SAFE INNOVATION WITH NANOMATERIALS IN INDUSTRIAL SETTINGS

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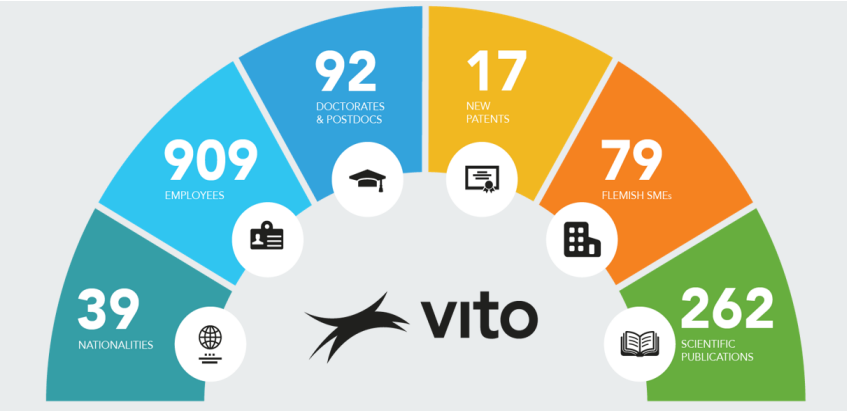
FLEMISH INSTITUTE FOR TECHNOLOGICAL RESEARCH

- Strategic research center of Flanders
- Funded (1/3) by the Flemish Government
- Headquarter located in Mol, Belgium



SUSTAINABLE CHEMISTRY

Sustainable industrial processes

New value chains from alternative feedstock

SUSTAINABLE LAND USE

Remote sensing

Air & climate

Water

Land use

SUSTAINABLE HEALTH

Sustainable health solutions

Environment, health & safety

SUSTAINABLE ENERGY

Interfaces for electrical storage

Buildings & Districts

Energy markets & strategies

Optimisation of thermal energy systems

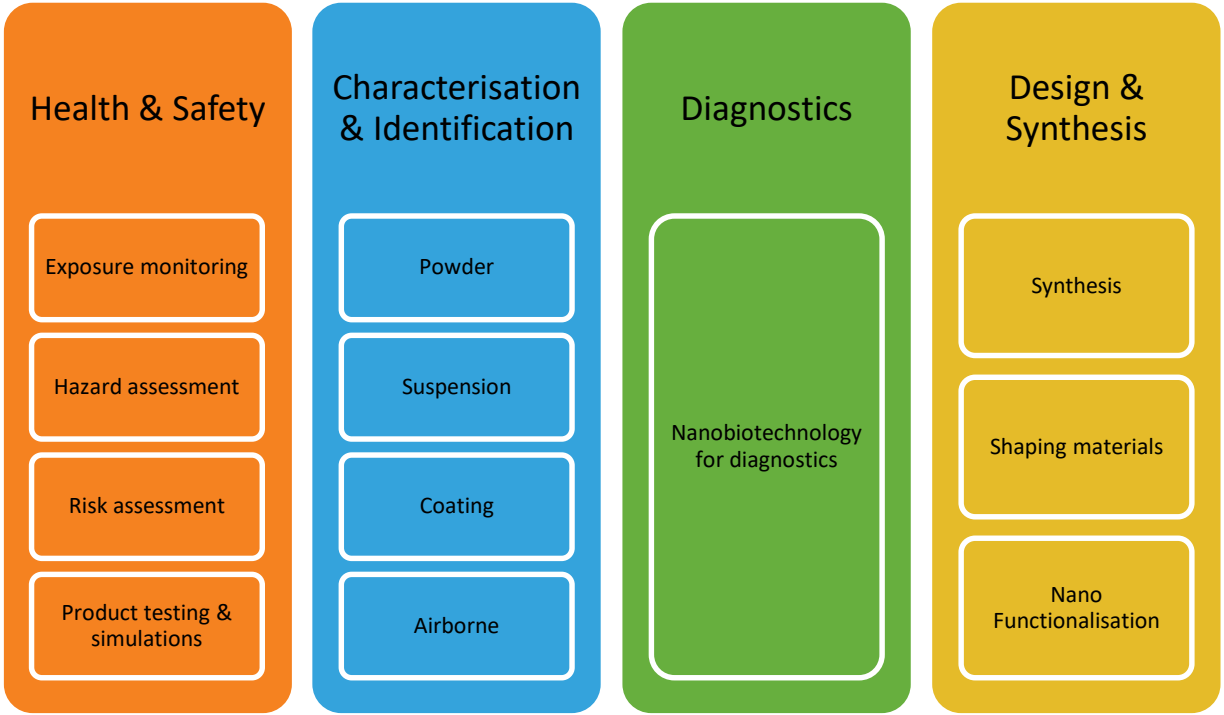
SUSTAINABLE MATERIALS

Circular economy strategies

Getting value out of waste

Product & process innovations

VITO'S *NANO* PORTFOLIO



https://nano.vito.be/

FUNDED NANO-PROJECTS

FP7, Horizon 2020, Interreg, Flemish government, …

SuperMEX

Get-A-Met

Met@link

SAFE INNOVATION WITH NANOMATERIALS

- Emerging technologies as ‘nanotechnology’ surrounded by uncertainties
- Uncertain risks + uncertain technology = public concern
- Clarity around safety is paramount for acceptance of new technology!

More cost efficient innovation

Faster to market

Prepare for future regulatory challenges

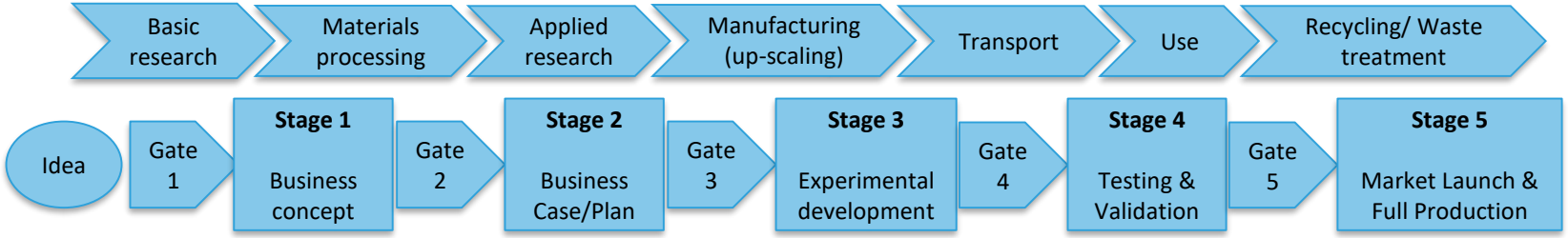
Safer products

Better consumer acceptance

SAFE-BY-DESIGN (SBD) CONCEPT

Aims at:

- reducing uncertainty of health and environmental risks before marketing
- applying substances with lowest feasible hazard, but still high functionality
- reduction of exposure of nanomaterials (NMs) to humans and its environment

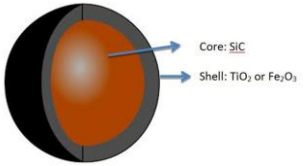


FROM UNCERTAINTIES AND POTENTENTIAL RISKS
TOWARDS CERTAINTY AND MANAGED RISKS

SBD CASE STUDIES

NANOTUN3D (H2020, 2015-2019)

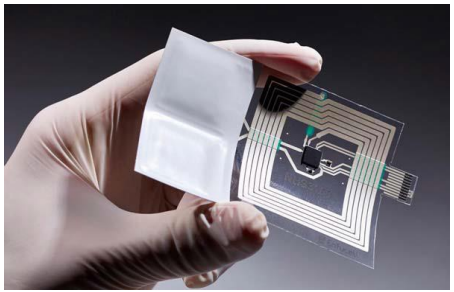
Development of nanomaterials for **metal additive manufacturing** and characterization of their operative life cycle from NP and raw metal powder to final parts



Applications in *e.g.* aircraft components

Met@link (SIM-VLAIO, 2015-2018)

Development of **silver**, copper **nanoparticle inks** for printing **metallic conductors** for electronic circuits (antennas for NFC and RFID tags) used in e.g. sensors, smart packaging, keyboards, internet of things, ...

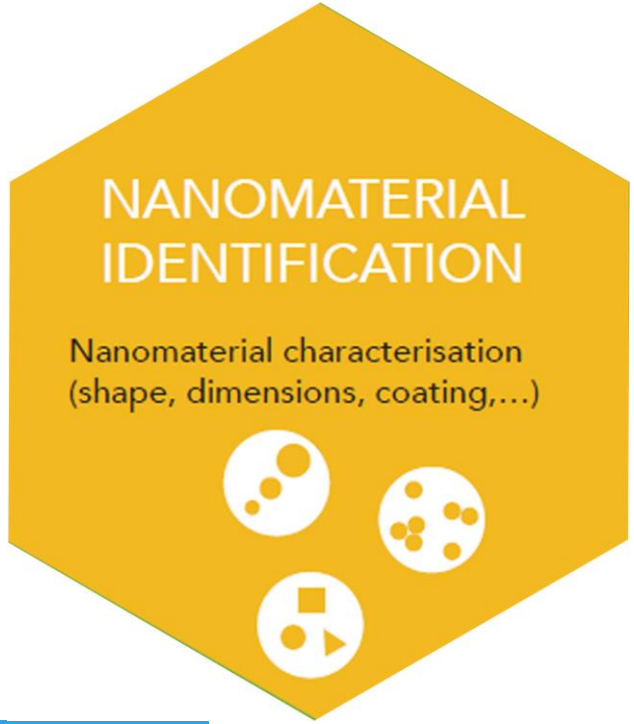


Printed antenna on flexible substrate

NFC: near-field communication; RFID: radio-frequency identification

SBD STEPS

SBD STEP 1: NANOMATERIAL IDENTIFICATION

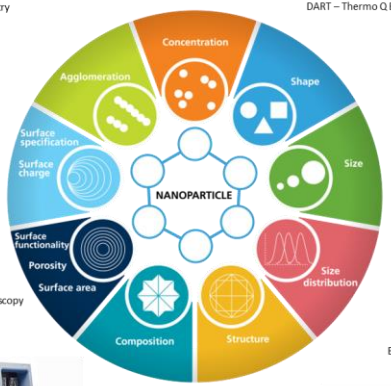


Single particle inductively coupled plasma mass spectrometry (sp ICP-MS) Perkin Elmer Nexion 300

Dynamic Light Scattering (DLS) ZetaSizer

Ambient ionization -high resolution mass spectrometer DART – Thermo Q Exactive

Energy dispersive X-ray fluorescence ED-XRF, XEPOS, Spectro



thermal desorption/pyrolysis -GCxGC-(TOF)-MS Frontier Lab Pyrolyzer - LECO Pegasus III

Inductively coupled plasma atomic emission spectroscopy Agilent 5100 ICP-OES

Field Emission Gun Scanning Electron Microscopy with STEM detector (FEI, Nova NanoSEM 450)

Micro-XRF Analyzer EDAX Orbis PC

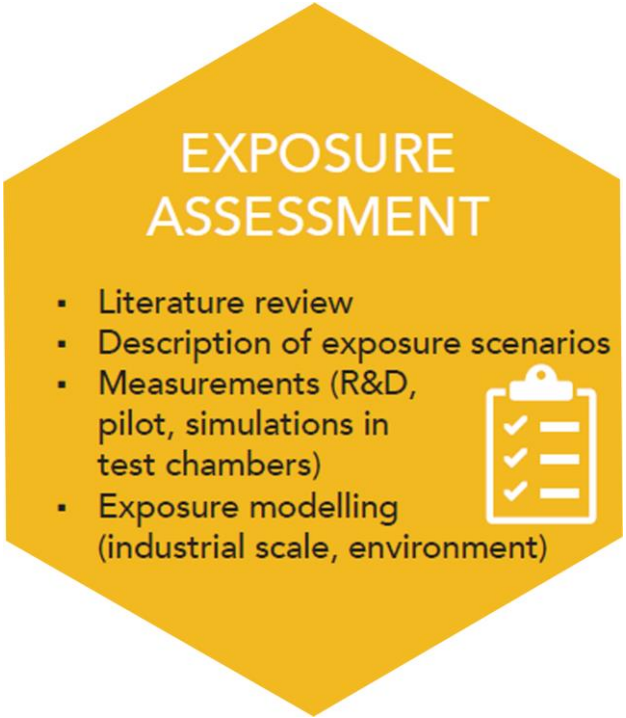
Nanoparticle Tracking Analysis (NTA) NanoSight NS500

CPS Disc Centrifuge DC2400

Microwave digestion, Multiwave PRO Anton Paar

High pressure/temperature digestion Berghof

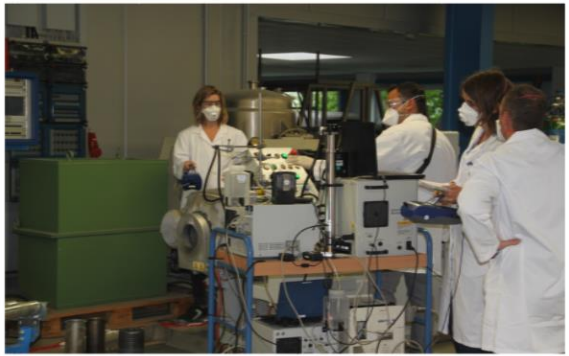
SBD STEP 2: EXPOSURE ASSESSMENT



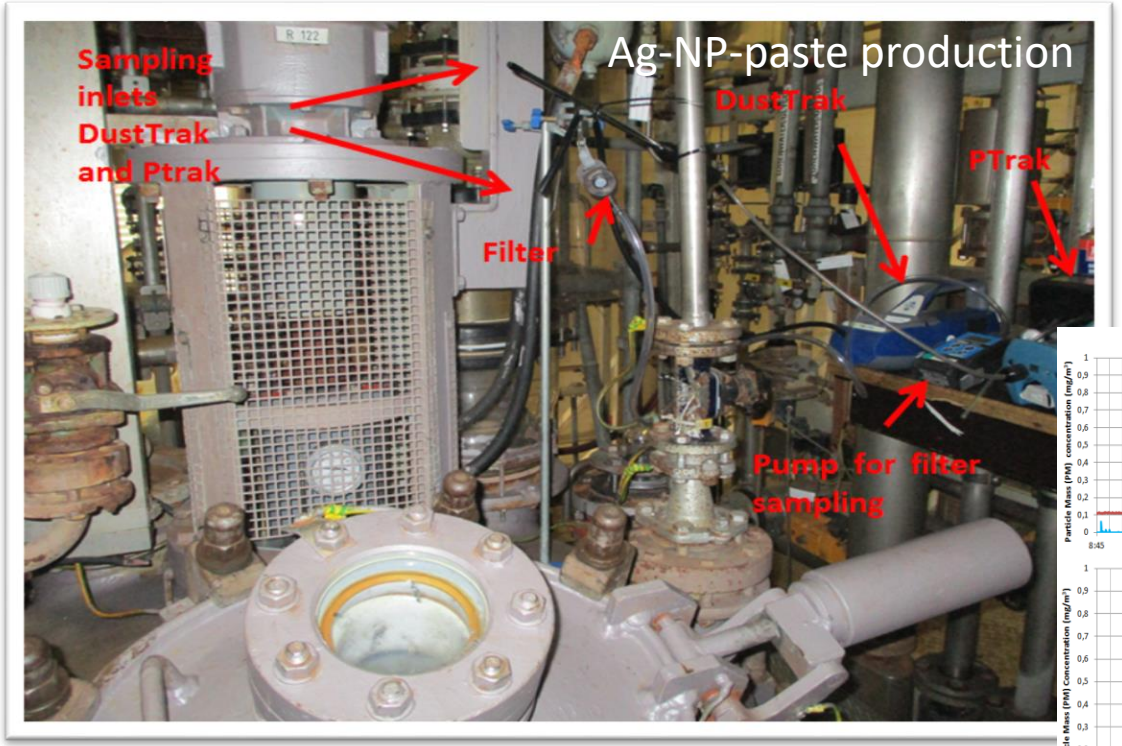
Exposure Scenario

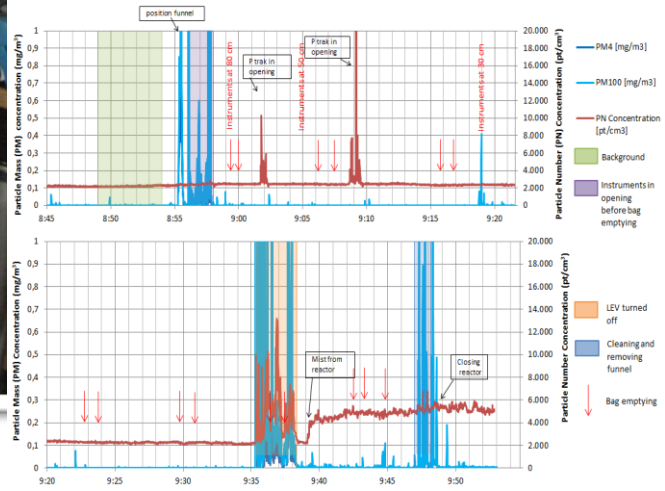
Activities	Gas atomization (VIGA); Pressure process (lab scale); Hot isostatic pressure (HIP)
Technical measures & operational conditions	Local exhaust ventilation for weighing balance; Fume cupboard for pressure process; VIGA, calcination, and HIP are contained
Personal protection	VIGA: short gloves, respiratory mask, overall Weighing: FFP3 mask, short nitrile gloves, lab coat
Environment	No direct release to surface water/soil /waste water; Release to air and possible deposition
Recommendations	First engineering controls than PPE, FP3 mask, long gloves; Separate nano-waste (label, bag-in-bag); clean with HEPA vacuum clearner followed by wet cleaning

SBD STEP 2: EXPOSURE ASSESSMENT



SBD STEP 2: EXPOSURE ASSESSMENT

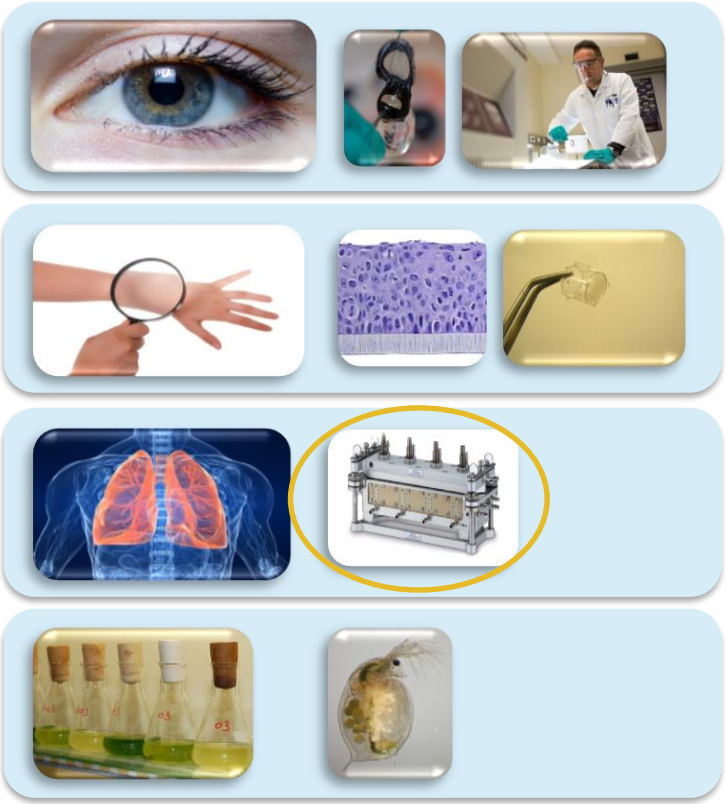




SBD STEP 3: HAZARD ASSESSMENT

HAZARD ASSESSMENT

- Literature review
- In vitro human hazard testing
- Ecotoxicity testing

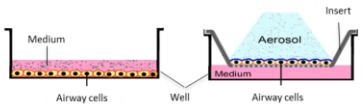


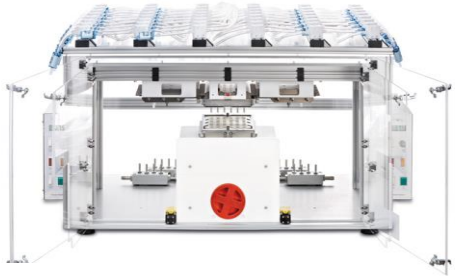
INHALATION TESTING WITH *IN VITRO* CELL MODELS

IN VIVO animal testing

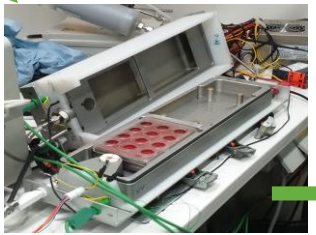
IN VITRO cell culture testing

Submerged **Air-Liquid Interface**





VITROCELL® SYSTEMS



Frijns *et al.*, ES&T 2017, 51 (9), pp 5259-5269
Patent (EP16200571.4; 2016)

SBD STEP 4 & 5: RISK ASSESSMENT & MANAGEMENT

RISK ASSESSMENT

- Comparison exposure values with available occupational exposure limits (OELs) or Nano-ReferenceValues (NRV)
- Identification residual health risks
- Regulatory support

RISK MANAGEMENT

Recommendations for safe use (general, plant-specific)

SBD STEP 4: RISK ASSESSMENT: EXAMPLE NANOTUN3D

Risk index = exposure concentration / occupational exposure limit (OEL)

Activity with potential NP or microparticle emission	Number concentration (10-700 nm) pt/cm^{-3}	PM100 (µg/m^3)	Compound (suppose 100%)	Nano-OEL	Risk index (RI)
Weighing	10343	4,8	Y2O3	66 µg/m^{3*} (Y)	0.07
			TiO2	300 µg/m^3	0.02
			TiO2	20000 pt/m^3	0.5
			SiC	330 µg/m^{3*}	0.01
Pouring calcine powder	43245	35,2	Y2O3	66 µg/m^{3*} (Y)	0.5
			TiO2	300 µg/m^3	0.1
			TiO2	20000 pt/m^3	2.2
			SiC	330 µg/m^{3*}	0.1

* bulk OEL*0,066 (British Standard Institute)

Refine assessment, Manage potential risk

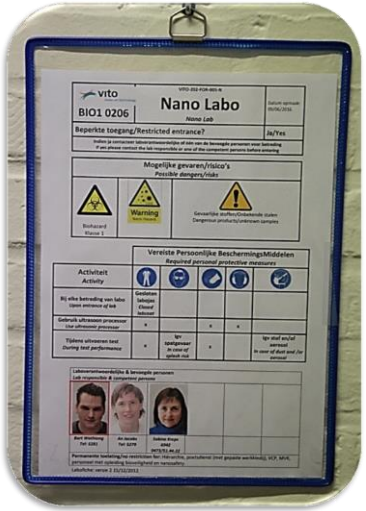
SBD STEP 5: RISK MANAGEMENT

- Technical guide to assist manufacturers and users of NMs in the selection of risk management measures to ensure health and safety of workers

- http://www.lifenanorisk.eu/phocadownload/MULTIMEDIA_GUIDANCE_PDF_VERSION.pdf

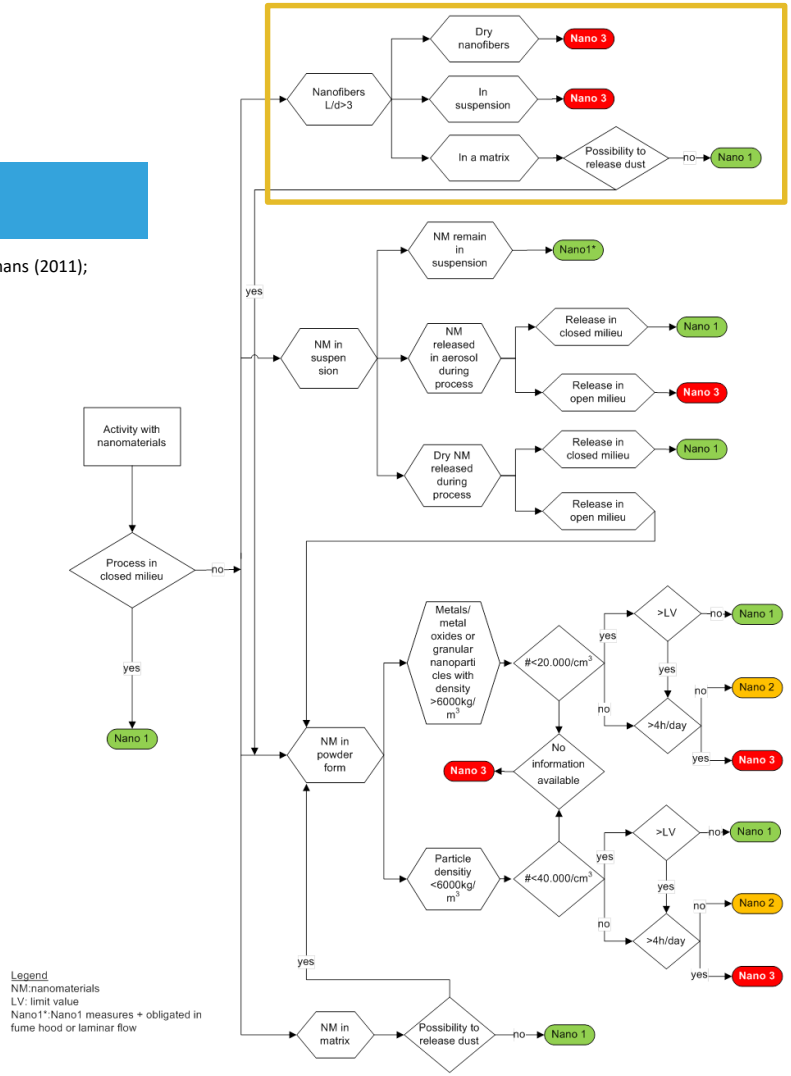
SBD STEP 5: RISK MANAGEMENT

- Safe handling of nanomaterials at VITO
- Groso *et al.* (2010). Management of nanomaterials safety in research environment, Particle and Fibre Toxicology 7, p 40



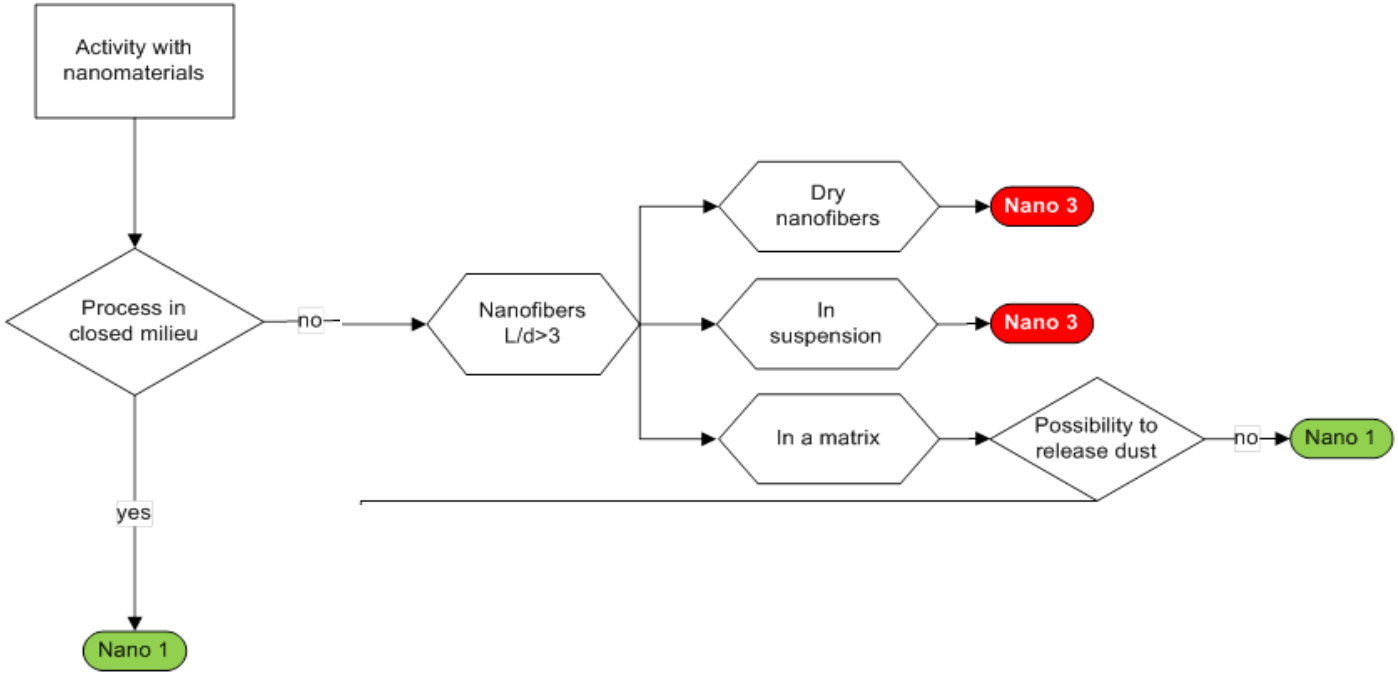
DECISION TREE

From masterthesis prevention advisor level 1- Brigitte Borremans (2011); adapted from Groso *et al.* 2010



Use of NM in research activities, not for production

DECISION TREE



Technical
Organisatory
PPE's
Maintenance

TECHNICAL MEASURES

Measures			Nano 1	Nano 2	Nano 3
Technical	**Ventilation**	Extraction	x	x	x
		Underpressure	Optional	x	>-20Pa
		Source extraction		x	x
	Manipulation in fume hood or laminar flow cabinet if sterile conditions are required	Optional	x		
		Obligated	x*	x	x
	Limited access	Through magnetic badge or door lock			x
		Presence of log book			x
	Access through passageway	Passageway			x
		Safety shower			x
	Use of vacuum cleaner with HEPA-filter		(x)	x	x

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