

## FAST FACTS

**Duration:**

42 Months

**Completion Date:**

February 2019

**Total Funding:**

€10 Million

**Partners:**

42 across 15+ countries

**Objective:**

Establish Safe by Design as a fundamental pillar in the development of nanomaterials or nano-enabled products

**Outcomes:**

- Nanomaterial
- grouping strategy
- Associated
- integrated testing
- strategy

**Learn More:**

[NanoReg2.eu](http://NanoReg2.eu)

## NANOGAP Industrial Demonstrator

**Safe by Design in Action**

**Safe by Design goals:** To reduce nanosilver in waste and reduce employee exposure

**Safe by Design measures:** The production process was re-designed, with solvents and temperatures changed to reduce liquid waste, and automated to reduce employee exposure.

**Outcomes:** Significant reduction in employee exposure and reduced loss of silver nanomaterials in waste

NANOGAP is a nanomaterials manufacturer from Spain which produces silver nanowires and is at the market launch stage in the value chain.

NANOGAP's primary aim within NanoReg2 was to improve the production output of its silver nanowires by reducing and recycling waste. Prior to NanoReg2, NANOGAP was losing almost 50% of the silver introduced into the production process. This was financially inefficient, as materials could be better processed to create greater product yield and purchase costs could be reduced. Because of the hazardous nature of the waste, NANOGAP was also contracting an external organisation for its disposal, an additional financial inefficiency.

In addition to the costs associated with the waste, came the hazards. Because of the nature of the waste, many barrels of potentially hazardous waste would be created on site and this was not only a risk to the employees and visitors, but also to the localised environment. Whilst the production waste at the time was at a manageable level, plans to scale up the production of silver nanowires meant that NANOGAP had to either improve production efficiency, recycle waste or purchase additional storage space. Through the NanoReg2 Industrial Demonstrator, NANOGAP opted in first instance for the waste recycling approach, but after proving this was not an efficiency measure the production process was optimised. NANOGAP also implemented an alternative purification process to reduce the occupational and environmental hazards associated with the processes. It achieved this through employing a Safe by Design approach.

**NANOGAP**  
SUBNMPARTICLES



The objective of NANOGAP within the Industrial Demonstrator was to produce the silver nanowires more safely, by reducing the amount of waste generated throughout the synthetic process and recycling waste. NANOGAP already adhered to common safety measures during production of nanowires, however there was a risk that expansion and scale up could expose employees to harmful levels of nanomaterials during filtration and purification. It was also anticipated that this risk would be higher if the production was scaled up without Safe by Design measures being implemented.

## Industrial Demonstrator Activities within NanoReg2

Before any experimental work was performed, NANOGAP reviewed recycling possibilities for some of the waste fractions and potential exposure reduction of potentially nanowires to employees. NANOGAP set out four clear objectives for the Industrial Demonstrator:

- Reduce the amount of generated waste
- Separate and classify the generated waste
- Design a recycling procedure for the suitable fractions of the generated waste
- Quantify and reduce exposure levels linked to the waste management toxicity, irritation, inflammation, ecotoxicity and Zeta potential in lung fluids

NANOGAP focused on the 'safe production' pillar of Safe by Design. The initial plan was to develop protocols at the end of the production cycle to manage the waste. However, as the Demonstrator progressed NANOGAP redesigned synthetic and purification protocols using developments that had been tested internally. NANOGAP opted to undertake exposure and Life Cycle Assessments (LCA) to better evaluate the impact of the Safe by Design approach.

To complete these assessments, NANOGAP needed to complete knowledge gaps that existed in its production processes. These were specifically identified to accurately understand the loss of silver throughout the production processes and the level of exposure to both employees and the environment.

To fulfill Demonstrator objectives and identify gaps in data, NANOGAP sampled the waste at different purification stages to identify and isolate both non-fibrous particles and the shortest particles. Samples were then analysed using scanning electron microscopy energy dispersive X-ray spectroscopy (SEM-EDX) and inductively coupled plasma mass spectrometry (ICP-MS) to identify the chemical properties and morphology of the waste silver. This was in addition to occupational exposure analyses throughout the whole production process. Finally, the silver nanowire products were characterised to determine their toxicity, irritation, inflammation, ecotoxicity and Zeta potential in lung fluids.

## Outcomes from Waste Reduction and Exposure Assessments

The results of the Safe by Design approach met the stated ambitions of NANOGAP and also improved production, operating as a process through which valuable information was provided to the company. The NanoReg2 Industrial Demonstrator also enabled NANOGAP to identify hot spots within the production process and implemented changes to reduce occupational exposure.



Within production, NANOGAP selected to increase the amount of silver used in its reactions, as this contributed to increased synthesis reaction rate. Silver nanowire product increased from 40% to 90% as a result, with a corresponding reduction in the amount of liquid waste produced. It also enabled NANOGAP to test different purification processes that might further reduce the amount of waste produced. As a result of process changes, product specifications also changed, from a nanowire diameter of 100 nm to 70 nm, however this was still deemed acceptable once all factors had been considered.

The results of the occupational exposure assessments suggested that only one out of six production stages presented a possibility of a low level of exposure to nanowires, this being the filtration stage where lower quantities were detected by SEM-EDX. The new improved production process allowed the substitution of this filtration step by a different purification method, achieving a further reduction in workers exposure to nanowires.

The silver nanowires were determined to produce reactive oxygen species (ROS) in intracellular environments however showed no skin irritation. In terms of ecotoxicity, nanowire impact on fish metabolism was found to be similar to that of other silver nanomaterials, however their environmental mobility was found to be higher than silver ions.

Results for risk assessment before and after the implementation of Safe by Design, obtained through the tools NanoRiskCat, the Swiss Precautionary Matrix and NanoSafer, were determined by the hazard properties of silver, which are inherent to the composition and not modifiable. However, taking into account that employees use personal protection, and there is likely negligible environmental exposure during normal operations, precautionary needs beyond existing practise is very low.

The LCA performed indicated that the improved process efficiency resulted in a substantial reduction of production waste and energy demand per kg of AgNF produced, significantly improving product sustainability. All impact categories in the LCA study showed a decrease following SbD implementation, up to 90% in some cases.

### Summary

Safe by Design implementation for NANOGAP resulted in a reduction in employee exposure and a reduced loss of silver nanomaterials in waste.

Whilst implementing a Safe by Design approach, the only barrier that NANOGAP encountered was obtaining the necessary information from external contractors to complete the assessments. As a result of the NanoReg2 Industrial Demonstrator, NANOGAP now has a clear vision of how to implement Safe by Design principles and protocols in the future.

For practical commercial implementation of Safe by Design, NANOGAP has stated that financial and technical barriers exist as it would require the services of either in-house experts or subcontractors. For an SME, it is difficult to access and afford this expertise and, in its current location, it is challenging to find a health and safety expert specialised for nanomaterials.