

CLEANING LABORATORY EVALUATION SUMMARY

SCL #: 2019

DateRun: 07/29/2019

Experimenters: Kevin Smith, Othon Pagounes

ClientType:

ProjectNumber: Project #1

Substrates: Stainless Steel

PartType: Coupon

Contaminants: Coatings

Cleaning Methods: Immersion/Soak

Analytical Methods: Gravimetric, Visual

Purpose: Determine a safer alternative for cleaning applications to remove solvent-based coatings using Hansen Solubility Parameters in Practice (HSPiP) off stainless steel surfaces.

Experimental Procedure: Initial weights for the stainless-steel coupons, 2" x 4" in size, were recorded before applying the supplied coating to the bottom one third of the coupons using a swab. The coupons were enclosed from any light and aged for 24 hours. After aging, the contaminated weights were recorded before immersing each coupon in a beaker containing 50-60ml of a solvent for five minutes. Final weights were recorded after the coupons were removed and wiped with a Wypall. The same process was repeated for a set of coupons that were aged 48 hours and immersed for two minutes.

Results: Aging Duration: 24 hours / Immersion Duration: 5 minutes

| Solvent | Soil Added | Soil Removed | Percent Removal | Effective |
|---|------------|--------------|-----------------|-----------|
| Dimethyl carbonate | 0.6895 | 0.6886 | 99.87 | Yes |
| Propylene carbonate | 0.5102 | 0.5069 | 99.35 | Yes |
| 1-Butanol | 0.5083 | 0.508 | 99.94 | Yes |
| Dimethyl Glutarate | 0.4224 | 0.4214 | 99.76 | Yes |
| 1:1 Blend (Dimethyl Carbonate: 1-Butanol) | 0.4131 | 0.4133 | 100.05 | Yes |
| Camger Current Cleaning Blend | 0.3913 | 0.3911 | 99.95 | Yes |

Aging Duration: 48 hours / Immersion Duration: 2 minutes

| Solvent | Soil Added | Soil Removed | Percent Removal | Effective |
|---|------------|--------------|-----------------|-----------|
| Dimethyl carbonate | 0.4239 | 0.418 | 98.68 | Yes |
| Propylene carbonate | 0.3862 | 0.384 | 99.43 | Yes |
| 1-Butanol | 0.3375 | 0.3363 | 99.64 | Yes |
| Dimethyl Glutarate | 0.4222 | 0.4213 | 99.79 | Yes |
| 1:1 Blend (50% Dimethyl Carbonate: 50% 1-Butanol by volume) | 0.3789 | 0.3776 | 99.66 | Yes |

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|--|--------|--------|-------|-----|
| Camger Current Cleaning Blend | 0.3834 | 0.3826 | 99.79 | Yes |
|--|--------|--------|-------|-----|

The coating sphere determined by the HSPiP software from the given soil was defined as: D = 18.27, P = 8.77, H = 13.10

The HSP values of the current blend are:

| Solvent | D-Value | P-Value | H-Value |
|-------------|---------|---------|---------|
| Toluene | 18 | 1.4 | 2 |
| Acetone | 15.5 | 10.4 | 7 |
| Xylenes | 17.8 | 1 | 3.1 |
| Total Blend | 15.75 | 7.15 | 12.75 |

The HSP values of the proposed alternatives are:

| Solvent | D-Value | P-Value | H-Value |
|---------------------|---------|---------|---------|
| Dimethyl Carbonate | 15.5 | 8.6 | 9.7 |
| Propylene Carbonate | 20 | 18 | 4.1 |
| 1-Butanol | 16 | 5.7 | 15.8 |
| Dimethyl Glutarate | 16.1 | 7.7 | 8.3 |
| 1:1 Blend | 15.75 | 7.15 | 12.75 |

EHS Hazard Profile Analysis

The identified solvent alternatives were evaluated for overall environmental health and safety (EHS) compared to the original solvent blend. The following solvents were reviewed:

Original Solvent Blend:

- 1) Toluene
- 2) Acetone
- 3) Xylene

Alternative:

- 4) Dimethyl Carbonate
- 5) Propylene Carbonate
- 6) 1-Butanol
- 7) Dimethyl Glutarate
- 8) 1:1 Dimethyl Carbonate / 1-Butanol

A detailed review of the (8) Pollution Prevention Options Analysis System (P2OASys.turi.org) EHS categories was conducted for original blend (Toluene, Acetone, and Xylene) and compared to the potential alternative as seen figure below:

| Categories | Toluene | Acetone | Xylene | Dimethyl Carbonate | Propylene Carbonate | 1-Butanol | Dimethyl Glutarate |
|--------------------------------|---------|---------|--------|--------------------|---------------------|-----------|--------------------|
| Acute Human Effects | 9 | 6 | 9 | 3 | 7 | 9 | 2 |
| Chronic Human Effects | 8 | 7 | 8 | 2 | 2 | 6 | 2 |
| Ecological Hazards | 8 | 2 | 8 | 2 | 2 | 2 | 2 |
| Environmental Fate & Transport | 5 | 6 | 7 | 6 | 4 | 2 | 8 |
| Atmospheric Hazard | 6 | 2 | 6 | 2 | 2 | 2 | 2 |
| Physical Properties | 10 | 9 | 9 | 9 | 3 | 9 | 5 |
| Process Factors | 7 | 5 | 7 | 3 | 4 | 5 | 4 |
| Life Cycle Factors | 9 | 6 | 9 | 4 | 4 | 7 | 3 |
| Weighted Average | 7.8 | 5.4 | 7.9 | 3.9 | 3.5 | 5.3 | 3.5 |

| Score | Description |
|-------|--------------|
| 7-10 | High Hazards |

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|---------------------------------------|--------------------------|
| 5-6 | Moderate Hazards |
| 2-4 | Low Hazards |
| | No Information Available |
| *Lower score = Lower toxicity/hazard. | |

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Within the full data set in Appendix B for the alternative, a few significant differences have been identified relative to blend being currently being used.

The following is a summary of the hazards:

Original Blend Cleaner:

- Toluene: High hazard of exposure limits, oral toxicity, endocrine system, and chronic organ effects. High acute aquatic toxicity and a listed NESHAP chemical. Physical properties had a high hazard rating due to vapor pressure, high flammability, low flashpoint, and a noxious odor. Lifecycle factors had a high rating due to hazards to those working with this chemical upstream, as a consumer, and during disposal.
- Acetone: High hazard for chronic organ effects through multiple uses, air t ½ days. Physical properties had a high hazard rating due to flammability, and flashpoint.
- Xylene: High hazard of, oral toxicity, eye irritation, health, neurotoxicity, and chronic organ effects. High acute and chronic aquatic toxicity as well as rapid degradable substance. Listed as a NESHAP chemical. Physical properties had a high hazard rating due to high flammability, low flashpoint, and as a volatile organic compound. Lifecycle factors had a high rating due to hazards to those working with this chemical upstream, as a consumer, and during disposal.

Proposed Identified Alternative:

1. Dimethyl carbonate: High hazard for persistence in air, and for physical properties such as vapor pressure, flammability for liquid
2. Propylene carbonate: High hazard for eye irritation
3. 1-Butanol: High hazard for dermal and eye irritation. Physical properties had a high hazard for liquid flammability as well as a volatile organic compound. This solvent is also a high disposal hazard
4. Dimethyl glutarate: High hazard for persistence in air
5. 1:1 Blend (Dimethyl Carbonate/1-Butanol): High hazard for persistence in air, and for physical properties such as vapor pressure, flammability for liquid, gas and is a volatile organic compound. High hazard for dermal and eye irritation. This solvent is also a high disposal hazard.

Summary:

| Substrates: | | Stainless Steel | | | |
|----------------------|---|-----------------|-------------|-------------------------------------|---------------|
| Contaminants: | | Coatings | | | |
| Company Name: | Product Name: | Conc.: | Efficiency: | Effective: | Observations: |
| Alfa Aesar | Dimethyl Carbonate 99% | 100% | 99.87 | <input checked="" type="checkbox"/> | |
| Fisher Scientific | Propylene carbonate 99.5% (CAS: 108-32-7) | 100% | 99.35 | <input checked="" type="checkbox"/> | |
| Alfa Aesar | 1-Butanol 99.4%+ | 100% | 99.94 | <input checked="" type="checkbox"/> | |
| Fisher Scientific | Dimethyl glutarate (CAS:1119-40-0) | 100% | 99.76 | <input checked="" type="checkbox"/> | |
| No Specific Vendor | 1:1 Blend (Dimethyl carbonate:1-Butanol) | 100% | 100.05 | <input checked="" type="checkbox"/> | |
| No Specific Vendor | Toluene, Acetone, and Xylene Mixture | 100% | 99.95 | <input checked="" type="checkbox"/> | |

Conclusion:

Dimethyl carbonate, Propylene carbonate, 1-Butanol, Dimethyl glutarate, 1:1 Blend (Dimethyl Carbonate/1-Butanol) are considered safer alternatives to the current cleaner solvent blend. The next step would be to undergo a cost analysis of each solvent and conduct a test in the production facility.

Update: Based on the client's feedback, only propylene carbonate and dimethyl glutarate will be tested at the facility due to their lower flammability properties compared to the other identified alternatives.