Enabling Multi-Functional Performance through Multi-Material Additive Manufacturing

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# Is nanotechnology safe at the workplace? ISQ exposure risk assessment to nanoparticles

The incorporation of nanotechnology in MAM materials can lead to large benefits due to outstanding material properties. Parallelly to the design and development of nanomaterials, health and safety conditions will be ensured in MULTI-FUN through a risk evaluation methodology applied to each step of the innovation process. Nanomaterials can pose several risks during the different life cycle stages of the (nano)product. One of the stages of greatest concern is the synthesis and manufacture of nanomaterials, as these are likelihood scenarios of exposure to nanomaterials, and therefore workers, engineers and researchers may be directly exposed to nanomaterials. Among all possible exposure routes, namely, ingestion or dermal, exposure by inhalation is the most frequent. Due to the nanoscale dimensions, nanoparticles have the capability of entering the human body through the lungs, reaching inaccessible regions for coarser particles. Considering the limited number of occupational exposure limits (OEL's) available for a wide range of nanomaterials, nanosafety strategies such as design practices for safer nanotechnologies and exposure mitigation actions are adopted to promote occupational safety in the workplace.

The harmonized tiered approach was adopted for a cost-effective risk assessment of MULTI-FUN demonstrators. In Tier 1, an initial risk assessment aims to collect information related with nanomaterials hazards and potential for the exposure. For the definition of the exposure scenario, a questionnaire was sent to the MULTI-FUN partners requesting the description of site, processes, materials (nanoparticles), operational conditions, workers task and intervention, as well as risk management measures already implemented. The information gathered is used as inputs in Control Banding tools, such as the *Stoffenmanager Nano* tool, with the aim to obtain hazard and exposure classes. In Tier 2, a visit to the MULTI-FUN partner is required for a quantitative exposure assessment through the monitoring of nanoparticles emissions during the production processes and associated activities, and the background (nanomaterials emission from external sources), using a multi-metric approach. Tier 3 assessments presuppose the collection of samples and laboratory analysis, which are not part of MULTI-FUN.

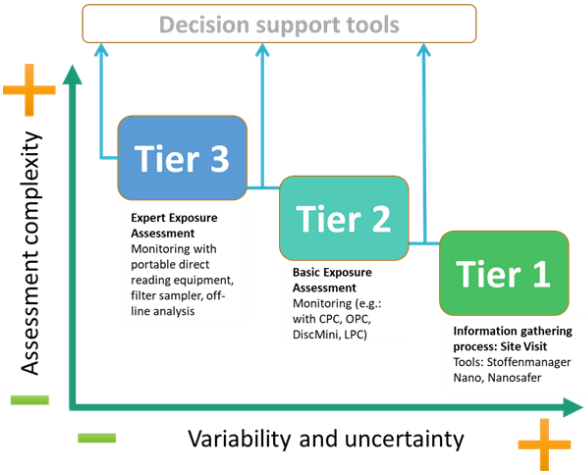



*Figure 1. Tiered approach exposure assessment to nanoparticles.*

Several MULTI-FUN partners are involved in the design and development of multimaterials containing nanotechnology for AM powders and wires. In close collaboration with MULTI-FUN partners, ISQ performed an initial risk assessment identifying the potential exposure scenarios

to nanoparticles in the production lines of the MULTI-FUN demonstrators. During the month of December 2021, a monitoring campaign was performed at BCMaterials, which is one of the key partners involved in the nanomaterials production stage. The emissions of NPs were evaluated at the emission sources using two equipment, as a multi-metric approach. Additionally, the efficiency of the control measures already in place was also evaluated. From the risk assessment carried out, ISQ positively concluded that no significant concentrations of airborne NPs were measured, indicting no risk for the health of workers and researchers, when handling the materials involving nanotechnology at BCMaterials.

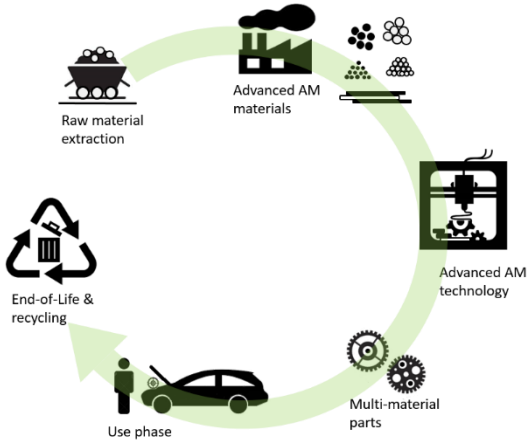
*Figure 2. Monitoring of NPs emission at BCMaterials.*

RHP Technology, another key partner involved in the use nano-enabled materials, is also cooperating with ISQ in the planning of the best strategy to identify and measure the NPs concentration in the working air environment. The monitoring campaign is planned to be carried out during July 2022.

Along with the activities under MULTI-FUN project, ISQ is also compromised with the dissemination of the results and knowledge transfer. A health and safety consciousness is of at most importance during the research and development stages, for the easy market acceptance of the innovative materials and processes. Therefore, ISQ is actively dedicated on creating awareness for the exposure risks to nanomaterials and providing best mitigation strategies. It was on the 10$^{th}$ Sustainable Nanotechnology Organization Conference, between 3-5 November 2021, that the risk assessment carried out to the MULTI-FUN materials and processes was presented. Additionally, as a result from the monitoring activities at BCMaterials, complemented by toxicology studies carried out by BCMaterials research team, the work will be presented during the Nanotech France, between 15-17 June 2022.

## ISQ is supporting MULTI-FUN's developments through Sustainability Assessment methodologies: Life Cycle Assessment, Costing, and Eco-efficiency analysis

Metal additive manufacturing (MAM) technologies have the potential to change the way manufacturing is designed, allowing the production of simple and complex geometries. As opposed to subtractive methods, or in combination with them, MAM technologies build parts by depositing the metal material mainly where it is required, reducing milling activities, the associated waste, and achieving improved buy-to-fly ratios. Multi-material combinations and functionalities are being developed in MULTI-FUN. To understand the potential benefits of MULTI-FUN developments, ISQ have been actively involved in applying sustainability assessment methodologies such as Life Cycle Assessment, Life Cycle Costing, and Eco-efficiency Analysis.




Aiming to support MULTI-FUN partner decisions in an early stage of development to ensure not only significant resource efficiency but also the overall reduction of environmental impacts and manufacturing costs along the process, ISQ has been collaborating with partners responsible for MAM technologies and materials that will be implemented in the MULTI-FUN demonstrators. Ongoing WP1 activities have been focusing on the preliminary life cycle inventory data collection regarding mock-ups or trials of Demo 1 – Actuator housing (from CRANFIELD), Demos 2 – Aeronautic bulkhead panel (from LORTEK and AEROTECNIC), Demo 5 – Mould for Al Casting (from RHP), and Demo 6 – Mould for CRFP parts (from CRANFIELD).

Preliminary outputs of WP1 have been presented in a poster the EuroNano Forum 2021, and in 8th International Conference on Energy and Environment Research ICEER 2021 on 13–17 September 2021 and recently published (https://doi.org/10.1016/j.egyr.2022.01.035).

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