

Authors' Reply to the Letter to the Editor:

Reply to "Non green perspective on biodegradable polymer nanocomposites"

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Dear Editor,

We appreciate the effort of Dr. Swapnil L. Fegade for writing a letter to editor entitled "Non green perspective on biodegradable polymer nanocomposites", on the published review article by Ong *et al.* (2010). Below is the response to his comment.

Biodegradable polymers have attracted many interests to replace non-renewable petroleum-based polymers because of their degradability. Carbon nanotubes (CNTs) have been widely used as fillers for biodegradable polymers creating nanocomposites with enhanced mechanical properties (Sitharaman *et al.*, 2008) and thermal stability (Song and Qiu, 2009), thereby extending the durability of the biodegradable polymer. In the review article (Ong *et al.*, 2010), the CNTs with biodegradable polymer in green nanocomposite design is viewed from the green engineering perspective. The green nanocomposite design embraces 3R (reduce, reuse and recycle) concept and it is in line with the green engineering principles (Anastas and Zimmerman, 2003; Hodzic, 2004). Based on the 3R concept, Ong *et al.* (2011) reported on the bulk-aligned functionalised multi-walled CNTs (MWCNTs) into chitosan matrix which embrace the "reduce" element of the 3R concept by reducing the amount of MWCNTs required to provide enough mechanical strength. In addition, upon degradation of the biodegradable polymer nanocomposite, the CNTs are recovered and can be reused and recycled (Cheng *et al.*, 2014). The above examples rationalise the 3R concept in the green nanocomposites design as described in the review paper.

Hence, the application of green engineering principles through the 3R concept in green nanocomposite design helps to reduce the potential release and minimize the waste disposal of the CNTs to the environment. However, even though some studies have reported on the toxicity and risk of CNTs (Lam *et al.*, 2004; Muller *et al.*, 2005), the aforementioned discussion showed that the green engineering perspective cannot rule out the utilization of CNTs in green nanocomposite design.

The utilization of CNTs in the green nanocomposite design is tally with the Green Engineering Principles (Anastas and Zimmerman, 2003) such as Principle 3: design for separation, Principle 7: durability rather than immortality, and Principle 11: design for commercial "afterlife". In addition, it also conforms the green engineering perspective defined by the United States Environmental Protection Agency (U.S.E.P.A., 2014), where green engineering is referring to the design, commercialization and use of processes and products that are economically feasible while reducing the generation of the source of pollution and minimizing the risk to human health and the environment.

To conclude, CNTs in green nanocomposites design that embraces 3R concept, employs green engineering principles as a tool in designing engineering solution for biodegradable polymer nanocomposite in order to achieve sustainability.

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