Synergistic strategies for management of nanotechnologies safety

João Laranjeira[1], Cristina Matos[1], Ana Rita Alberto[1], Carla F. Martins[1]
[1]*ISQ-Instituto de Soldadura e Qualidade, Oeiras, Portugal,*

Background, Motivation and Objective

Nanotechnology has been highlighted as one of the occupational safety and health challenges [1]. Due to rapid technological development of industries and societies, preventive measures are not always straightforward and can have limited action. This results from the unknown potential new risks and the complex relationships between variables in the nanotechnology field, which might compromise public health and safety, and the environment. Indeed, there are vast uncertainties concerning hazards (toxicology and health effects), exposures (reference values) and risks associated to the use of nanomaterials [2]. Therefore, it is vital to implement synergistic strategies to nanotechnology challenges by combining proactive, preventive, and holistic approaches for safety management, rather than reactive actions. This paper aims to discuss strategies for managing nanotechnologies safety and, analyse the advantages and limitations of combining risk-prevention design principles with control banding as an initial synergistic strategy for occupational safety management.

Statement of Contribution/Methods

Nanomaterials exposure can occur throughout their entire lifespan and affect workers, consumers, the general public, and the environment [3]. The high level of complexity of factors over the nanomaterial lifecycle that affect the management of nanotechnologies safety have been leading to the development of several proactive and preventive approaches, some of them with an holistic perspective to aspects such as the environment, society, and technology. These approaches include risk-prevention design principles, control banding, safe-by-design (SbD), and safe- and sustainable-by-design (SSbD).

There are a few risk-prevention principles to help guide product designers to produce a safer nanotechnology solution, such as changing size, surface and structure; alternative materials; functionalization (intentional bonding of atoms or molecules to nanomaterials); reduction of the quantity; and encapsulation [5]. Nano-masterbatches design is an example of a risk-prevention principle, as potential hazardous nanomaterial can be encapsulated within a less hazardous material [5], while maintaining their functionality.

Control banding (CB) is another proactive approach for initial managing of nanotechnologies safety, as it is based on potential exposures to nanomaterials and recommends basic control measures to minimize identified exposure [6]. There are several nano-specific CB tools that have been developed particularly for occupational safety (e.g., Stoffenmanager Nano, NanoSafer). These CB tools can be combined with the control band matrix described in ISO/TS 12901-2 [6] to setup preventive exposure measures, based on a balance of simplicity and effectiveness.

The Safe-by-design (SbD) holistic approach has been used for years in industry and more recently applied to nanotechnologies to address the safety of the nanomaterial/nanoproduct and associated processes through the whole lifecycle. The main aim of SbD is to minimize risks and uncertainties for humans and the environment at the earliest possible/feasible stage of the innovation process [7].

More recently, SbD shifted to the concept of safe- and sustainable-by-design (SSbD) by focusing on safe and sustainable new nanomaterials/nanoproducts, and thus assess their full socioeconomic potential in line with the European Green Deal in a circular economy [8]. These broad and integrated concepts are an attempt to support the decision-making process, by identifying decision points along the development process and help to define options for those decisions, based on an holistic perspective. Although several European R&D projects and initiatives have been working on these holistic approaches applied to nanomaterials, SSbD criteria's are still lacking, as well as predictive tools to support their implementation.

The synergistic strategy of combining nano-masterbatch design with control banding approaches is analysed, using metal matrix composites reinforced with ceramic nanomaterials (aluminium oxide, silicon carbide, and titanium carbide) and considering prototype and industrial scenarios.

Results/Discussion

This study demonstrated that there are several proactive, preventive, and holistic approaches available for managing nanotechnologies safety, with different degrees of complexity, development, and consolidation. The adoption of synergistic strategies based on the combination of proactive, preventive, and holistic approaches can be a prudent solution to limit the uncertainty level associated with current knowledge gap of nanomaterial hazards, exposure limits, and potential new risks. Safety management as a dynamic process should be updated

to the challenges of nanotechnologies. This requires a broad dialogue and collaboration between different stakeholders throughout the value chain, due to the interdisciplinary field of nanotechnologies, as well as the wide-ranging implications that their use can have on workers, consumers, the general public, and the environment.
The use of risk-prevention design principles, such as nano-masterbatches, combined with control banding seems to be a simple and cost-effective approach for initial safety management of the nanotechnology case study. Although in-situ measurements of the potential nanomaterial's exposure were not performed in this initial safety management approach.

Funding information
This study was developed under the H2020 project FLAMINGo (101007011).

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