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The use of life cycle tools to support decision making for sustainable nanotechnologies

David E. Meyer · Venkata K. K. Upadhyayula

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Abstract Nanotechnology is a broad-impact technology with applications ranging from materials and electronics to analytical methods and metrology. The many benefits that can be realized through the utilization of nanotechnology are intended to lead to an improved quality of life. However, numerous concerns have been expressed regarding the unchecked growth of nanotechnology and the unforeseen consequences it may bring. To address the concerns, nanotechnology must be examined under the microscope of sustainability. This work applies the life cycle perspective to provide an understanding of the challenges facing the development of sustainable nanotechnology. A discussion of the holistic tools used to assess the components of sustainability serves as the basis to examine how a harmony between policy and product development can be maintained using decision making for sustainability. This harmony will be most readily achieved using an enhanced risk management strategy for sustainability that combines sustainability assessment with sustainable chemical design.

Keywords Nanotechnology · Sustainability · Life cycle assessment (LCA) · Life cycle risk assessment (LCRA) · Life cycle costing (LCC) · Social life cycle assessment (SLCA) · Life cycle sustainability assessment (LCSA)

D. E. Meyer (✉)
National Risk Management Research Laboratory, US Environmental Protection Agency, 26 W. Martin Luther King Dr., Cincinnati, OH 45268, USA
e-mail: meyer.david@epa.gov

V. K. K. Upadhyayula
Oak Ridge Institute of Science and Education (ORISE), MC-100-44, PO Box 117, Oak Ridge, TN 37831, USA

Introduction

The field of nanotechnology involves the control or manipulation of matter at dimensions in the 1–100-nm range to create structures, devices, and systems that have unique properties and functions leading to novel applications (NSTC 2011). The widespread commercialization of nanotechnology is inevitable because of the many applications to which it can be introduced. The potential fields that will be affected by nanotechnology, as envisioned in the US National Nanotechnology Initiative (NNI), include materials, electronics, healthcare, environmental science, energy, robotics, security, and metrology (Shea 2005). In 2000, the National Science Foundation sensationalized the impact of nanotechnology when predicting a trillion-dollar market by 2015 (National Science Foundation (NSF) 2001). Recent market analysis supports this trend, with the market forecasted to grow more substantially nearing 2015 as the global economy rebounds (Global Industry Analysts, Inc. 2010). Global Industry Analysts, Inc. (2010) reported a global nanotechnology market worth $278.48 billion USD for 2010 and projected a value of $2.4 trillion USD by 2015.

As industry capitalizes on the many benefits of nanotechnology, careful consideration of its potential impacts must receive due diligence. At this point, efforts in this area have focused largely on traditional issues of human health (HH) and ecological toxicity, and rightly fully so. However, this approach does not account for a growing global sentiment calling for societies to migrate toward a sustainable existence. For this discussion, the various aspects of sustainability, including sustainable design and sustainable technology, are intended to fulfill the well-known concept of sustainable development as defined by the Brundtland Commission, "development that meets the

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