Supplementary Materials

Hypothesizing the Systemic Resilience and Dynamic Recirculation of Nanoplastics: A Conceptual Biological Framework

Umberto Cornelli [1*], Rafael Luque [2,3] and Claudio Casella [4*]

1 Department of Molecular Pharmacology and Therapeutics, School of Medicine, Loyola University, 2160 1st Ave, Maywood, IL, 60660, (USA)

2 Universidad ECOTEC, Km 13.5 Samborondón, Samborondón EC092302, (Ecuador)

3 Peoples Friendship University of Russia (RUDN University), 6 Miklukho Maklaya Str., Moscow, 117198, (Russian Federation)

4 Department of Chemistry, University of Pavia, Viale Taramelli 12, 27100, Pavia (Italy)

* Correspondence: ucornelli@gmail.com; claudio.casella01@universitadipavia.it

Table S1. Summary of literature search strategy, database records, and screening workflow (up to March 2026).

Search Stage / Parameter	Operational Details and Record Count
Search Timeframe	Up to March 2026
Pubmed/MEDLINE	142 records retrieved
Scopus	215 records retrieved
Web of Science	180 records retrieved
Google Scholar	Top 100 relevant record screened
Total Records Identified	637 total new records
Duplicates Removed	180 duplicates eliminated
Screened (Title/Abstract)	457 records screened for eligibility
Excluded Records	361 records excluded (ecological, non–mammalian, lack of biological fate mechanism)
Final Narrative Synthesis	96 peer–reviewed articles included in the conceptual framework

Figure S1. Certificate of analysis of PCC



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NUTRATRADE S.r.l.		Certificate of analysis	
Name **Chitosan**		SOURCE: **PROCAMBARUS CLARKII**	
Issued by *QA*	Approved by	*Riccardo Cultraro*	
Manufacturing date: **31/08/2025**	Best Before: **30/08/2027**	Batch number: **2025083114**	

Product Name	Chitosan	**Solvent Used**	NA
Country Origin	China	**Grade**	Food ☒ Feed ☐ Pharma ☐
CAS No.	9012-76-4	**Quantity**	300kg
Part No.	4.010-126.0	**Shelf life**	24 months when properly stored
Molecular Formula	$C_{56}H_{103}N_9O_{39}$		
Packing	Paper-drums and two plastic-bags inside, food contact material compliant with EC Reg. 1935/2004 and EU Reg. 10/2011	**Storage**	Store in cool & dry place. Do not freeze. Keep away from strong light and heat.

Analysis Item	Specification	Method	Result
Deacetylated Degree	>90%	NA	90.27%
DER	NA	NA	NA

Chemical and Physical Characteristics			
Analysis Item	**Standard value**	**Method**	**Result**
Appearance	Powder	Visual	Conform
Color	White to light yellow	Visual	Conform
Odor& Taste	Characteristic	Organoleptic	Conform
Identification	Positive	NA	Conform
Excipient	NA	NA	NA
Loss on drying	≤10.0%	Ph.Eur.9.0<2.2.32>	6.17%
Total ash	< 1%	Ph.Eur.9.0<2.4.16>	0.23%
Solubility in Water	NA	Organoleptic	NA
Solubility in oil	NA	NA	NA
Apparent density	NA	Eur.Ph.<2.9.34>	NA
Tapped density	NA	NA	NA
Solubility((in 1% Acetic Acid))	> 99.0%	NA	99.86%
Viscosity	90-130 mPa·s(cP)	NA	Conform
Sieve analysis	95% through 100 mesh	USP39<786>	Conform
Arsenic (As)	NMT 1 ppm- Reg.EU 2023/915	Ph.Eur.9.0<2.2.58>ICP-MS	Conform
Cadmium (Cd)	NMT 1 ppm- Reg.EU 2023/915	Ph.Eur.9.0<2.2.58>ICP-MS	Conform
Lead (Pb)	NMT 3 ppm- Reg.EU 2023/915	Ph.Eur.9.0<2.2.58>ICP-MS	Conform
Mercury (Hg)	NMT 0.1 ppm - Reg.EU 2023/915	Ph.Eur.9.0<2.2.58>ICP-MS	Conform
Heavy Metals	NMT 10 ppm- Reg.EU 2023/915	Ph.Eur.9.0 <2.4.8>	Conform
Pesticides Residues	Conform Reg.(EC) .396/2005 and amendments.	Gas Chromatography	Conform
Solvent Residues	Conform Eur.Ph. 9.0 <5,4 > and EC Dir. 2009/32	Ph.Eur.9.0<2.4.24>	Conform
Hydrocarbons PAHs	≤ 50 ppb -Reg.EU 2023/915	GC-MS	Conform
Benzo(a)pyrene	≤ 10 ppb -Reg.EU 2023/915	GC-MS	Conform
Radioactivity	≤ 600 Bq/Kg - Reg. EC 2020/1158	NA	Conform
Aflatoxin B1	≤ 5 ppb - Reg.EU 2023/915	Ph.Eur.9.0<2.8.18>	Conform
Aflatoxins Σ B1, B2, G1, G2	≤ 10 ppb - Reg.EU 2023/915	Ph.Eur.9.0<2.8.18>	Conform

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Figure S2. ^{1}H-NMR spectra of PCC

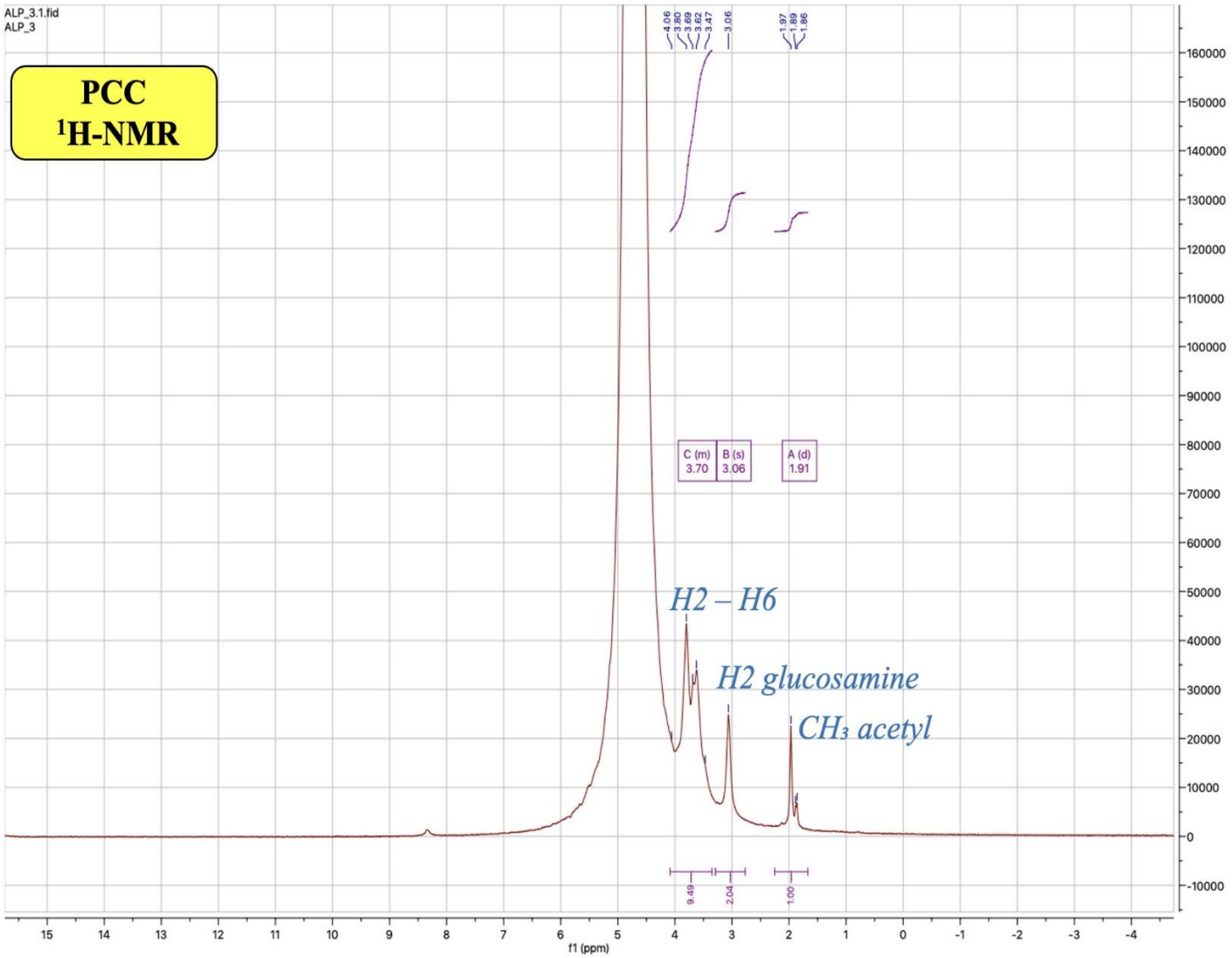


Figure S3. SEM images of NP-PS 100 nm standard (from Fig.3a to Fig. 3c); SEM images of PCC with NP-PS 100 nm (from Fig. 3d to Fig. 3f)

