derived from plant based product, the CO_2 generated when they are disposed is absorbed back by the same generation of the plants. Thus, the process of manufacturing biocomposites from plant based raw material does not contribute to CO_2 in the environment. On the other hand, biocomposites made from organic wastes would act as a carbon sink making the whole process carbon negative.

The basis of a sustainable system requires the utmost utilization of renewable resources, and materials processed from lignocellulosic sources/organic wastes are paragon of renewability. These biomass based materials aptly fit into the current scenario of industrial products. Thus, the use of petroleum derived plastics would be abated resulting in the lower release of CO_2 to the atmosphere and less expenditure of

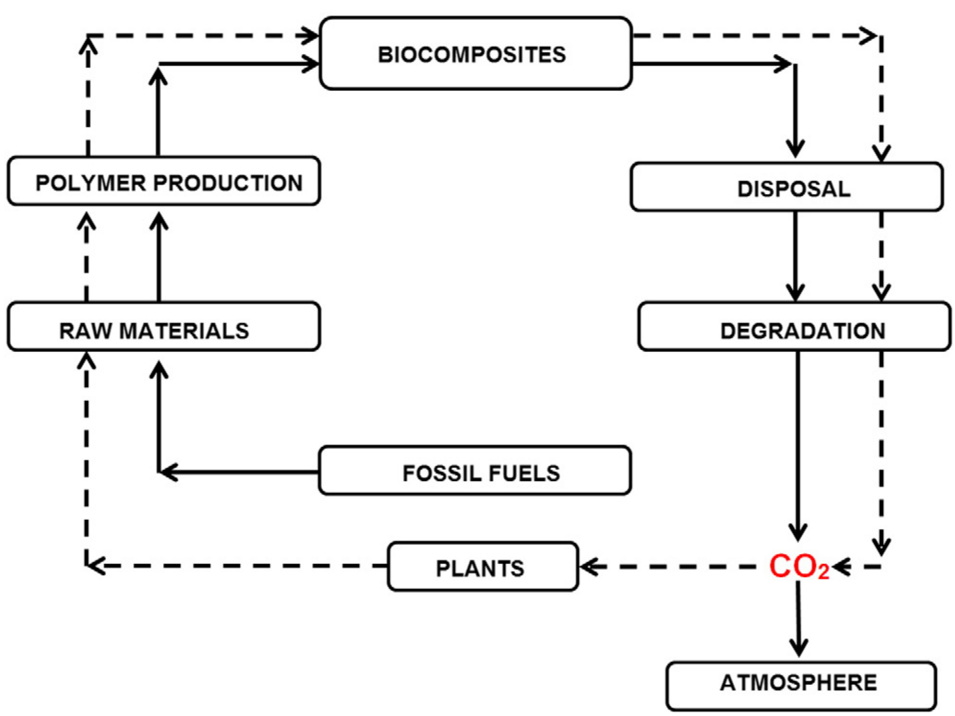

Fig. 1. Carbon negative/neutral process involving biocomposites.