

Solvent, Wash-Water and Contaminated-Waste Management

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Treatment: An evidence-gap and decision-architecture review. It assigns no universal waste class and prescribes no treatment or disposition route.

Statement of significance

Photoresin waste is not one material. Unused resin, contaminated wash solvent, aqueous wash, sludge, filters, wipes and cured solids differ in composition, physical state, contamination history and legal status. A technical operation such as filtration, distillation or further curing can change a stream without proving that the output is safe, equivalent to virgin material or acceptable for discharge, reuse or disposal. ER-178 separates stream identity, hazard evidence, technical treatment, verification, regulatory determination and final disposition. Its principal unresolved result is contaminant-resolved treatment and disposition of operational wash water.

Abstract

Vat-photopolymerisation operations generate chemically distinct liquid and solid waste streams. Direct evidence recovered for this review is uneven. An abstract-level aquatic-toxicity study and its publisher supplement show that six commercial uncured-resin categories produced formulation-dependent biological responses and distinguishable aqueous HPLC-UV profiles under the study conditions [1]. The evidence supports conservative segregation and a no-discharge posture, but not a universal waste class, toxicity ranking, discharge threshold or treatment endpoint. Two industrial supplier case studies demonstrate that distillation can recover a large solvent fraction from the specific resin-contaminated isopropanol streams and devices tested [2,3]; they do not establish virgin-solvent equivalence, residue classification or legal permission. A recent abstract describes a photooxidation-pyrolysis route for a defined photocured solid waste [4], not wash water or contaminated solvent. European Union waste instruments and United States generator guidance establish jurisdiction-specific decision architectures rather than a single classification for photopolymer waste [5–7]. United States industry guidance from 2010 identifies contaminated cleaning water as a controlled waste question and warns against assuming direct sewer disposal [8]. On this basis, ER-178 defines a stream-first control architecture: identify and preserve provenance, segregate, determine the applicable jurisdiction, characterise to the extent needed for the decision, assess a stream-specific treatment, verify the treated outputs, and obtain the applicable disposition decision. Cure-out is treated as a state change requiring verification, and solvent recovery as a separation operation requiring qualification. The unresolved limb remains operational wash-water composition, treatment performance and disposition under the governing local requirements.

Keywords: vat photopolymerisation; photoresin waste; wash water; contaminated solvent; isopropanol recovery; cure-out; waste classification; segregation; evidence gap

1. Scope and ownership

ER-178 addresses solvent, wash-water and contaminated-waste management arising from photoresin manufacture, vat photopolymerisation, part washing and associated handling. It owns stream identification, segregation, characterisation for a waste decision, technical recovery or state-change evaluation, output verification and the boundary between a treatment result and a lawful disposition.

It does not own the environmental comparison of products or processes. ER-017, *Life-Cycle Assessment of Vat Photopolymerisation: Functional Units, System Boundaries, Inventory Quality and Uncertainty*, retains life-cycle assessment and environmental-superiority claims [9]. ER-033, *Washing- and Drying-Induced Extraction, Property Change and Dimensional Response in Vat-Printed Photopolymers: A Qualification Note*, and ER-086, *Analytical Extractables and Leachables from Vat-Printed Photopolymers: Specimen State, Extraction Design, Analytical Coverage and Cross-Study Comparability*, retain part-cleaning qualification

and the effect of extraction on the printed part [10,11]. ER-183, *Mechanical Recycling and Reuse of Cured Photopolymer Waste: Size Reduction, Resin Reincorporation and Requalification*, retains intentional mechanical recycling and reincorporation of identified cured solids [12]. ER-177 retains verification of occupational exposure controls [13].

ER-178 does not qualify recovered solvent for reuse in printing, authorise incorporation of a contaminated stream into photorexin, or establish product conformity. Waste treatment and product qualification answer different questions.

2. The central result: the stream must be identified before the route is selected

The term *photorexin waste* collapses distinct objects. At minimum, an operation should distinguish:

1. unused, expired or off-specification liquid resin;
2. wash solvent contaminated with dissolved or dispersed resin constituents;
3. aqueous wash contaminated with resin constituents, cleaning agents or both;
4. vat sludge, settled material, filters and treatment residues;
5. wipes, gloves, absorbents, packaging and other contaminated solids;
6. failed, surplus or end-of-life solids whose extent and uniformity of cure are known or unknown; and
7. outputs from a treatment step, including recovered solvent, distillation bottoms, filtrate, concentrate, emissions-control residue and treated solid.

These categories are operational starting points, not legal waste codes. The final classification can depend on composition, concentration, physical properties, contamination history, origin, jurisdiction and the route by which the material became waste. A change of physical appearance does not erase that history.

The decision sequence is therefore stream first, route second. Choosing filtration, evaporation, distillation, further light exposure, thermal treatment, discharge or disposal before establishing what stream is being managed reverses the evidentiary order.

3. What the direct evidence establishes

3.1 Uncured-resin aquatic hazard: a basis for segregation, not classification

Ballentine and co-workers studied acute and chronic effects of six uncured vat-photopolymerisation resin feedstocks on *Ceriodaphnia dubia* [1]. The article's bibliographic identity and abstract were resolved, but the main article was not obtained for this review. The abstract supports only the high-level propositions that the study evaluated six formulations, used acute and chronic endpoints, and identified isopropanol as relevant to miscibility, fate, transport and bioavailability during cleaning and waste handling. No endpoint value, effect concentration, statistic or method detail from the main article is used here.

The official publisher supplement was read. Its first figure presents concentration-response information for the six categories, but the tested ranges are not common. Tough and Black were shown at 0, 3.13, 6.25, 12.5, 25 and 50 mg/L; Clear, Castable and High Temp at 0, 6.25, 12.5, 25, 50 and 100 mg/L; and Durable at 0, 1.56, 3.13, 6.25, 12.5 and 25 mg/L [1]. The caption assigns the line to neonate count on the left axis and the bars to days to first brood on the right axis. Because the ranges differ, the panels do not support a potency ranking. For Clear, no concentration-response was apparent over the range tested for that resin and endpoint; this is not evidence that the resin is non-toxic, safe or dischargeable.

The second supplemental figure contains aqueous HPLC-UV traces at 210 nm for the same six categories [1]. The profiles are distinguishable under the reported measurement, but the traces are vertically offset and cannot be compared as though they shared a common zero. They support neither cross-resin peak-height or peak-area comparison nor compound identification or concentration inference.

The bounded engineering consequence is conservative: resin-contaminated water and solvent should remain segregated and should not be discharged without a stream-specific determination. The evidence does not assign a legal class, treatment endpoint, discharge limit or cure-out equivalence.

3.2 Contaminated-solvent recovery: feasibility without equivalence

Two CBG Biotech application tests report distillation of resin-contaminated isopropanol in the supplier's S700 and S700V equipment [2,3]. The reported test pages are industrial supplier case studies, not independent peer-reviewed studies. One page reports 29.6 lb input, 27.2 lb recovered isopropanol and 1.6 lb residue, with 96.2% net mass recovery and an estimated isopropanol concentration of approximately 99% [2]. The dental case reports 27.6 lb input, 25.8 lb recovered isopropanol and 1.02 lb residue, with 97% net mass recovery and a corrected concentration estimate of approximately 99% [3].

These observations establish technical feasibility only for the reported streams, devices and test conditions. They do not identify every contaminant in the distillate, demonstrate equivalence to virgin solvent, qualify the recovered solvent for every photoresin or wash process, classify the residue, or provide legal authority for operation, emission, reuse or disposal.

3.3 Photocured-solid treatment: a separate stream and route

Zhang and co-workers report a photooxidation-pyrolysis treatment for photocured waste, with evaluation of photoinitiator degradation and gas, liquid and solid products [4]. The source was available only at abstract depth for this review. It establishes that a defined coupled treatment route has been studied for a defined photocured solid. It does not support an instruction for contaminated wash solvent, aqueous wash, sludge or untreated liquid resin. It also does not establish that ordinary post-curing converts an unidentified waste into a universally non-hazardous or disposable material.

3.4 The unresolved wash-water limb

No contaminant-resolved primary evidence was recovered that connects operational photoresin wash-water composition to a validated treatment train, verified treated-water endpoint and jurisdiction-specific disposition. General waste law cannot fill this technical gap. The Ballentine evidence concerns prepared aqueous resin solutions and not an operational wash stream with a declared cleaning chemistry and use history [1]. Supplier solvent-distillation cases concern isopropanol rather than water [2,3]. The photocured-solid study concerns a different physical state and treatment route [4].

This unresolved limb is the principal finding of ER-178. It is not a recommendation to improvise a treatment. It is the reason a site must retain and characterise the actual stream, consult the applicable authority or authorised waste contractor, and avoid discharge until a defensible decision exists.

4. Law and guidance provide an architecture, not a universal answer

4.1 European Union framework, read as of 15 September 2026

Directive 2008/98/EC, in its consolidated European Union form, establishes the waste hierarchy, duties directed to the waste holder, protection of human health and the environment, and additional controls for hazardous waste [5]. Commission Decision 2000/532/EC establishes the European list of waste and the associated classification architecture [6].

These instruments do not assign one universal entry to every photoresin wash solvent, wash water, sludge or cured solid. Applying the architecture requires the stream's origin and composition to be compared with the applicable list entry and hazardous-property rules. ER-178 neither selects an entry nor decides a classification.

4.2 United States framework, read as of 15 September 2026

Current United States Environmental Protection Agency generator guidance describes a generator's duty to identify each waste and make a hazardous-waste determination under 40 CFR 262.11 before selecting management and disposal arrangements [7]. This is a United States, generator-specific architecture. It does not classify every photopolymer waste as hazardous and does not transfer to another jurisdiction.

RadTech's *Guidance on Cleanup and Disposal of UV/EB-Curing Waste Materials* is 2010 United States industry guidance, not current universal law [8]. It identifies contaminated cleaning wastewater as a waste stream, places aqueous-cleaner disposal within applicable water-discharge requirements, and warns that direct sewer discharge may require pretreatment, a permit or both. It supports a conservative decision path; it does not supply a present-day site classification or permission.

4.3 The jurisdictional rule

Every classification and disposition statement must name the jurisdiction and the date of the rule or determination. A technically successful separation is not regulatory acceptance. Conversely, a permitted disposal route does not qualify recovered material for reuse in a manufacturing process.

5. Decision architecture

The architecture below is a constructed engineering control system over the bounded evidence. It is not a treatment prescription.

5.1 Establish identity and custody

Record the source operation, resin or formulation identity, safety-data information, wash medium, additives, prior contents, dates, batch or lot, process history, known cross-contamination, physical state and container identity. Where the composition is proprietary or incomplete, record that limitation rather than replacing it with a generic product category.

5.2 Segregate pending compatibility and classification

Keep chemically or operationally distinct streams separate until mixing compatibility and the effect on classification, recovery and disposal have been assessed. Segregation preserves evidence and prevents a manageable stream from becoming an unidentified mixture. Ballentine's formulation-dependent observations support this conservative rule [1]. They do not define a universal segregation scheme.

5.3 Define the decision before selecting the test

Characterisation should answer a declared question: classification, treatment control, recovered-solvent reuse, emission control, transport, contractor acceptance or discharge compliance. A test suitable for one decision may be insufficient for another. Total solids, a single optical signal or a nominal solvent concentration cannot by itself establish contaminant identity, hazard or reuse suitability.

5.4 Evaluate the proposed operation as a mass-balance problem

For filtration, settling, distillation, adsorption, oxidation, further curing or another proposed operation, identify all expected outputs: product or recovered fraction, concentrate, bottoms, filters, sludge, off-gas, condensate and equipment-cleaning residue. Moving contamination from one phase to another is separation, not disappearance.

The assessment should state the input identity, operating conditions, sampling points, analytical coverage, balance closure, repeatability and stop conditions. Any unmeasured output remains an unresolved branch.

5.5 Verify the output against its intended destination

A treated liquid intended for discharge requires evidence against the applicable discharge requirements and permission for that site and stream. A recovered solvent intended for reuse requires composition and process-performance evidence under the intended wash operation. A residue sent to a contractor requires the classification and acceptance information that contractor and jurisdiction require. A solid intended for recycling requires the ER-183 requalification route [12].

5.6 Record the disposition and its limits

The record should identify who made the determination, the applicable jurisdiction, the evidence reviewed, the route selected, the receiving party or permit basis where applicable, and any conditions or expiry. A route established for one stream, formulation, site or date should not silently become a universal rule.

6. Distillation does not prove recovered-solvent suitability

Distillation can separate a volatile solvent fraction from less volatile material, as the supplier case studies demonstrate for their reported isopropanol streams [2,3]. That physical result is only the first gate.

Reuse in part washing requires a separate qualification. The recovered fraction can differ from virgin solvent in water content, volatile co-contaminants, dissolved species, suspended matter and accumulated components carried through repeated cycles. ER-033 and ER-086 retain the effect of washing and extraction on the printed part [10,11]. A recovered-solvent decision should therefore specify the intended resin and wash stage, analytical checks, part-response endpoints, replacement or bleed rule, cycle history and conditions that

terminate reuse.

No value reported in the supplier cases is adopted as a universal purity threshold or recovery expectation. The cases do not classify the still bottoms and do not authorise atmospheric release, sewer disposal or landfill.

7. Wash water must remain unresolved until the actual stream is resolved

Water-based or water-miscible cleaning does not make the contaminant benign. The stream can contain dissolved, dispersed or suspended resin constituents, cleaning agents, reaction products and solids. Its composition can change with resin, wash chemistry, loading, residence time, temperature, filtration and prior use.

No recovered source provides a universal relation between a simple field measurement and a safe or lawful endpoint for photoresin wash water. Turbidity, colour, conductivity, pH, total organic carbon or solids may be useful within a validated site method, but none is promoted here as a universal surrogate. The absence of a visible phase is not evidence that dissolved constituents are absent.

Accordingly, ER-178 provides no instruction to discharge, evaporate, filter and discharge, cure and discharge, or mix wash water with another stream. The no-discharge posture remains until contaminant-resolved evidence and the applicable site decision support a route.

8. Cure-out is a state change, not automatic declassification

Additional light or thermal exposure may reduce mobile or reactive content in a defined material, but the achieved state depends on optical access, thickness, geometry, oxygen, exposure, temperature and composition. Shadowed sludge, opaque material, filled resin and contaminated absorbents can contain regions that do not receive the same treatment.

Even when conversion is demonstrated, curing does not prove removal of every hazardous property, destruction of every photoinitiator or additive, absence of leachable constituents, or acceptance under a particular waste code. Zhang's abstract-level solid-treatment study reinforces the distinction between a designed treatment route and ordinary cure-out [4]. Cure-out must therefore be described by the actual operation and verified endpoint; it cannot be used as an automatic legal or safety conclusion.

9. Failure modes of a waste-management programme

Using one container label for unlike streams. A generic *resin waste* label loses the composition and history needed for classification and treatment.

Treating a supplier case as a universal process window. The CBG Biotech reports are device- and stream-specific industrial supplier cases [2,3].

Calling a distillate virgin-equivalent from solvent concentration alone. Concentration does not establish the identity or absence of relevant co-contaminants, nor performance in a defined washing process.

Treating a clear liquid as clean water. Dissolved constituents may remain when suspended material is absent.

Assuming cure-out eliminates hazardous status. State change and legal classification are separate gates.

Applying one jurisdiction's guidance elsewhere. The European Union instruments, United States EPA guidance and 2010 United States industry guidance have different authority and scope [5–8].

Ignoring secondary outputs. Filters, still bottoms, concentrates, sludge and off-gas controls remain material streams requiring their own decisions.

Using waste treatment as product qualification. A recovered stream is not qualified for reincorporation or printing merely because a treatment was technically successful.

10. Minimum reporting set

A reviewable record should include:

1. stream category and source operation;
2. formulation, product, lot and safety-data references available to the holder;
3. wash medium, additives, loading history and known cross-contamination;

4. physical state, quantity, container and custody dates;
5. applicable jurisdiction, site and decision date;
6. proposed treatment and every expected output;
7. sampling plan, analytical methods, detection capability and unresolved analytes;
8. input-output mass balance and uncertainty where treatment is evaluated;
9. recovered-fraction specification and intended use, if reuse is considered;
10. residue and emissions-control disposition;
11. authorised contractor, permit or other decision basis where applicable;
12. deviations, expiry, change triggers and the person or function approving the disposition.

The public record need not disclose proprietary formulation composition. The controlled record must nevertheless preserve enough identity and evidence for the responsible party to make and defend the decision.

11. Change control

Reassessment is triggered by a change in resin or formulation, wash chemistry, water source, solvent grade, loading, temperature, residence time, equipment, filter or adsorbent, distillation settings, cure geometry, throughput, mixture of waste streams, site, contractor, intended reuse, analytical method, permit or applicable law.

A bridge is acceptable only when the retained measurements can detect the consequence of the change and the comparison is made under controlled conditions. A previous disposition should not be extended merely because the new stream has the same generic name.

12. Evidence limitations and research priorities

The main Ballentine article and the Zhang article were not read in full [1,4]. No main-article endpoint, statistical result, material composition or treatment detail is promoted from them. The Ballentine supplement contains two figures and their captions, not the full methods needed to reconstruct or generalise the experiments [1]. The supplier case studies are not independent peer-reviewed evidence [2,3]. The legal sources establish frameworks, not a classification for the streams addressed here [5–7]. RadTech is 2010 United States industry guidance [8].

The highest-value research need is a contaminant-resolved study of operational photoresin wash water that links formulation and wash history to analytical composition, treatment mass balance, residual hazard-relevant endpoints and a declared jurisdictional decision. Further needs are independent validation of contaminated-solvent recovery, contaminant carryover across repeated reuse cycles, verified treatment of mixed sludge and absorbents, and cure-state measurements connected to rather than substituted for waste classification.

13. Conclusions

1. Photoresin waste must be divided into identifiable streams before treatment or disposition is selected.
2. The recovered toxicity evidence supports conservative segregation and a no-discharge posture only; it supplies no universal class, safety conclusion, threshold or permission [1].
3. Distillation of resin-contaminated isopropanol is technically feasible in the reported supplier cases, but recovered-solvent equivalence, residue classification and legal permission remain separate questions [2,3].
4. A defined photocured-solid treatment study does not transfer to wash water, contaminated solvent or ordinary cure-out [4].
5. European Union and United States sources establish jurisdiction-specific decision architectures, not a universal classification for photopolymer waste [5–7].
6. Cure-out is a state change requiring verification and is not automatic declassification.
7. The principal unresolved limb is contaminant-resolved wash-water treatment and disposition.
8. No discharge, evaporation, landfill, distillation, cure-out or reuse prescription is provided by this review.

Related Engineering Review boundaries

ER-178 owns waste-stream identity, segregation, treatment-evidence boundaries and disposition architecture. ER-017 retains life-cycle assessment and environmental-superiority claims. ER-033 and ER-086 retain part washing, extraction and their effects on the printed part. ER-177 retains occupational exposure verification. ER-183 retains deliberate mechanical recycling and reincorporation of identified cured solids. None of those subjects is reopened here.

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Competing interests

The author is Founder, CEO and CTO of 3Dresyns by Resyner Technologies S.L. This review does not qualify any 3Dresyns product, treatment system, waste stream or disposition route.

Data availability

No new experimental dataset was generated. The source-gate package preserves the publisher supplement and its fidelity-controlled extraction; the manuscript does not reproduce those data as a new dataset.

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