Use life cycle assessment and risk assessment tools to oversee the development of nanomaterial in building industry

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ABSTRACT

While nanotechnologies offer tremendous benefits for society, they may also pose significant risks. The same properties that make nanomaterial's promising-those that make them behave quite differently from bulk forms of the same materials-could lead to negative health and environmental consequences. Nano materials have already been applied and integrated into variety building materials and will have long-term effect to environment and immediate impact on users.

This paper aims to investigate how risks from emerging nanotechnologies can be assessed and managed through life-cycle perspective as they are created, used, recycled and discarded. By setting up a comprehensive monitoring framework, it will be possible to identify the key gaps that must be addressed if risks to be managed effectively. Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Risk Assessment (RA) are tools that will be used to create the framework.

Keywords: LCA,LCC, Building, Risk

1 INTRODUCTION

In 2009 European Federation of Building and Woodworks (EFBWW) and the European Construction industry Federation (FIEC) published a report " Nanontechnology in the European Construction Industry-State of the art Executive Summary". "The total market share of nano-products in the construction industry is expected grow from $20 million (US) in 2007 to $400 million (US) before the end of 2017". Already now nano product could be found in nearly all kind of building products and components, such as concrete, glass, coating, paints, etc. Using life cycle assessment as a tool to address potential impact on the environment and human health is good application of this methodology, both for the evaluation of manufactured nanomaterials and the products they are used in. Particularly, for the nano materials application in building sector, we should consider the impact for the full building life cycle, from raw material extraction to used products recycled and reuse.

2 BUILDING LIFE CYCLE STAGES

Life Cycle Assessment (LCA) is a comprehensive frame work that quantifies ecological and human impact of a product or system over its complete life cycle. (Hischier et al. 2012) In order to get a better idea of life cycle use of nano materials use in building sector, we need to have a clear definition of building life cycle. Every product or process goes through various phases or stages in its life. Each stage is composed of a number of activities. For architectural products, these stages can be broadly defined as materials acquisition, manufacturing, use and maintenance, and end-of-lie. In case of buildings, these stages are more specifically delineated as: materials manufacturing, construction, use and maintenance, and end of life.

The life-cycle stages of a building are:

- Materials Manufacturing: Removal of raw materials, transporting of materials, manufacture and engineer of the materials, building product fabrication and packaging.
- Construction: All activities relating to the actual building project construction.
- Use and Maintenance: Building operation including energy consumption, water usage, environmental waste generation, repair and replacement, etc.
- End of Life: Includes energy consumed and waste produced due to building demolition and disposal of materials to landfills, and transport of waste materials.

The impact of use of nanomaterial should be assessed based on those four different stages.

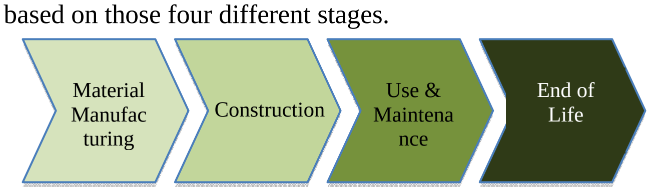

Figure 1: Building Life Cycle Stages

3 LIFE CYCLE COST (LLC)

There are numerous costs associated with acquiring, operating, maintaining, and disposing of nano-materials. nano-materials -related costs usually fall into the following categories:

- Initial Costs—Purchase, Acquisition, Construction Costs

- Fuel Costs
- Operation, Maintenance, and Repair Costs
- Replacement Costs
- Residual Values—Resale or Salvage Values or Disposal Costs
- Finance Charges—Loan Interest Payments
- Non-Monetary Benefits or Costs

Only those costs within each category that are relevant to the decision and significant in amount are needed to make a valid investment decision. Costs are relevant when they are different for one alternative compared with another; costs are significant when they are large enough to make a credible difference in the LCC of a project alternative. All costs are entered as base-year amounts in today's dollars; the LCCA method escalates all amounts to their future year of occurrence and discounts them back to the base date to convert them to present values.

4 RISK ASSESSMENT

Evidence is building up that nano-materials could behave more hazardous to humans than their microscale equivalents. A precautionary approach towards working with these materials is therefore advisable. The two main factors influencing the novel toxicity of nano-materials are size and shape. Safety concerns with engineered nanomaterials for human health or environmental protection have been highlighted by various recent reports and studies (see e.g. Auffan et al., 2009; Oberdörster, 2010; Savolainen et al., 2010). An extensive review of nanooxide interactions with biological systems, highlighting the problem of persistency, can be found in Stark (2011). Also the currently still limited number of published (chronic) toxicological studies indicates that the release of nanoparticles may have adverse effects on human health (see e.g. Oberdörster et al., 2004, 2007).

4.1 Affected Groups

In building and construction industry and potential risk might happen to two groups: Construction workers and space occupant. The risk the second-hand user might be facing through the release of nanoparticles should also be included.

4.2 Exposure through Inhale

Nanomaterial could be released from point sources, such as factories or landfills, and from nonpoint sources, such as wet deposition from the atmosphere, storm-water runoff, and attrition from products containing nanomaterials. Bio-chemical cycling of nanomaterials, may involve photochemical reactions in the atmosphere; aggregation; or uptake, accumulation, transformation, and degradation in organisms. Long-range atmospheric transport, as well as transport in saturated and unsaturated regions in the subsurface, are possible.

As a general rule of thumb for inhalation of dust and aerosols: the smaller the particles, the more deeply they can penetrate the lungs before they deposit, the more severe their effect on health might be. Typical health effects observed are (NEAA 2005 and references therein): Inflammation of the airways; Bronchitis; Asthma; Cardiovascular effects. However, for nano-particles, this rule of thumb is no longer valid and an important fraction of inhaled nano-particles does deposit in the nose. With respect to any further transportation in the body, it has been observed that some of these nano-particles do translocate to the nervous system, the brain tissue and to other organs like the blood, heart and liver and the bone marrow where they might cause inflammatory effects leading to a cascade of secondary health effects (Oberdorster et al. 2004 and references therein; and for a more recent review on the topic by Politis et al. 2008), like irritation, inflammation, cell death, extraordinary cell growth, DNA damage and hormonal distortion (Donaldson et al., 1996; Zang et al., 1998).

The exposure could happen during a) occupation, b) industrial wastes and leftovers, c) waste water from production process and from cleaning of painting tools

4.3 Exposure through Contact

Some nano particles have the potentials to penetrate through human skin, such as TiO2. Therefore skin structure, composition, and penetration paths need to be concisely reviewed for each and every single nano-material application

5 PROPOSED INTEGRATED ASSESSEMENT FRAMEWORK

For Engineered nanomaterial, current product-related assessment tools includes Life Cyle Assessment (LCA), Material Flow Analysis (MFA), Life Cycle Costing (LCC), Substance Flow Analysis (SFA) and Energy Analysis. They all evaluate different flows in relation to a product or service. However, most of these tools focus on particular part of environmental aspects and thus do not integrate the economic and social dimension of sustainability, or do so only partially. We need a new framework can be applied to any kind of product and to any decision where environmental impacts to occupancy and workers are of interest. Also the framework could be used by researchers, policy makers, governmental organizations and industry leaders to make decision about a project base a solid scientific basis.

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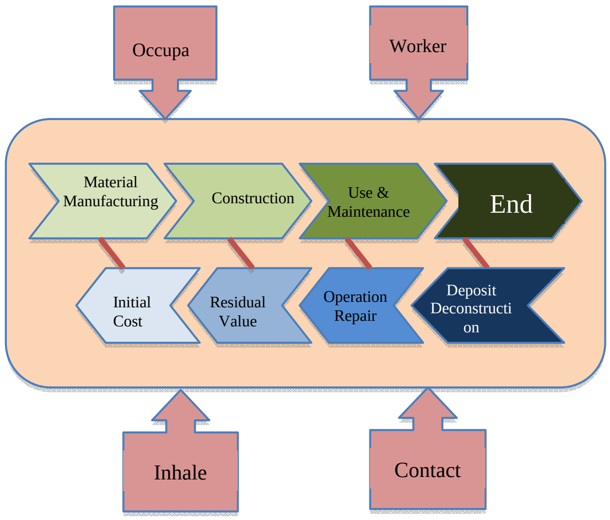

Figure 2: Assessment Framework

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