Improve Environmental and Economic Performance with Streamlined Life Cycle Assessment (SLCA)

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ABSTRACT

Streamlined Life Cycle Assessment (SLCA) is a pre-regulatory exercise that analyzes industrial processes and products to assess efficacy of existing production efforts and identify priorities for enhancing triple bottom line performance for product lines. SLCA includes aspects of standard Risk Assessment, Life Cycle Risk Assessment (LCRA), and Life Cycle Analysis (LCA) methodologies. It also draws upon technical understanding of environmental management, health risk assessment, industrial ecology, energy management and real estate and business planning. Importantly, SLCA offers an effective high-level screening of key product design criteria that focuses subsequent deeper assessments, allowing for low cost and rapid product assessments built on LCA principles [1]. This process can be especially useful when applied to nanomaterial product development since nanomaterials are not yet widely regulated and their impacts have not yet been widely studied. However the framework is effective for screening potential impacts and risks of various sectors at both the facility and individual product level.

Keywords: nanomaterials, life cycle analysis, sustainable product design

1 INTRODUCTION

Many new technologies offer significant improvements in environmental performance over existing ones. In some applications, there may be some uncertainty about the health or environmental impacts, positive or negative, of new technologies, which can adversely affect their introduction into the market due to perception and fear, regardless of actual impact. Streamlined Life Cycle Assessment (SLCA) of new technologies offers the opportunity for early stage product performance assessment, to identify and measure environmental impacts, such as carbon emissions, water consumption, and use of hazardous materials, in ways that can improve product performance and market penetration. An assessment that demonstrates a positive environmental profile enhances market access, while conversely, through a screening level assessment, concerns about potential adverse effects can be identified and addressed prior to market introduction, creating more sustainable products.

An initial baseline environmental assessment is the starting point, to ensure that SLCA recommendations augment or integrate with programs already being implemented by a business or production line. Specific criteria in the assessment are established in consultation with key personnel. This ensures the assessment is performed in the context of existing knowledge and accounts for internal recommendations based on process experience. Reliance on existing knowledge in combination with scenario building leads to the quick identification of durable recommendations. The developed criteria can include impacts of novel (e.g. nanoscale) materials, energy use, water use, and waste/materials management.

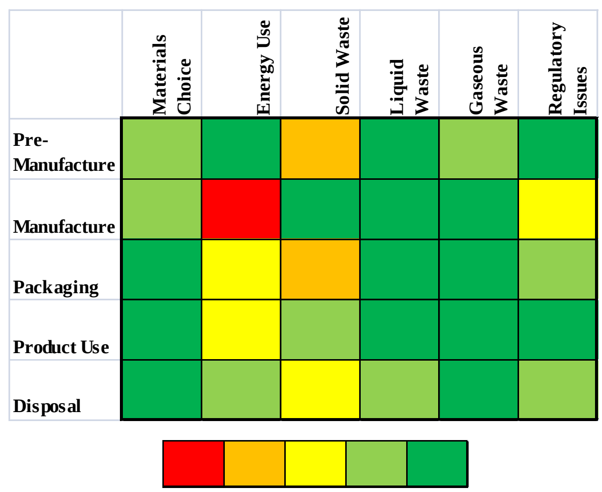

Figure 1. Example of a SLCA matrix. Red indicates poor performance; dark green means acceptable performance.

The SLCA process provides beneficial outcomes: product developers gain a clear understanding of potential product risks and are able to "design out" negative long term impacts. The screening assessment identifies aspects of production that offer opportunities for improvement, leading to improved production economics and more sustainable products and outcomes. The "quick and dirty" analysis identifies areas requiring further investigation to assess potential impacts. Finally, an SLCA allows developers to demonstrate the environmental performance of their products.

 NSTI-Nanotech 2011, www.nsti.org, ISBN 978-1-4398-7142-3 Vol. 1, 2011

2 THE COMPONENTS OF SLCA

The SLCA screening process is a top-line and short-term exercise to highlight priority areas of exposure and strategic opportunity. SLCA is not designed to be a comprehensive evaluation, but a tool for identifying “hot spots” and highlighting key opportunities for demonstrating or instituting environmental improvements.

There are three unique components to the SLCA framework: screening-level risk assessment, adaptive management, and life cycle thinking. The National Nanotechnology Initiative (NNI) is proposing to take a life cycle approach to risk assessment for evaluating the environmental health and safety aspects of nanotechnology [2]. The SLCA framework is applied as a screening tool to identify and prioritize potential risk concerns throughout a product’s life cycle and develop strategies for further investigating and managing them in the product development stage. This allows developers to make informed decisions about product risk despite the data limitations of nanoscale materials, technologies and products. Traditional quantitative risk assessment, as well as life cycle analysis, remains difficult to perform for nanomaterials due to the current limitations of data and understanding of nanomaterial behavior.

2.1 Screening-Level Risk Assessment

The philosophy for an adaptive framework incorporating life cycle thinking into risk assessment is that an early screening-level analysis with considerable uncertainty and a lack of available data will have two valuable outcomes: it develops key information needed to make sound decisions; but it also offers an opportunity to make decisions amidst the uncertainty. The screening level risk assessment identifies potential hazards to health and the environment at critical stages of the product life cycle, and scenarios that might lead to exposures or risk. Further, stepping through the process in a qualitative manner identifies the critical missing information for more detailed evaluation as the product design develops closer to commercialization.

2.2 Adaptive Management

The timing of analysis ties directly to stages of product development, and is revisited at each stage with more detailed levels of refinement. An adaptive approach, updating an analysis with increasing levels of knowledge and understanding, presents a path forward for evaluating and managing the risks of nanomaterials and other novel products. This process allows adaptation to new information, decision making under uncertainty, and a manageable process for identifying and prioritizing concerns about health and environmental risks or environmental performance. This approach is founded in the use of science for environmental decision-making but is focused on: assessing risks under uncertainty, requiring updated evaluations as new information develops, but allowing decision making without a complete data set [3]. This interative approach is a proactive way to manage the risks of technology development early in the product development cycle, informing product design in real time. In earlier stages, conservatism can be incorporated into risk management decisions because they are made under uncertainty. At the same time the analysis provides timely key inputs for future data needs to inform more detailed and quantitative assessments as products progress in development nearer commercialization.

2.3 Life Cycle Thinking

It is critical to consider not only how products are manufactured, but also how they are used by consumers and their ultimate fate in the environment. This affects considerations for product design, including, for example, recylability, or fate of components in the waste stream [4]. The concept of a life cycle risk perspective is to conduct a mini hazard assessment and exposure assessment—the first two steps of risk analysis – for each step of a product or process life cycle. These assessments inform product developers and risk assessors in which step(s) to focus future efforts to evaluate toxicity and to conduct a risk characterization. Evaluation early in product development can help identify mitigation measures that ought to be used, but it also will highlight what information is missing in order to develop a more detailed characterization of risk.

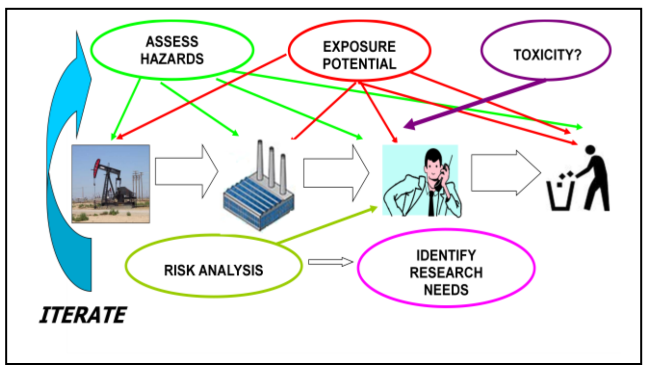

Figure 2: NANO SLCA Framework [5]

3 NEW NANOTECHNOLOGY PRODUCTS

The SLCA is a proactive process that allows risk to be indentified *before and during* product development. Early stage risk identification leads to understanding of potential impacts and an action plan to investigate or mitigate them. This puts the developer in the position to anticipate and manage risks rather than react later and allows better economic decisions to be made during product development. For example, the SLCA might call out energy use as a hot spot that when addressed allows products to be manufactured less expensively. Further, SLCA analysis can create a prioritized research strategy to focus on critical data needs and proactive mitigation.

This can be particularly helpful when developing nano "enabled" products or even engineered nanomaterials. There are still few regulations specifically governing the use and development of nanomaterials, and the broader impacts of engineered nanomaterials on the environment are poorly understood. The SLCA process can evaluate potential risk based on current knowledge while also identifying the information that is needed to make the next round of decisions. The process follows a ten step framework:

1. Describe the life cycle of the product.
2. Identify the materials and assess potential hazards in each life cycle stage.
3. Conduct a qualitative exposure assessment for materials at each life cycle stage.
4. Identify stages of the life cycle when exposure may occur.
5. Evaluate potential human and non-human toxicity at key life cycle stages.
6. Analyze risk potential for selected life cycle stages.
7. Identify key uncertainties and data gaps.
8. Develop mitigation/risk management strategies and next steps.
9. Gather additional information.
10. Iterate process, revisit assumptions, adjust evaluation and management steps.

Iterating the process and adapting the product development based on the feedback leads to good decision making despite potentially incomplete information or a lack of specific information about novel nanomaterials.

4 PRACTICAL APPLICATIONS OF SLCA

CLF Ventures (CLFV) uses the SLCA framework to assess and manage environmental health and safety risks, as well as to consider broader life cycle impacts during nano-product development. We also perform high level screening assessments for other clean tech products such as renewable energy components and emerging "green" technologies. The process is applicable and useful to any scale of business and can be used to evaluate new products in development or to provide risk-based guidance for existing products.

4.1 Start up/small nanotechnology companies

CLF Ventures recently worked with a company that wanted to put engineered nanomaterials into a coating product that would be applied by spraying. We conducted a screening level risk assessment to characterize the health and environmental risks associated with the new nanotechnology product during its development. The assessment analyzed in-lab production, packaging and transporation, use, disposal, and end-of-life product fate in the environment. At each stage of the product life cycle we identified hazards based on known properties of the product component materials and assessed exposure pathways based on multiple scenarios. These were put into context using a review of current knowledge about toxicology to characterize potential risk associated with the nano-enabled coating product at each life cycle stage.

The framework was applied in two phases. During the initial Phase I screening, described above, we identified several potential pathways of concern related to the use and disposal of the product.This allowed us to make an initial risk characterization that was used to revise the product design and identify priorities for targeted laboratory testing of exposure to nanoparticles.

CLFV worked with the product developer to undertake the lab tests. We developed testing scenarios that would evaluate the potential for exposure at critical points in the product life cycle. The Phase I assessment indicated that product use was a life cycle stage of concern. CLFV and the product developer therefore tested the potential exposure associated with product use.

In Phase II we used the findings from these laboratory tests, coupled with the most recent findings from the toxicological literature, to refine the preliminary risk assessment. The focus of our analysis on the early stages of new product development enabled product developers to test for and/or design out problematic issues early in the product development process before the more resource-intensive development and manufacturing stages. The product development cycle was shortened and uncertainty about risk was reduced. The assessment identified exposure pathways and potential risks, which informed the development of safe handling guidelines and recommendations for product use. The ultimate result was a product that was inherently safer and had well understood properties that allowed it to be used safely without compromizing its effectiveness.

4.2 Large/international consumer product companies

In addition to new products being developed with nanomaterials, there is regulatory uncertainty for how existing products may be treated if it is determined they contain nanomaterials. Few regulations specifically govern the use of nanomaterials in consumer products, and many companies manufacture products that contain nano-scale materials, if not actual engineered nanomaterials.

The SLCA framework is also effective for screening potential risk associated with this regulatory uncertainty, as well as to screen, evaluate, and recommend action based on emerging regulatory frameworks. The high level screens can match internal understanding of product components with emerging understanding of nanomaterials and the likely regulatory response. The results of this “hot spot” identification allow companies to proactively modify the materials used in their manufacturing processes, prioritize internal product testing scenarios, and generally prepare to respond to local, state, and federal regulation.

4.3 Clean tech companies

The SLCA framework is not specific to products containing nanomaterials and can be applied to any production process, including, for example, the manufacture of photovoltaic panels. This technology has made rapid progress to gain electric conversion efficiencies and economy of scale, but the technology is not necessarily environmentally benign.

SLCA can be used by the product developer to assess potential areas of concern at each life cycle stage of the panels. Just as with nanomaterials, environmental health and safety risks may be well controlled during the manufacturing process, however, the SLCA process can also be used to assess the potential impacts of the panels once they are in use in the environment, as well as for disposal at the end of their useful life.

Potential issues of concern during manufacture may relate to facility water and energy use. Assessment of end-of-life impacts may indicate certain materials are problematic and should be designed out during the production stage. For example, a certain material may be exceedingly rare or require significant resources for extraction and transporation to the facility, or be located in a volatile political geography. Alteratives may be more sustainable in the long term, both economically and environmetnally.

Risks may inlcude environmental and human health and safety risk, but could just as easily include supply chain shortages, material price increases, and regulatory hurdles associated with disposal. By applying the SLCA framework, product developers will better understand the potential risks associated with their products at each stage of the product life cycle, and they will have the information they need to take action to mitigate these risks.

5 CONCLUSION

Further development and refinement of SLCA frameworks will help facilitate sustainable development of emerging nanotechnologies and other technological innovations. This will be accomplished through improved risk characterization in the product development stage of new products that informs iterative and adaptive development life cycles, and improves anticipation of and adaptation to emerging regulatory frameworks that govern the use of engineered nanomaterials and other nano-scale consumer product components. The timeliness of the analysis contributes to speedier product development and design, ultimately lowering costs, and leads to the creation of more sustainable products.

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