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INTEGRANO

MULTIDIMENSIONAL INTEGRATED QUANTITATIVE APPROACH TO ASSESS SAFETY AND SUSTAINABILITY OF NANOMATERIALS IN REAL CASE LIFE CYCLE SCENARIOS USING NANOSPECIFIC IMPACT CATEGORIES

WP[1]

Name of the presentation

12M Annual General Meeting

Turin - Italy

29-30 January 2025

This project has received funding from the European Union's Horizon Europe research and innovation programme under GA No 101138414

Tasks and Gantt

WP1			Year 1				Year 2				Year 3				Year 4			
Task	**Title**	**Leader**	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1.1	Data generation and management plan for impact assessment	CNR	D 1.1					D 1.4										
1.2	Addressing case studies specific goal and scope	CNR						D 1.2										
1.3	Dedicated Algorithms and digital Decision Support Toolbox implementation for NMs	PRJ								D 1.3				MS 1				

D1.2	Report on the goal and scope of addressed case studies, including KDFs and KPIs definition	PRJ	SEN	18	June 2025
D1.4	Final data management Plan	CNR	PU	18	June 2025

Task 1.1

Data generation and management plan for impact assessment

Preliminary DMP encompasses a significant part of the life cycle of the data produced within INTEGRANO. (D1.1, Month 3)
Expected final DMP at Month 18 (D1.4)

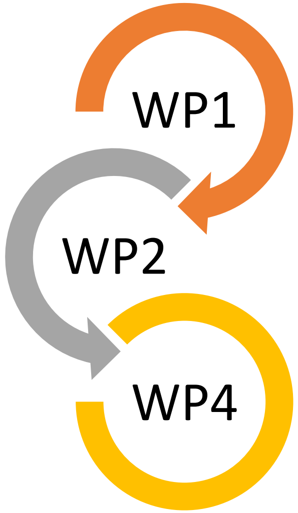
D1.1	First data management plan	CNR	PU	3	March 2024
D1.4	Final data management Plan	CNR	PU	18	June 2025

Link to:

T2.2 **Data mining**,

T2.3 **NMs Characterisation program for selected NMs (p-chem properties)** (D2.2, Month 36).

T4.2 **In silico-modelling – Integrated Database** (D4.2, Month 44).



Task 1.2 Addressing case studies specific goal and scope

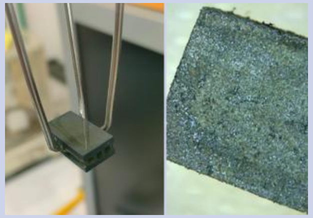
CS leaders

CS N. 1 (CNR-ISSMC)

	NMs	Synthesis/Extraction	Incorporation technology	Product/Functionality
1.1	Egyptian Blue based materials. Ag@biopolymer. (Bio)SiO_2@TiO_2. (Bio)SiO_2@Essential Oils.	Solid state synthesis Sol-gel Sol-gel Heterocoagulation	Spray-coating	Antimicrobial textile 
1.2	CuO/ZnO	In-situ sonochemical synthesis and coating		

LINKED PROJECTS: ASINA, PROTECT, SECURECOAT

CS N. 2 (CNR-ISMN)

NMs	Synthesis/Extraction	Incorporation technology	Product / Functionality
Perovskite-type Ce-doped strontium ferrate (CSF) - Silica Thermocatalysts. (Bio)SiO_2@TiO_2 Photocatalyst.	Citrate-assisted Solution Combustion Synthesis (CNR-ISMN) Sol-gel (CENTI)	Dip-coating (ISMN-B4C) Ultrasound (BIU) Spray Coating (CENTI)	Nano-enabled water membranes based on SiC, in flat or scraps form (B4C)  Abatement of contaminants of emerging concern and bacteria

LINKED PROJECTS: NANOTHEC-ABA, NANOPERWATER

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Task 1.2 Addressing case studies specific goal and scope

CS leaders

CS N. 3 (CNR-IPCB e SCITEC)

NMs	Synthesis/Extraction	Incorporation technology	Product / Functionality
Bio-SiO_2–F (Functionalised bio-silica) (SCITEC)	Extraction from rice-husk Extraction from waste material (CENTI)	Feeding (PU Bio-precursor + Bio-SiO_2) Mixing Moulding (IPCB)	Nano-enabled reinforced polyurethane foams  Mechanical properties Low thermal conductivity

CS N. 4 (CNR-ISAC)

LINKED PROJECTS: REINVENT, BIOMAT

NMs	Synthesis/Extraction	Incorporation technology	Product / Functionality
Ag@biopolymer.	Sol-gel	Electrospinning (Ag nanosol + Cellulose Acetate (CA) blend)	Electrospun nanofibers.  Antimicrobial properties Air filtration efficiency, Quality Factor

LINKED PROJECTS: MEDIC@TEX I & II

Task 1.2 Addressing case studies specific goal and scope

CS leaders

CS N. 5 (BIU)

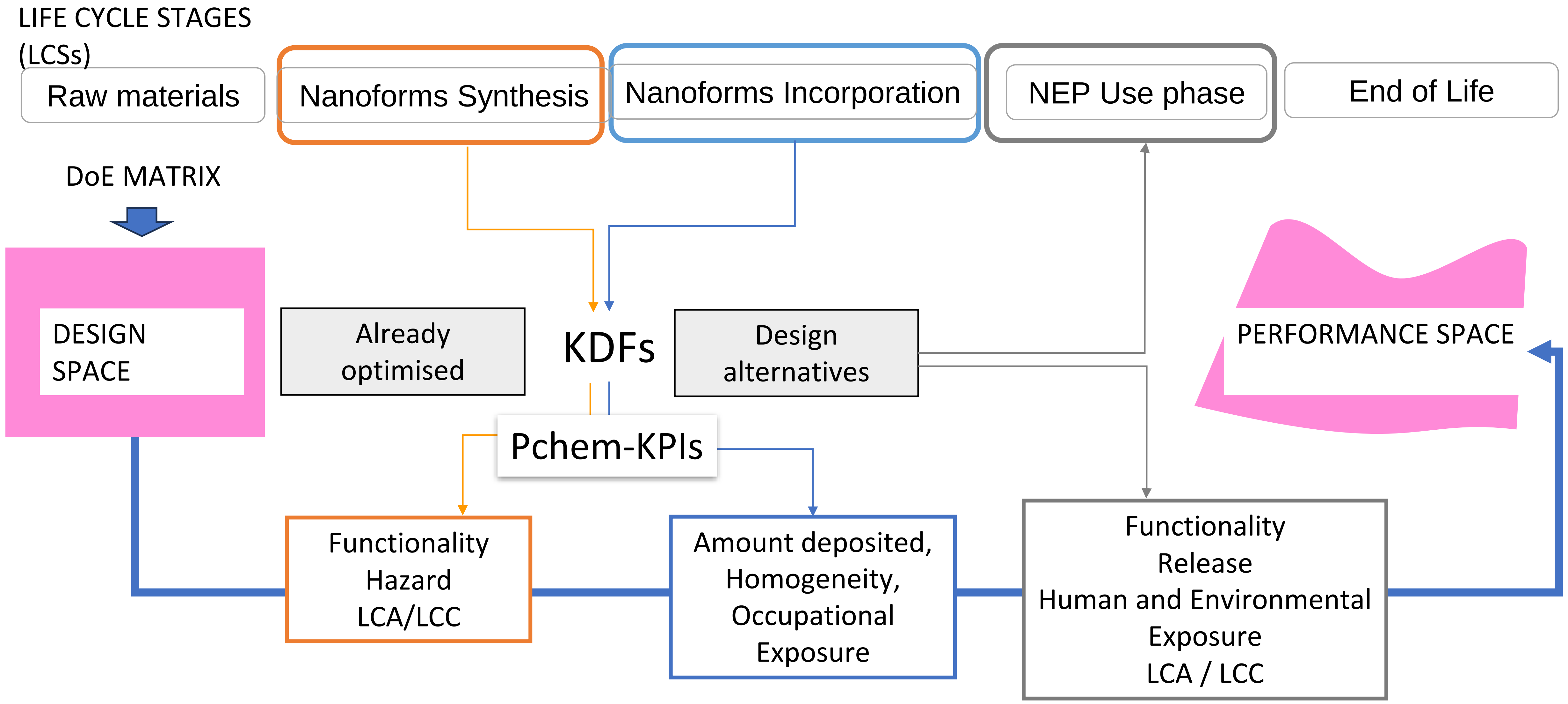
NMs	Synthesis/Incorporation	Product / Functionality
C-dots from Olive/Salvia/Aloe Vera/Thyme/Rosemary leaves (BIU)	Hydrothermal synthesis Sonication coating	Shelf-life extension of food packaging material (polyethylene film/paper)  Antimicrobial properties

CS N. 6 (ROV)

NMs	Synthesis/Extraction	Incorporation technology	Product / Functionality
(Bio) $SiO_2@TiO_2$ NPs + active ingredients (Bio) $SiO_2@TiO_2$ NPs + active ingredients in micropellet TiO_2 NPs + active ingredients in micropellet	Extraction of SiO_2 from rice-husk (CENTI) Micropelletisation (VERL)	Cosmetic formulation (ROV, VERL)	UV protection cream UV-shielding SPF 

Task 1.2 Addressing case studies specific goal and scope

CS leaders



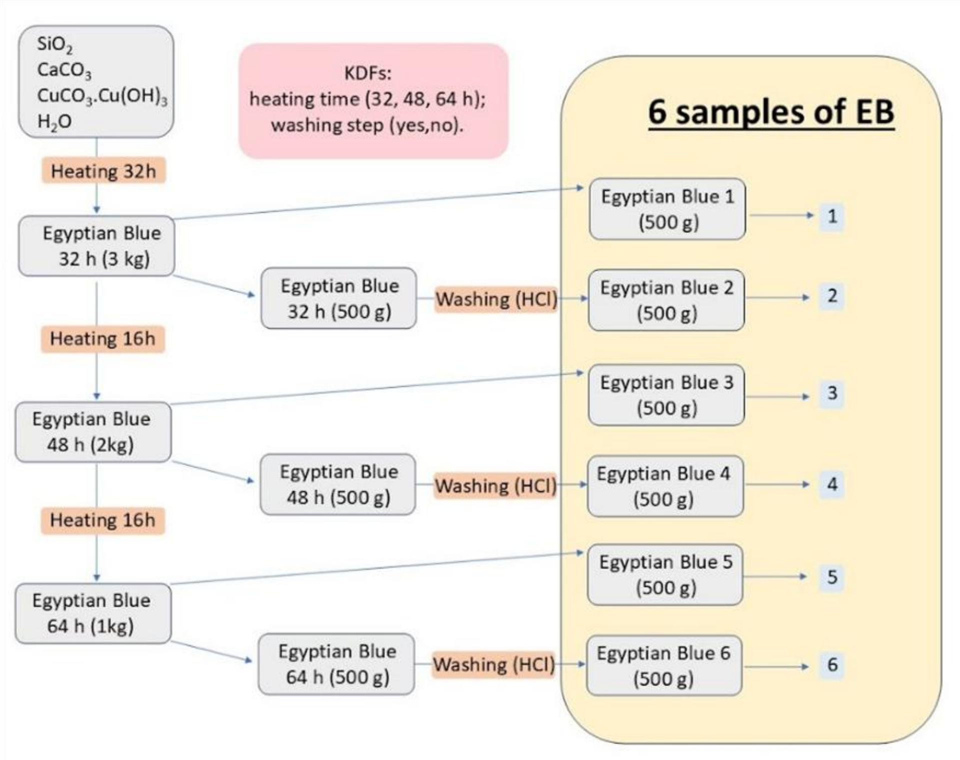
Task 1.3

PRJ

Dedicated Algorithms and digital Decision Support Toolbox implementation for NMs

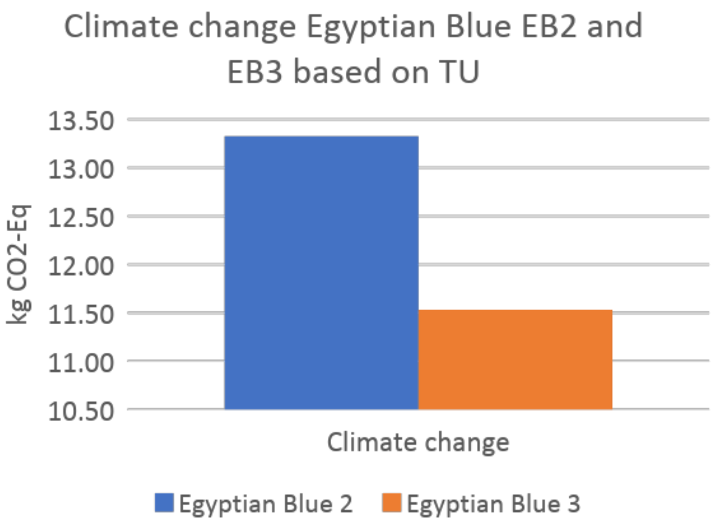
D1.3	Digital Decision Support Toolbox for quantitative based integrated impact assessment towards SSbD solutions	PRJ	SEN	24	December 2025

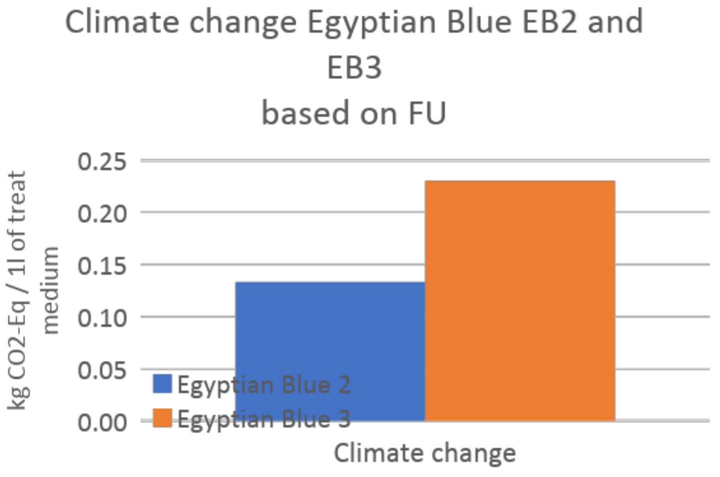
First implementation of INTEGRANO multi-optimisation



MBC (mg/ml)						
	EB1	EB2	EB3	EB4	EB5	EB6
S. aureus	>10	>10	>10	>10	>10	>10
E. coli	>10	>10	>10	>10	>10	>10

MIC (mg/ml)						
	EB1	EB2	EB3	EB4	EB5	EB6
S. aureus	>10	>10	>10	>10	>10	>10
E. coli	>10	5	10	>10	>10	>10





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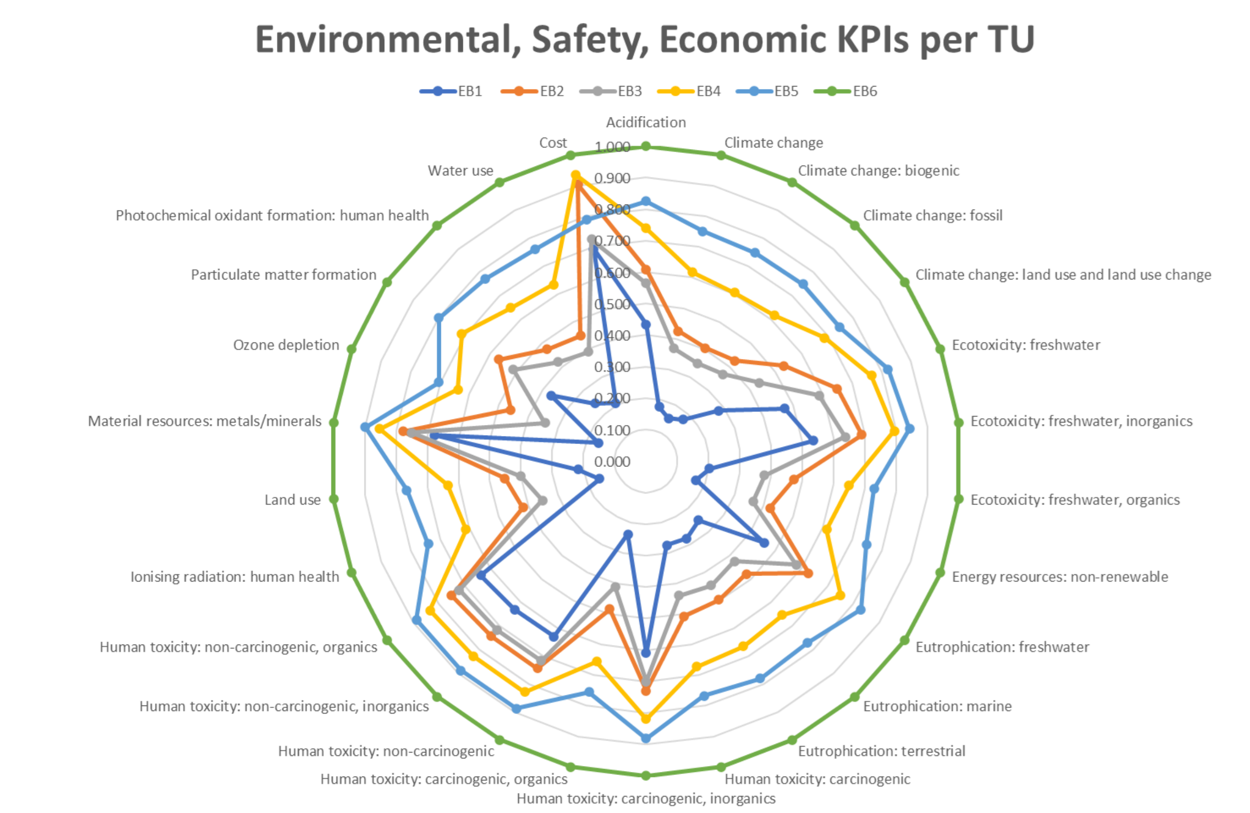
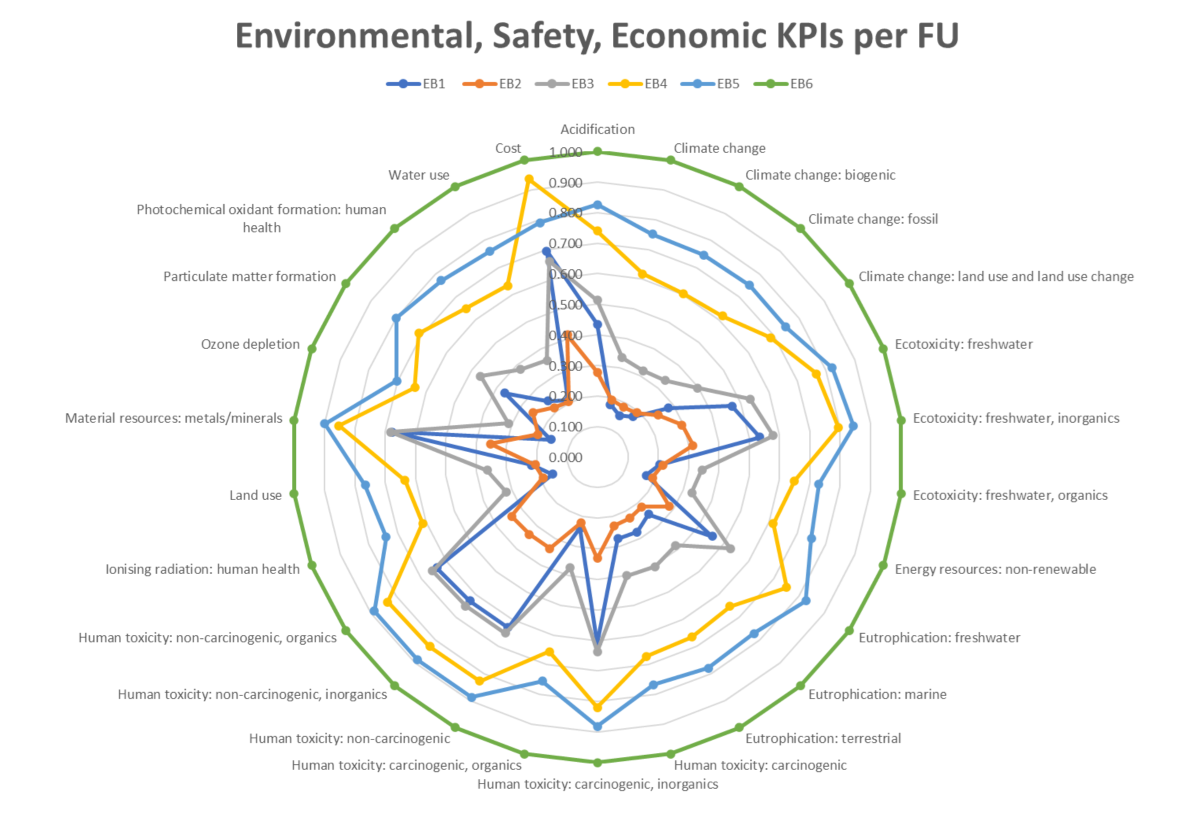
Task 1.3

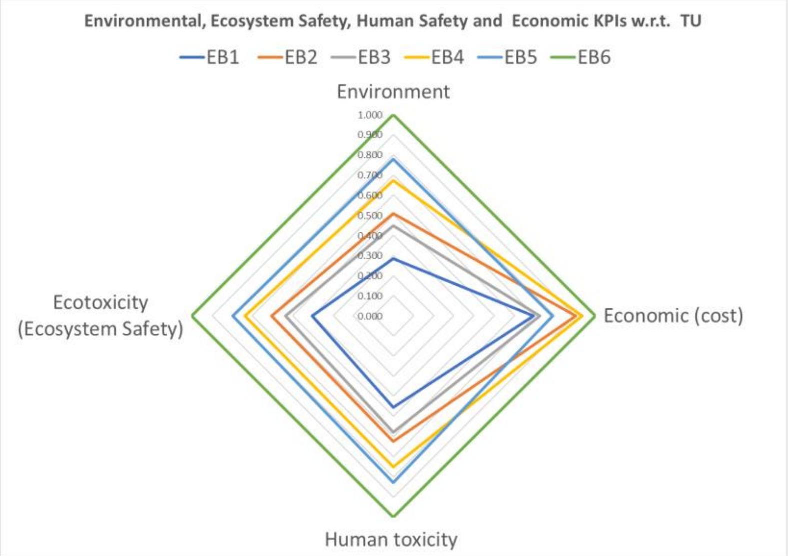
PRJ

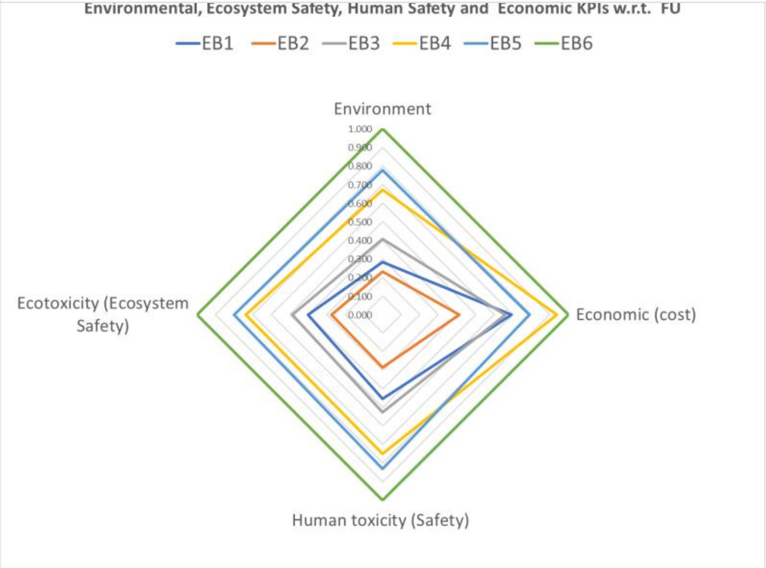
Dedicated Algorithms and digital Decision Support Toolbox implementation for NMs: Multi-performance assessment

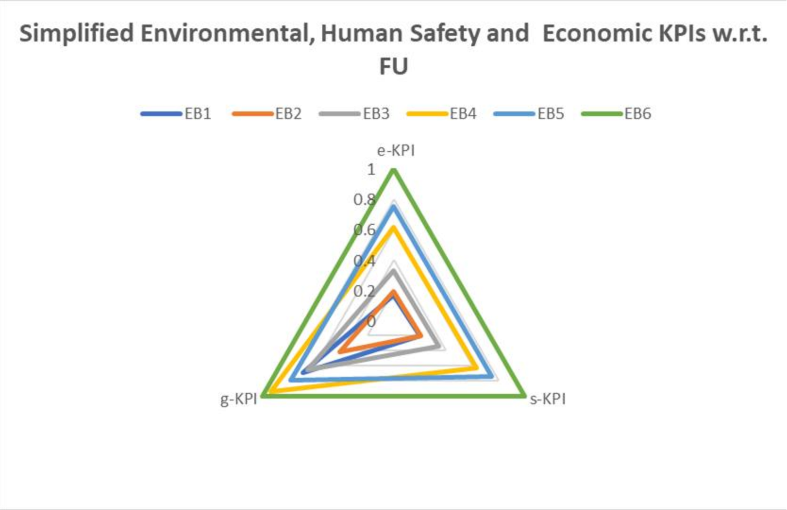


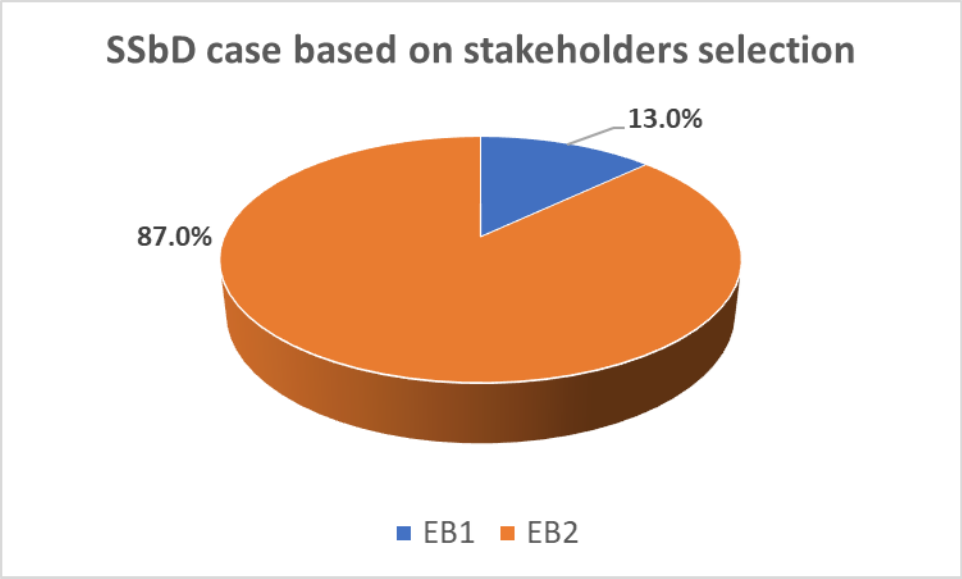


Dedicated Algorithms and digital Decision Support Toolbox implementation for NMs: the stakeholders perspective









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INTEGRANO

CNR-ISSMC

INTEGRANO

MULTIDIMENSIONAL INTEGRATED QUANTITATIVE APPROACH TO ASSESS SAFETY AND SUSTAINABILITY OF NANOMATERIALS IN REAL CASE LIFE CYCLE SCENARIOS USING NANOSPECIFIC IMPACT CATEGORIES

Case Study 1

Antimicrobial (medical) textile

	NMs	Synthesis/Extraction	Incorporation technology	Product/Functionality
1.1	Egyptian Blue based materials. Ag@biopolymer. (Bio)SiO_2@TiO_2. (Bio)SiO_2@Essential Oils.	Solid state synthesis Sol-gel Sol-gel Heterocoagulation	Spray-coating	Antimicrobial textile 
1.2	CuO/ZnO	In-situ sonochemical synthesis and coating		

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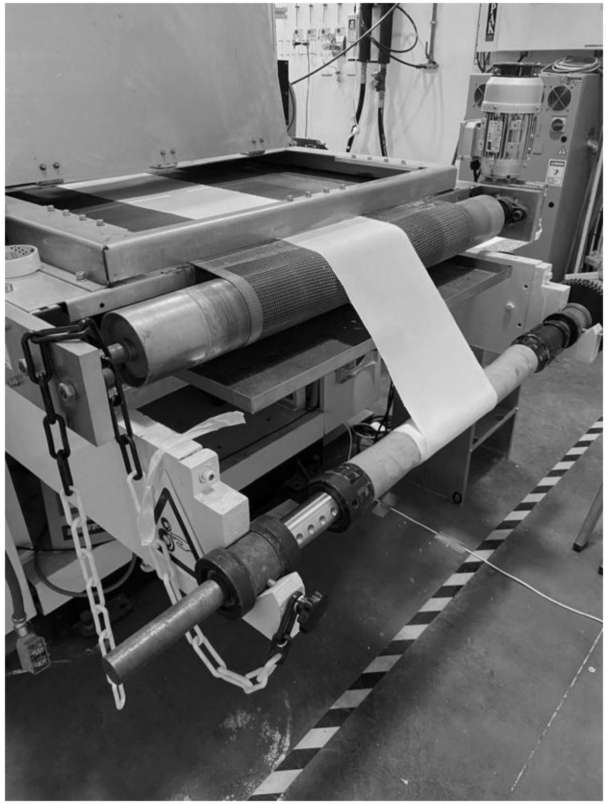
the European Union

INTEGRANO

CS1.1 + CS1.2 SCOPE, GOAL

CNR-ISSMC

SCOPE: PRODUCTION OF MEDICAL TEXTILE COATED BY ANTIMICROBIAL NANOFORMS



LC PHASES:

GOAL:

SYNTHESIS	INCORPORATION	USE
MINIMISING THE INTRINSIC HAZARD, IMPROVING SELECTIVITY: REACTIVITY AGAINST MICROBES, MINIMISING HUMAN HEALTH EFFECTS	MAXIMISING THE AMOUNT OF (NANO) PHASES DEPOSITED	MINIMISING THE RELEASE OF (NANO) PHASES
	MINIMISING THE AMOUNT (NANO) PHASES EMITTED	MAXIMISING ACTIVE INGREDIENT BIOAVAILABILITY

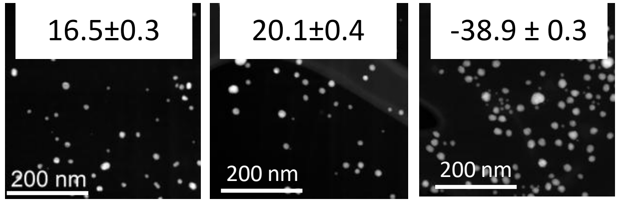
MINIMISING LCA and LCC IMPACTS

MAXIMISING ANTIMICROBIAL PROPERTIES

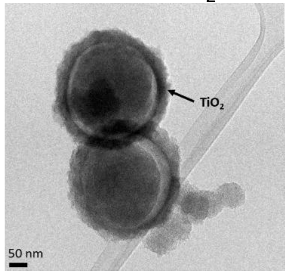
CS1.1 NANOFORMS

ALREADY OPTIMISED

AgHEC | AgHEC 6.4 | AgCur



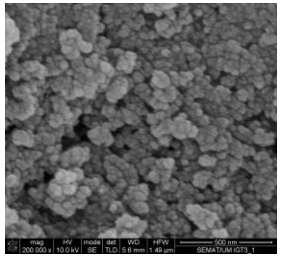
SILICA@TiO_2



SiO_2@TiO_2

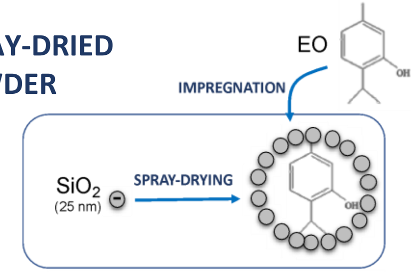
UNDER OPTIMISATION IN CS2

BIOSILICA@TiO_2



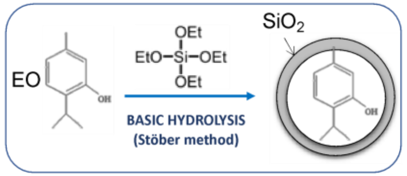
EO (Essential Oils)@SiO_2

SPRAY-DRIED POWDER

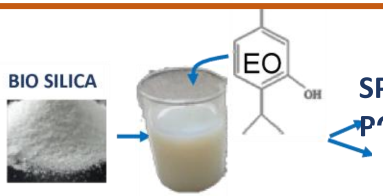


COLLOIDAL EASLY SCALABLE ROUTE

SOL



CORE_SHELL SOL-GEL



SPRAY-DRIED POWDER

SOL

COLLOIDAL EASLY SCALABLE ROUTE

$CaCuSi_4O_{10}$ Egyptian blue

Exfoliated Egyptian Blue (nano-EB)

UNDER OPTIMISATION IN CS 1.1

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CS1.1 DEPOSITION TECHNIQUES

DIP-COATING **SPRAY-COATING**

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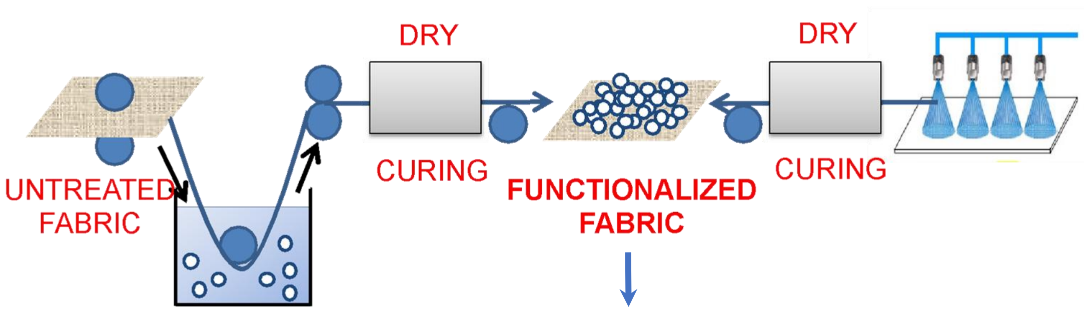
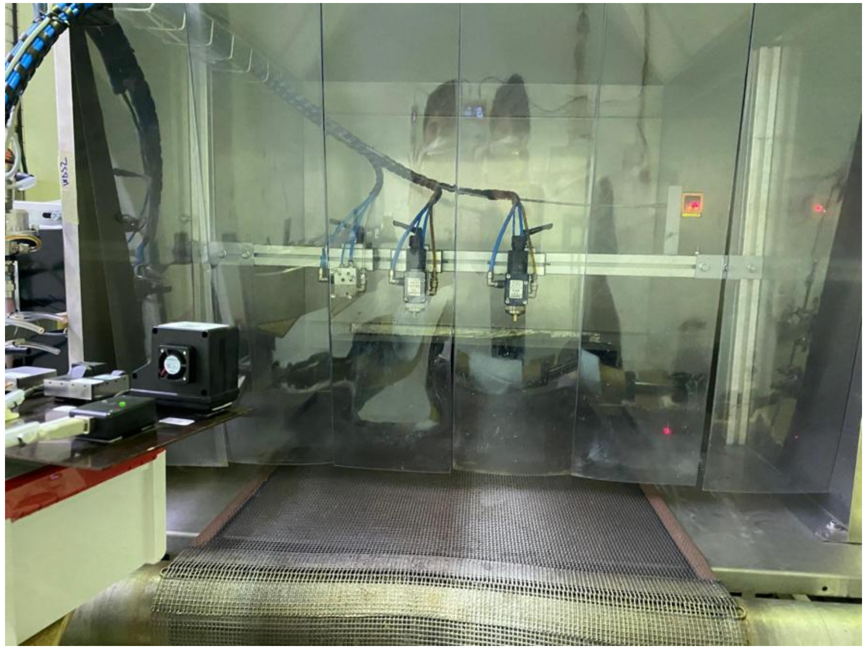


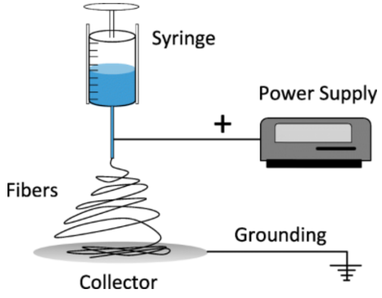
centi
Centre for Nanotechnology and Advanced Materials

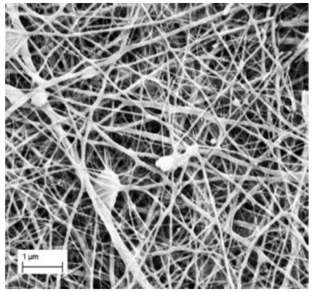
CS1.1



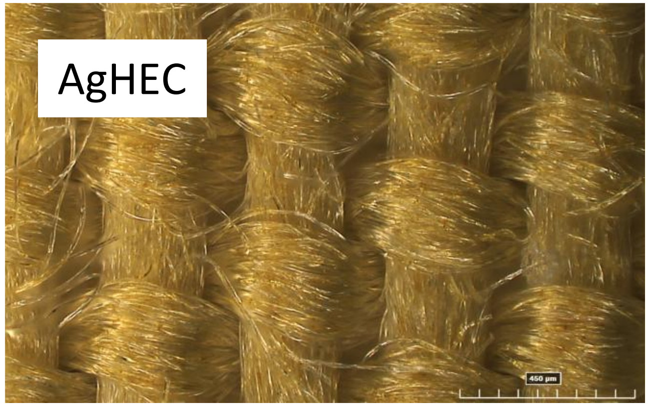
ELECTROSPINNING → CS4

aitex
textile research institute

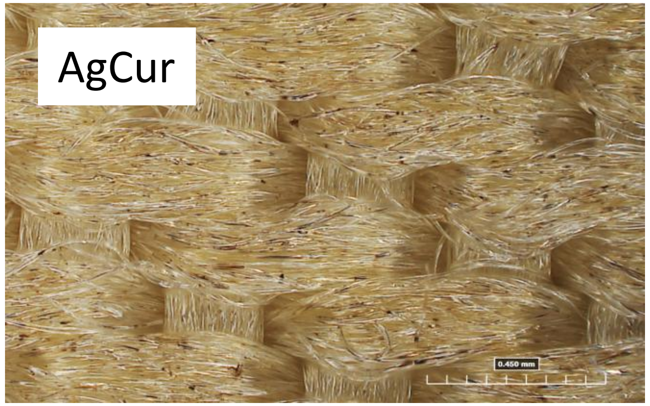


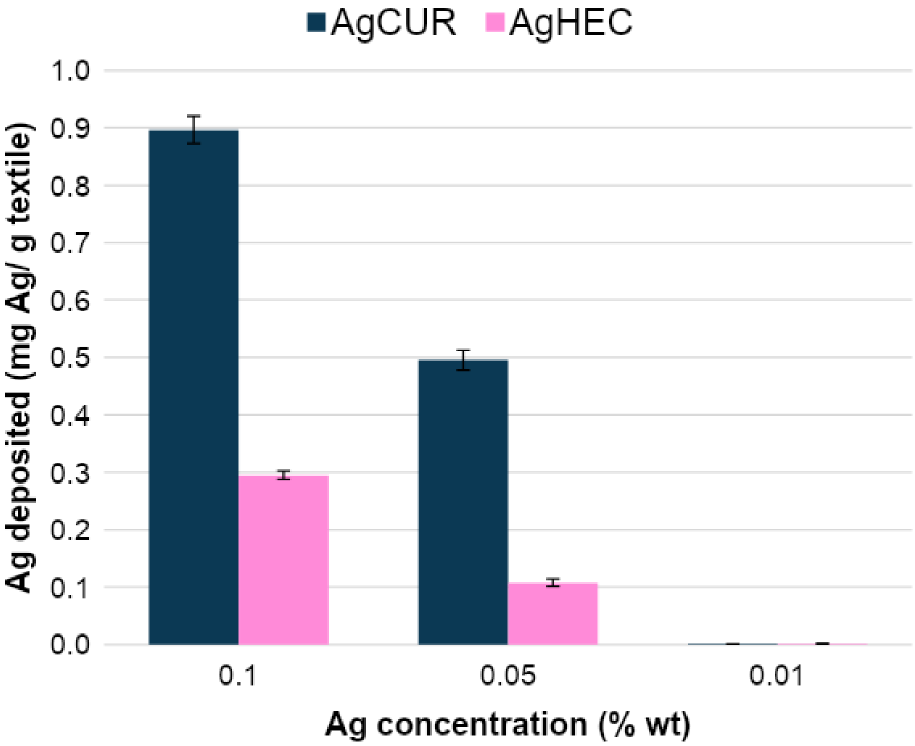


CS1.1 Ag-BASED NEPs



Medical grade PES, 150 g/m^2 (AITEX)





NEEDS:

Washing tests under ISO standard 105-C06

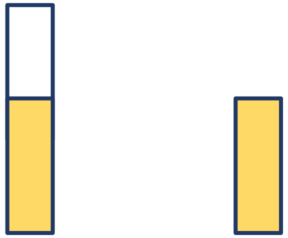
aitex research & innovation center ?

Antimicrobia tests

Bar-Ilan University אוניברסיטת בר-אילן ?

1 washing **5 washing**

RATIO $\frac{\text{Ag leached}}{\text{Ag deposited}}$ →



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CS1.1 MICRO -EGYPTIAN BLUE

CNR-ISSMC

MICRO SCALE EGYPTIAN BLUE

#	Sample name	Sample legend
1	I2A	Second firing
2	I2B	Second firing + washing + annealing (900 °C for 4 hours)
3	I3A	Third firing
4	I3B	Third firing + washing + annealing (900 °C for 4 hours)
5	I4A	Fourth firing
6	I4B	Fourth firing + washing + annealing (900 °C for 4 hours)

CS4

MULTIOPTIMISATION STUDY

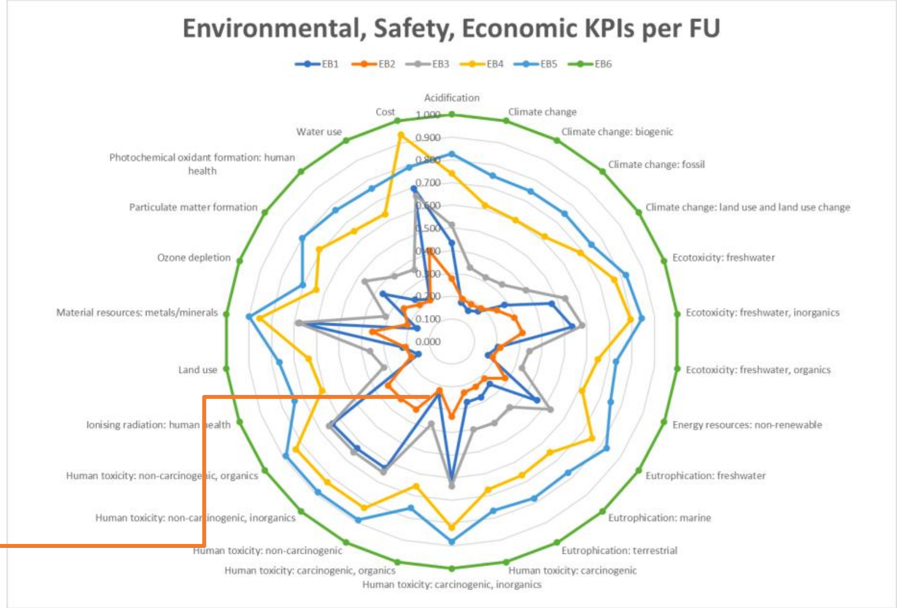

PROJECT HUB360

REPORT ON MICRO SCALE EGYPTIAN BLUE MULTIOPTIMISATION

CASE STUDY 4.1
MICRO SCALE EGYPTIAN BLUE MULTIOPTIMISATION
ANALYSIS REPORT
20/01/2025

Ns. Rif. CS 4.1 Egyptian Blue multioptimisation report
Avigliana, 20/1/2025

info@projecthub360.com +39 011.207.0981 www.projecthub360.com



I2B SAMPLE THAT DISPLAYED MINIMAL IMPACTS IN ALMOST ALL IMPACT CATEGORIES

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CS1.1 MICRO -EGYPTIAN BLUE

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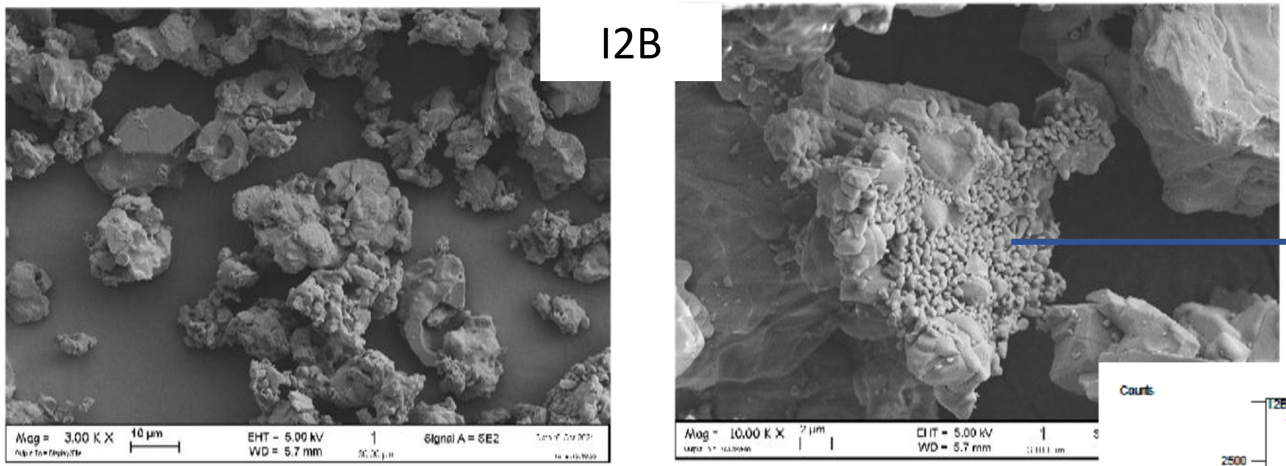
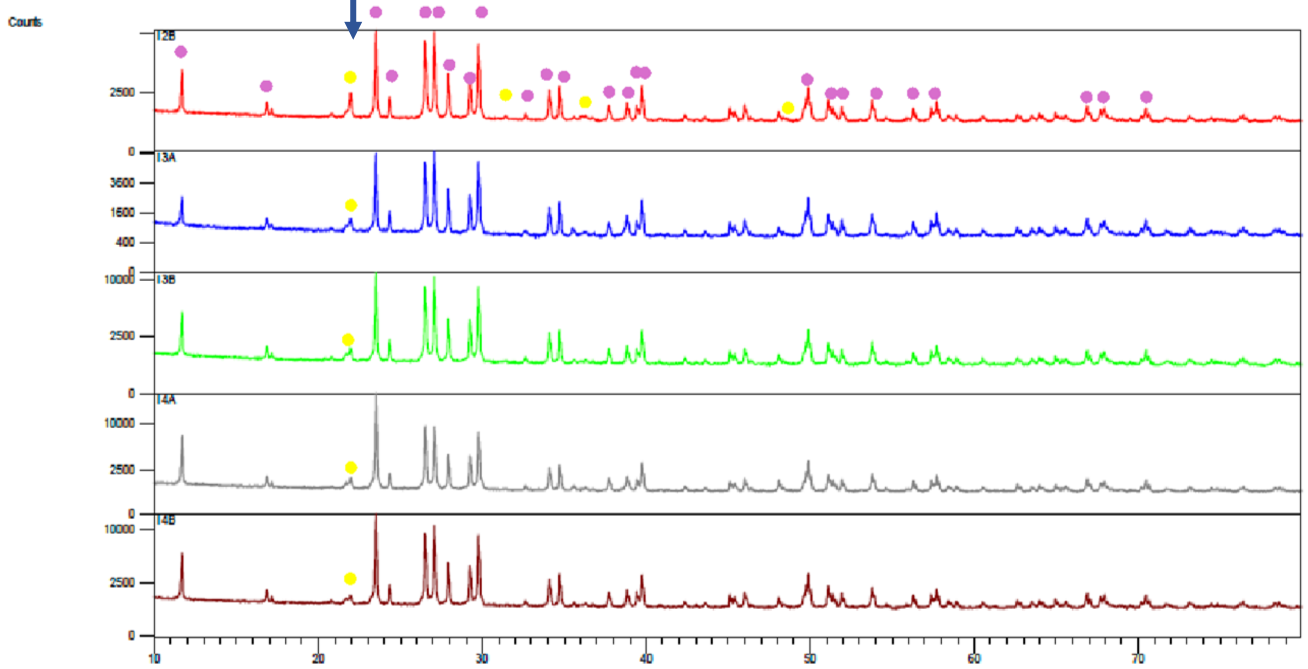
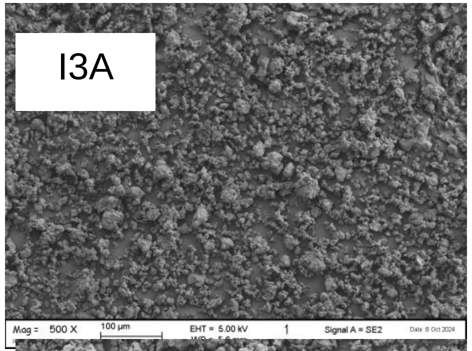
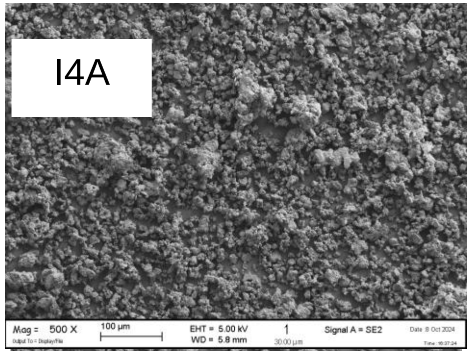
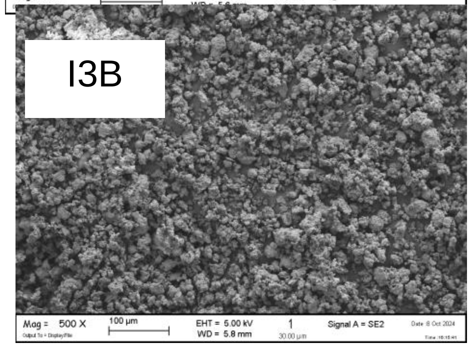


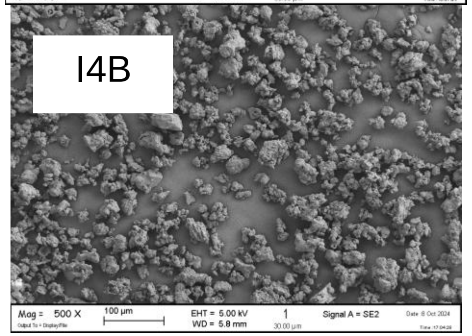


$\bullet$ Cuprorivaite $CaCuSi_4O_{10}$ (Egyptian Blue)
$\bullet$ Crystobalite – SiO_2









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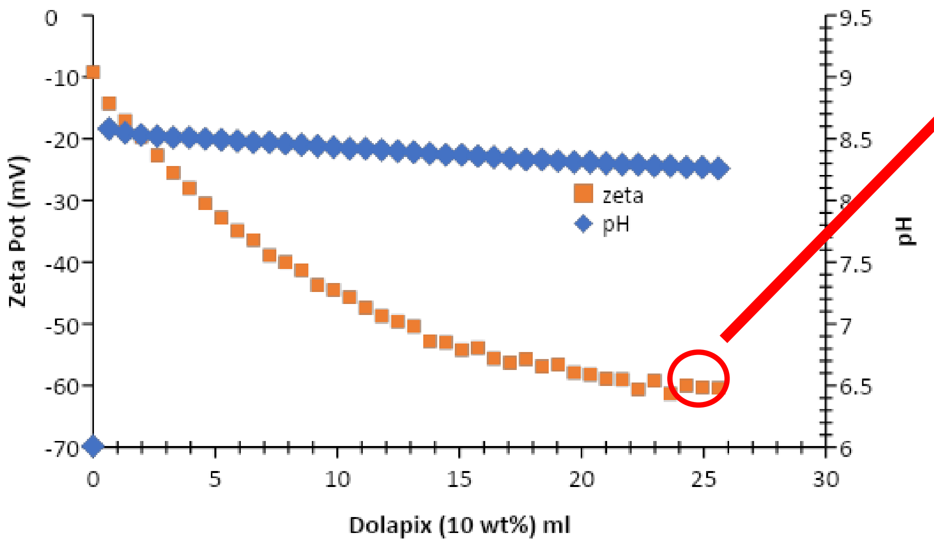
CS1.1 NANO-EGYPTIAN BLUE

CNR-ISSMC

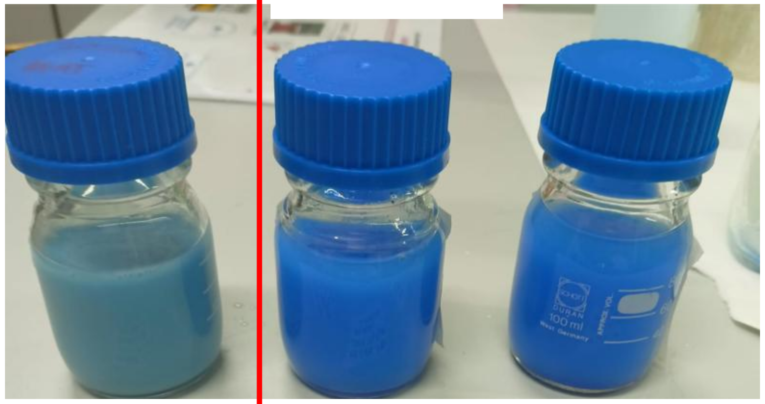
DISPERSABILITY OF MICRO EB



Dispersant: Dolapix : EB: 2:1 (wt%)

	Amount (g)
EB (g)	2,5
Dolapix CA (10%)	50
Water	48,5

FOR 90h

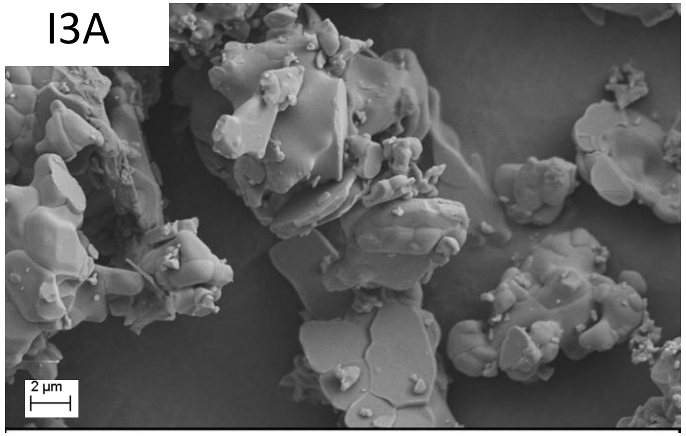


Ball milling with ZrO_2 MEDIA

Gentle milling

Thermostatic bath (50°C)

I3A



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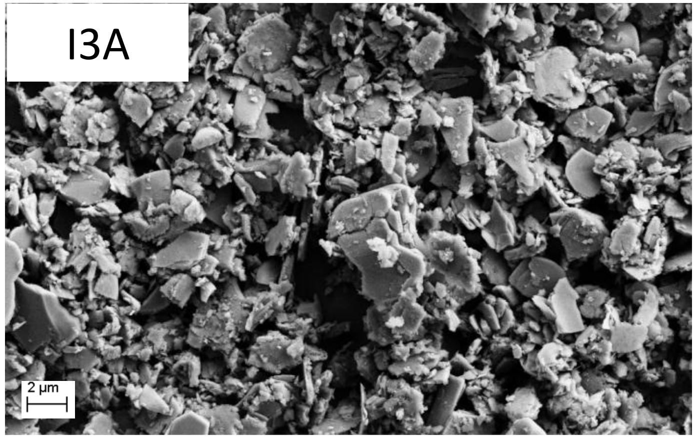
EXFOLIATION: FROM MICRO TO NANO (SUB-MICRON)

I3A



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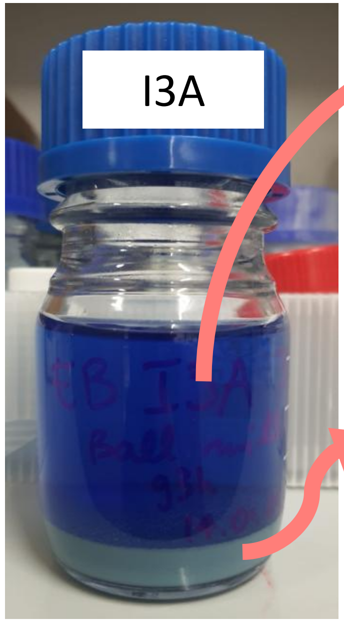
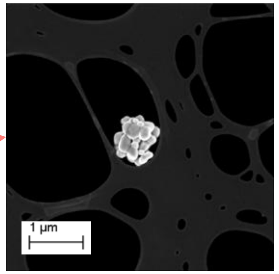
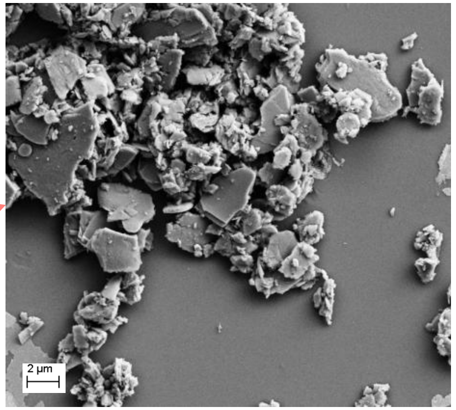
CS1.1 NANO-EGYPTIAN BLUE

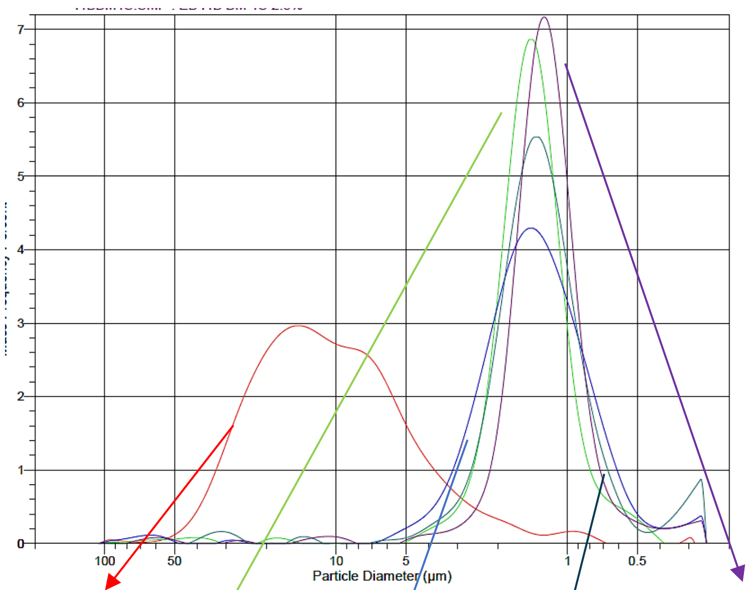
CNR-ISSMC

AFTER BALL MILLING









I3B

I3A ball milling

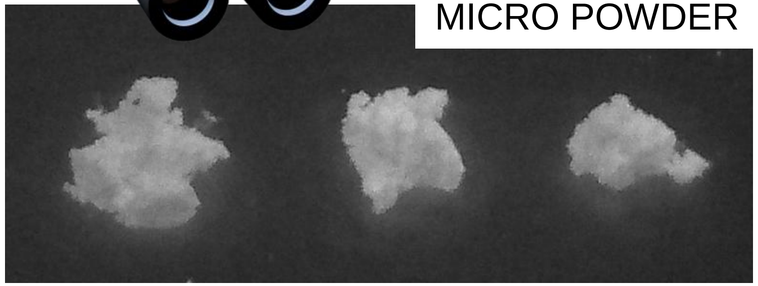
I3B ball milling

I4B ball milling

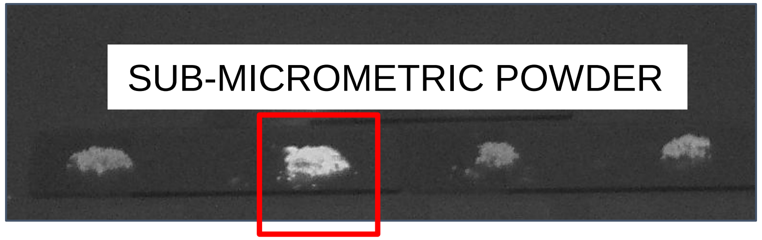
I4B ball milling 1 week

Dispersant (Ball milling, Mean size 1.5 µm, with a significant submicrometric fraction

IR visor



µ-I3A µ-I3B µ-I4B



I3A I3B I4B I4B

90 h 1 week

EB + DISPERSANT - BALL MILLING

SIZE COMPARISON AFTER BM:

I3A vs I3B

I3B vs I4B

I4B (BM 90h) vs I4B (BM 1 week)

No relevant differences on EB type

CS1.1 NEXT STEPS

Work planned for the NEXT 6 MONTHS

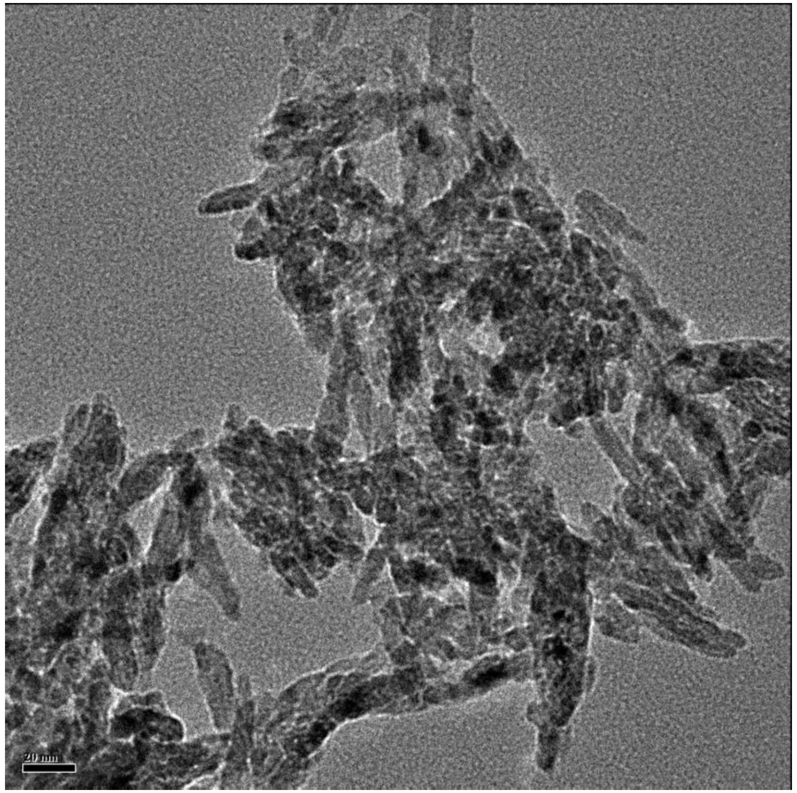
- Optimisation of nano-Ag dip-coating process, antimicrobial, washing fastness and skin irritation tests: KDF: Ag-nanosol concentration; KPI: Ag loading, washing fastness, antibacterial properties.
- Optimisation of EB exfoliation test: KDF: exfoliation process parameters (time, milling); KPI: luminescence.
- Optimisation of nano-EB dip-coating process: KDF EB concentration; KPI: EB loading, washing fastness, luminescence, antibacterial properties.
- Optimisation of essential oil (EO) incorporation on Bio-SiO_2: KDF EO/Bio-SiO_2 concentration; KPI: adsorption (loading) and desorption (release active ingredient); antibacterial properties.

Funded by the European Union

CS1.2 NANOFORMS

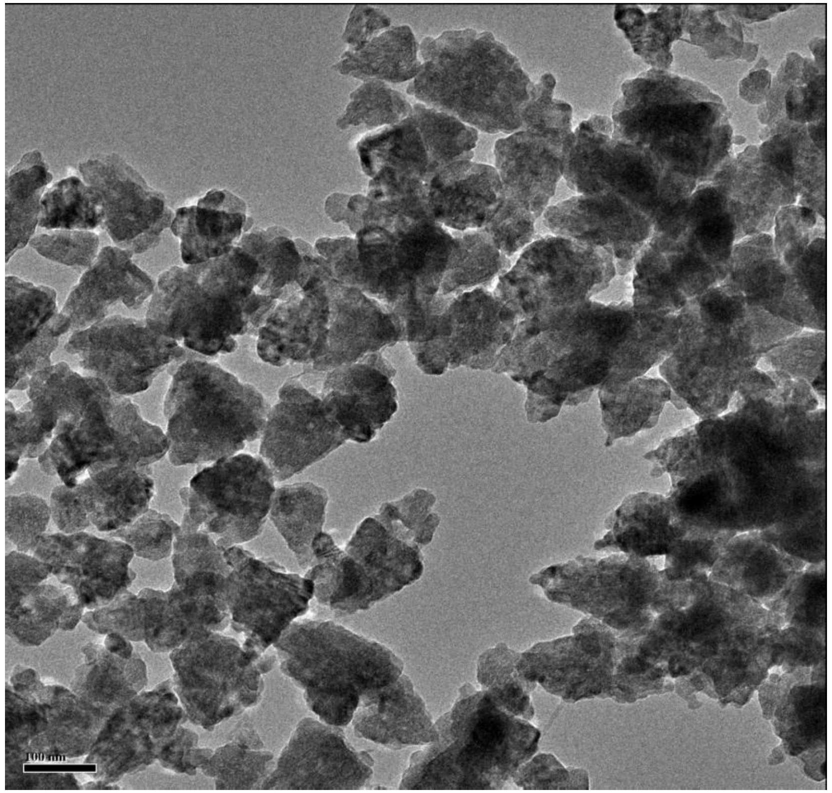
CuO

Length: 52±13 nm; Width: 8±3 nm



ZnO

Size: 90±18 nm



Funded by
the European Union

CS1.2 ZnO and CuO based NEPs

Cotton

Mix
cotton/polyester

ZnO

Reaction time:
30 min
Precursor
concentration
0,0025 M

Reaction time:
45 min
Precursor
concentration
0,0213 M

CuO

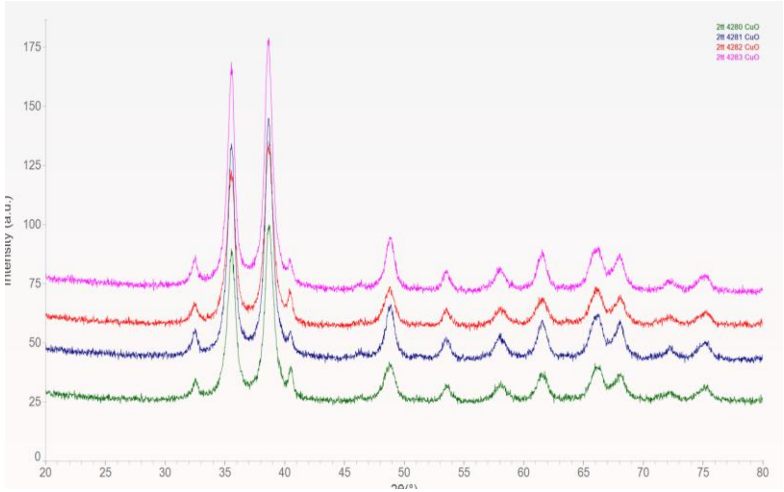
Reaction time:
60 min
Precursor
concentration
0,0288 M

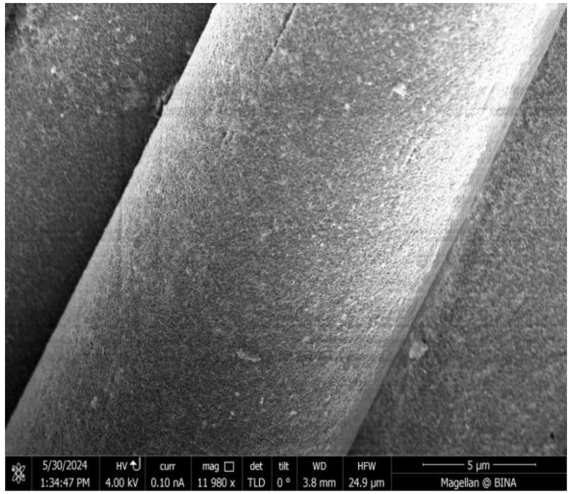
Reaction time:
60 min
Precursor
concentration
0,04 M

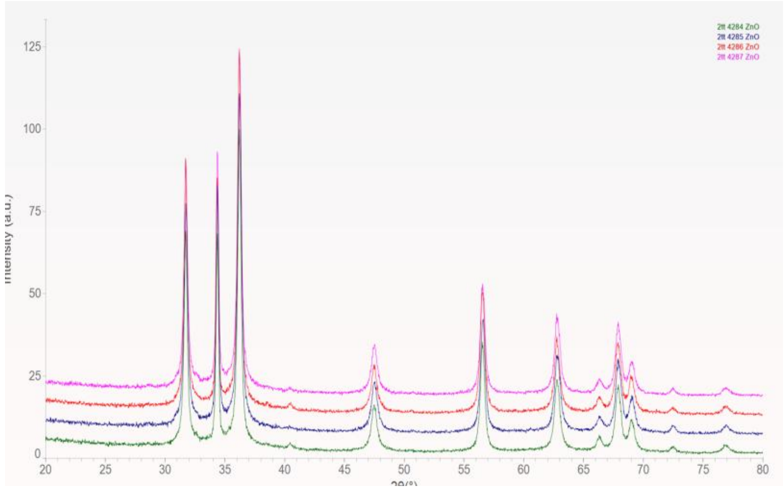
CS1.2. P-CHEM CHARACT.

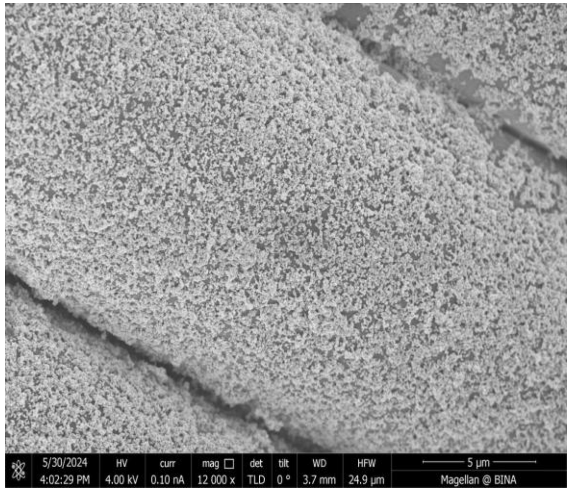
BIU

- Grain size and morphology (TEM)
- Phase composition (XRD)
- Coating homogeneity (SEM)
- Me^{+2} quantity on the fabric, wt% (ICP)
- MeO quantity on the fabric, wt% (ICP)
- Leaching



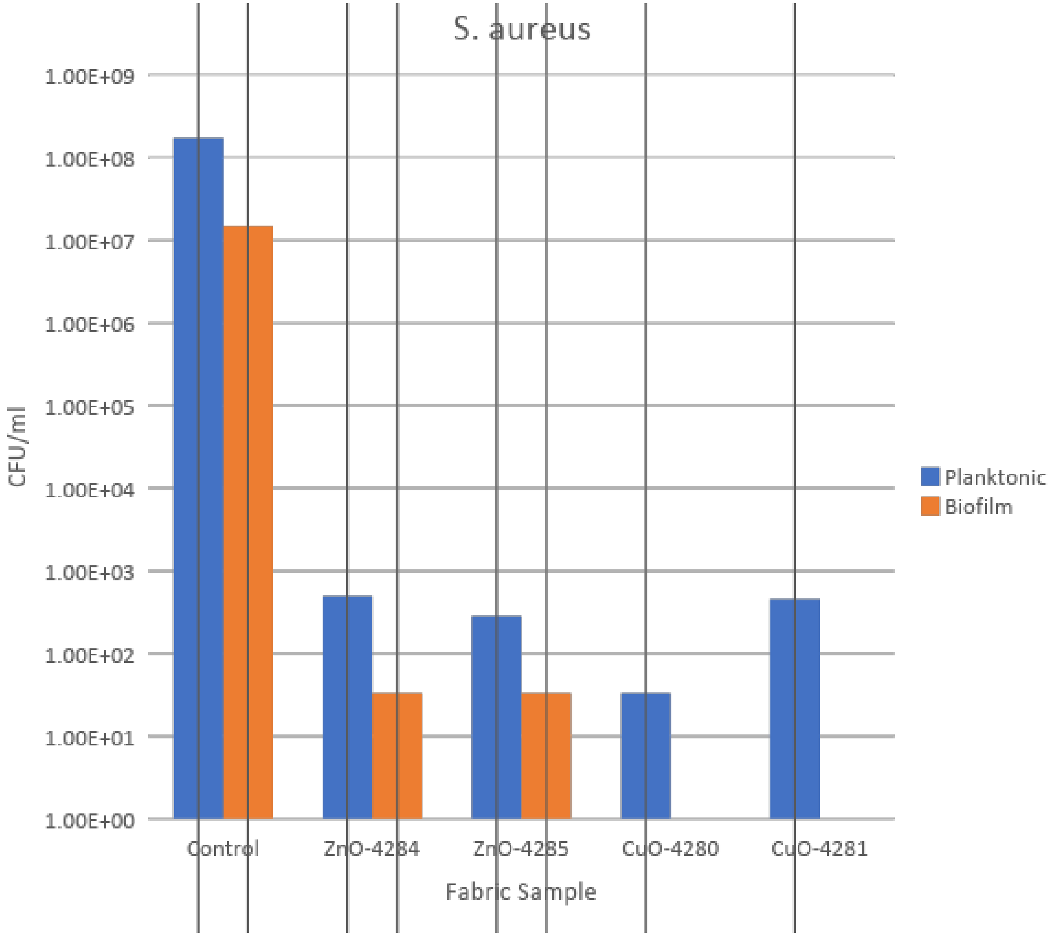


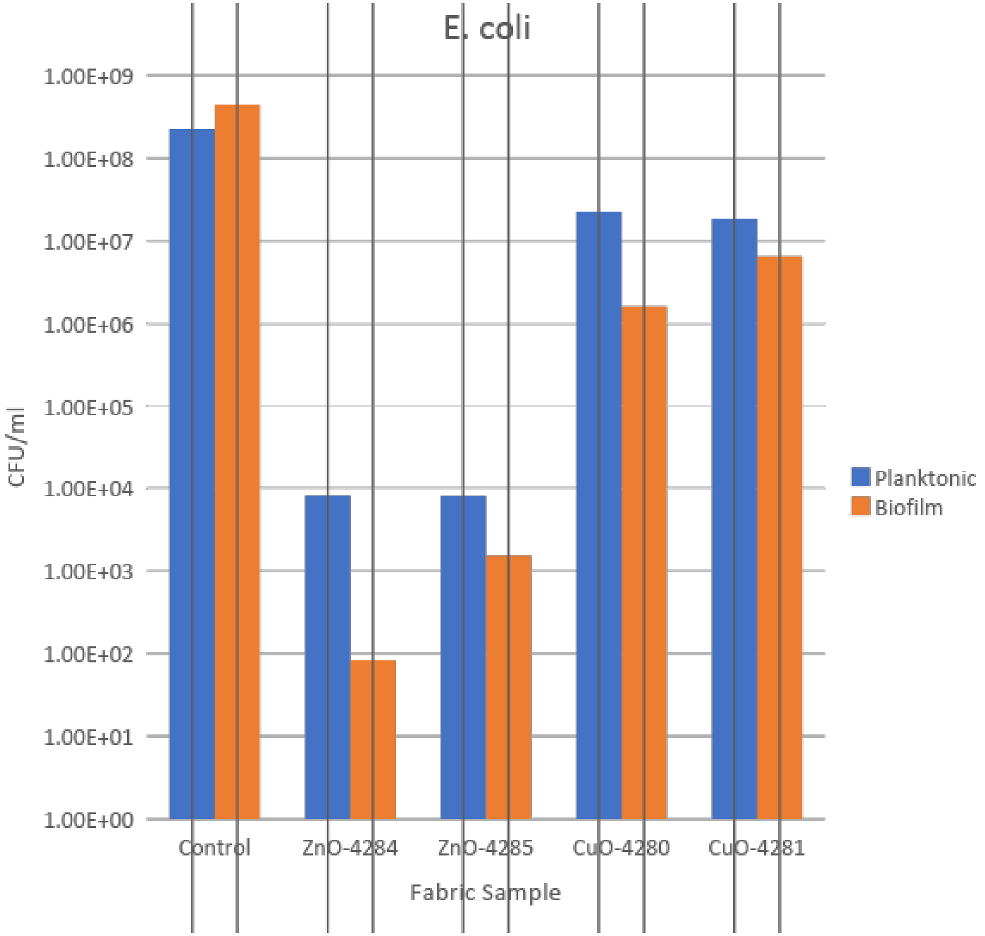




CS1.2 FUNCTIONALITIES / NEPs

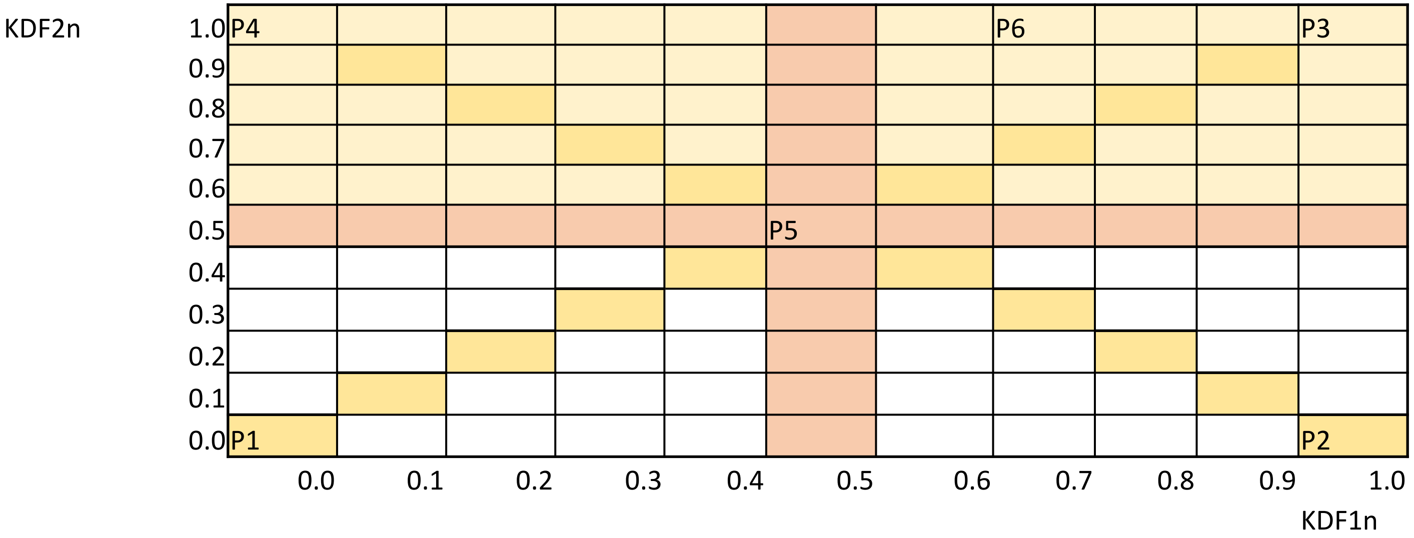
BIU





CS1.2 DoE / NEPs

DoE



	Precursor concentration	Reaction time			
	KDF1	KDF2		KDF1n	KDF2n
P1	0.0025	30.0	P1	0	0
P2	0.0400	30.0	P2	1	0
P3	0.0400	60.0	P3	1	1
P4	0.0025	60.0	P4	0	1
P5	0.0213	45.0	P5	0.5	0.5
P6	0.0288	60.0	P6	0.7	1

Precursor, M (g/mol)		Concentration, M	Weight, g **(X)**	Water volume, ml	Temp., °C	Sonic. power (Hischler), %	Reaction time, min	Batch number
Cotton								
$Zn(Ac)_2*2H_2O$	P1 (P1zc)	0.0025	0.1921	350	20-25	50	30	4309
	P2 (P2zc)	0.04	3.0731	350	20-25	50	30	4310
	P3 (P3zc)	0.04	3.0731	350	20-25	50	60	4311
	P4 (P4zc)	0.0025	0.1921	350	20-25	50	60	4312
	P5 ($P5zc_1$)	0.0213	1.6364	350	20-25	50	45	4313
	P5 ($P5zc_2$)	0.0213	1.6364	350	20-25	50	45	4315
	P5 ($P5zc_3$)	0.0213	1.6364	350	20-25	50	45	4316
	P6 (P6zc)	0.0288	2.2127	350	20-25	50	60	4314
Mix Polyester-cotton 65-35%								
$Zn(Ac)_2*2H_2O$	P1 (P1zm)	0.0025	0.1921	350	20-25	50	30	4317
	P2 (P2zm)	0.04	3.0731	350	20-25	50	30	4318
	P3 (P3zm)	0.04	3.0731	350	20-25	50	60	4319
	P4 (P4zm)	0.0025	0.1921	350	20-25	50	60	4320
	P5 ($P5zm_1$)	0.0213	1.6364	350	20-25	50	45	4321
	P5 ($P5zm_2$)	0.0213	1.6364	350	20-25	50	45	4322
	P5 ($P5zm_3$)	0.0213	1.6364	350	20-25	50	45	4323
	P6 (P6zm)	0.0288	2.2127	350	20-25	50	60	4324
Cotton								
$Cu(Ac)_2*1H_2O$	P1 (P1cc)	0.0025	0.1747	350	19-23	50	30	4325
	P2 (P2cc)	0.04	2.7951	350	19-23	50	30	4326
	P3 (P3cc)	0.04	2.7951	350	19-23	50	60	4327
	P4 (P4cc)	0.0025	0.1747	350	19-23	50	60	4328
	P5 ($P5cc_1$)	0.0213	1.4884	350	19-23	50	45	4329
	P5 ($P5cc_2$)	0.0213	1.4884	350	19-23	50	45	4330
	P5 ($P5cc_3$)	0.0213	1.4884	350	19-23	50	45	4331
	P6 (P6cc)	0.0288	2.0125	350	19-23	50	60	4332
Mix Polyester-cotton 65-35%								
$Cu(Ac)_2*1H_2O$	P1 (P1cm)	0.0025	0.1747	350	18-22	50	30	4333
	P2 (P2cm)	0.04	2.7951	350	18-22	50	30	4334
	P3 (P3cm)	0.04	2.7951	350	18-22	50	60	4335
	P4 (P4cm)	0.0025	0.1747	350	18-22	50	60	4336
	P5 ($P5cm_1$)	0.0213	1.4884	350	18-22	50	45	4337
	P5 ($P5cm_2$)	0.0213	1.4884	350	18-22	50	45	4338
	P5 ($P5cm_3$)	0.0213	1.4884	350	18-22	50	45	4339
	P6 (P6cm)	0.0288	2.0125	350	18-22	50	60	4340

INTEGRANO

BIU

Work done

We have synthesized:

1. ZnO nanoparticles for incorporation into cellulose acetate fibers via electrospinning (CS4, *Bruno Marco*);
2. ZnO and CuO nanoparticles for EcoTox investigations (*Maurizio Gualtieri*, UNIMIB).

NF_CuO • NP • 4280, 4282, 4283	
Provider	BIU
Sample Details	
Sample Description, Components	CuO nanoparticles
Lot Number and synthesis date	NF_CuO NP • 4280, 4282, 4283 (19/05/2024, 20/05/2024)
Total Sample Volume /Weight submitted	4.7 g
Number of Vials submitted	2 pcs
Amount of Sample per Vial	2.55+2.15 g
Concentrations/Weights (please include analytic method)	
Source	$Cu(Ac)_2 \cdot 1H_2O$ solid
Coating	-
Suspension Medium/buffer	dry
Physical and Chemical Properties	
Colour	brown
λ max absorbance (nm)	-
pH	-
ζ potential (mV)	-
IsoElectric Point (IEP)	-
Particle size, nm	Length: 52±13; Width: 8±3
Core-shell/coating information	-
TEM	needle-shaped nanoparticles
XRD	pure copper oxide
Conditions for Storage and Shipment	
Storage Conditions, Details	store at ambient temperature, contact with oxidizing agents
Shipment Conditions	Ambient temperature
Sample Stability at Storage Conditions	24 months
Special Instructions	
Notes	
Expected Outputs / Functionalities	Antibacterial activity

NF_ZnO • NP • 4343, 4344	
Provider	BIU
Sample Details	
Sample Description, Components	ZnO nanoparticles
Lot Number and synthesis date	NF_ZnO NP • 4343, 4344 (05/01/2025)
Total Sample Volume /Weight submitted	2.65 g
Number of Vials submitted	2 pcs
Amount of Sample per Vial	2.0+0.65 g
Concentrations/Weights (please include analytic method)	
Source	$Zn(Ac)_2 \cdot 2H_2O$ solid
Coating	-
Suspension Medium/buffer	dry
Physical and Chemical Properties	
Colour	white
λ max absorbance (nm)	-
pH	-
ζ potential (mV)	-
IsoElectric Point (IEP)	-
Particle size, nm	90±18
Core-shell/coating information	-
TEM	leaf-shaped nanoparticles
XRD	pure zinc oxide
Conditions for Storage and Shipment	
Storage Conditions, Details	store at ambient temperature, do not freeze, do not heat, and avoid contact with oxidizing agents
Shipment Conditions	Ambient temperature
Sample Stability at Storage Conditions	24 months
Special Instructions	
Notes	**Note**
Expected Outputs / Functionalities	Antibacterial activity

NF_ZnO • NP • 4341, 4342	
Provider	BIU
Sample Details	
Sample Description, Components	ZnO nanoparticles
Lot Number and synthesis date	NF_ZnO NP • 4341, 4342 (05/01/2025)
Total Sample Volume /Weight submitted	4.52 g
Number of Vials submitted	2 pcs
Amount of Sample per Vial	2.25+2.27 g
Concentrations/Weights (please include analytic method)	
Source	$Zn(Ac)_2 \cdot 2H_2O$ solid
Coating	-
Suspension Medium/buffer	dry
Physical and Chemical Properties	
Colour	white
λ max absorbance (nm)	-
pH	-
ζ potential (mV)	-
IsoElectric Point (IEP)	-
Particle size, nm	90±18
Core-shell/coating information	-
TEM	leaf-shaped nanoparticles
XRD	pure zinc oxide
Conditions for Storage and Shipment	
Storage Conditions, Details	store at ambient temperature, do not freeze, do not heat, and avoid contact with oxidizing agents
Shipment Conditions	Ambient temperature
Sample Stability at Storage Conditions	24 months
Special Instructions	
Notes	**Note**
Expected Outputs / Functionalities	Antibacterial activity

Work planned for the NEXT 6 MONTHS

- We have started to produce a set of textiles coated with CuO/ZnO, consisting of a total of 32 samples, based on a Design of Experiments (DoE) matrix for subsequent leaching investigations. The key decision factors (KDFs) being examined include KDF1 (precursor concentration) and KDF2 (reaction time). This study's key performance indicators (KPIs) are coating concentration and antibacterial properties.
- Investigating the functionality, and leaching behavior of the ZnO/CuO coating.

INTEGRANO

CNR-ISMN

INTEGRANO

MULTIDIMENSIONAL INTEGRATED QUANTITATIVE APPROACH TO ASSESS SAFETY AND SUSTAINABILITY OF NANOMATERIALS IN REAL CASE LIFE CYCLE SCENARIOS USING NANOSPECIFIC IMPACT CATEGORIES

Case Study n°2

Water membranes

PROJECT HUB360

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

CNR ISSMC Istituto di Scienza, Tecnologia e Sostenibilità per lo Sviluppo dei Materiali Ceramici

Bar-Ilan University אוניברסיטת בר־אילן

CNRISMN Istituto per lo Studio dei Materiali Nanostrutturati

B4C

centi Centre for Nanotechnology and Advanced Materials

INTEGRANO

Which nanomaterials in CS2?

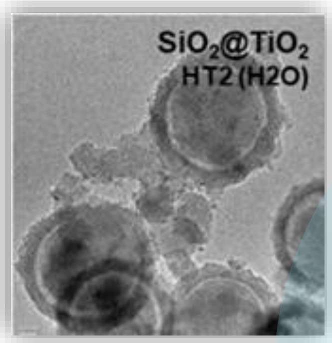
CNR-ISMN

General Scope: More sustainable production of functional coatings onto SiC membranes for wastewater treatment

Synthesis
Functional nanomaterials (Perovskite oxide-based and Titania –based active phases)

Incorporation
Nano-enabled SiC-based materials (SiC membrane and scraps)

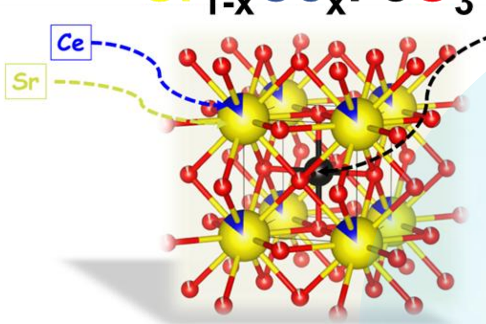
Use
Thermocatalytic and antimicrobial wastewater treatment



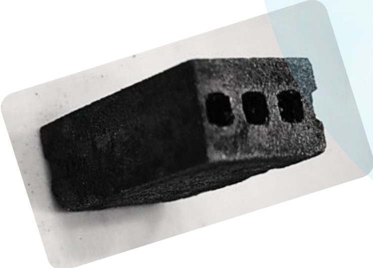
Anti Microbial (AM) unit

- The functional nanomaterials is $SiO_2@TiO_2$ with core-shell structure
- It has antimicrobial activity
- It is used after deposition onto SiC flat membranes

$Sr_{1-x}Ce_xFeO_3$



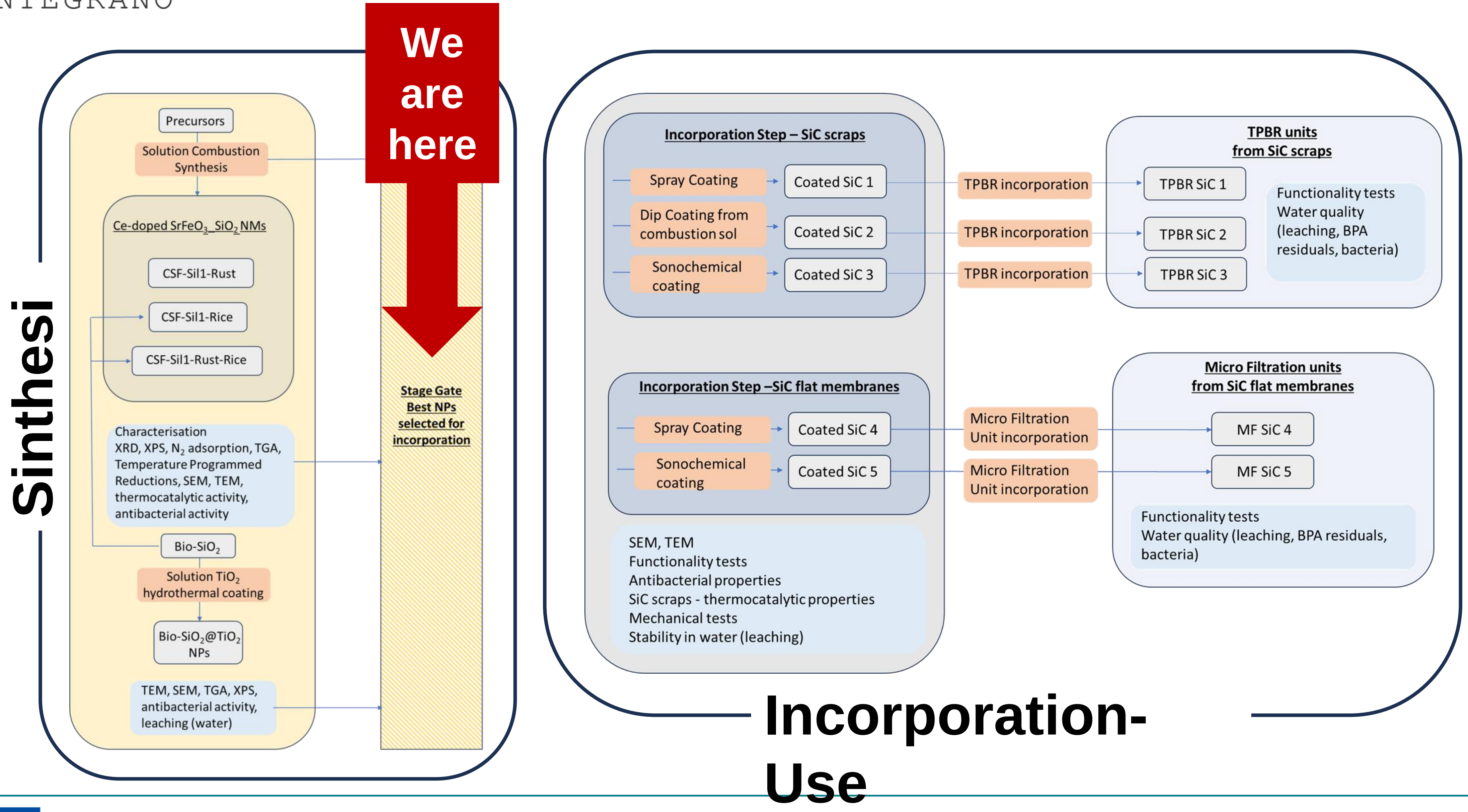
\+ Silica



Tthermocatalytic (TPBR) unit

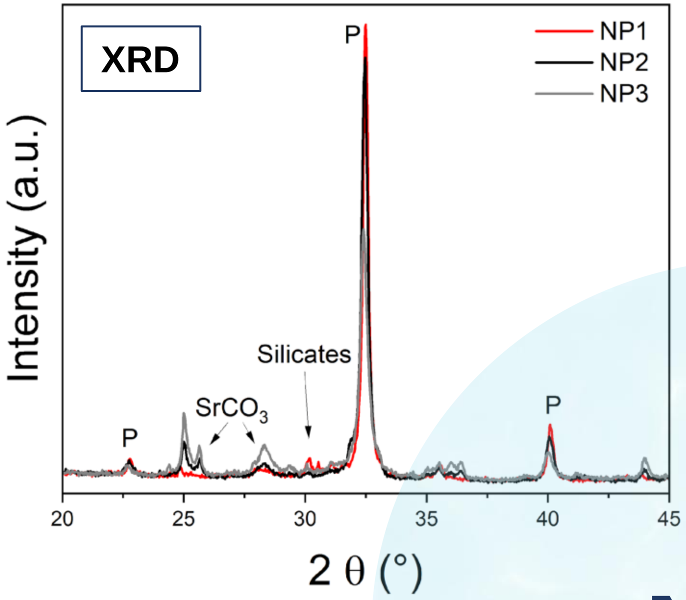
- The functional nanomaterial is a Ce-doped $SrFeO_3/SiO_2$ nanocomposite
- It has thermocatalytic activity for the abatement of organic contaminants
- It is used after deposition onto SiC scraps

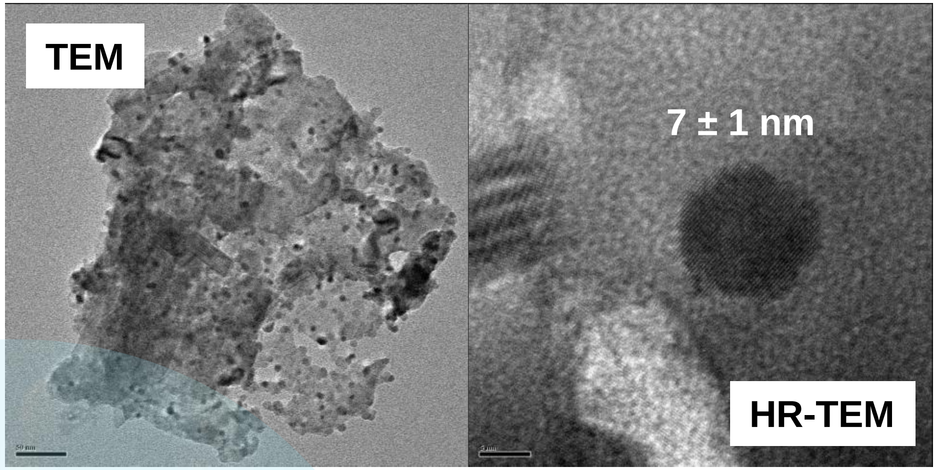
CS2 status

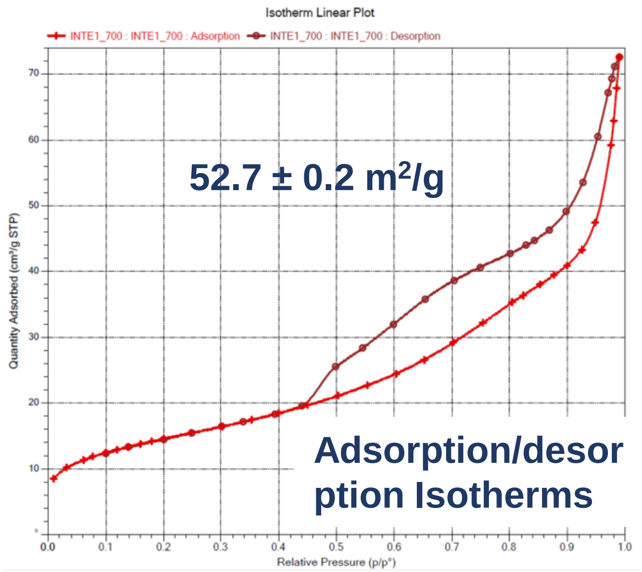

We are here
Sinthesi
Precursors
Solution Combustion Synthesis
Ce-doped $SrFeO_3$_SiO_2 NMs
CSF-Sil1-Rust
CSF-Sil1-Rice
CSF-Sil1-Rust-Rice
Characterisation XRD, XPS, N_2 adsorption, TGA, Temperature Programmed Reductions, SEM, TEM, thermocatalytic activity, antibacterial activity
Bio-SiO_2
Solution TiO_2 hydrothermal coating
Bio-SiO_2@TiO_2 NPs
TEM, SEM, TGA, XPS, antibacterial activity, leaching (water)
Stage Gate Best NPs selected for incorporation
Incorporation Step – SiC scraps
Spray Coating
Coated SiC 1
Dip Coating from combustion sol
Coated SiC 2
Sonochemical coating
Coated SiC 3
TPBR incorporation
TPBR incorporation
TPBR incorporation
TPBR units from SiC scraps
TPBR SiC 1
TPBR SiC 2
TPBR SiC 3
Functionality tests Water quality (leaching, BPA residuals, bacteria)
Incorporation Step –SiC flat membranes
Spray Coating
Coated SiC 4
Sonochemical coating
Coated SiC 5
Micro Filtration Unit incorporation
Micro Filtration Unit incorporation
Micro Filtration units from SiC flat membranes
MF SiC 4
MF SiC 5
Functionality tests Water quality (leaching, BPA residuals, bacteria)
SEM, TEM
Functionality tests
Antibacterial properties
SiC scraps - thermocatalytic properties
Mechanical tests
Stability in water (leaching)
Incorporation-Use

First optimization campaign

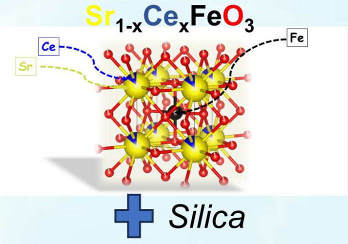
CNR-ISMN

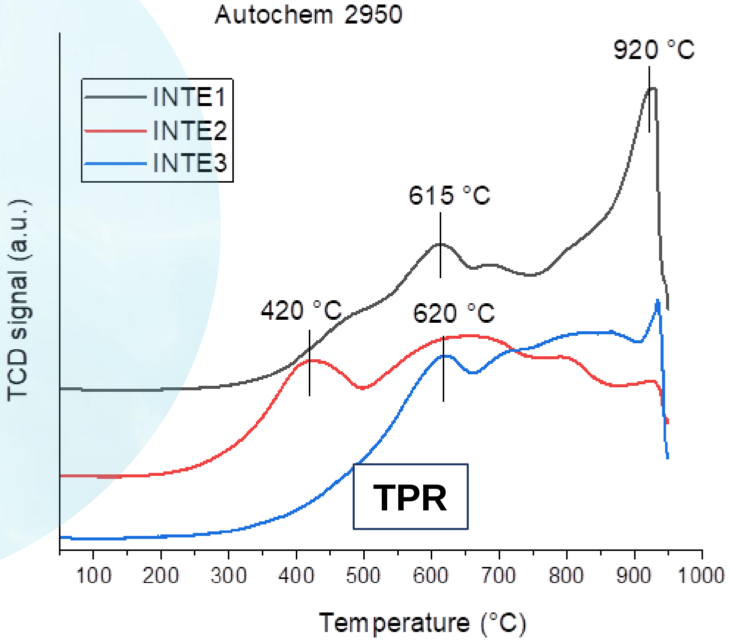


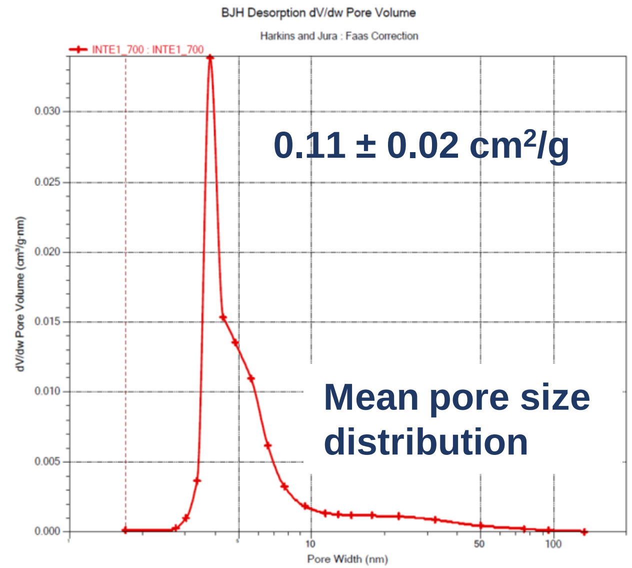




NP.1







Antibacterial activity

MIC (mg/ml)			
	NP1	NP2	NP3
S. aureus	>2.5	>2.5	2.5
E. coli	0.625	>2.5	>2.5

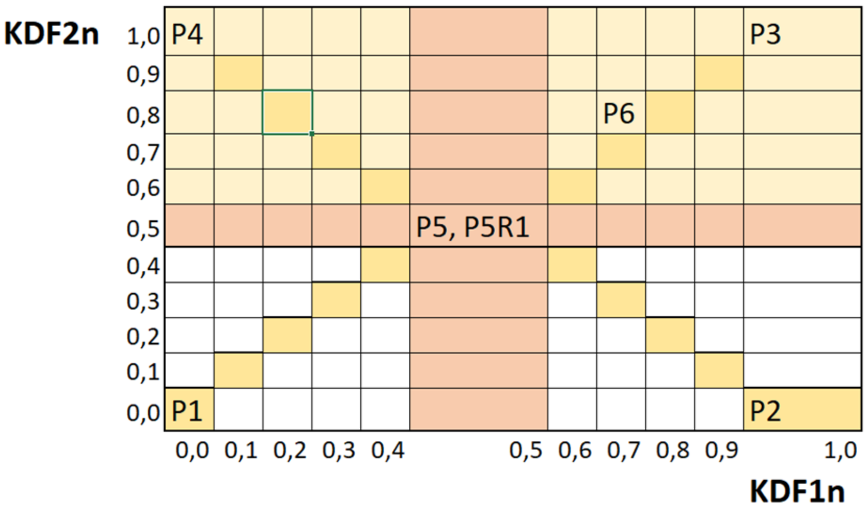
MBC (mg/ml)			
	NP1	NP2	NP3
S. aureus	>2.5	>2.5	>2.5
E. coli	>2.5	>2.5	>2.5

Funded by the European Union

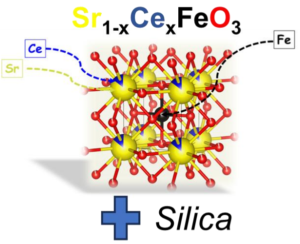
Second optimization campaign

		pH	Phi (red:ox)			
Sample ID		KDF1	KDF2		KDF1n	KDF2n
P1	**NP4**	3.00	1.00	P1	0	0
P2	**NP5**	7.00	1.00	P2	1	0
P3	**NP6**	7.00	1.50	P3	1	1
P4	**NP7**	3.00	1.50	P4	0	1
P5	**NP8**	5.00	1.25	P5	0.5	0.5
P5R1	**NP9**					
P6	**NP10**	5.80	1.40	P6	0.7	0.8
R1=first Replica						

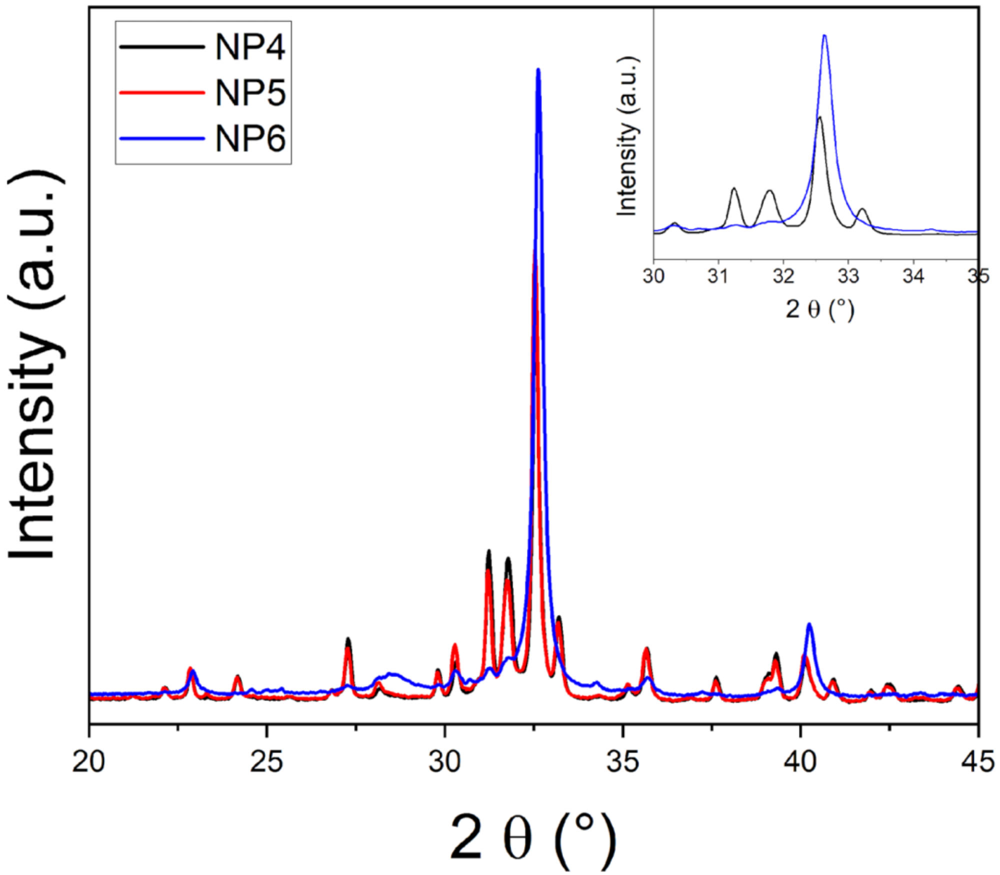
DoE Matrix

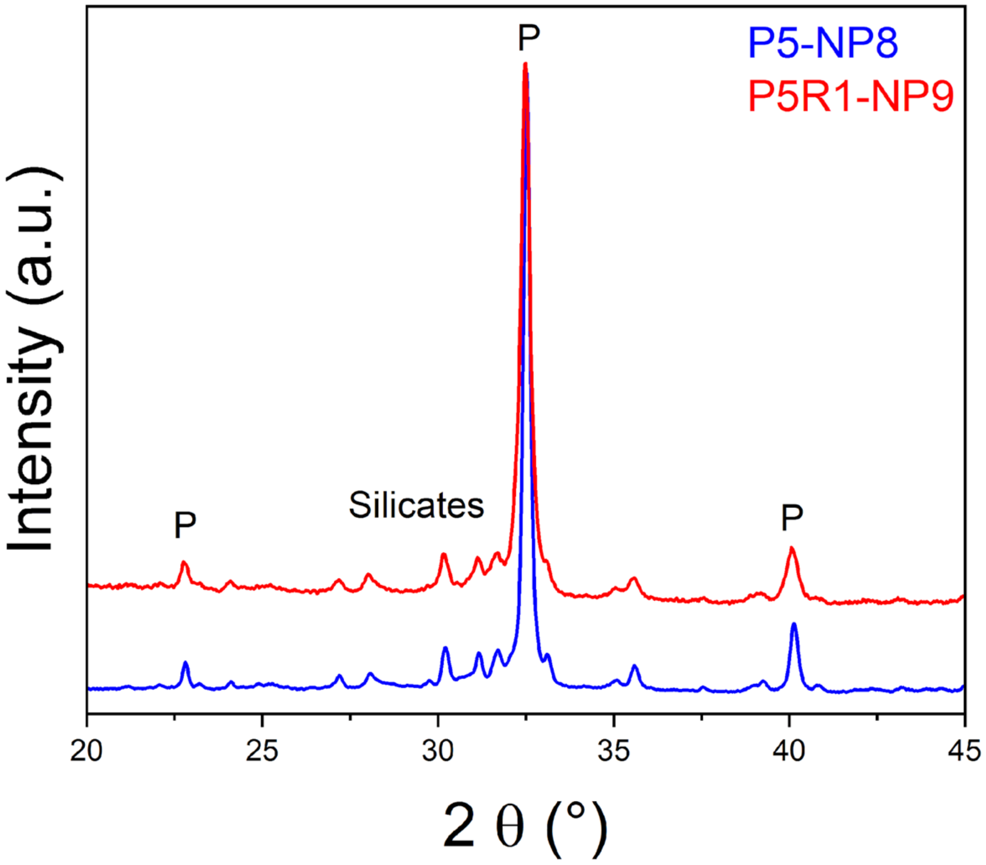


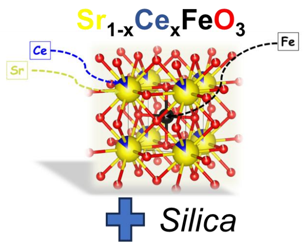
Clear differences have been noticed already in the synthesis process and in the as-burned powder appearance



Second optimization campaign

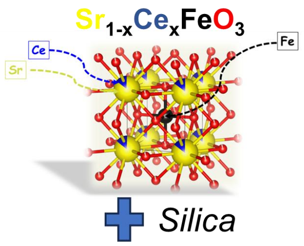






- ❑ XRD characterization was performed for all the samples
- ❑ Very evident differences are present among the samples regarding the crystallinity of the powders
- ❑ The replica is identical to the first batch

Work done so far



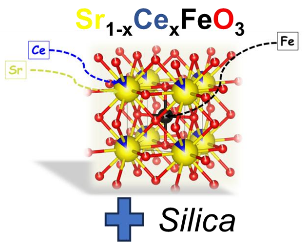
CSF-SIL Thermocatalysts

1. Characterization of the first 3 Nano Forms was almost completed
2. A best sample as a starting point for the next experiments with DoE matrix was selected
3. 40 g of (bio) SiO_2 for the synthesis of the new Nano Forms were prepared
4. 6 new Nano Forms + 1 replica according to the DoE matrix created by Project Hub were prepared
5. 1 Nano Form without silica was also prepared as a reference
6. XRD characterization was completed
7. Distribution of the 7 Nano Forms among the partners for the characterization campaign was organized

(bio)-SiO_2@TiO_2 Antibacterials

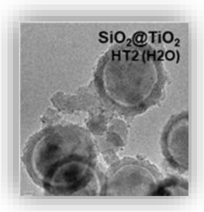
1. Characterization of the (bio)-SiO_2 Nano Forms was almost completed
2. Synthesis of the first (bio) SiO_2@TiO_2 Nano Forms was performed

Work planned for the NEXT 6 MONTHS



CSF-SIL Thermocatalysts

- SEM-EDX and thermocatalytic tests of the in batch mode of the first 10 Nano Forms (B4C)
- TEM and antibacterial tests of the new Nano Forms (BIU)
- Synthesis of a replica of four Nano Forms (CNR-ISMN) and delivery to UNIMIB for Eco-toxicological characterization
- TPR and N_2 adsorption characterization of the new Nano Forms (CNR-ISMN)
- Selection of the best Nano Form/s (All)
- Synthesis of a replica of the best Nano Form (CNR-ISMN) and delivery to CNR-ISSMC for leaching tests



(bio)-SiO_2@TiO_2 Antibacterials

- N_2 adsorption characterization
- Selection of the best experimental conditions for the Nano Form
- Sinthesis of a replica for the incorporation step

CNR-IPCB and SCITEC

INTEGRANO

MULTIDIMENSIONAL INTEGRATED QUANTITATIVE APPROACH TO ASSESS SAFETY AND SUSTAINABILITY OF NANOMATERIALS IN REAL CASE LIFE CYCLE SCENARIOS USING NANOSPECIFIC IMPACT CATEGORIES

Case Study n°3

Bio-Based nanocomposite PU foam

Letizia Verdolotti, Laura Boggioni

Partners involved

CS 3 Bio-BASED PU FOAM -NEPs

CNR-IPCB and SCITEC

CASE STUDY n°3 outline

1. Case Study 3 overview
2. Specific Goals
3. Scope and Early Synthesis-Process production
4. Results delivery

CS 3 Bio-BASED PU FOAM -NEPs

CNR-IPCB and SCITEC

NMs
NanoMaterals

NEPs
Nano Enabled Products

Selection of nanofiller $Bio\text{-}SiO_2$
CENTI

Functionalization of nanofiller: $Bio\text{-}SiO_2\text{-}F$
CNR-SCITEC

Ecotox monitoring of functionalization process charge to **UNIMIB**

Incorporation of $Bio\text{-}SiO_2\text{-}F$ in PUR foams

Production at pilot scale of PUR foams

Cutting step of produced foams

CNR-IPCB

DoE

Original Design

NMs FILLER
Mixture of $Bio\text{-}SiO_2\text{-}F$/ diatomite
+
PROCESS TECHNOLOGY
Open mould configuration

Re-Design

NMs FILLER
Mixture of : $Bio\text{-}SiO_2\text{-}F$/ diatomite
+
PROCESS TECHNOLOGY
Mould with lid configuration

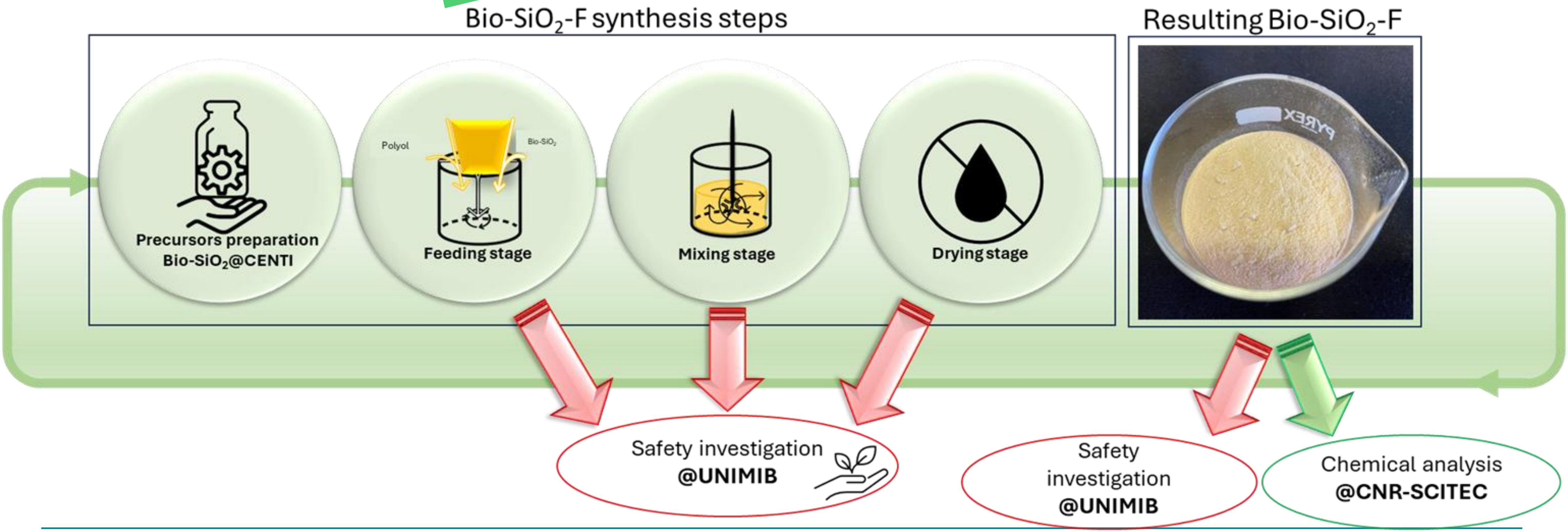
NMs FILLER
Mixture of : $Bio\text{-}SiO_2\text{-}F$/ G-Beton
+
PROCESS TECHNOLOGY
Open mould configuration

NMs FILLER
Mixture of : $Bio\text{-}SiO_2\text{-}F$/ G-Beton
+
PROCESS TECHNOLOGY
Mould with lid configuration

Ecotox monitoring in charge to **CNR-ISAC, ARCHE and UNIMIB** during the PU process production and cutting

1. Case Study 3.a overview

The CASE STUDY n°3 aims to a) monitor the ecotoxicity of the production process of **Bio-SiO_2 Functionalization.** (**CNR-SCITEC**)



CS 3 NANOFORMS

2. Specific Goals

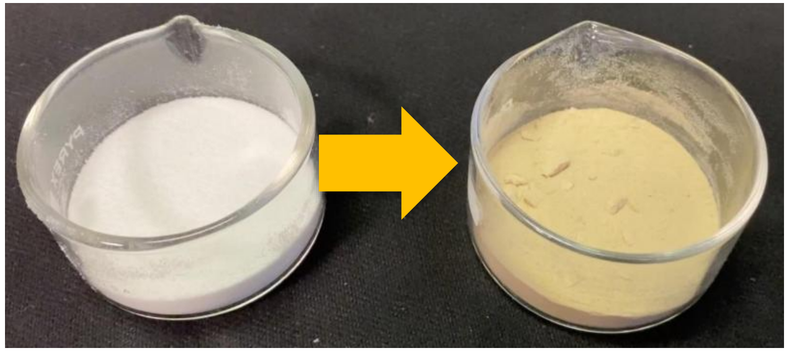
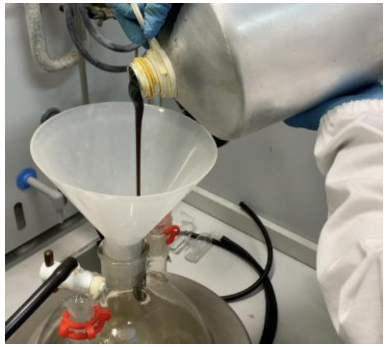
CNR-SCITEC aims to functionalize&characterize bio-SiO_2 nanofillers @CENTI

<table>
<tr><th colspan="11">KDFs</th></tr>
<tr><th>List of reagents</th><th colspan="5">PROCESS PRODUCTION STEPS</th><th>Design</th><th>Characterization</th><th>Partners involved</th></tr>
<tr><td>Bio-SiO_2</td><td rowspan="2">Drying 1</td><td rowspan="2">Weighing 2</td><td rowspan="3">Addition&Mixing Step 3</td><td rowspan="3">Grafting reaction 4</td><td rowspan="3">Drying 5</td><td rowspan="3">Production of functionalized Bio-SiO_2 with polyol: T, SiO_2/polyol ratio, reaction time</td><td rowspan="3">•TGA
•FTIR
•Ecotoxicty</td><td rowspan="3">CNR-SCITEC
CNR-IPCB
UNIMIB
CNR-ISAC
CENTI</td></tr>
<tr><td>Polyol</td></tr>
<tr><td>Potassium hydroxide (KOH)</td><td colspan="2">Weighing
2</td></tr>
</table>

Funded by the European Union

3. Scope and Early Synthesis-Process production

Bio-SiO_2-F functionalization

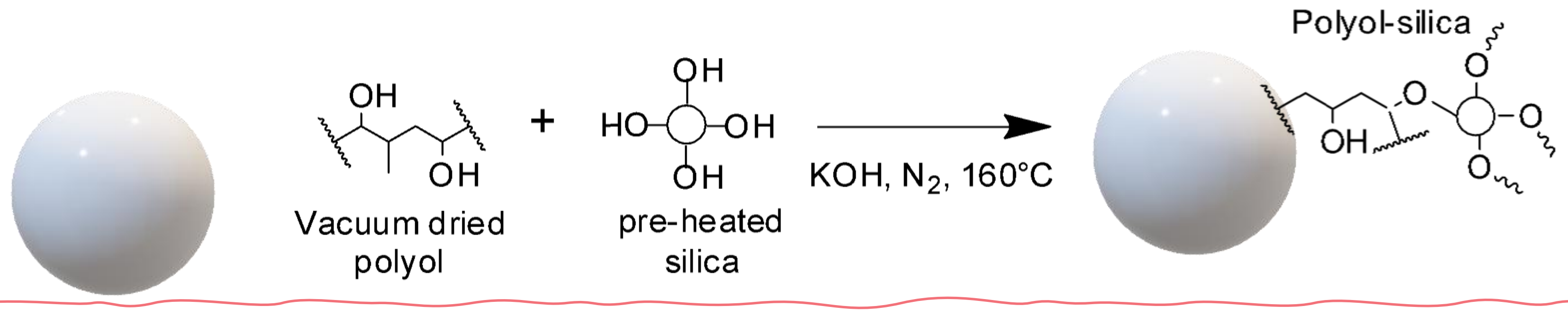




CS 3 NANOFORMS

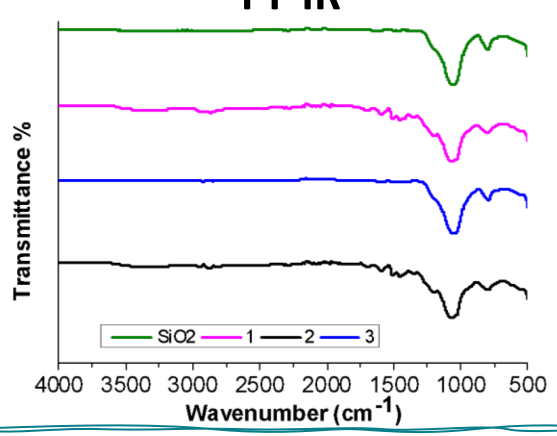
4. Results delivery

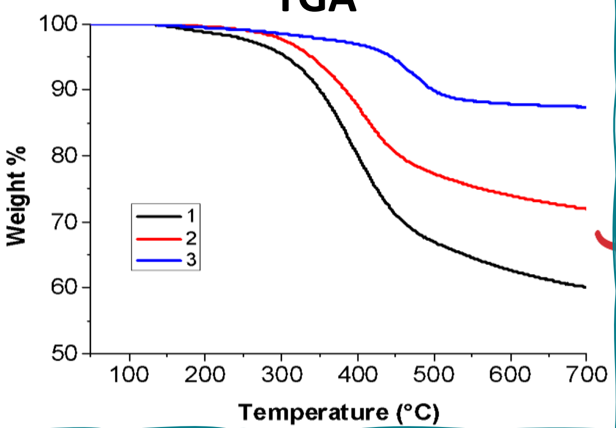
DESIGN:
Bio-SiO_2

→ Functionalization of Bio-SiO_2
→ Characterization of Bio-SiO_2-F



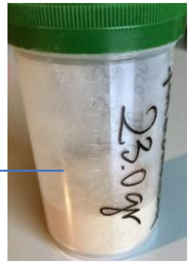
Chemical-physical properties





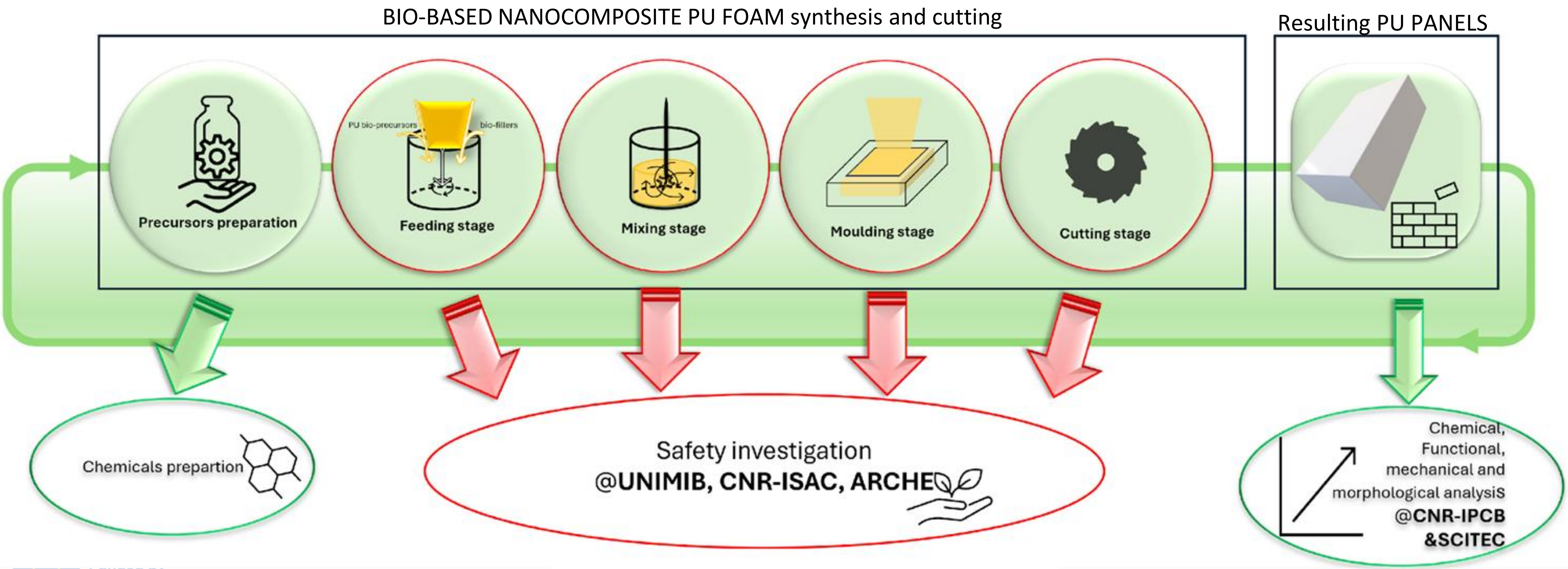
Sample	Grafted polyol, wt%
1	64%
2	42%
3	10%

selected



1. Case Study 3.b overview

The CASE STUDY n°3 aims to b) monitor the ecotoxicity of the production process of **BIO-BASED NANOENABLED PU FOAM** from the synthesis step at pilot scale to the realization of foam panels by cutting process. (**CNR-IPCB**)



CS 3 Bio-BASED PU FOAM -NEPs

CNR-IPCB and SCITEC

2. Specific Goals

CNR-IPCB aims to synthesize&characterize Nanocomposisite Polyurethane Foams

KDFs

List of reagents	PROCESS PRODUCTION STEPS							End-of-life
Castor oil	Mixing step 1	Addion&Mixing step 2	Mixing step 3	Mixing step 4	Polymerization /Foaming step	PANELS PRODUCTION	Cutting step	Existing solution: Chemical and mechanical recycling
n-pentane (blowing agent)								
Mixture of dual fillers (5wt%): Bio-SiO_2-F*+ sustainable filler[&]	Weighing 1							
Bio-based Polyol/additives[$]	Weighing 2							
Isocyanate-MDI	Weighing 3							
OPEN MOULD or MOULD with Lid								

[$]Catalysts/Silicone surfactants/H_2O; *BioSilica@CENTI functionalized by SCITEC; [&] GasBeton or Diatomite

CS 3 Bio-BASED PU FOAM -NEPs

CNR-IPCB and SCITEC

2. Scope and Early Synthesis-Process production

ORIGINAL DESIGN:
Nanocomposite PU foams &
Bio-SiO_2-F + Diatomite/OP ([1], [2], [3])

KDFs		List of process production steps	Design	Characterizations	Partners involved
OPEN MOULD-OP	Fillers: Bio-SiO2-F + DIATOMITE	Mixing step 1	Production of PU batches @defined quantities, process and rheological parameters: T, mixing time, humidity, volume to produce.	Rheological, Ecotoxicity	**CNR-IPCB, CNR-SCITEC, CNR ISAC, UNIMIB, ARCHE**
		Weighing 1			
		Mixing step 2			
		Weighing 2			
		Mixing step 3			
		Weighing 3			
		Mixing step 4			
		CUTTING PANELS	Production of PU panels @defined shape: $65x63x5cm^3$	Chemico-physical, morphological, mechanical and functional. Ecotoxicity	

CS 3 Bio-BASED PU FOAM -NEPs

3. Scope and Early Synthesis-Process production

RE-DESIGN:
Nanocomposite PU foams &
Bio-SiO_2-F + Diatomite/LID ([10], [11], [12])

KDFs		List of process production steps	Design	Characterizations	Partners involved
MOULD with LID-LID	Fillers: Bio-SiO_2-F + DIATOMITE	Mixing step 1	Production of PU batches @defined quantities, process and rheological parameters: T, mixing time, humidity, volume to produce.	Rheological, Ecotoxicity	**CNR-IPCB, CNR-SCITEC, CNR ISAC, UNIMIB, ARCHE**
		Weighing 1			
		Mixing step 2			
		Weighing 2			
		Mixing step 3			
		Weighing 3			
		Mixing step 4			
		CUTTING PANELS	Production of PU panels @defined shape: $65x63x5cm^3$	Chemico-physical, morphological, mechanical and functional. Ecotoxicity	

CS 3 Bio-BASED PU FOAM -NEPs

3. Scope and Early Synthesis-Process production

RE-DESIGN:
Nanocomposite PU foams &
Bio-SiO_2-F + GB/OP ([4], [5], [6])

KDFs		List of process production steps	Design	Characterizations	Partners involved
OPEN MOULD-OP	**Fillers: Bio-SiO_2-F + GASBETON**	Mixing step 1	Production of PU batches @defined quantities, process and rheological parameters: T, mixing time, humidity, volume to produce.	Rheological, Ecotoxicity	**CNR-IPCB, CNR-SCITEC, CNR ISAC, UNIMIB, ARCHE**
		Weighing 1			
		Mixing step 2			
		Weighing 2			
		Mixing step 3			
		Weighing 3			
		Mixing step 4			
		CUTTING PANELS	Production of PU panels @defined shape: $65x63x5cm^3$	Chemico-physical, morphological, mechanical and functional. Ecotoxicity	

CS 3 Bio-BASED PU FOAM -NEPs

CNR-IPCB and SCITEC

3. Scope and Early Synthesis-Process production

RE-DESIGN:
Nanocomposite PU foams &
Bio-SiO_2-F + GB/LID ([7], [8], [9])

KDFs		List of process production steps	Design	Characterizations	Partners involved
MOULD with LID-LID	Fillers: Bio-SiO_2-F + GASBETON	Mixing step 1	Production of PU batches @defined quantities, process, and rheological parameters: T, mixing time, humidity, volume to produce.	Rheological, Ecotoxicity	**CNR-IPCB, CNR-SCITEC, CNR ISAC, UNIMIB, ARCHE**
		Weighing 1			
		Mixing step 2			
		Weighing 2			
		Mixing step 3			
		Weighing 3			
		Mixing step 4			
		CUTTING PANELS	Production of PU panels @defined shape: $65x63x5cm^3$	Chemico-physical, morphological, mechanical and functional. Ecotoxicity	

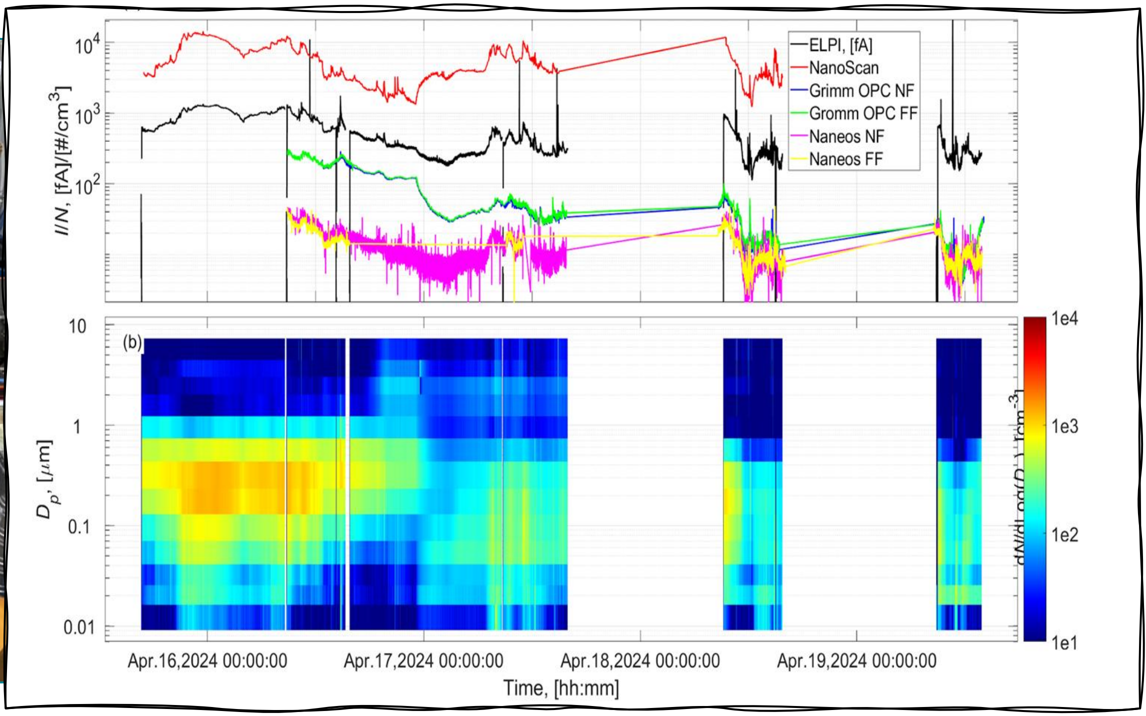
CS 3 Bio-BASED PU FOAM -NEPs

CNR-IPCB and SCITEC

DESIGN and RE-DESIGN *IN*

Joint Campaign

CNR-IPCB, CNR-SCITEC, CNR ISAC, UNIMIB, ARCHE



CS 3 Bio-BASED PU FOAM -NEPs

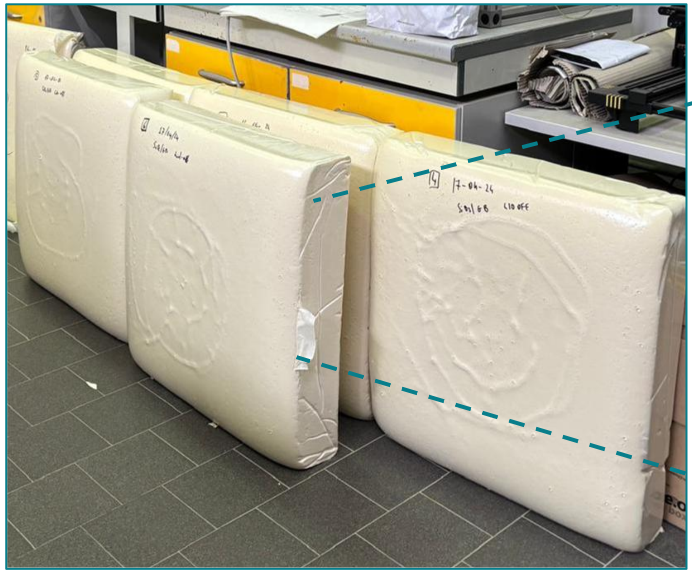
CNR-IPCB and SCITEC

4. Results delivery

DESIGN & RE-DESIGN:

Nanocomposite PU foams characterizations

- → Rheological
- → Chemico-physical
- → Morphological
- → Mechanical
- → functional



Evaluation of the effect of design and re-design on final properties of Nanocomposite PU foams

CS 3 Bio-BASED PU FOAM -NEPs

CNR-IPCB

Bio-SiO_2-F + D [Day 1 & Day 4]

4. Results delivery

Nanocomposite PU foams characterizations :

PROCESS TECHNOLOGY	NEPs	MECHANICAL PROPERTIES			FUNCTIONAL PROPERTIES
		ρ (kg/m_3)	σ (MPa)	E(MPa)	λ (W/mk)
Open Mould [Day 1]	Bio-SiO_2-F + D /OP [1]	114.35 ± 0.01	0.98 ± 0,05	18.91 ± 0.41	0.034
	[2]	107.33 ± 0.58	0.95 ± 0,04	21.20 ± 6.15	0.034
	[3]	108.00 ± 1.00	0.98 ± 0,02	26.06 ± 1.46	0.034
	Average	**109.9 ± 3.87**	**0.97 ± 0,02**	**22.06 ±3.65**	**0.034**
Mould with LID [Day 4]	Bio-SiO_2-F + D /LID [10]	95.67 ± 1.15	0.87 ± 0.12	18.62 ± 3.73	0.034
	[11]	107.33 ± 1.15	0.91 ± 0.01	22.92 ± 2,58	0.034
	[12]	110.33 ± 0.58	0.96 ± 0.07	21.86 ± 3.75	0.034
	Average	**104.44 ± 7.75**	**0.91 ± 0.04**	**21.14 ± 2.4**	**0.034**

CS 3 Bio-BASED PU FOAM -NEPs

CNR-IPCB

Bio-SiO2-F + GB [Day 2 & Day 4]

4. Results delivery

Nanocomposite PU foams characterizations :

PROCESS TECHNOLOGY	NEPs	MECHANICAL PROPERTIES			FUNCTIONAL PROPERTIES
		ρ (kg/m_3)	σ (MPa)	E(MPa)	λ (W/mk)
Open Mould [Day 2]	Bio-SiO_2-F + GB /OP [4]	103.00 ± 1.00	0.86 ± 0.02	22.85 ± 1.59	0.034
	[5]	104.33 ± 1.15	0.88 ± 0.05	29.57 ± 1.05	0.034
	[6]	100.67 ± 0.58	0.84 ± 0.02	21.26 ± 1.78	0.034
	Average	**102.67 ± 1.86**	**0.86 ± 0.03**	**24.56 ± 4.41**	**0.034**
Mould with LID [Day 4]	Bio-SiO_2-F + GB /LID [7]	103.67 ± 0.58	0.82 ± 0.03	20.04 ± 3.98	0.034
	[8]	101.33 ± 0.50	0.84 ± 0.01	22.65 ± 1.02	0.034
	[9]	103.50 ± 1.12	0.81 ± 0.02	20.58 ± 2.35	0.034
	Average	**103.50 ± 2.09**	**0.82 ± 0.02**	**21.09 ± 1.38**	**0.034**

CS 3 Bio-BASED PU FOAM -NEPs

CNR-IPCB and SCITEC

4. Results delivery

ORIGINAL DESIGN:

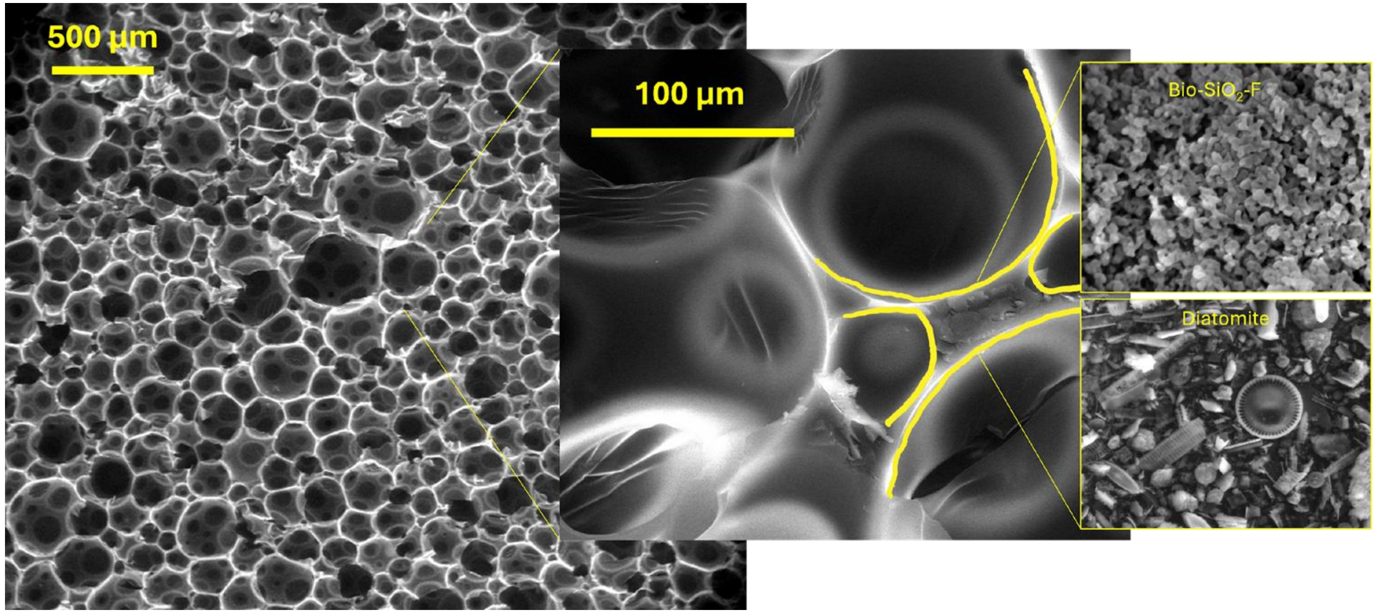
Nanocomposite PU foams &

Bio-SiO_2-F + Diatomite/OP

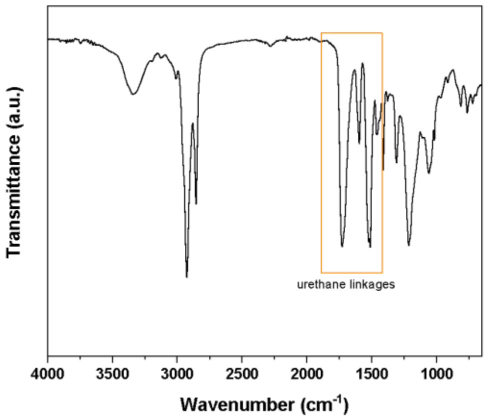
Bio-SiO_2-F + D /OP [1]
[2]
[3]

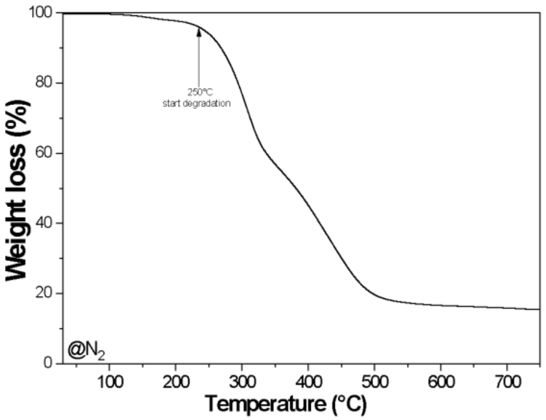
- → Rheological
- → Chemico-physical
- → Morphological
- → Mechanical
- → functional

Morphological properties



Chemico-physical properties





CS 3 Bio-BASED PU FOAM -NEPs

Next 6 months

DESIGN and RE-DESIGN:

Nanocomposite PU foams **characterizations to be completed**

- Rheological
- Chemico-physical
- Morphological
- Mechanical
- Functional

Thanks for your attention

CNR | iPCB Institute of Polymers, Composites and Biomaterials

SCITEC ISTITUTO DI SCIENZE E TECNOLOGIE CHIMICHE GIULIO NATTA

Funded by
the European Union

INTEGRANO

MULTIDIMENSIONAL INTEGRATED QUANTITATIVE APPROACH TO ASSESS SAFETY AND SUSTAINABILITY OF NANOMATERIALS IN REAL CASE LIFE CYCLE SCENARIOS USING NANOSPECIFIC IMPACT CATEGORIES

CASE STUDY N.4

Air Filter Media

Annual General Meeting
29th - 30th January 2025
Turin - Italy

This project has received funding from the European Union's Horizon Europe research and innovation programme under GA No 101138414

Air Filters

- Air filters devices are designed to remove airborne contaminants, including particles, pollutants, and microorganisms, in applications such as medical face mask, HVAC systems, cabin air car and others.
- The air filter media must have a porous and intricate structure, to allow the passage of air and at the same time collect airborne particles.
- The most common categories are pleated (e.g HVAC) and electret (e.g. face mask) often made in fiberglass/nylon and having poor biodegradability.
- After Covid, the production of filters increases, but they are often not discarded properly and end up polluting the oceans.

There is an increasing need for:

i) **sustainable** alternatives to poorly biodegradable **air filters**

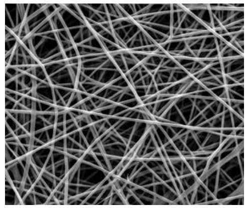
ii) **functionalised with antimicrobial agents**

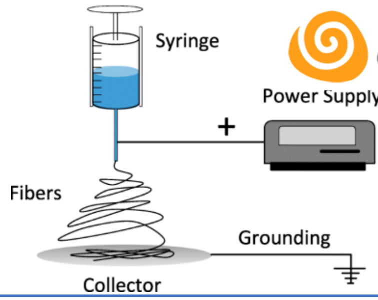
Case Study 4

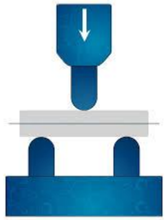
CNR-ISAC

SCOPE AND GOAL:

Sustainable air Filter in Cellulose Acetate Functionalized with Antimicrobial Agent (e.g. **AgHec**, ZnO, EB)







Design Specification

Electrospun CA nanofibers for an open and intricate pattern.

Synthesis

Incorporation

Safety Investigation:

- on Cellulose Acetate @UNIMIB
- integrating AgHEC* data from CS1 (*)or other antimicrobial agents

Use Phase

- Friction Tests (minimising the release of the NMs);
- Skin Irritation Tests (eventually, for face masks)

End Of Life

- Minimizing LCA and ecotox impacts @ProjectHub @IAS

Maximize filtration Efficiency and Quality Factor performance

Funded by the European Union

INTEGRANO

Case Study 4.1

UNITO,CNR-ISAC

Egyptian Blue (micro-EB) optimization

Adjustment of the synthesis, initially for EB in micrometric size (then transferable to nanometric and/or bio-based material).

$CaCuSi_4O_{10}$

GOAL: adjustment of the synthesis for the micrometric EB.

KDFs

KDF 1	**Heating Cycle** Discrete (hours)	**32/48/64 hours**
KDF 2	**Rinsing Cycle** Discrete (Yes or No)	**washed or unwashed**

PROJECT HUB360

Scope: determine the best combination for a "lower energy consumption" strategy and good quality.

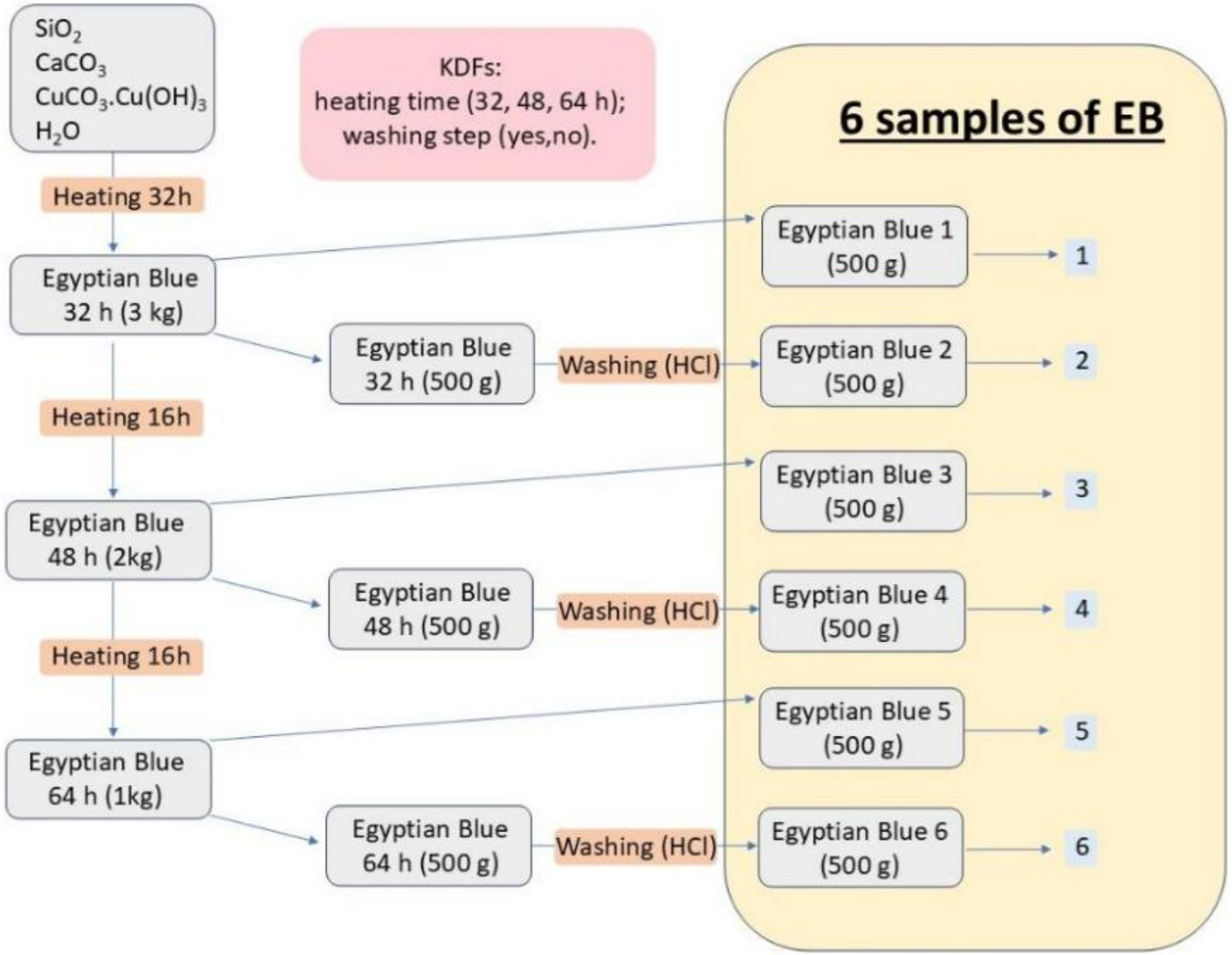
Six different EB micropowders **samples**

#	Sample name	Sample legend
1	I2A	Second firing
2	I2B	Second firing + washing + annealing (900 °C for 4 hours)
3	I3A	Third firing
4	I3B	Third firing + washing + annealing (900 °C for 4 hours)
5	I4A	Fourth firing
6	I4B	Fourth firing + washing + annealing (900 °C for 4 hours)

Egyptian Blue (micro-EB) optimization

UNITO,CNR-ISAC

$CaCuSi_4O_{10}$



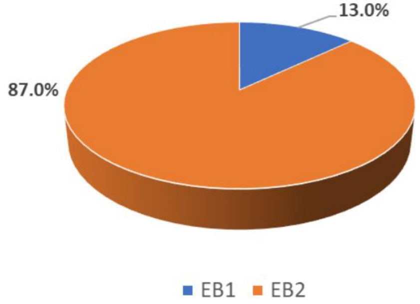
MIC (mg/ml)						
	EB1	EB2	EB3	EB4	EB5	EB6
S. aureus	>10	>10	>10	>10	>10	>10
E. coli	>10	**5**	**10**	>10	>10	>10

Minimum Inhibition Concentration against S.Aureus and E.Coli

MBC (mg/ml)						
	EB1	EB2	EB3	EB4	EB5	EB6
S. aureus	>10	>10	>10	>10	>10	>10
E. coli	>10	>10	>10	>10	>10	>10

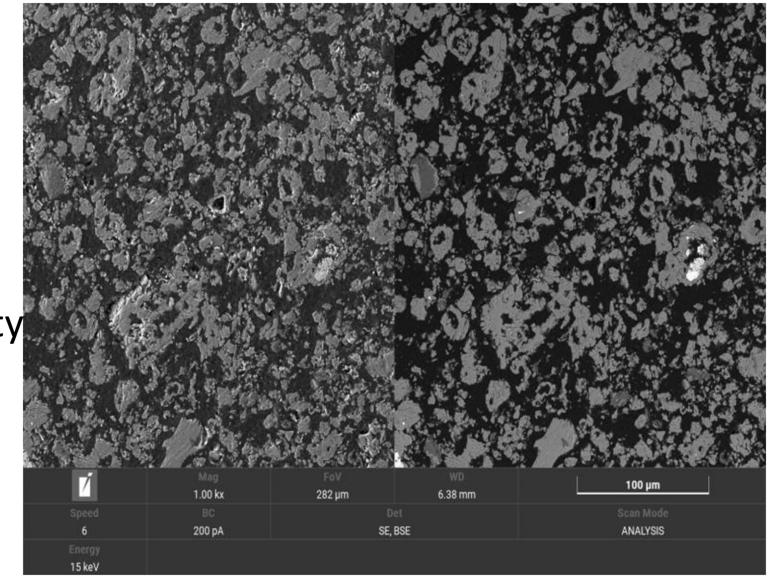
Minimum Bactericidal Concentration against S.Aureus and E.Coli

SSbD case based on stakeholders selection



EB2 synthesis route shows to be the selected process

UNITO,CNR-



Notes

Identification of KDF for micro-EB powders :

data on energy consumption and synthesis collected by ProjectHub

Optimization of the synthesis for micro-EB powders:

- Six different samples made and fully characterized (SEM, Z-Potential, antimicrobial activity
- DOE performed by ProjectHub to indicate the best sample
- Information available to proceed with the nanometric and/or bio-based material.

Considerations

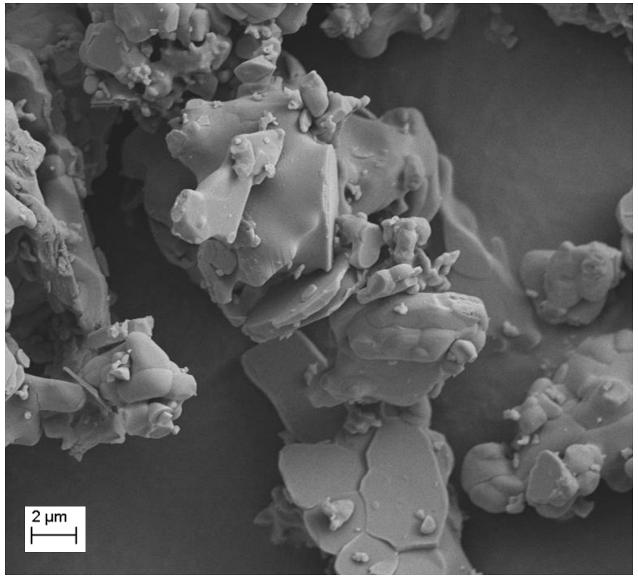
Nano-EB will be further developed inside CS1 considering that:

- no effect found on VOC removal
- bulk EB material not efficient enough as air filter
- micro EB : too large amount required (possible clogging for air filter
- nano EB: at developing stage, much time for incorporation into air filter

Egyptian Blue (nano-EB) optimization

Target Functionality for optimization: luminescence and/or antimicrobial.
Possible KDF for optimizing nanoEB can be the quantity of dispersant used.

CNR ISSMC
Istituto di Scienza, Tecnologia e Sostenibilità per lo Sviluppo dei Materiali Ceramici



Case Study 4.2

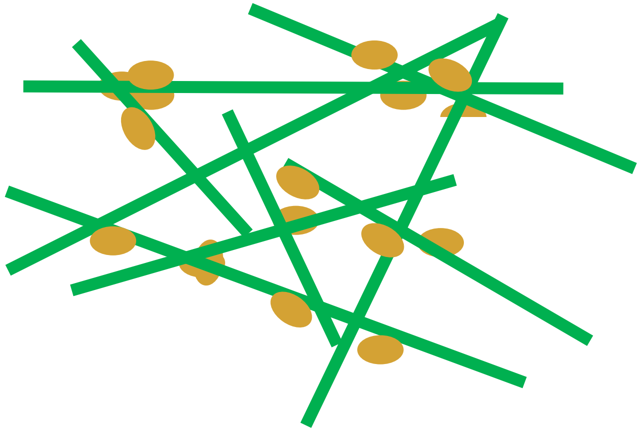
From now on we will only refer to this as CS 4

⍰ Synthesis

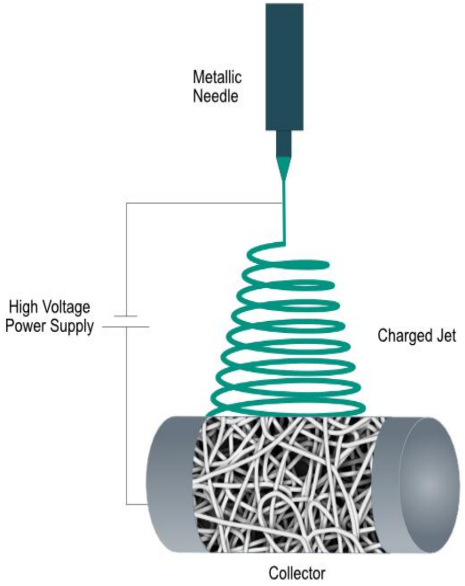
- Adjustment of the precursor polymer solutions

⍰ Incorporation

- Inclusion of AgHEC to the spinning solution
- Electrospinning of Cellulose Acetate with and without AgHEC (or another antimicrobial agent as ZnO).



Cellulose Acetate & Antimicrobial Agent



Electrospinning

MAIN GOALS

- High Efficiency and Quality Factor ⍰ determined by grammage (KDF1)
- Antimicrobial effects ⍰ amount of antimicrobial agent(KDF2)

KDFs

KDF 1	**Membrane Grammage** (g/m^2)	**from 0.5 to 7.5 g/m^2**
KDF 2	**Amount of antimicrobial agent** (% in weight of the concentration)	~~**From 0% to 5%**~~ **From 0% to 0.3%**

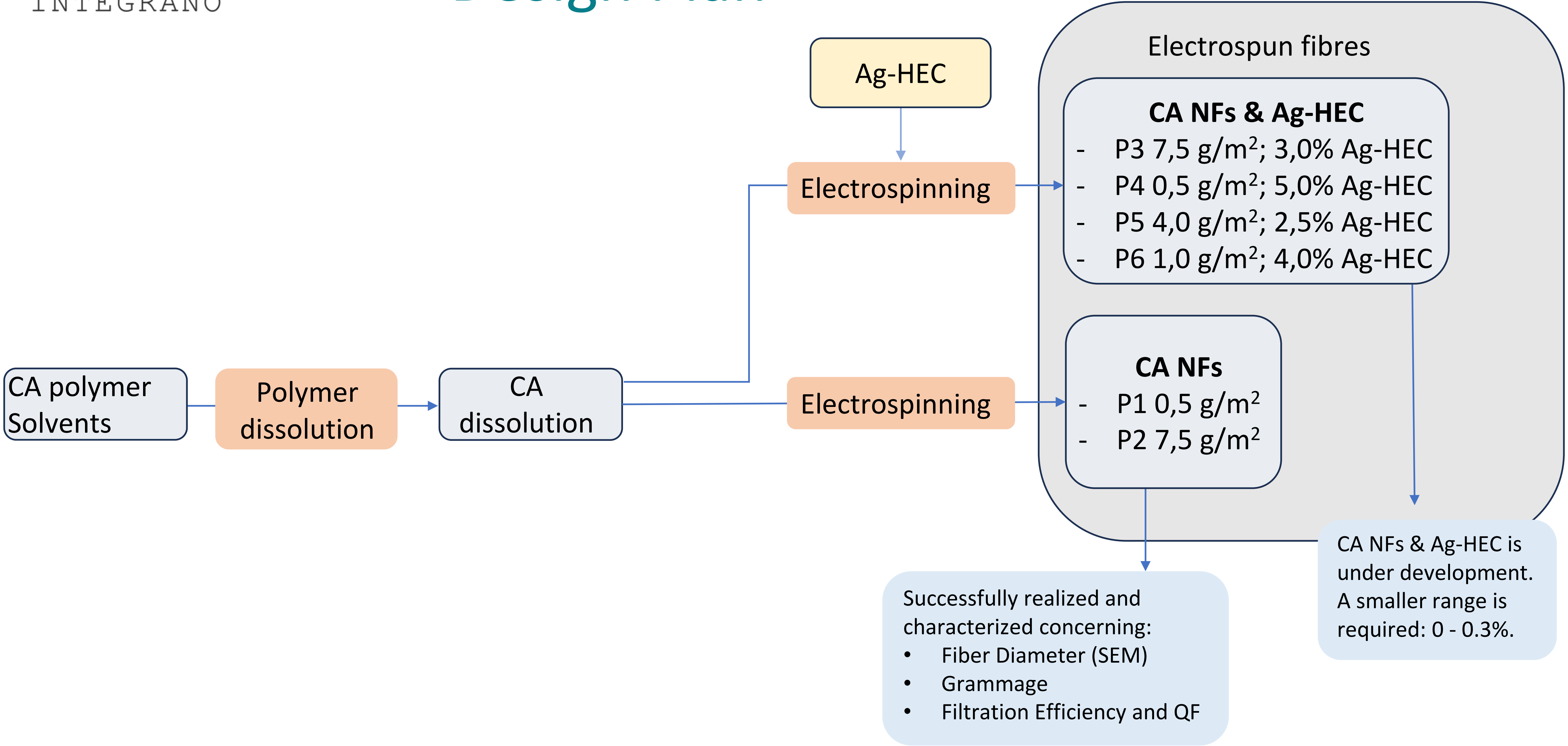
PROJECT HUB360

Antimicrobial Agent:
- **AgHEC nanoparticles** from ISSMC (largely studied in past projects and already available);
- Egyptian Blue from UNITO (discarded, as explained before);
- ZnO from BIU, possibility to evaluate sonochemical incorporation.

A total amount of **6 (up to 10) different samples** to be characterised with AgHEC (*) as antimicrobial agent.

Design Plan

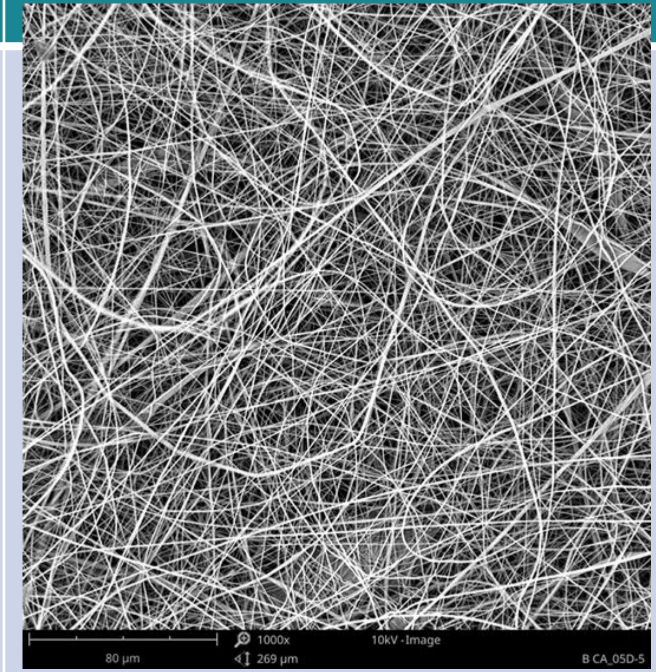
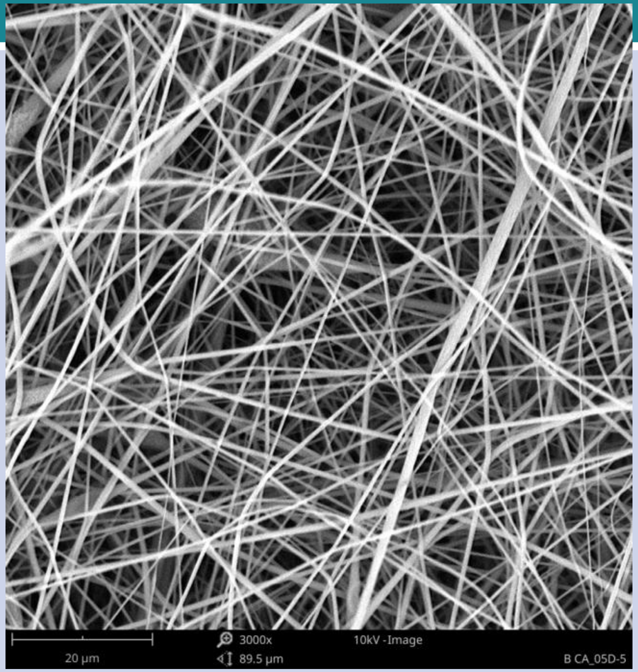
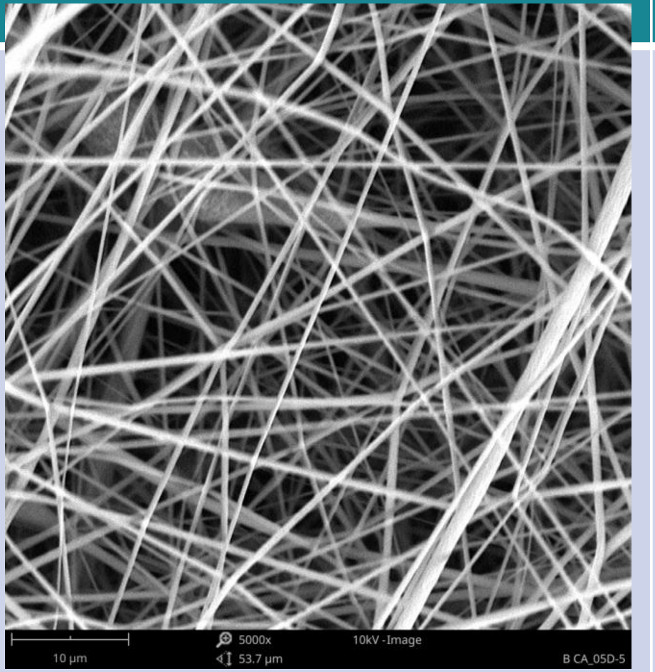
AITEX, CNR-ISAC



Polymer Nanofibers

Characterization

SEM-EDS

Sample	SEM	Avg. diameter (nm)
CA NF	  	547,60

Polymer Nanofibers

Characterization

GRAMMAGE

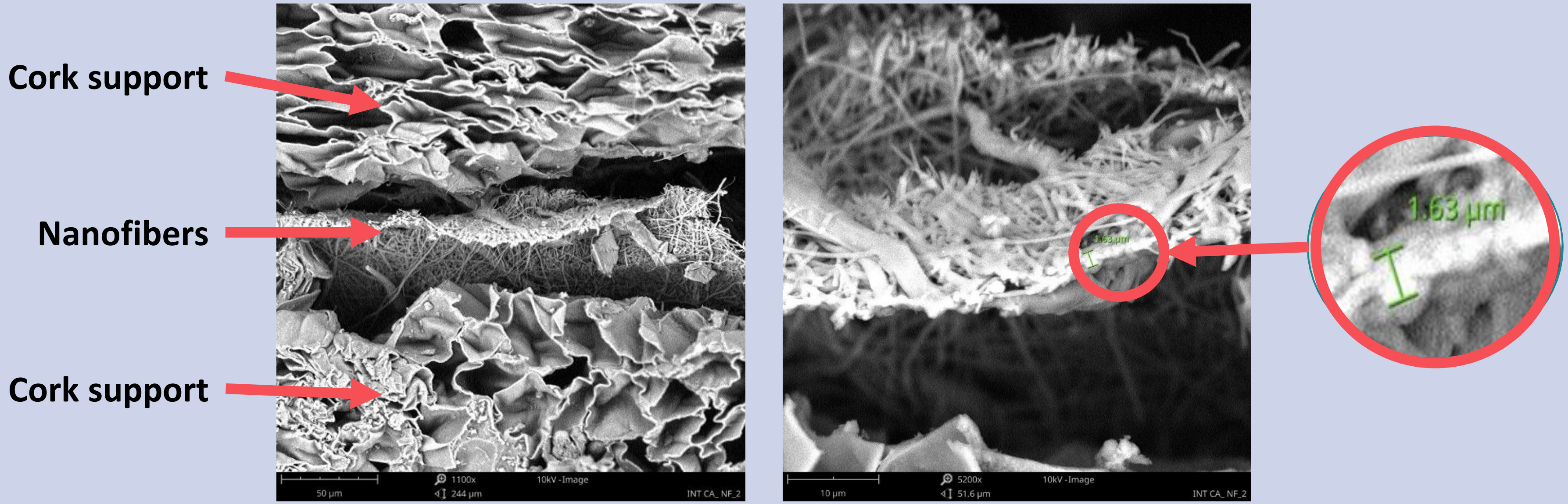
Sample	Sampling area	GRAMMAGE (g/m^2)	Avg. grammage (g/m^2)
CA NF_1	1 (left +3)	0,0	0,34
	2 (left +2)	0,1	
	3 (left +1)	0,5	
	4 (center)	0,5	
	5 (right +1)	0,3	
	6 (right +2)	0,3	
	7 (right +3)	0,0	

Sample	Sampling area	GRAMMAGE (g/m^2)	Avg. grammage (g/m^2)
CA NF_2	1 (left +3)	1,5	4,15
	2 (left +2)	3,2	
	3 (left +1)	5,1	
	4 (center)	6,8	
	5 (right +1)	5,4	
	6 (right +2)	2,9	
	7 (right +3)	0,8	

Polymer Nanofibers

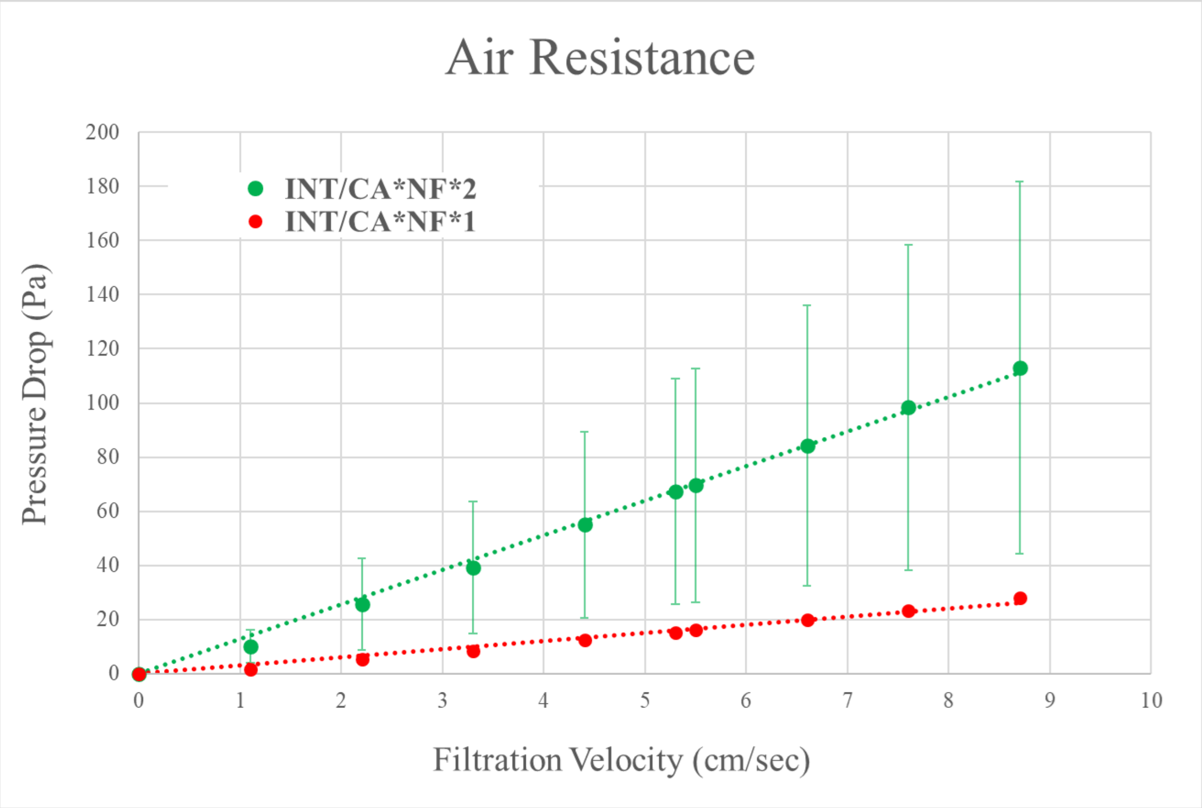
Characterization

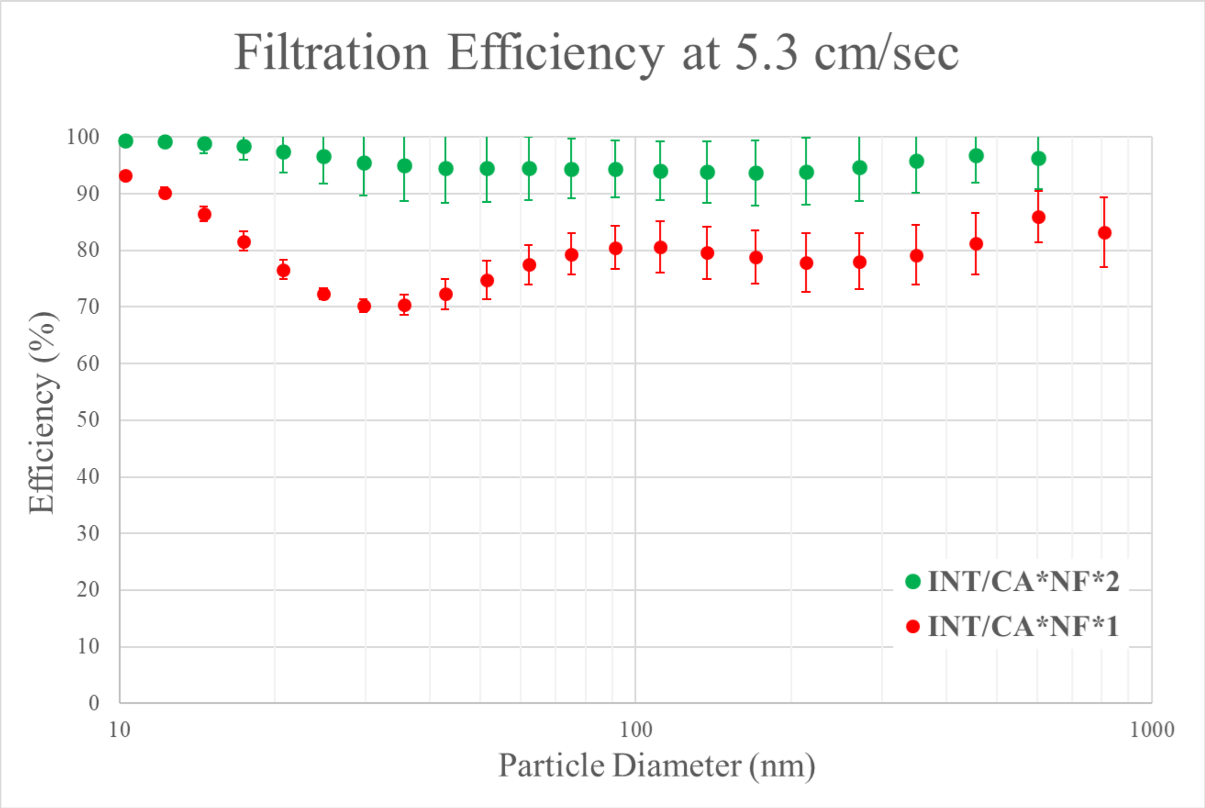
THICKNESS

Sample	THICKNESS (µm)	
CA NF_2	1,63	

Pressure Drop and Filtration Efficiency Test

Functionality





Test similar to EN149 standard

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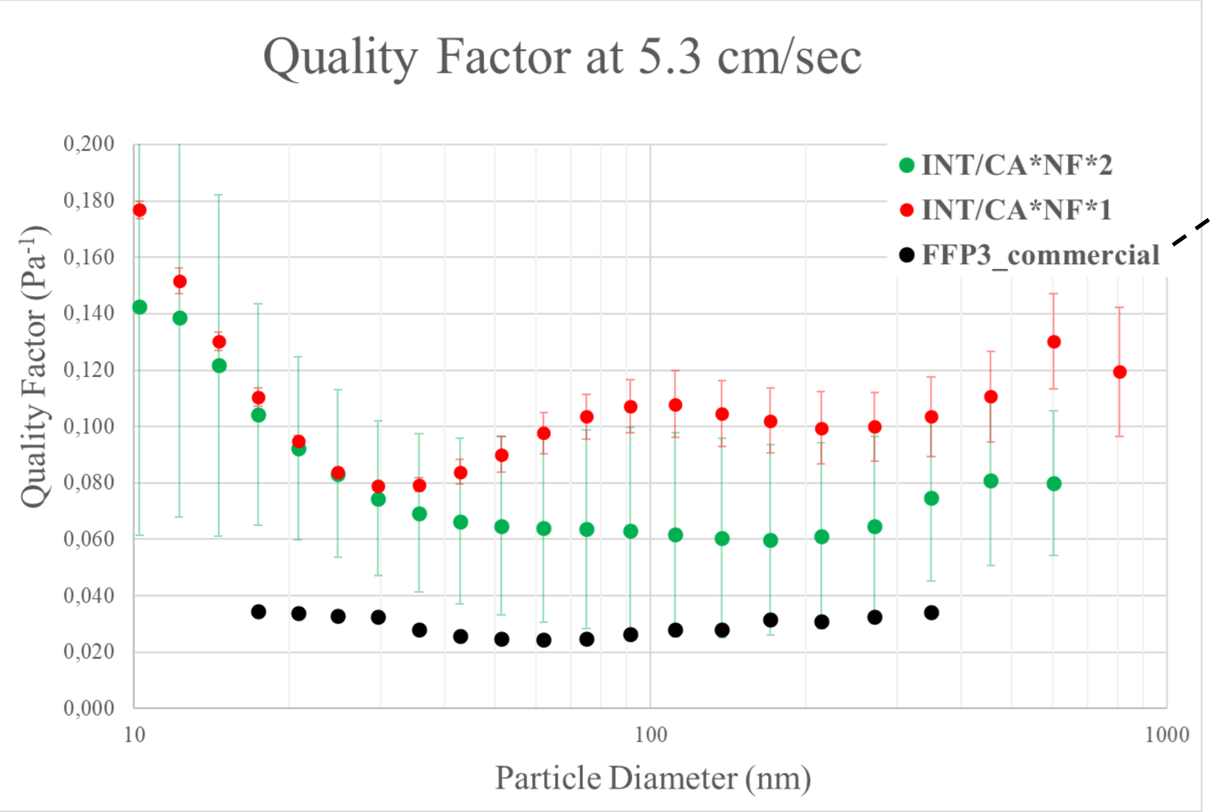
CNR-ISAC

Quality Factor

Functionality



Comparing to a commercial FFP3, both membranes exhibit an exceptionally high quality factor, indicating that the electrospun cellulose acetate is a promising air filter that effectively removes particles while ensuring good breathability.

Work planned for the NEXT 6 MONTHS

Optimisation of the Electrospinning of CA NF & Ag-HEC

- KDF: AgHEC concentration, grammage of electrospun membrane
- KPI: quality factor, antibacterial properties, safety and ecotox tests

Tentative Optimisation of the ZnO incorporation

- KDF: ZnO concentration, grammage of electrospun membrane
- KPI: quality factor, antibacterial properties, safety

Depending on the results obtained, we will have a **better focus on the application** (as HVAC or face masks) **and further develop of KPI associated to the use phase** as:

- KPI: friction testing
- KPI: skin irritation testing

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MULTIDIMENSIONAL INTEGRATED QUANTITATIVE APPROACH TO ASSESS SAFETY AND SUSTAINABILITY OF NANOMATERIALS IN REAL CASE LIFE CYCLE SCENARIOS USING NANOSPECIFIC IMPACT CATEGORIES

Case Study 5

Food packaging

12M Annual General Meeting

Turin - Italy

29-30 January 2025

This project has received funding from the European Union’s Horizon Europe research and innovation programme under GA No 101138414

CS5 Food packaging

SCOPE, GOAL

Scope – Developing a new food packaging (Cdots) to elongate the fresh produce shelf-life.

Goals

- Synthesis of fluorescent Carbon dots with antibacterial properties using Olive, Rosemary, Aloe Vera, Thyme, and Salvia Leaves as precursors
- Optimization of coating of PE/paper with synthesized C-dots.

KDF1: precursor concentration, KDF2: reaction time. KPIs for this study are coating concentration and antibacterial properties.

Funded by the European Union

INTEGRANO

CS5 Food packaging

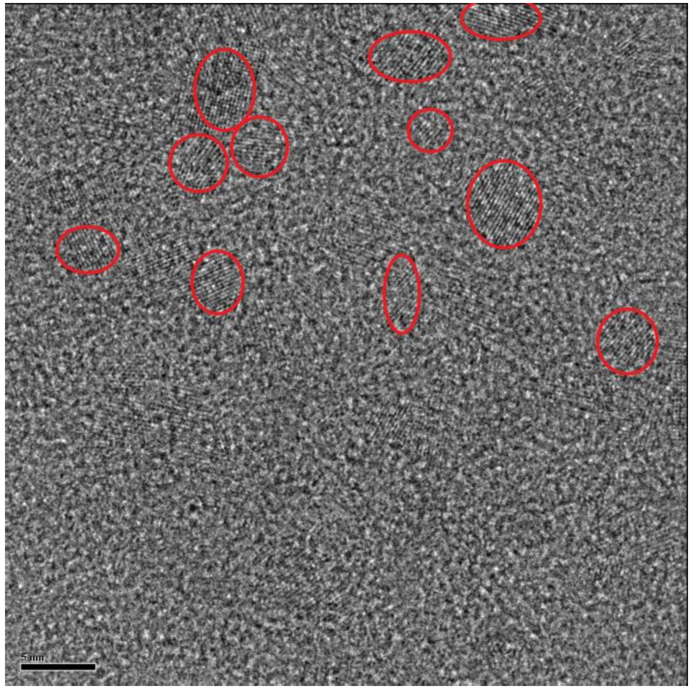
BIU

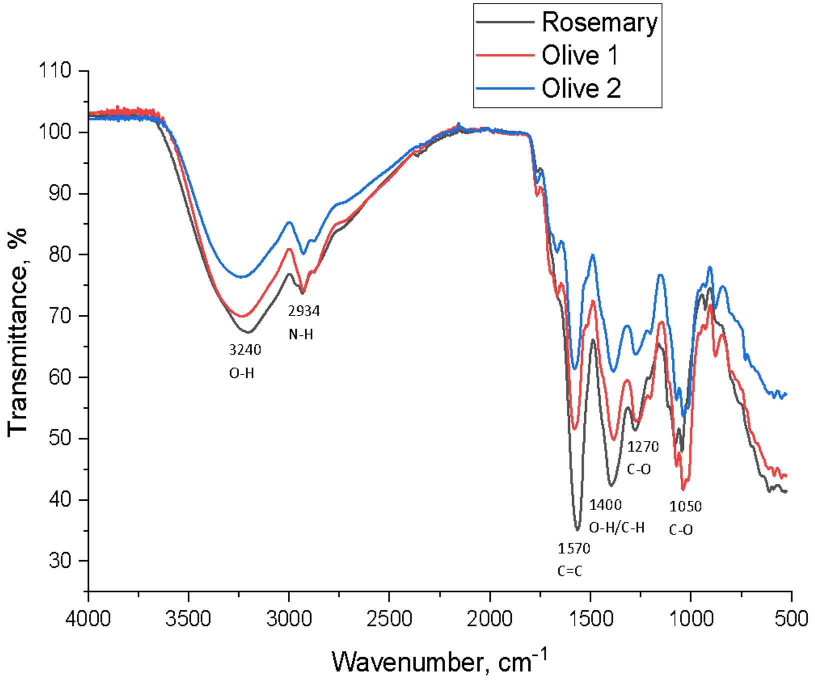
C-dots synthesis

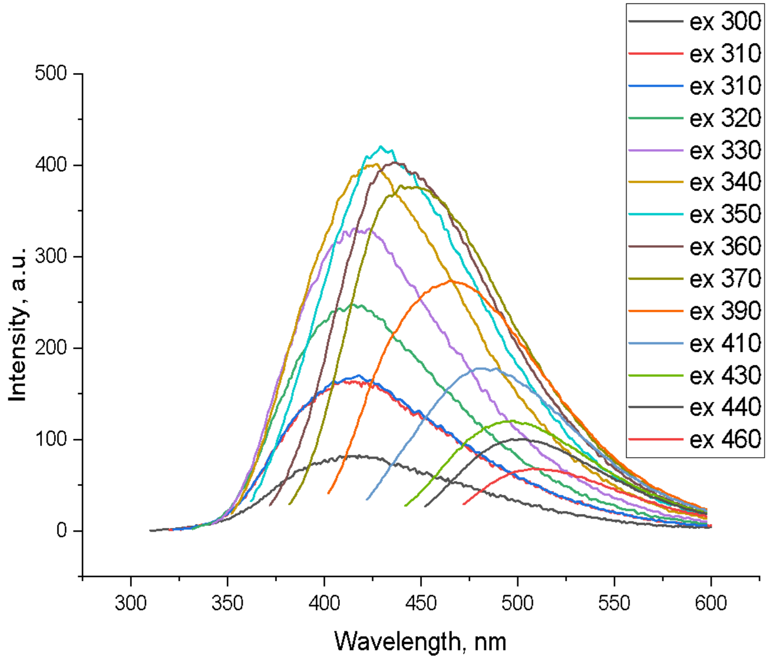
#	Sample source	Sample weight for synthesis, g	Water volume, ml	T, °C	Time, hours	Fluorescence, λ_{max}, color	MIC, mg/ml	Number experiments	Size, nm (TEM)
1	Rosemary leaves fresh	2	25	180	10	~450 nm, blue	2,5 (S.aureus)	2	3.5 ± 1.5
2	Olive leaves dried at 60°C for 48 hours	6	60	180	12		0,625 (S.aureus)	4	3.2 ± 0.8
3	Aloe Vera leaves dried at 60°C for 48 hours	6	60	180	12		-	2	4 ± 1.5
4	Salvia leaves dry	6	60	180	12		1,25 (S.aureus)	1	4.7 ± 1.3
5	Thyme leaves dried at 60°C for 48 hours	5,5	55	180	12		0,625 (S.aureus)	1	3 ± 0.7
6	Rosemary leaves dried at 60°C for 48 hours	6	60	180	12		0,625 (S.aureus)	1	~4

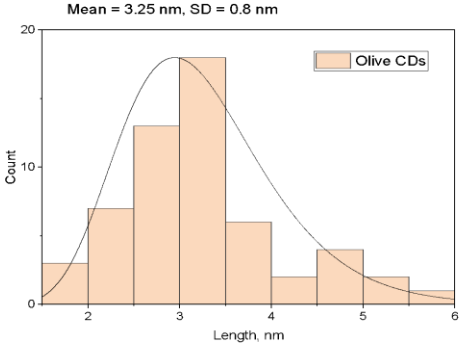
CS5 Food packaging

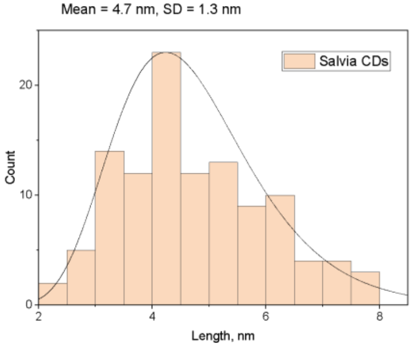
P-Chem characterization

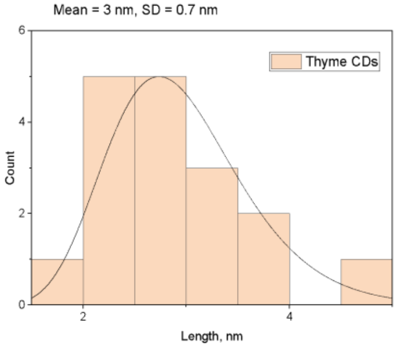












The color of synthesized CDs' aqueous solution under daylight is yellow and blue under UV light.

Funded by the European Union

CS5 Food packaging

Antibacterial properties

Bacteria tested

All samples were tested against *Staphylococcus aureus, Listeria innocua, Escherichia coli, P. aeruginosa*, Methicillin-resistant *Staphylococcus aureus* (MRSA), *E. coli* MDR, *Klebsiella pneumoniae* MDR.

Olive

	MIC (mg/ml)	MBC (mg/ml)
S. aureus	**0.625**	2.5
L. innocua	**1.25**	2.5
E. coli	5	10
P. aeruginosa	5	10
MRSA	**0.625**	2.5
E. coli MDR	20	20
K. pneumoniae MDR	10	20

Salvia

	MIC (mg/ml)	MBC (mg/ml)
S. aureus	**1.25**	2.5
L. innocua	Was not tested	Was not tested
E. coli	10	10
P. aeruginosa	5	10
MRSA	**1.25**	2.5
E. coli MDR	20	20
K. pneumoniae MDR	10	20

Rosemary

	MIC (mg/ml)	MBC (mg/ml)
S. aureus	**0.625**	2.5
L. innocua	**1.25**	5
E. coli	10	10
P. aeruginosa	5	10
MRSA	**0.625**	1.25
E. coli MDR	20	20
K. pneumoniae MDR	10	20

Thyme

	MIC (mg/ml)	MBC (mg/ml)
S. aureus	**0.625**	2.5
L. innocua	Was not tested	Was not tested
E. coli	10	10
P. aeruginosa	10	10
MRSA	**0.625**	1.25
E. coli MDR	10	20
K. pneumoniae MDR	10	20

Work planned for the NEXT 6 MONTHS

- Optimization of coating of PE/paper with synthesized C-dots. KDF1: precursor concentration, KDF2: reaction time.

  KPIs for this study are coating concentration and antibacterial properties.

Funded by the European Union

INTEGRANO

MULTIDIMENSIONAL INTEGRATED QUANTITATIVE APPROACH TO ASSESS SAFETY AND SUSTAINABILITY OF NANOMATERIALS IN REAL CASE LIFE CYCLE SCENARIOS USING NANOSPECIFIC IMPACT CATEGORIES

CASE STUDY 6

Advanced sunscreen and anti-aging formulations

ROV / VERL

12M Annual General Meeting Turin - Italy

29-30 January 2025

This project has received funding from the European Union's Horizon Europe research and innovation programme under GA No 101138414

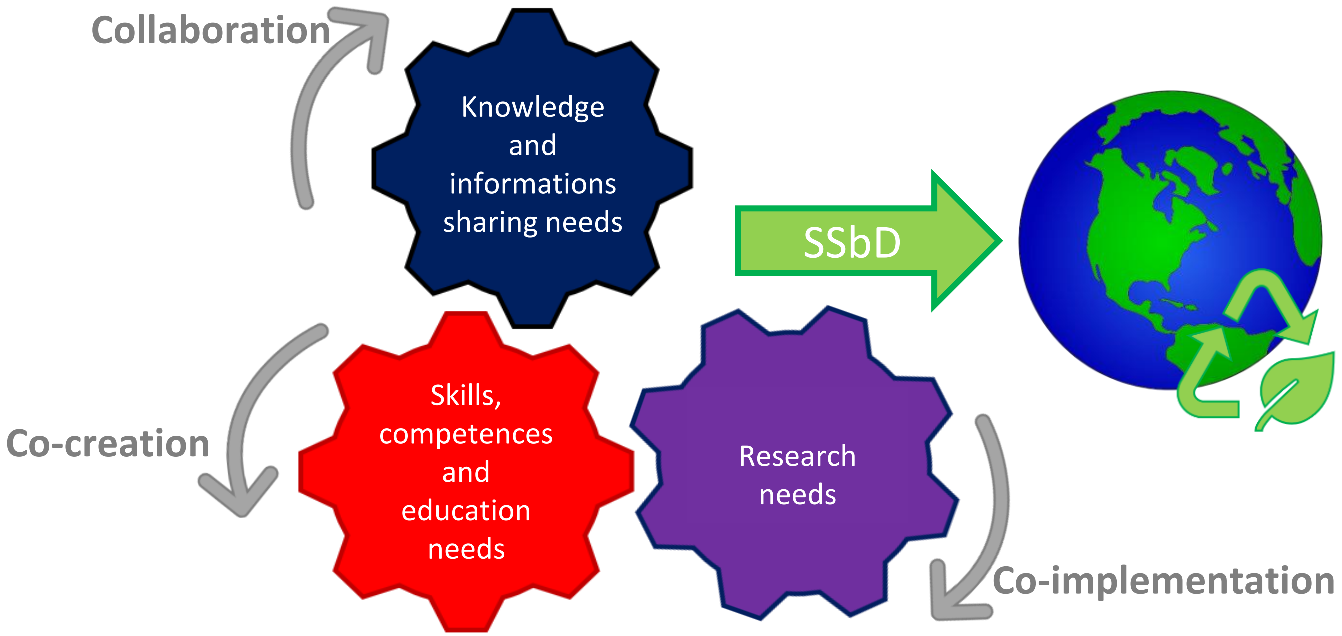
Introduction to the case study

Case study 6 focuses on the development of **advanced sunscreen and anti-aging formulations** designed for the European market.

The main goal is the application of a Safe and Sustainable by Design (**SSbD**) **method for the optimization of prototypes.**

The key benefit is the balance between:

- high performance;
- improved safety;
- environmental sustainability.



Introduction to the case study

Our formulation will focus on the **development of three prototypes** that will be subjected to optimization:

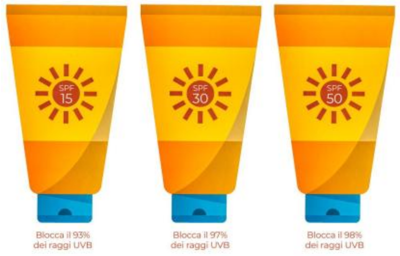
Product	Anti UV functionality	Anti Aging functionality	Notes
Actual standard	**Titanium Dioxide Nano** already available on the market and commonly used in cosmetic preparations - supplied by ROV.	**Anti-aging active** (Vit C derivative) supplied by ROV.	ROV will incorporate Titanium Dioxide and anti-aging in the cosmetic base.
Tier 1	**SiO2@TiO2** by Centi.	**Anti-aging active** (Vit C derivative) supplied by ROV.	ROV will incorporate SiO2@TiO2 by Centi and anti-aging in the cosmetic base
Tier 2	**Micropellet** provided by VERL **with SiO2@TiO2** by Centi and anti-aging active provided by VERL.	**Micropellet** provided by VERL with **SiO2@TiO2** by Centi and anti-aging active provided by VERL (Vit C derivative)	ROV will incorporate micropellet (NPs+ Vit C) from VERL into the cosmetic base.

Functionality and safety goals

Our goals:

Enhanced sun protection

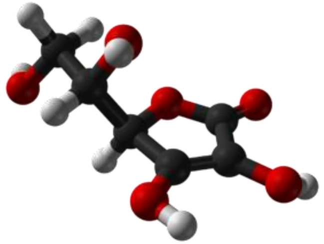
To demonstrate that the combination of nanoparticles (NPs) and organic UV filters offers superior UV absorption, minimizing white cast and ensuring a pleasant sensoriality.



Reduction of oxidative radicals

To develop a formulation that helps limit oxidative stress on the skin.

Vitamin C stability



Thanks to micro-pelletization, to demonstrate improved bioactivity and stability of Vitamin C compared to conventional products.

Reduction of penetration and adverse effects of nano ingredients

To ensure, through advanced formulation and characterization choices, that the nano materials used in the product have minimal skin penetration, do not cause undesirable effects, while preserving safety for the end user.

Combined anti-aging activity and Increased stability prospects

Recent updates: KPIs and KDFs

From the beginning of the project, one of the main goals was to **define KPIs and KDFS** that would allow precise and targeted monitoring of the effectiveness of the solutions developed.

- **For micropellets**, KDFs and KPIs were designed to evaluate aspects related to their physical structure, stability and incorporation into the final matrix.
- **For nano-enabled cosmetic products**, the emphasis was placed on the performance of the final product, safety and aesthetic perception.

This differentiated approach was key to ensuring an adequate and targeted assessment of each area of the case study.

KPIs and KDFs

MATERIAL	KPI	KDF
Micropellets	• **Particle size** • **Stability of Vitamin C** (monitored by VERL). • **Collagenase inhibition activity**: Test to evaluate anti-aging efficacy (VERL). • **Antioxidant activity**: Monitored and tested by DRT.	• **Process Temperature** • **Excipients**
Nanoenabled Products (NeP)	• **Collagenase inhibition activity** (VERL). • **Antioxidant activity**: Tested by DRT. • **UV protection features**: In vitro SPF (DRT?).	• Percentage of nanomaterial **(%NM)** in the product. • **Oil/water ratio**: Essential to optimize the emulsion.

Thanks to this selection of KDFs and KPIs, the project aims not only to develop innovative cosmetic solutions, but also to **provide a strong and replicable analytical framework for the evaluation of advanced cosmetic products**, ensuring the achievement of **high standards of functionality and safety**.

The current situation

FIRST STEP

THE OPTIMAL W/W RANGE FOR THE INSERTION OF THE $SiO_2@TiO_2$ NP WITHIN THE FORMULATION	THE PRESENCE OF A DARK PARTICULATE MATTER IN THE $SiO_2@TiO_2$ SAMPLE
Use of an integrated approach that cross-referenced • the efficacy data available on nano titanium • the regulatory limitations (limit of use of nano TiO2 at 25%) • the results of preliminary formulation tests.	**Observation** of the **presence of a dark particulate matter** in the $SiO_2@TiO_2$ sample. This has led a **progressive chromatic alteration of the sample**, which tends to turn towards grayer shades over time.
Conduction of preliminary formulation tests by incorporating progressive amounts of nanomaterial into already established formulations.	It raises **questions about** the nature of the phenomenon and the **potential impact** on the technical performance of the final product and on its aesthetic acceptability.
It has been determined that the optimal w/w range is 2% to 10%. Above 10%, the dispersion of the SiO2@TiO2 becomes more difficult, the formulation is less homogeneous, and the application loses its pleasantness.	In this context, it might be useful to consider the **introduction of an additional $SiO_2@TiO_2$ sample purification step to reduce or eliminate dark particulate matter**, a discussion with Centi is underway on this issue.

The current situation

NEXT STEP

Key objectives have been identified to ensure progress in research and optimization:

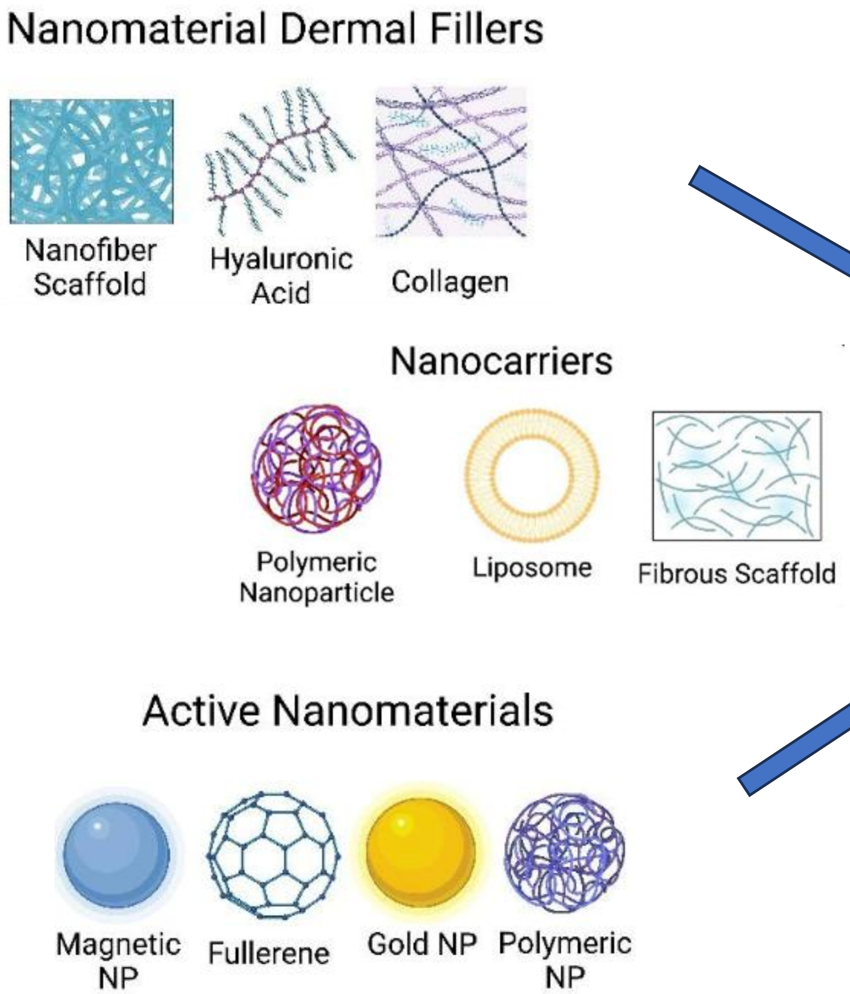
Planning of antioxidant tests with Dermatest: the details of antioxidant tests will be defined with Dermatest.
The goal is to meet in mid-February.

Generation of Nano-Tox and Nano Eco-Tox data: It will be essential to coordinate with the partners involved to select the most relevant analyses and identify the suitable materials to be tested.

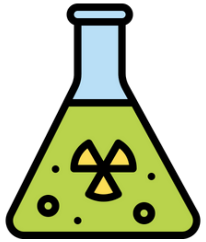
Exposure Assessment and Prediction Models activities: this initiative will focus on the analysis and modelling of exposure to nanomaterials, to assess their potential impact on human health and the environment.

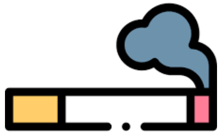
Impact Assessment: methodologies will be developed and to examine the overall impact of nanomaterials.
It will consider the functional performance of the product and the aspects of environmental and social sustainability.

Antiaging activity

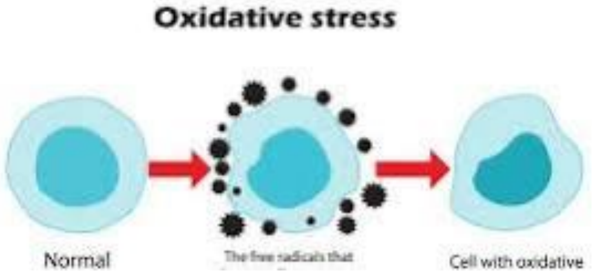


Extrinsic

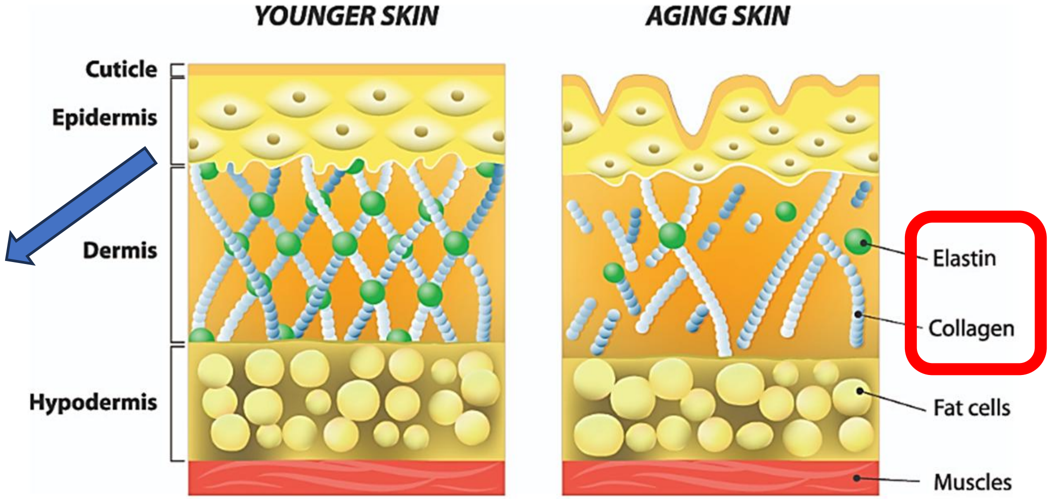




Intrinsic



Antiaging activity



Nanoparticles (NPs) are increasingly being incorporated into micropellet formulations to **improve drug delivery systems (solubility, stability, and bioavailability** of active pharmaceutical ingredients)

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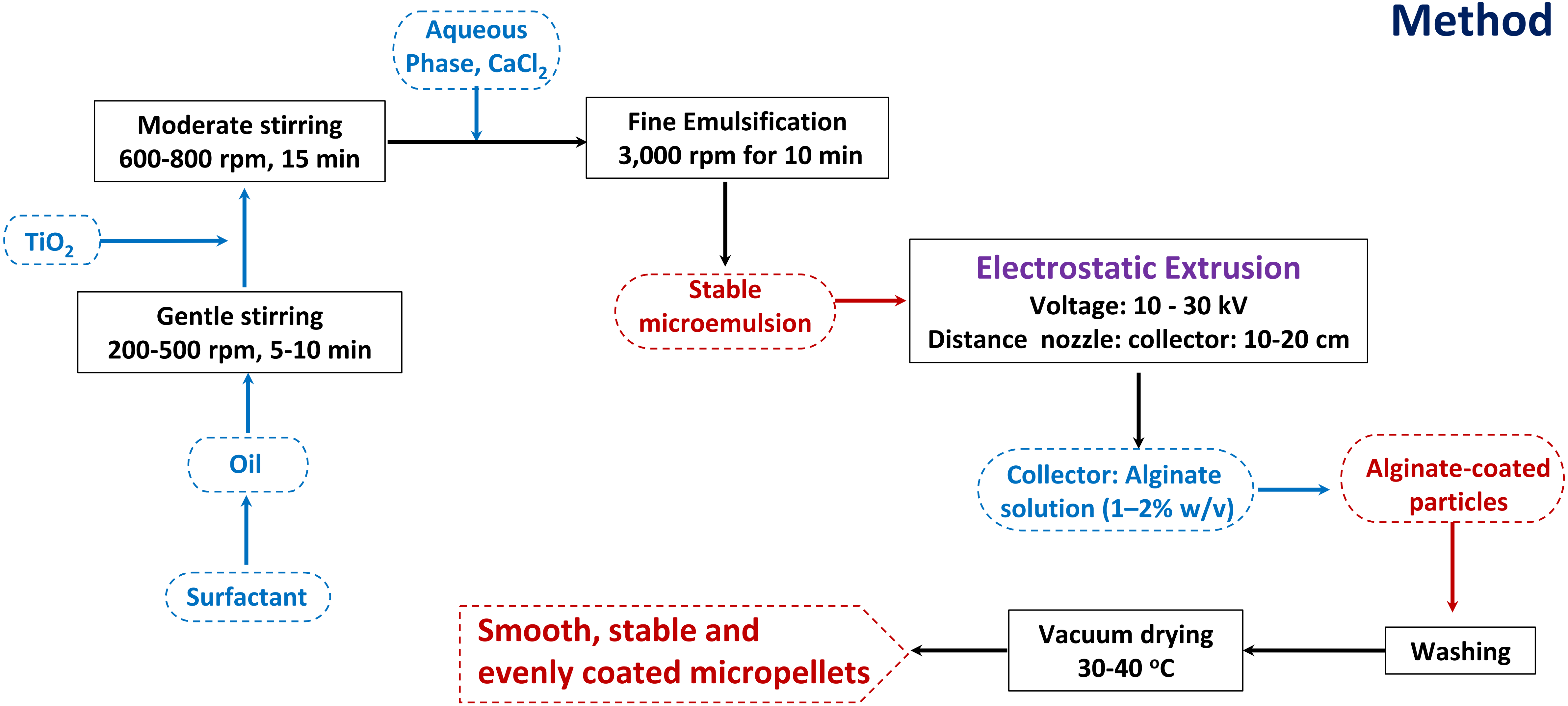
Micropelletisation Process

VENUSROSES

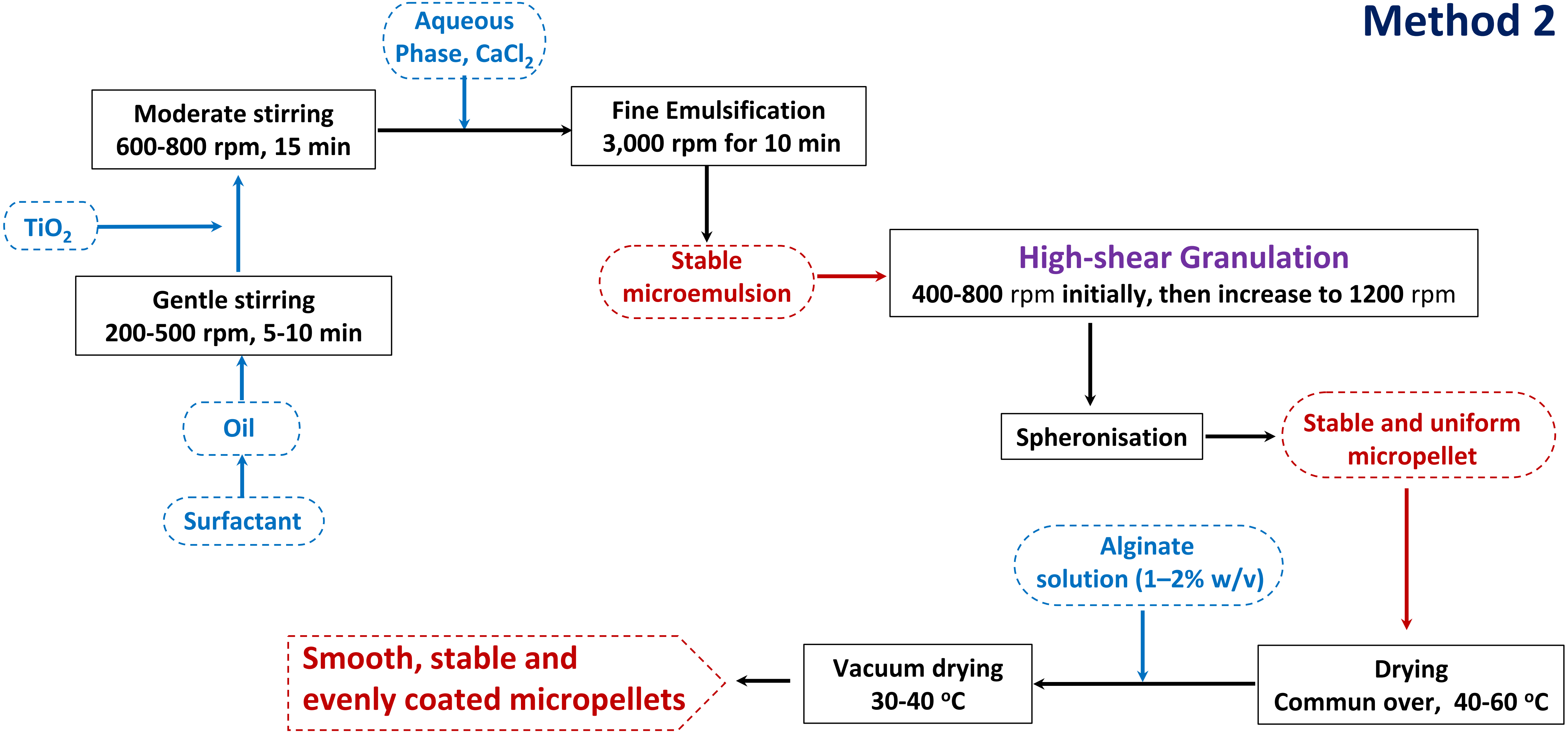
Method 1



Micropelletisation Process

VENUSROSES

Method 2



Work planned for the NEXT 6 MONTHS

Micropelletization with commercial TiO_2 using Method 1

Micropelletization of Vitamin C using method 1

Micropelletization of TiO_2 and Vitamin C using Method 1

THANK YOU FOR YOUR ATTENTION!