Pollution Prevention Institute

SOLVENT ALTERNATIVE TESTING: EVALUATING SAFER SUBSTITUTES

PROJECT BACKGROUND

Project summary

The metal fabrication industry heavily relies on solvents for cleaning and degreasing processes to ensure high-quality final products. These solvents play a critical role in maintaining surface preparation standards, which can directly impact subsequent manufacturing steps such as painting and coating applications. However, many of the solvents traditionally used in these processes contain hazardous chemicals that pose significant environmental and health risks. Recognizing the need for safer alternatives, companies have begun exploring ways to reduce or replace these toxic substances while maintaining operational efficiency.

Incentives to change

Many commonly used cleaning and degreasing solvents are classified as hazardous air pollutants (HAPs) and volatile organic compounds (VOCs), which contribute to air pollution and can pose serious worker exposure risks. The shift toward safer solvent alternatives is driven by several key incentives:

- Regulatory compliance: Companies must adhere to increasingly stringent environmental and occupational health regulations, especially in industries like aerospace and automotive parts manufacturing.
- Worker health and safety: Reducing exposure to harmful chemicals decreases the risk of respiratory issues, skin irritation and long-term health complications among employees.
- Liability reduction: Using less hazardous substances minimizes legal and financial risks associated with worker health claims and regulatory fines.
- Cost savings: While some alternative solvents may have a higher upfront cost, they can lead to significant long-term savings through reduced hazardous waste disposal fees, lower insurance premiums and decreased personal protective equipment (PPE) requirements.
- Sustainability and corporate responsibility: Many companies are committed to improving their environmental footprint and meeting long-term sustainability goals, making solvent replacements with eco-friendly alternatives one of their strategic priorities.

Barriers to solvent replacement

Despite the clear benefits of switching to safer solvents, companies face several challenges that can slow or complicate the transition:

- Process compatibility: Alternative solvents must meet strict cleaning and degreasing efficiency requirements without negatively impacting production quality.
- Cost considerations: Some replacement solvents may have a higher purchase price or require modifications to existing equipment, increasing initial investment costs.
- Employee training: Workers may need additional training on handling and applying new solvents, ensuring safe and effective use.
- Regulatory restrictions: Industry-specific regulations, particularly in sectors like aerospace, may limit the types of solvents that can be used, requiring careful selection and validation of alternatives, with zero tolerance for any compromise in product performance.
- Resistance to change: Companies may be hesitant to switch from well-established processes due to concerns about performance and potential operational disruptions.
- Testing and validation time: Evaluating and approving alternative solvents requires extensive testing to confirm effectiveness and compliance.

The role of the Toxics Use Reduction Institute (TURI)

The Toxics Use Reduction Institute (TURI) at the University of Massachusetts Lowell plays a crucial role in helping businesses navigate the transition to safer solvents. TURI provides research, technical assistance and financial support to companies looking to reduce their reliance on hazardous substances. Their key activities include:

- Identifying and evaluating safer alternatives: Conducting research and pilot testing to assess the effectiveness of nontoxic and less-hazardous solvents.
- Technical assistance and training: Offering workshops, webinars and on-site consultations to support businesses in implementing safer practices.
- Policy and regulatory guidance: Helping companies understand and comply with changing environmental regulations while exploring practical alternatives.
- Funding and incentive programs: Providing grants and financial resources with estimated costs associated with transitioning to safer solvent solutions.
- Free resources and tools: TURI offers multiple free resources, including Safer Solutions and P2OASYS, which help companies kickstart the process of identifying potential chemical replacements. These tools leverage a database of tests previously conducted by TURI, providing businesses with scientifically backed data to evaluate safer alternatives.

TURI PPI collaboration

Through collaborative efforts between TURI and the Kansas State Pollution Prevention Institute (PPI), with funding from the Environmental Protection Agency (EPA), PPI received training from TURI on safer chemical replacements. In turn, PPI identified local clients interested in switching to less-toxic solvent alternatives but facing one or more of the previously listed barriers.

With the support of the grant, PPI facilitated four chemical evaluations conducted by TURI to assist companies on exploring potential replacement of hazardous solvents. These tests helped businesses evaluate the performance, cost implications and regulatory compliance of safer alternatives, ultimately enabling a smoother transition to environmentally friendly solutions.

Through this collaboration, TURI and PPI continue to support companies with recommended solutions in reducing toxic chemical usage, improving workplace safety and fostering sustainable industry practices.

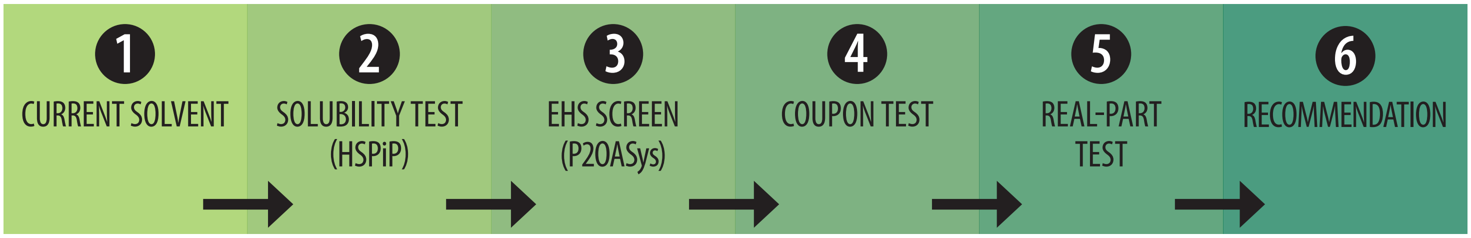
TESTING PROTOCOL

Test plan development: Based on the criteria and process information provided by the company.

- **Site visit:** A Kansas State University PPI staff member conducted a site visit to visually observe the process and facility space.
- **Solvent identification:** Using the Hansen Solubility Parameters in Practice (HSPiP), TURI identified 6-10 potential solvent alternatives for specific cleaning applications and further performance testing.
- **Environmental, health and safety (EHS) assessments:** Alternative solvents and cleaners were evaluated using TURI's Pollution Prevention Options Analysis System (P2OASys) Hazard Assessment Tool.
- **Performance testing:** The identified alternatives were tested on standard test coupons (typically 2" x 4" flat substrates) using the cleaning method specified within the company's process.
- **Remote review:** Testing results were reviewed via phone and email with Kansas PPI and company representatives.
- **Final performance testing:** The top 2-4 most effective cleaners were tested on actual parts provided by the company.
- **Final report:** A summary of testing, results, chemical and cost evaluations, and recommendations was prepared to guide future on-site pilot testing and implementation of the identified alternatives.

To help prevent the occurrence of regrettable substitutes, TURI conducted an environmental, health and safety

***Figure 1.* Testing pathway used by TURI**



(EHS) assessment of alternative solvents and cleaners compared to current solvents using the P2OASys Hazard Assessment Tool. TURI then conducted performance testing of the alternative solvents and cleaners to validate cleaning performance for various contaminants and material compatibility for specified substrate materials. Based on the EHS assessments and performance testing results, TURI provided recommendations for safer solvents and cleaning products for each evaluation case.

EVALUATION CASES

Evaluation No. 1:

- Process: Cleaning aluminum panels and aluminum honeycomb soiled with Royco 27A grease.
- Royco 27A grease is a synthetic ester-based grease that has high oxidation, corrosion resistance, as well as rust protection and extreme pressure anti-wear properties.
- Current cleaning method: Vapor degreasing with trichloroethylene (TCE).

Evaluation No. 2:

- Process: Cleaning composite fiberglass honeycomb soiled with Glyconol wax.
- Glyconol wax is an industrial additive with gelling and viscosity-modifying properties used as a plasticizer in waxes.
- Current cleaning method: Vapor degreasing with perchloroethylene (PERC).
- PERC is a common solvent used in the manufacturing industry for effectively removing grease, oil and other contaminants from metal components.

Evaluation No. 3:

- Process: Cleaning aluminum alloy substrates before paint application.
- Current cleaning method: Manual wipe-down using methyl ethyl ketone (MEK) to remove small amounts of primer.

Evaluation No. 4:

- Process: Cleaning wet paint from paint applicator guns.
- Focus: Cleaning the interior and nozzle areas of the paint gun.

RESULTS

Evaluation No. 1 and 2: Safer alternative to TCE and PERC

Four alternatives—1-propanol, thiophene, 1-butanol, and Dowanol PnBGE—were evaluated for their ability to remove Royco 27A grease and Glyconol wax in unheated immersion or ultrasonics. Overall cleaning effectiveness ranged from 97.8% to 99.0% (Table 1), illustrating that the tested alternatives can perform comparably to trichloroethylene (TCE) and perchloroethylene (PERC).

An environmental, health and safety (EHS) assessment using TURI's P2OASys tool showed significantly lower overall hazard scores for each alternative solvent compared to TCE and PERC, whose weighted averages were 8.4 and 8.6, respectively (Table 2). By considering TCE and PERC safer alternatives, the Dowanol PnBGE achieved the lowest hazard score (4.6), followed by 1-butanol (5.3), 1-propanol (5.4), and thiophene (5.9). While each alternative carries some specific concerns (e.g., flammability, eye irritation, or VOC content), they present substantially reduced chronic toxicity and ecological hazards.

***Table 1.* Alternative solvents to TCE and PERC with their functionalities and effectiveness**

Product	Proposed cleaning method	Flammability NFPA rating	Flash point	Effectiveness
Safer alternative to TCE				
1-Propanol	Unheated Ultrasonics	3	72	98.1%
Thiophene	Unheated Ultrasonics	3	30	98.5%
1-Butanol	Unheated Ultrasonics	3	95	99.0%
Dowanol PNBGE	Unheated Ultrasonics	2	145	97.8%
Safer alternative to PERC				
1-Propanol	Unheated Immersion	3	72	98.1%
Thiophene	Unheated Immersion	3	30	98.5%
1-Butanol	Unheated Immersion	3	95	99.0%
Dowanol PNBGE	Unheated Ultrasonics	2	145	97.8%

Table 2. ***P2OASys of Perchloroethylene (PERC), Trichloroethylene (TCE), and identified alternatives***

Category*	Original Solvents		Identified Alternatives			
	PERC	**TCE**	**1-Propanol**	**Thiophene**	**1-Butanol**	**Dowanol PnBGE**
Acute human effects	9	8	8	7	9	8
Chronic human effects	9	9	5	5	6	3
Ecological hazards	8	8	2	4	2	2
Environmental fate and transport	10	9	5	5	2	4
Atmospheric hazard	6	6	2	5	2	2
Physical properties	9	10	9	9	9	6
Process factors	8	7	6	6	5	8
Life cycle factors	10	10	6	6	7	4
Weighted average	8.6	8.4	5.4	5.9	5.3	4.6

Low **Medium** **High** **Very high**

**Please refer to TURI's score matrix for each category of classification, and numbered based on risk factors. A summary score is generated ranging from 2 to 10, 2 meaning of "Low" concern (coded green) and 10 meaning of "Very high" concern (coded red).*

Evaluation No. 3 and 4: Removing primer from aluminum alloy and wet paint cleaning in guns

Two alternatives — dimethyl carbonate (DMC) and ethyl acetate — were tested via manual wipe as replacements for methyl ethyl ketone (MEK). Both alternatives achieved 100% cleaning effectiveness (Table 3), matching or exceeding MEK's performance for removing small amounts of primer. The P2OASys hazard assessment revealed (Table 4):

Dimethyl carbonate had the lowest weighted hazard average (3.9), demonstrating significantly fewer acute and chronic health risks compared to MEK (6.1). Its primary concern is flammability, indicated by its flash point of 60°F and National Fire Protection Association flammability score of 3.

Ethyl acetate showed moderate hazard reduction (5.1). Its main concerns include eye irritation (Global Harmonized System Category 1) and a low flash point.

Table 3. ***Safer Choice for MEK and wet paint removal from applicator gun***

Product	Proposed cleaning method	Flammability NFPA rating	Flash point	Effectiveness
Cleaning aluminum alloy substrates before paint application				
Dimethyl carbonate	Manual wipe	3	64.4	100%
Ethyl cetate	Manual wipe	2	24.8	100%
Cleaning wet paint from applicator guns				
Ethyl acetate (62%) / Dimethyl carbonate (38%)	Manual wipe	3	24.8	100%

An ethyl acetate/dimethyl carbonate mixture (62%/38%) was tested for cleaning the interior and nozzle areas of paint guns. The mixture achieved 100% effectiveness, demonstrating that a blend of these solvents can be a viable replacement for other higher-hazard solvents. As with many flammable solvents, proper handling procedures, enclosed cleaning systems or adequate ventilation can mitigate risks associated with low flash points and high vapor pressures.

Environmental, health and safety (EHS) considerations

Across all four evaluations, TURI used its P2OASys Hazard Assessment Tool to compare original solvents (such as TCE, PERC, and MEK) with proposed alternatives. This approach helps avoid regrettable substitutes by examining chronic toxicity, ecological impact, physical properties (like flash point and vapor pressure) and process/life-cycle factors.

The results illustrate that even when flammability concerns or acute health hazards (e.g., eye irritation) arise with these alternatives, they generally present lower chronic human health and ecological risks than the original solvents. Proper operational controls and employee training can help address these short-term hazards, while companies benefit from overall reduced toxicity and lower environmental impact.

***Table 4.* P2OASys evaluation of selected alternatives for MEK**

Category*	Original solvent	Alternatives	
	MEK	Dimethyl carbonate	Ethyl acetate
Acute human effects	7	3	7
Chronic human effects	7	2	5
Ecological hazards	6	2	2
Environmental fate and transport	6	6	4
Atmospheric hazard	2	2	2
Physical properties	9	9	9
Process factors	6	3	6
Life cycle factors	6	4	6
Weighted average	6.1	3.9	5.1

Low **Medium** **High** **Very high**

**Please refer to TURI's score matrix for each category of classification, and numbered based on risk factors. A summary score is generated ranging from 2 to 10, 2 meaning of "Low" concern (coded green) and 10 meaning of "Very high" concern (coded red).*

CONCLUSION

These evaluations demonstrate that safer solvent alternatives can effectively replace higher-hazard chemicals such as TCE, PERC and MEK in various cleaning and degreasing applications. While each alternative presents its own trade-offs — often related to flammability, VOC content or acute irritation hazards — the overall environmental and human health risks are substantially lower than the original solvents.

By combining performance testing with comprehensive EHS assessments through TURI's P2OASys tool, participating companies gained insight into both the cleaning effectiveness and hazard profiles of potential substitutes. This holistic approach helps ensure that replacements do not introduce new, unforeseen risks, supporting a smooth transition to safer and more sustainable manufacturing processes.

Moving forward, companies can use these findings to:

- Refine their selection of solvents based on specific process requirements and hazard profiles.
- Implement appropriate engineering controls (e.g., enclosed systems, proper ventilation) and workplace safety measures to address flammability or acute health concerns.
- Continue exploring emerging safer solvents or process innovations with TURI and PPI's ongoing technical support.

With this collaboration between TURI, PPI, and the EPA, organizations enhance workers' health, reduce environmental impacts and align with evolving regulations, ultimately promoting a more sustainable and competitive manufacturing sector.

Acknowledgements
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