Supporting Information

Contamination control in micro- and nanoplastics research: a diagnostic framework for reproducible analysis

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Scoring scheme for MNP-CCS1.0

For each category, a weighted average score is calculated. The Process Control Score (PCS) is the mean of the five process categories, calculated as $PCS = \frac{1}{5}\sum_{k=1}^{5} D_k$ where $D_k = \frac{\sum_{i=1}^{n}(g_i/2)\, w_i}{\sum_{i=1}^{n} w_i}$, and each indicator i in that category has a raw grade $g \in \{0,1,2\}$ normalized to $g/2 \in [0,1]$, and a risk weight $w_i \in \{1,2,3\}$. Intermediate scores (e.g., 0.5 or 1.5) are assigned where practices partially meet indicator definitions, reflecting graded implementation rather than binary presence or absence. Partial implementation is determined based on the extent to which a practice is documented as being applied across the analytical workflow. Partial scores are used, for example, when mitigation measures are applied to some but not all workflow stages, when controls are implemented inconsistently across batches, or when practices are described qualitatively without quantitative verification. These intermediate values are intended to structure evaluator judgment and improve transparency instead of enforcing rigid scoring rules. The Transparency Score (TS) is the normalized value of the transparency and reporting category. The final score is scaled from 1-100 as:

$$MNP\text{-}CCS1.0 = 100 \times \sqrt{PCS \times TS} \quad \text{(S1)}$$

The contamination control scorecard (CCS) combines PCS and TS using a geometric mean to reflect their interdependence, particularly in nanoscale analysis, where analytical sensitivity is highest. This multiplicative structure ensures that strong performance in one dimension cannot compensate for severe deficiencies in the other. Accordingly, lower composite scores arising from imbalances between PCS and TS are intentional, as the CCS is designed to highlight limitations that materially constrain interpretability. In this formulation, PCS captures intrinsic contamination-control practices within the analytical workflow, whereas TS captures the extent to which those practices and associated risks are visible and interpretable based on reported information.

Table S1: Diagnostic contamination indicators, associated risk weights, and raw scoring scheme (0-2) used in the MNP-CCS1.0 framework to evaluate contamination control practices and reporting transparency across MNP analytical workflows. Raw indicator scores are normalized to a 0-1 scale for calculation of the PCS and combined with the TS as described in the Supporting Information.

Category		Indicator	Weight (1-3)	Score (0-2)	Rationale
PCS	**Lab environment**	Clean room or laminar flow hood used	High (3)	0-1	Primary barrier against airborne fibers/particles.
		Passive/active air monitoring conducted	High (3)	0-2	Detects airborne MPs/NPs and temporal variation.
		No synthetic fibers in lab (e.g., carpets, curtains)	Medium (2)	0-1	Prevents pervasive fiber fallout.
		Regular environmental particle checks (settle plates, sticky pads)	Medium (2)	0-2	Tracks cumulative background load.
	Consumables and equipment	Glass/metal labware is used instead of plastic	High (3)	0-1	Reduces particle shedding from plastics.
		Consumables pre-cleaned (combusted, rinsed, filtered)	High (3)	0-2	Removes residual contamination before use.
		Enclosed systems for measurement equipment	Medium (2)	0-1	Prevents airborne particles from entering the workflow.
		Storage in a dust-free environment (foil, cabinets)	Medium (2)	0-1	Avoids particle settling on consumables.
		Regular equipment decontamination	Low (1)	0-2	Ensures buildup doesn't bias measurements.
	Reagents and solvents	Ultrapure water filtered or verified particle-free	High (3)	0-2	Ultrapure water often contains more MNPs than the samples.
		Chemical reagents (organic solvents, buffers, salts) filtered or verified particle-free	High (3)	0-2	Covers ethanol, methanol, salts, and digestion buffers - merged to avoid duplication.
		Contamination-free storage (glass ampoules, sealed vessels)	Low (1)	0-1	Prevents leaching from plastic containers.

	Blank controls	Procedural blanks included for each batch	High (3)	0-2	Critical baseline for workflow contamination.
		Reagent blanks or field blanks, as appropriate	Medium (2)	0-1	Identifies contamination from reagents and sampling.
		Positive/recovery controls included	Medium (2)	0-1	Validates method recovery and detection accuracy.
	Personnel and practices	Cotton/non-shedding lab coats	High (3)	0-1	Minimizes fiber shedding.
		Regular surface decontamination (e.g., EtOH, filtered water)	Medium (2)	0-2	Limits lab background.
		Gloves tested for MPs/NPs or avoided	Low (1)	0-1	Reduces particle shedding from gloves.
		Personnel training on contamination risks	Low (1)	0-1	Sustains good practice across staff.
TS	**Transparency and reporting**	Blank results disclosed (quantitative, variability, replicates)	High (3)	0-1	Essential for interpreting contamination burden.
		QA/QC metadata shared (LOD, calibration, monitoring)	Medium (2)	0-1	Improves reproducibility and comparability.
		Replicates/sample variability reported	Medium (2)	0-1	Indicates robustness of findings.
		SOPs documented/shared	Medium (2)	0-1	Enables reproducibility of workflow.
		External QA participation disclosed (if applicable)	Low (1)	0-1	Strengthens credibility via inter-lab testing.

Study 1 example of MNP-CCS1.0 score calculation (see Table S2)

Step 1: PCS calculation

Each of the five process categories is scored on the risk weights 0-3 scale. In study 1, the laboratory achieved: Lab environment = 0.4, Consumables and equipment = 0.77, Reagents and solvents = 1.0, Blank controls = 0.71, and Personnel and practices = 0.86. This gives PCS = 0.75.

Step 2: TS calculation

The transparency category is assessed against five reporting indicators, and if the laboratory reports 4 of these 5, the TS is 0.90 based on the weights of different indicators.

Step 3: Final score

The overall score calculated (from Equation S1) based on the PCS and TS scores is ~82.

A score of ~82 indicates strong laboratory practices and substantial reporting. Full reporting of all five transparency indicators would raise the TS to 1.0 and increase the score, signifying high-quality, reproducible workflows. This example demonstrates how MNP-CCS1.0 indicates rigorous practice and comprehensive reporting, encouraging balanced improvements rather than relying on a single dimension.

All scores in studies below are based exclusively on contamination control practices and reporting information described in the published studies; unreported measures could not be evaluated.

Table S2: MNP-CCS1.0 scoring of Study 1.[1] Reported practices included glass/metal consumables, rigorous cleaning, and procedural blanks, with transparent QA/QC metadata. Environmental monitoring and recovery controls were not reported.

Category		Indicator	Weight	Score	Rationale
PCS	**Lab environment**	Clean room or laminar flow hood used	High (3)	1	All sample preparation done in laminar flow bench.
		Passive/active air monitoring conducted	High (3)	0	No mention of air monitoring; airborne load unquantified.
		No synthetic fibers in lab (e.g., carpets, curtains)	Medium (2)	0.5	Cotton coats confirmed, but infrastructure (e.g., carpets/curtains) not reported.
		Regular environmental particle checks (settle plates, sticky pads)	Medium (2)	0	No checks reported.
	Consumables and equipment	Glass/metal labware used instead of plastic	High (3)	1	Sintered steel filters, muffled glassware, ZnSe windows used; plastics minimized.
		Consumables pre-cleaned (combusted, rinsed, filtered)	High (3)	2	Glassware muffled at 500 °C; reagents pre-filtered; strong measure.
		Enclosed systems for measurement equipment	Medium (2)	0	Raman/µFTIR not enclosed; exposure possible.
		Storage in dust-free environment (foil, cabinets)	Medium (2)	1	Filters stored in muffled Petri dishes.
		Regular equipment decontamination	Low (1)	1	Flow bench wiped with EtOH; no mention of FTIR/Raman cleaning.
	Reagents and solvents	Ultrapure water filtered or verified particle-free	High (3)	2	Milli-Q water is systematically filtered (0.7 µm GF membrane) before use.
		Chemical reagents (organic solvents, buffers, salts)	High (3)	2	SDS, EtOH filtered through muffled

		filtered or verified particle-free			membranes; comprehensive.
		Contamination-free storage (glass ampoules, sealed vessels)	Low (1)	1	Chemicals and samples stored in glassware/Petri dishes.
	Blank controls	Procedural blanks included for each batch	High (3)	2	Daily field blanks in replicates; strong implementation.
		Reagent blanks or field blanks as appropriate	Medium (2)	1	Field blanks (10 replicates) included.
		Positive/recovery controls included	Medium (2)	0	No recovery experiments reported.
	Personnel and practices	Cotton/non-shedding lab coats	High (3)	1	Pure cotton lab coats worn throughout.
		Regular surface decontamination (EtOH, filtered water)	Medium (2)	2	Flow bench and surfaces regularly cleaned with EtOH.
		Gloves tested for MPs/NPs or avoided	Low (1)	1	Plastic gloves avoided to reduce contamination.
		Personnel training on contamination risks	Low (1)	0	Not mentioned.
TS	**Transparency and reporting**	Blank results disclosed (quantitative, variability, replicates)	High (3)	1	Blank means reported and subtracted from sample values.
		QA/QC metadata shared (LOD, calibration, monitoring)	Medium (2)	1	LOD/LOQ thresholds, statistical corrections provided.
		Replicates/sample variability reported	Medium (2)	1	Triplicate samples analyzed; ANOVA statistics.
		SOPs or checklists documented/shared	Medium (2)	1	SOPs available in the study.
		External QA participation disclosed	Low (1)	0	No inter-lab QA reported.

Table S3: MNP-CCS1.0 scoring of Study 2.[2] Reported measures included filtered ultrapure water, replication, and procedural blanks. Reliance on some plastic consumables and limited blank/QC are the points to improve.

Category		Indicator	Weight	Score	Rationale
PCS	**Lab environment**	Clean room or laminar flow hood used	High (3)	0	Dedicated "special laboratory rooms" used, but not cleanroom or laminar flow hood.
		Passive/active air monitoring conducted	High (3)	0	No mention of air monitoring; airborne load unquantified.
		No synthetic fibers in lab (e.g., carpets, curtains)	Medium (2)	0.5	Cotton clothing worn; lint roller used; strong personal fiber mitigation, though infrastructure not fully described.
		Regular environmental particle checks (settle plates, sticky pads)	Medium (2)	0	Not performed.
	Consumables and equipment	Glass/metal labware used instead of plastic	High (3)	1	Plastics minimized; Teflon wash bottle used.
		Consumables pre-cleaned (combusted, rinsed, filtered)	High (3)	1	Glassware washed with soap/filtered water; but not muffled or combusted.
		Enclosed systems for measurement equipment	Medium (2)	0	No enclosed instruments reported.
		Storage in dust-free environment (foil, cabinets)	Medium (2)	1	Materials stored under foil/aluminium cover.
		Regular equipment decontamination	Low (1)	1	Floors mopped, benches wiped with ethanol, but no explicit instrument cleaning reported.
	Reagents and solvents	Ultrapure water filtered or verified particle-free	High (3)	2	Milli-Q water systematically filtered (0.45 µm) and stored in glass.
		Chemical reagents (organic solvents, buffers, salts) filtered or verified particle-free	High (3)	1	Ethanol filtered, but no report of all reagents filtered or tested.

		Contamination-free storage (glass ampoules, sealed vessels)	Low (1)	1	Ultrapure water stored in glass containers.
	Blank controls	Procedural blanks included for each batch	High (3)	1	One laboratory blank (ultrapure water) per campaign processed in parallel; not per batch.
		Reagent blanks or field blanks as appropriate	Medium (2)	0	No reagent blanks or field blanks reported.
		Positive/recovery controls included	Medium (2)	1	Glitter particle recovery control (n=50) performed: strong feature.
	Personnel and practices	Cotton/non-shedding lab coats	High (3)	1	Cotton clothing + cotton lab coat consistently used.
		Regular surface decontamination (EtOH, filtered water)	Medium (2)	2	Benches wiped with ethanol; floors mopped regularly.
		Gloves tested for MPs/NPs or avoided	Low (1)	0	Nitrile gloves used, not tested/reported as MP-free.
		Personnel training on contamination risks	Low (1)	0	Training not reported.
TS	**Transparency and reporting**	Blank results disclosed (quantitative, variability, replicates)	High (3)	1	Blank and positive control results disclosed.
		QA/QC metadata shared (LOD, calibration, monitoring)	Medium (2)	0	No detailed LODs or calibration data.
		Replicates/sample variability reported	Medium (2)	0	No mention of replicate analyses/statistical variability.
		SOPs or checklists documented/shared	Medium (2)	1	SOPs shared in the text.
		External QA participation disclosed	Low (1)	0	No inter-lab QA participation.

Table S4: MNP-CCS1.0 scoring of Study 3.[3] Reported strengths were glass bottles, avoidance of plastics, and cotton lab coats. Points that can be improved include laminar flow use, blanks (one DI blank reported), and the recovery tests.

Category		Indicator	Weight	Score	Rationale
PCS	**Lab environment**	Clean room or laminar flow hood used	High (3)	0	Used a negative-pressure ventilation system, but no laminar hood or cleanroom reported.
		Passive/active air monitoring conducted	High (3)	0	No mention of active or passive air monitoring.
		No synthetic fibers in lab (e.g., carpets, curtains)	Medium (2)	0.5	Cotton coats confirmed, but infrastructure (e.g., carpets/curtains) not reported.
		Regular environmental particle checks (settle plates, sticky pads)	Medium (2)	0	Not reported.
	Consumables and equipment	Glass/metal labware used instead of plastic	High (3)	1	Used dark glass bottles for sampling, avoided plastics.
		Consumables pre-cleaned (combusted, rinsed, filtered)	High (3)	2	Glassware rinsed 3× with filtered DI water; foil between bottle/cap.
		Enclosed systems for measurement equipment	Medium (2)	0	SEM/Raman work not enclosed beyond standard setup.
		Storage in dust-free environment (foil, cabinets)	Medium (2)	1	Samples covered with aluminum foil.
		Regular equipment decontamination	Low (1)	1	Surfaces cleaned repeatedly with 1M NaOH. No explicit mention of instrument decontamination.
	Reagents and solvents	Ultrapure water filtered or verified particle-free	High (3)	2	Used filtered DI water.
		Chemical reagents (organic solvents, buffers, salts) filtered or verified particle-free	High (3)	0	H_2O_2, $ZnCl_2$, $FeSO_4$ used but not filtered or tested for MPs.

		Contamination-free storage (glass ampoules, sealed vessels)	Low (1)	0	No details on reagent storage.
	Blank controls	Procedural blanks included for each batch	High (3)	1	One blank sample (filtered DI water) processed. But only one across study, not per batch.
		Reagent blanks or field blanks as appropriate	Medium (2)	0	No reagent blanks or field blanks described.
		Positive/recovery controls included	Medium (2)	0	No recovery testing reported.
	Personnel and practices	Cotton/non-shedding lab coats	High (3)	1	Cotton lab coats worn.
		Regular surface decontamination (EtOH, filtered water)	Medium (2)	2	Surfaces cleaned repeatedly with NaOH.
		Gloves tested for MPs/NPs or avoided	Low (1)	0	Nitrile gloves used, not tested.
		Personnel training on contamination risks	Low (1)	0	Not described.
TS	**Transparency and reporting**	Blank results disclosed (quantitative, variability, replicates)	High (3)	0	Mentioned blanks but no quantitative results provided.
		QA/QC metadata shared (LOD, calibration, monitoring)	Medium (2)	0	No LOD, calibration, or monitoring data.
		Replicates/sample variability reported	Medium (2)	1	Replicate SEM subsamples (cut-outs) and size fractions reported.
		SOPs or checklists documented/shared	Medium (2)	1	SOPs shared.
		External QA participation disclosed	Low (1)	0	Not mentioned.

Table S5: MNP-CCS1.0 scoring of Study 4.[4] Reported controls included careful handling, glassware, foil covers, and blanks prepared with identical procedures. Personnel practices and recovery/positive controls were not reported.

Category		Indicator	Weight	Score	Rationale
PCS	**Lab environment**	Clean room or laminar flow hood used	High (3)	0.5	Fume hood used. Laminar flow use not reported.
		Passive/active air monitoring conducted	High (3)	0	No mention of active or passive air monitoring.
		No synthetic fibers in lab (e.g., carpets, curtains)	Medium (2)	0	No mention of cotton lab coats or infrastructure (e.g., carpets/curtains).
		Regular environmental particle checks (settle plates, sticky pads)	Medium (2)	0	No routine checks (e.g. sticky pads) are described.
	Consumables and equipment	Glass/metal labware used instead of plastic	High (3)	1	Use of glass apparatus reported.
		Consumables pre-cleaned (combusted, rinsed, filtered)	High (3)	2	Chromic acid pre-cleaning, rinsed with bottled water, careful filter prep.
		Enclosed systems for measurement equipment	Medium (2)	0	Open multiphoton microscope, no enclosure.
		Storage in dust-free environment (foil, cabinets)	Medium (2)	1	Samples sealed in Petri dishes, foil covers, humidified D_2O.
		Regular equipment decontamination	Low (1)	0	No decontamination practices reported.
	Reagents and solvents	Ultrapure water filtered or verified particle-free	High (3)	1	Used Milli-Q water, but found it contaminated with nanoplastics. No alternative reported.
		Chemical reagents (organic solvents, buffers, salts) filtered or verified particle-free	High (3)	0	D_2O and agarose chosen to reduce background, but not explicitly tested for MPs/NPs.
		Contamination-free storage (glass ampoules, sealed vessels)	Low (1)	1	Foil covers, Petri dish storage → good practice.

	Blank controls	Procedural blanks included for each batch	High (3)	2	Anodisc blanks run, processed the same as samples.
		Reagent blanks or field blanks as appropriate	Medium (2)	0	No reagent blanks reported.
		Positive/recovery controls included	Medium (2)	0	No spiked recovery controls.
	Personnel and practices	Cotton/non-shedding lab coats	High (3)	0	No mention of cotton coats.
		Regular surface decontamination (EtOH, filtered water)	Medium (2)	1	Chromic acid cleaning of the apparatus, but no explicit lab bench cleaning routine.
		Gloves tested for MPs/NPs or avoided	Low (1)	0	Not mentioned.
		Personnel training on contamination risks	Low (1)	0	Not mentioned.
TS	**Transparency and reporting**	Blank results disclosed (quantitative, variability, replicates)	High (3)	1	Blanks reported (FOV-based, compared with samples).
		QA/QC metadata shared (LOD, calibration, monitoring)	Medium (2)	1	Calibration curves, detection limits, spectral thresholds.
		Replicates/sample variability reported	Medium (2)	1	Replicates, stats, Bonferroni correction.
		SOPs or checklists documented/shared	Medium (2)	1	SOPs reported. Extensive SI methods.
		External QA participation disclosed	Low (1)	0	No inter-lab comparisons.

Table S6: MNP-CCS1.0 scoring of Study 5.[5] Reported strong controls included glass/metal consumables, thorough cleaning, multiple blanks, and recovery tests, with high transparency in reporting. Glove testing was not reported.

Category		Indicator	Weight	Score	Rationale
PCS	**Lab environment**	Clean room or laminar flow hood used	High (3)	0.5	Fume hood used. Laminar flow use not reported.
		Passive/active air monitoring conducted	High (3)	1	Passive air monitoring through airborne deposition samplers (MilliQ blanks in fume hood) captured fallout.
		No synthetic fibers in lab (e.g., carpets, curtains)	Medium (2)	0.5	Cotton lab coats are used, but infrastructure (e.g., carpets/curtains) not reported.
		Regular environmental particle checks (settle plates, sticky pads)	Medium (2)	0	No routine checks (e.g. sticky pads) are described.
	Consumables and equipment	Glass/metal labware used instead of plastic	High (3)	1	All labware glass/metal, no plastics.
		Consumables pre-cleaned (combusted, rinsed, filtered)	High (3)	2	Rigorous triple rinses with DCM + MilliQ.
		Enclosed systems for measurement equipment	Medium (2)	1	Stirred cell closed system, foil covers, sealed handling.
		Storage in dust-free environment (foil, cabinets)	Medium (2)	1	Covered with DCM-cleaned foil during storage/processing.
		Regular equipment decontamination	Low (1)	1.5	Frequent system cleans, instrument blanks reported. No explicit mention of a physical decontamination procedure for the instrument.
	Reagents and solvents	Ultrapure water filtered or verified particle-free	High (3)	2	MilliQ filtered (0.7 µm GFF) before use.
		Chemical reagents (organic solvents, buffers, salts) filtered or verified particle-free	High (3)	1	Used high-grade reagents in glass; no direct nanoparticle screening beyond blanks.

		Contamination-free storage (glass ampoules, sealed vessels)	Low (1)	1	All reagents stored in glass bottles.
	Blank controls	Procedural blanks included for each batch	High (3)	2	Included, run with each sample set.
		Reagent blanks or field blanks as appropriate	Medium (2)	1	Field blanks and reagent blanks included.
		Positive/recovery controls included	Medium (2)	1	Spiking with PS/PMMA standards.
	Personnel and practices	Cotton/non-shedding lab coats	High (3)	1	100% cotton coats used.
		Regular surface decontamination (EtOH, filtered water)	Medium (2)	2	Routine ethanol cleaning before work.
		Gloves tested for MPs/NPs or avoided	Low (1)	0	Nitrile gloves used, not tested for shedding.
		Personnel training on contamination risks	Low (1)	0	Not explicitly described.
TS	**Transparency and reporting**	Blank results disclosed (quantitative, variability, replicates)	High (3)	1	Procedural/field blanks reported (Table S4).
		QA/QC metadata shared (LOD, calibration, monitoring)	Medium (2)	1	Full reporting of LOD/LOQ, calibration ($R^2 \geq 0.96$).
		Replicates/sample variability reported	Medium (2)	1	Triplicates across sample types, error bars reported.
		SOPs or checklists documented/shared	Medium (2)	1	Detailed workflows and SI protocols provided.
		External QA participation disclosed	Low (1)	0	No inter-laboratory calibration or external QA mentioned.

Table S7: Illustration of five different studies on MNP research based on MNP-CCS1.0.

Study	Lab environment	Consumables and equipment	Reagents and solvents	Blank controls	Personnel and practices	PCS (0-1)	TS (0-1)	Score (0-100)	Strengths	Points to improve based on MNP-CCS1.0
Study 1 [1]	0.40	0.77	1.00	0.71	0.86	0.75	0.90	≈82.0	Excellent control of reagents (filtered, muffled glassware, EtOH rinses). Strong personnel practices (cotton lab coats, no plastic gloves). High transparency in reporting blanks and corrections.	Limited lab environment controls (no air monitoring). No recovery controls included.
Study 2 [2]	0.10	0.64	0.79	0.50	0.71	0.55	0.50	≈52.0	Dedicated MP lab, strict cleaning, filtered ultrapure water, and positive controls included. Good procedural blanks.	Weak lab environment monitoring (no settle plates/air traps). Transparency limited (no QA/QC metadata).
Study 3 [3]	0.10	0.77	0.43	0.21	0.71	0.45	0.40	≈42.0	Strong consumables control (glass bottles, avoidance of plastics). Moderate personnel practices (cotton lab coats, NaOH cleaning).	Weak lab environment (no laminar hood/monitoring). Minimal blanks (single DI blank only). No recovery controls. Limited reporting.
Study 4 [4]	0.3	0.78	0.57	0.71	0.14	0.36	0.9	≈57.0	Careful sample handling with glass apparatus and foil covers during filtration. Inclusion of blank samples prepared with the same filtration and embedding procedure. Transparent reporting of blank results and particle count corrections.	Personnel practices not clearly described (no mention of cotton coats or glove checks). No recovery or positive controls included to benchmark detection efficiency.
Study 5 [5]	0.9	1	0.79	1	0.71	0.78	0.9	≈84.0	Strong QA/QC framework: cotton lab coats, cleaned work surfaces, and extensive procedural/lab blanks. Rigorous cleaning of all glassware and equipment. Instrumental blanks were included to capture contamination at multiple stages. Transparent disclosure of blank levels, recoveries, and detection limits.	Synthetic fibers in the lab not explicitly addressed. No mention of glove checks.

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