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LCA as an environmental technology development performance indicator of engineered nano-materials and their application in polymers

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Abstract

Engineered nano-material (ENM) application in products has in recent years developed to an important market segment but with rising environmental concerns, as the environmental life cycle impacts, especially toxicity of nanoparticles, are not assessed. Life cycle assessment (LCA) is a holistic tool to assess products and systems, but current knowledge about the development of ENM's environmental impacts is too scarce to be included for application within the LCA framework.
In the EUFP7 project MINANO the aim is to develop an efficient, continuous method of large-scale, low cost synthesis of ENM's with functionalities of flame retardancy, UV protection and antimicrobial properties through functionalized $Mg(OH)_2$, ZnO and Ag nanoparticles. The aim is also to apply the ENM's in plastic and wood-plastic matrixes and thereby develop products that have a new and improved way of attaining these properties, compared to the conventional ways of attaining these in the polymer product industry. To assure environmental sustainability LCA will be performed within the MINANO project and more precisely comparing the new ENM technology and the conventional technology approach to attain the same functionalities. The LCA in the MINANO project is aimed to be holistic and thereby include the entire life cycle of the nano-polymer products and not be like the current frequently applied nano-material LCA case study approaches where the life cycle is reduced and system boundaries substantially limited. In order to perform accurate assessments LCA needs to be further developed and adjusted according to this material class as there is currently a large uncertainty related to the chemical and biological interactions and toxicological properties of ENM's during their life cycle.

Background

Humans are daily encountered with naturally occurring nanomaterials e.g. as dust, ash and viruses, but the engineered nanomaterials (ENM's) are rapidly introduced in the environment through consumer products. Just on this basis there is a need to assess the impacts of the ENM's, and more precisely the life cycle impacts of such. LCA has been proven to be a valuable assessment tool, but in the material case of ENM's the tool is reaching its limitations and thus there is a need to adapt and improve LCA to better fit the new material class that is defined to have at least one dimension within the range 1-100 nm.

The challenge and aim of my PhD is to improve the life cycle impact assessment (LCIA) of LCA through improvement of inventory data and thereby to a better extent being able to environmentally and toxically impact assess ENM's. This will be performed on the basis of the current state of the LCA performed on ENM's and the MINANO EUFP7 project where ENM's are incorporated in plastic and wood-plastic consumer products.

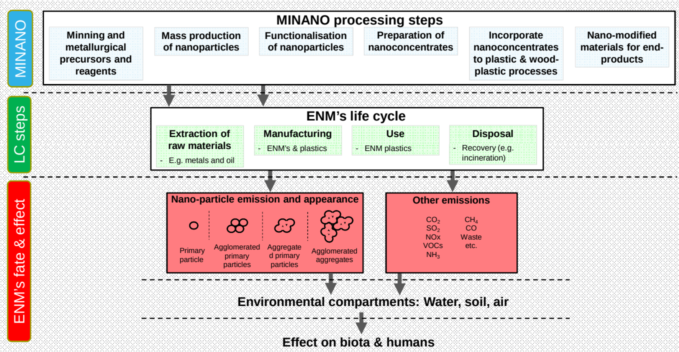

Figure 1: Overview of MINANO processes and life cycle and fate and effects of ENM's [14].

LCA on ENM's: state of knowledge

The current state of LCA on ENM's is not well developed and currently only counts about 13 scientifically published case study articles. When reviewing these, it is possible to conclude certain tendencies across the studies that reflect the current state of knowledge:

- Usually cradle-to-gate or manufacturing system boundary consideration.
- Use and disposal life cycle stages are poorly covered.
- Common use of generic life cycle inventory (LCI) data and assumptions.
- No toxicity consideration from released nano-particles (fate & effect).
- Cradle-to-gate LCA comparison of counterpart products (with ENM's and without) show that ENM products are more energy demanding and therefore have a worse cradle-to-gate environmental profile e.g. in polymer nanocomposites vs. steel [7].
- Cradle-to-grave LCA comparison of counterpart products (with ENM's and without) show that the use phase is better for ENM products as usually an improved functionality is achieved e.g. comparing clay-propylene nanocomposites with steel or aluminium in light duty vehicles [4].

These conslusions underline the limiting inventory and low understanding of characterisation (fate & effect) factors, but also highlight the disadvantage of manufacturing and advantage of using ENM products.

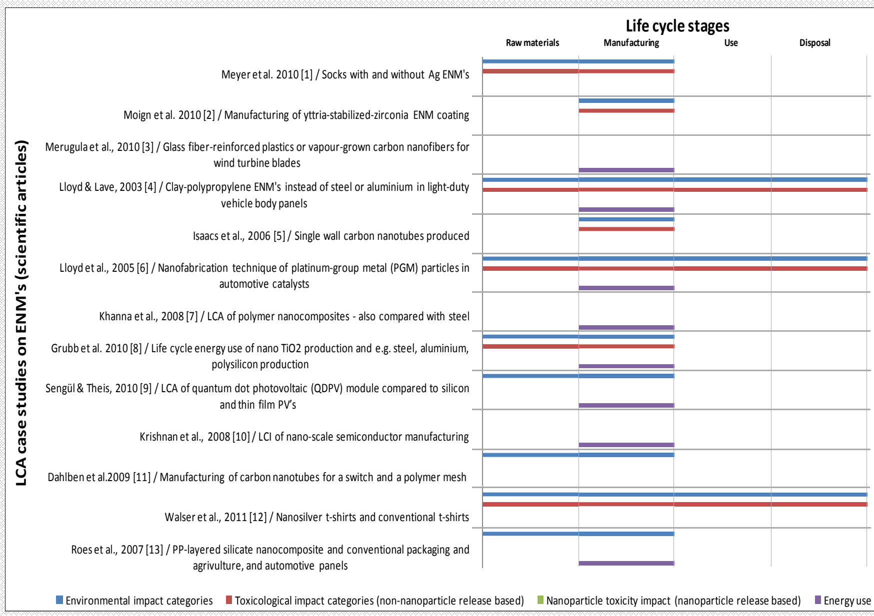

Figure 2: Life cycle stages covered by LCA on ENM's case studies – 13 scientific articles found.

Outlook

Currently there is a lack of holistic LCA studies performed on ENM's, mainly due to a lack in LCI and LCIA understanding. To improve this and apply LCA as an environmental performance indicator of engineered nanomaterials and their applications in plastics and wood-plastics the MINANO EUFP7 project will contribute with data that can be applied in performing LCA's on MINANO ENM products, containing metal oxides/metal ENM's (ZnO, $Mg(OH)_2$ and Ag).

My PhD has the aim to improve LCI and LCIA knowledge in order to yield a better understanding and decision making of ENM's through LCA. This will be performed by gathering ENM specific data and developing characterisation (fate & effect) factors reflecting the release of ENM's so LCA improvement is achieved and is able to assess and cover more life cycle stages. The outcome is aimed toward promoting sustainable development and assessment based decision making by improving and integrating assessment of ENM's through LCA, and more precisely through LCIA.

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