Life Cycle Assessment of Developmental Carbon Nanotube Applications

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Poster

Short Description: **Given uncertain risks and outcomes, it is prudent to assess the environmental attributes for nanomanufacturing processes while in the developmental phase. Results can inform the development of safe, economically competitive, and environmentally responsible nanotechnologies. Work on the environmental assessment of the fabrication of a carbon nanotube switch and carbon nanotube-polymer mesh was undertaken.**

Keywords: Carbon nanotubes, environmental impact, life cycle assessment, nanotechnology

Abstract: Nanotechnology shows great potential for a wide range of applications including electronics, materials, energy, and biomedicine. Substantial investment has been afforded to nanotechnology research and development worldwide by governments and corporations. To date, however, there are a very limited number of publications regarding the environmental impacts of nanotechnology processes or products. In particular, there is significant uncertainty over the health effects and handling of carbon nanotubes (CNTs). With unique electrical, mechanical, and thermal properties, CNTs are desirable in industrial applications such as a SWNT switch for nonvolatile memory devices, biosensors, SWNT batteries, and electromagnetic interference (EMI) shielding. The market for these applications is projected to exceed $1.9 billion by 2010. Some studies report that single-walled carbon nanotubes (SWNTs) appear to damage lung tissue in mice, whereas other studies state that there is little detrimental effect. Nanoscale properties of CNTs such as surface area and particle size may also contribute to potential toxicological effects. The U.S. Environmental Protection Agency has recently ruled that CNTs are chemical substances distinct from graphite or other allotropes of carbon listed in the Toxic Substances Control Act (TSCA) Inventory. Thus under TSCA, the many variations of functionalized CNTs may be classified as new chemicals. Given these uncertain risks and unknown outcomes, it is prudent to assess the environmental attributes for nanomanufacturing products and processes while in the developmental phase. Results can inform the development and commercialization of safe, economically competitive, and environmentally responsible nanotechnologies.

Environmental assessment for the manufacture of two developmental CNT applications was carried out using life cycle assessment (LCA) tools: a CNT switch and a CNT-polymer mesh. Process parameters and life cycle inventory data are collected for all of the inputs (raw materials, energy and equipment used) and outputs (emissions to land, water and air) by observation of laboratory scale processes and discussions with researchers. for the manufacture of each device are collected on the laboratory-scale at CHN. These data are input into SimaPro™, a LCA software program, using the Eco-Indicator 1999 method, for the environmental impact assessment. By using Eco-Indicator 1999 methods, emissions are categorized into impact areas such as climate change, acidification, eutrophication, land use, mineral depletion, ecotoxicity, ozone layer depletion, and carcinogens.

Results indicate that significant, measurable impacts are found to fossil fuels, airborne inorganics, and climate change for the manufacture of both applications. The impact on fossil fuels is dominated by processes that require energy-intensive equipment. In terms of airborne inorganics, the process steps that have the greatest environmental impact include pre-diffusion cleaning and piranha etch & rinse cleaning. These larger impacts are due to the quantity of sulfuric acid used in these process steps. Effect on climate change is primarily due to the release of carbon dioxide from energy use. These results highlight process drivers associated with the environmental burdens of manufacturing both CNT applications.