

Aquatic and Terrestrial Ecotoxicity of Uncured Photoresin Constituents and Mixtures: Exposure Realism and Evidence Gaps

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Abstract

Uncured photoresin is a reactive multicomponent mixture whose environmental hazard cannot be inferred from the cured article or from one ingredient safety classification. Ballentine and co-workers measured acute and chronic toxicity of six uncured vat-photopolymerisation resin feedstocks to *Ceriodaphnia dubia* and found resin-dependent responses across the tested aqueous exposures [1]. Separate SLA studies show that additives can migrate from printed polymer into water and produce developmental effects in zebrafish [2], while printed-part toxicity can be reduced by post-processing without becoming equivalent to uncured-feedstock toxicity [3]. ER-278 defines an ecotoxicity evidence architecture for uncured photoresin constituents and mixtures. It separates intrinsic hazard from realistic environmental exposure, requires mixture and carrier controls, treats solubility and dispersion as measured test conditions, and prevents one aquatic species or one nominal concentration from being converted into a universal environmental-risk conclusion. Terrestrial evidence is explicitly identified as a gap where direct photopolymer data are absent.

Keywords: uncured photoresin; ecotoxicity; aquatic toxicity; terrestrial exposure; mixtures; photoinitiators; methacrylates; exposure realism; evidence gaps

1. Significance, scope and ownership

ER-278 owns ecotoxicity evidence for uncured photoresin constituents and mixtures, with emphasis on how test-medium preparation, mixture composition, bioavailability and environmental exposure determine interpretation. ER-086 retains extractables from finished articles; ER-178 [4] retains waste management and legal disposition; ER-277 [5] retains particle/microplastic release; ER-279 retains analytical monitoring of contaminated wastewater. ER-278 does not issue a discharge limit or classify a waste stream.

1.1. Corpus boundary

ER-86 retains finished-article extractables, and ER-178 retains waste management and disposition. ER-278 narrows the question to biological effects of uncured or incompletely controlled resin mixtures and their constituents. ER-277 and ER-279 are current-series neighbours for particle release and wastewater analytics respectively and are not used here as published evidentiary authority. ER-278 does not treat a toxicity endpoint as an exposure assessment, and it does not transfer one species response into a regulatory environmental threshold.

2. Test the actual mixture state

Ballentine and co-workers tested six uncured VPP resin feedstocks with *Ceriodaphnia dubia* and reported resin-dependent acute and chronic responses [1]. Their work demonstrates that commercial resin mixtures can produce materially different toxicity profiles. The test object must therefore include formulation identity, lot, age, prior light/heat exposure, dilution vehicle, preparation method and visible phase state. A nominal resin concentration is incomplete when undissolved droplets, precipitate or carrier solvent changes bioavailability.

3. Separate mixture hazard from constituent attribution

A mixture response establishes that the tested preparation caused an effect; it does not identify which constituent or interaction caused it. Attribution requires analytical composition and, where justified, constituent or reconstructed-mixture testing. Walpitagama and co-workers detected migration of the photoinitiator 1-hydroxycyclohexyl phenyl ketone from SLA-printed plastic and linked defined aqueous exposures to developmental and neurobehavioural effects in zebrafish [2]. That finished-part leachate study demonstrates constituent migration and biological response but is not an uncured-resin dose-response study.

4. Preserve the cured/uncured boundary

Oskui and co-workers evaluated toxicity of 3D-printed parts from FDM and SLA and showed that post-processing could alter the observed toxicity of printed objects [3]. A cured and washed article is therefore a different material state from uncured feedstock. ER-278 does not use cured-part toxicity to dilute concern about uncured mixtures, nor does it use uncured-mixture toxicity as a direct prediction of a fully processed article.

5. Exposure realism is a separate axis

Environmental risk depends on both hazard and exposure. A laboratory test may intentionally use a severe aqueous preparation to characterize hazard, while a site-specific exposure model may predict far lower or differently partitioned concentrations. Record receiving compartment, dilution, sorption to solids, hydrolysis or photolysis where known, treatment history and release frequency. Do not label a hazard-test concentration environmentally realistic without a defensible pathway and mass balance.

6. Carrier solvents and water-miscible cleaners can change bioavailability

Ballentine and co-workers note that isopropyl alcohol can increase resin miscibility in water and therefore influence exposure [1]. Carrier or cleaning solvent must be treated as an experimental factor with its own control. A mixture prepared in solvent, a dispersed neat-resin preparation and a treated wastewater sample are not interchangeable exposure states even at the same nominal mass concentration.

7. Use multiple biological levels without averaging them together

Acute survival, reproduction, development, behaviour, growth and chronic population-relevant endpoints address different biological questions. Ballentine et al. included acute and chronic cladoceran endpoints [1], while Walpitagama et al. evaluated developmental and neurobehavioural effects in zebrafish [2]. Evidence from one endpoint cannot compensate for an unresolved high-consequence response in another. Cross-species comparison should retain exposure route, life stage and test chemistry.

8. Terrestrial evidence remains a controlled gap

Direct photopolymer-resin ecotoxicity evidence is presently much stronger for aquatic preparations than for soil organisms, plants or terrestrial invertebrates. ER-278 therefore does not invent a terrestrial threshold by applying aquatic factors or generic polymer data. A terrestrial claim requires a defined soil or sediment exposure preparation, sorption/aging state, appropriate organisms and measured concentrations or a clearly bounded screening approach.

9. Non-compensatory release gates

Gate	Minimum evidence	Blocking failure
Mixture identity	Formulation/lot/state and preparation documented	Generic resin category used
Exposure state	Dissolved/dispersed/particulate state bounded	Nominal concentration only
Carrier control	Solvent/cleaner control and concentration	Carrier effect unseparated
Analytical verification	Exposure concentration measured or justified	Prepared dose assumed stable
Endpoint	Species, life stage and biological endpoint declared	One endpoint generalized to ecosystem
Hazard/exposure split	Laboratory hazard and environmental scenario separated	Test concentration called environmental risk
Mixture attribution	Causal constituent only when supported	Mixture effect assigned to one ingredient
Terrestrial claim	Direct terrestrial evidence or explicit gap	Aquatic data extrapolated as terrestrial proof

10. Minimum experiment

Freeze one uncured formulation and lot; analytically document the preparation and carrier; measure or bound the dissolved, dispersed and particulate state; include blank and carrier controls; expose at least a concentration series with replicates and a defined biological endpoint; verify exposure concentration at appropriate times when instability or sorption is credible; and record mixture changes during the test. For environmental interpretation, add a separate exposure scenario and mass balance rather than relabeling the laboratory test concentration as an environmental dose.

11. Knowledge boundary

Direct evidence supports aquatic toxicity of several uncured VPP resin mixtures and biological effects from chemicals migrating from printed SLA articles [1-3]. Those studies do not establish a universal mixture threshold, identify all causal ingredients or close terrestrial ecotoxicity. ER-278 therefore reports the gap explicitly and supplies an evidence architecture rather than a generic safe concentration.

12. Conclusions

Uncured photoresin ecotoxicity is a mixture-state and exposure-state problem. Credible interpretation requires formulation identity, controlled preparation, analytical confirmation of exposure, biological endpoint specificity and a separate environmental-exposure model. Cured-part leachates, uncured feedstock and treated wastewater are related but non-interchangeable states. Terrestrial conclusions remain withheld until direct evidence exists.

References

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