

Particle and Microplastic Release from Printed Photopolymers: Wear, Weathering, Measurement and Exposure Boundaries

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ER-277 · Engineering Review · Version 0.2 · 23 September 2026

Abstract

Printed photopolymers can lose matter through abrasion, fracture, surface ageing and combined environmental-mechanical loading, but a measured mass loss or airborne particle signal does not by itself establish a microplastic-release rate. Direct VPP evidence shows measurable wear of SLA photopolymer denture teeth under controlled tribological loading [1] and task-resolved particle emission during vat-photopolymerisation processing, including sanding [2]. Broader polymer evidence shows that ultraviolet exposure and mechanical abrasion can interact to accelerate surface degradation and particle release [3]. ER-277 defines how those observations should be converted into a defensible release assessment for printed photopolymers. It separates article wear from manufacturing aerosol, distinguishes mass loss from particle number and size distribution, requires recovery-efficiency and blank controls, and treats weathering history, surface state and exposure compartment as part of the measured state. No universal microplastic emission factor, particle-size distribution or environmental exposure threshold is claimed.

Keywords: printed photopolymers; particle release; microplastics; wear; weathering; abrasion; exposure; measurement; vat photopolymerisation

1. Significance, scope and ownership

ER-277 owns particle and microplastic release from finished printed photopolymer articles under wear, weathering and combined service exposures. It covers the chain from defined article state and exposure history to recovered particles, particle-size/number/mass metrics and bounded exposure interpretation. ER-040 [4] retains tribology as a material-performance subject; ER-072 [5] retains environmental ageing and property retention; ER-178 [4] retains waste management; ER-278 owns ecotoxicity of uncured constituents and mixtures. Manufacturing-task aerosols are useful measurement context but remain a distinct exposure pathway from service-generated microplastics.

1.1 Corpus boundary

ER-40 retains tribological wear as a performance subject, ER-72 retains environmental ageing/property retention, and ER-178 retains waste disposition. ER-277 does not reclassify those subjects. It asks a narrower question: when a printed article loses material, what evidence is needed to identify, quantify and interpret the released particle population without conflating wear, aerosol generation, leaching and chemical toxicity. ER-278 is a current-series neighbour for uncured-mixture ecotoxicity and is not used here as evidentiary authority.

2. Define the released-material claim before selecting a method

A wear scar, gravimetric mass loss, turbidity increase, filtered residue, particle count and chemically identified microplastic population are different observations. The claimed endpoint should therefore be stated before sampling. Pham and co-workers measured three-body wear depth in SLA-printed methacrylate denture teeth [1]. That study demonstrates material loss under a controlled tribological system but does not provide a particle-size-resolved environmental emission factor. The measurement architecture must preserve that distinction.

3. Freeze the printed article state

Record resin identity and lot, printer, wavelength, orientation, layer schedule, wash, drying, post-cure, finishing, coating, sterilisation or cleaning, storage and ageing. Surface cure and finishing can dominate early release. A polished test coupon cannot represent an as-printed textured surface unless polishing is the qualified production state. Exposed support scars, channels, thin edges and interfaces require deliberate inclusion when they are credible release sites.

4. Separate service particles from manufacturing aerosols

Bowers and co-workers measured particles and gases throughout SLA and DLP tasks, with particle release varying by task and sanding included among post-processing operations [2]. Those observations establish that VPP workflows can generate airborne particulate exposure, but they do not quantify long-term particle shedding from a delivered article. ER-277 records manufacturing aerosol only when it is part of the declared exposure question and never substitutes it for service-wear release.

5. Weathering changes both source strength and particle identity

Sun and co-workers showed in polyethylene and thermoplastic polyurethane films that combined ultraviolet exposure and mechanical abrasion accelerated surface degradation and altered the amount and size of released microplastics relative to either stress alone [3]. This is adjacent polymer evidence rather than direct VPP class evidence. It nevertheless demonstrates why a photopolymer release test should declare radiation spectrum/dose, temperature, humidity or liquid exposure and abrasion sequence rather than treating the pristine surface as representative of the aged article.

6. Close the particle-recovery balance

Sampling should record the exposed area or article, exposure duration or cycles, receiving medium, collection surfaces, filtration/cascade stages, recovery efficiency, field blanks, procedural blanks and losses. Report at least one primary release quantity with its denominator, such as mass per area and cycle, particles per article and interval, or size-resolved concentration in a receiving phase. Recovery below the method capability cannot be silently treated as zero release.

7. Characterise particle size and composition together

Optical microscopy, light scattering, nanoparticle tracking, electron microscopy or spectroscopic mapping provide different size windows and biases. Chemical confirmation may use FTIR, Raman or another validated material-specific method. A particle count without composition can include dust, filter fragments or environmental background; a polymer spectrum on a few selected particles cannot establish the numerical distribution of the whole population. Size, morphology and identity therefore require an explicit sampling and subsampling plan.

8. Distinguish particulate release from dissolved release

Weathering can produce both particles and soluble or colloidal chemical species. ER-277 assigns solid/particulate material to the particle pathway and routes dissolved constituents to chemical-characterisation and toxicity frameworks such as ER-086 and ER-278. A filter retentate result cannot prove absence of dissolved photoinitiator, monomer or degradation product, and a dissolved-organic measurement cannot quantify particles retained above the analytical cutoff.

9. Non-compensatory release gates

Gate	Minimum evidence	Blocking failure
Article state	Final print/wash/cure/finish/ageing state frozen	Undefined or idealised coupon
Exposure	Load, medium, weathering and duration/cycles declared	Wear history not reproducible
Recovery	Collection efficiency and blanks quantified	Unrecovered mass treated as zero
Size window	Method range and censoring reported	Micro/nano claim beyond method
Identity	Particle composition confirmed with controls	All counted particles called photopolymer
Dissolved fraction	Separated or explicitly unresolved	Leachables conflated with particles
Denominator	Area/article/time/cycles defined	Release number without basis
Exposure interpretation	Compartment and transfer assumptions stated	Emission directly called dose or risk

10. Minimum experiment

Use at least one final-state article and a matched unexposed control. Apply a declared wear, weathering or combined sequence that represents the intended question. Collect all receiving media and contact surfaces through a method with measured recovery and blanks. Quantify article mass or dimensional change where meaningful, then measure the released population over a defined size window and chemically confirm the relevant particle family. Repeat across specimens and report censored values, recovery limits and unresolved size fractions rather than extrapolating beyond the method.

11. Knowledge boundary

Direct VPP evidence supports controlled wear of printed photopolymer articles and task-resolved particle generation during manufacturing [1,2]. Direct weathering-plus-abrasion microplastic evidence used here comes from other polymers [3]. ER-277 therefore does not claim a VPP-wide microplastic emission factor or universal degradation mechanism. It defines the evidence needed to produce one for a specific printed material, article state and exposure scenario.

12. Conclusions

Particle release from printed photopolymers is a state-resolved measurement problem, not a synonym for wear or ageing. A defensible claim connects the final article, declared exposure history, closed recovery balance, validated size window and chemical identity of the released population. Manufacturing aerosols, dissolved leachables, tribological performance and environmental toxicity remain separate evidence streams that can be coupled only after each has been measured on compatible states.

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