David Pasin, President and Founder
TBF Environmental Technology Inc.

Green Solvents
Replacing Dirty and Toxic
with
Clean and Green
TBF Environmental Technology Inc.

Develops, manufactures, markets, and distributes environmentally-friendly solvents to industrial markets in North America:

• Paints and coatings
• Adhesives
• Printing inks
• Polymers
• Personal care
• General industrial cleaning and degreasing
This $10,000 bottle of Bordeaux is also a powerful solvent. It entirely dissolved my savings account.
Many alternatives to MEK, Xylene, IPA and Acetone have been developed, but few work well:

The opportunity to develop and market solvents with lower ecological and toxicological profiles is excellent… however, the perfect solvent is not available. Tradeoffs have to be made regarding efficiency, cost and environmental impact.

Chemical Insight & Forecasting, Nov 2010.
Green Solvent Issues

- Over 10,000,000 US workers Exposed to toxic solvents on a daily basis.
- Solvent emissions destroy human health and pollute the atmosphere.
- US EPA and State regulators continually impose lower limits on VOCs.
- Methyl Ethyl Ketone (MEK) and Xylene do not meet new regulations.
- Substitute green solvents currently available have serious limitations that limit their efficacy and acceptance.
Hydrocarbon Solvents
A Huge Problem

• Many states are restricting companies annual usage of various hydrocarbon solvents, particularly Xylene and Toluene.

• Companies are trying to scale back usage of solvents and are looking for effective alternatives due to serious legal, health and environmental concerns.

• “Green” solvent alternatives are proving problematic.
Regulations Increasing

• EPA and State regulators, especially California, Texas, Massachusetts are continually imposing lower limits on VOCs of various products.

• Most “Biomass” produced solvents do not meet new regulations, and are shown to have serious environmental problems.

• Carbon footprint, emission byproducts and VOC issues are primary concerns in “biomass” based solvents.
New Regulations

Massachusetts

- **Section 7.18 is currently under review**
- Proposing to add a new section (30):
- Adhesives, Adhesive Primers, Sealants and Sealant Primers to the list of regulated products.
- Limits are set to come into effect in 2015 and 2016.
Volatile Organic Compounds (VOCs) are not the only measurement of the impacts on air quality.

CARB developed and has initiated the use of the Maximum Incremental Reactivity (MIR) value to quantify the propensity of a chemical compound to react in the atmosphere to form ground-level ozone.
California Air Resources Board (CARB)

Maximum Incremental Reactivity (MIR):

• MIR is being adopted as a replacement for Low Vapour Pressure as more flexible standard in determining suitability of a solvent as “VOC-exempt” or “low VOC”.
• Focus on eliminating high-MIR compounds which will have the greatest impact in lowering ambient VOC levels.
California Air Resources Board (CARB)

- Any product that meets the definition of an aerosol coating is regulated.
- Product could default to the lowest general-purpose coatings category limit if not properly labelled.
- General Coatings Maximum Incremental Reactivity (MIR) limits lowered. Effective date 01/01/2017.
- New categories and New MIR limits for some categories called Specialty Coatings (A) effective date 01/01/2017.
California Air Resources Board (CARB)

More Reporting Requirements

Largest Issue:

• General coating limits will be very challenging to meet. Aerosol coatings producers should review this regulation completely to ensure their products are compliant and categorized properly.

• CARB enforcement to be strict and target incorrectly labelled products.
# MIR Data

## Maximum Incremental Reactivity (MIR) (Contribution to ozone and smog)

<table>
<thead>
<tr>
<th>Substance</th>
<th>MIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl Ethyl Ketone</td>
<td>1.48</td>
</tr>
<tr>
<td>0 VOC MEK Substitute</td>
<td>0.49</td>
</tr>
<tr>
<td>Acetone</td>
<td>0.36</td>
</tr>
<tr>
<td>0 VOC Acetone Substitute</td>
<td>0.065</td>
</tr>
<tr>
<td>Xylene</td>
<td>5.84</td>
</tr>
<tr>
<td>Toluene</td>
<td>4.00</td>
</tr>
<tr>
<td>Parachlorobenzotrifluoride (PCBTF)</td>
<td>0.11</td>
</tr>
<tr>
<td>Tertiary Butyl Acetate (TBAc)</td>
<td>0.18</td>
</tr>
<tr>
<td>0 VOC Xylene Substitute</td>
<td>0.079</td>
</tr>
</tbody>
</table>
Comparison of MIR Values

![Bar chart comparing Methyl Ethyl Ketone and 0 VOC MEK substitute](image)

Methyl Ethyl Ketone: 1.48

0 VOC MEK substitute: 0.47
Comparison of MIR Values

- Xylene: 5.84
- Toluene: 4.00
- PCBTF/Oxsol: 0.11
- TBAc: 0.18
- 0 VOC: 0.079
Green Solvent Alternative

0 VOC MEK Alternative

A safe, effective, efficient and cost effective replacement for MEK
• Benzene-free
• Non-carcinogenic
• No hazardous air pollutants (HAPs)
• No ozone-depleting or creator chemicals
• Considered an Ultra-Low VOC Solvent (LVOC) in SCAQMD, 0 VOC in 49.75 states
• EPA Test Method 24: 2.66 g/l VOC
• Personal Care Council (INCI) Approved
# Green Solvent Alternative

## 0 VOC MEK Alternative

**Can be used in:**
- paints and coating formulations and cleaning
- paint and varnish removers
- ink and marker formulations and cleaning
- adhesive formulation and cleaning
- adhesive removers
- gelcoat formulation and cleaning
- fiberglass manufacturing

**Can be used in or as:**
- surface preparation and precision cleaner
- general purpose surface wipe cleaner
- general and heavy duty degreaser
- laboratory and equipment wipe solvent
- brake and contact cleaner
- paint gun and paint line cleaner
- lubricating greases and oils
- automotive chemicals and cleaners
- undercoat formulation and cleaning
- waterproofing compounds
- household dyes and tints
### Green Solvent Alternative

<table>
<thead>
<tr>
<th>Physical / Chemical Characteristics</th>
<th>0 VOC MEK Sub</th>
<th>Methyl Ethyl Ketone</th>
<th>Methyl Acetate</th>
<th>DiMethyl Carbonate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (@25 °C)</td>
<td>0.97</td>
<td>0.804</td>
<td>0.932</td>
<td>8.9</td>
</tr>
<tr>
<td>Boiling Point (°C)</td>
<td>75.31</td>
<td>79.6</td>
<td>58</td>
<td>90</td>
</tr>
<tr>
<td>Evaporation Rate (n-BuAc=1)</td>
<td>3.62</td>
<td>3.62</td>
<td>6.0</td>
<td>3.2</td>
</tr>
<tr>
<td>Flash Point (°C)</td>
<td>9.0</td>
<td>-9.0</td>
<td>-13</td>
<td>17.2</td>
</tr>
<tr>
<td>Vapour pressure @20 °C (mm Hg)</td>
<td>125</td>
<td>74</td>
<td>165</td>
<td>42</td>
</tr>
<tr>
<td>Freezing Point (°C)</td>
<td>-71.54</td>
<td>-86.7</td>
<td>-98</td>
<td>4</td>
</tr>
<tr>
<td>Solvency (Kb Value)</td>
<td>79.1</td>
<td>na</td>
<td>na</td>
<td>64</td>
</tr>
<tr>
<td>Maximum Incremental Reactivity (MIR)</td>
<td>0.47</td>
<td>1.48</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>Hansen Solubility Parameters (MPA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>δd (dispersion)</td>
<td>7.87</td>
<td>7.8</td>
<td>15</td>
<td>15.5</td>
</tr>
<tr>
<td>δP (polarity)</td>
<td>3.72</td>
<td>4.4</td>
<td>3.5</td>
<td>3.9</td>
</tr>
<tr>
<td>δH (hydrogen bonding)</td>
<td>3.59</td>
<td>2.5</td>
<td>3.7</td>
<td>9.7</td>
</tr>
</tbody>
</table>
Green Solvent Alternative

0 VOC Alternative

% Better Solvency than DMC

D.E.R. 331 (EPON 828)
Epoxy Resyn

- 0 VOC MEK Sub vs DMC
- %MEK vs DMC
Green Solvent Alternative

0 VOC Alternative Advantages

• Lower, milder odour compared to MEK
• Similar evaporation rate to MEK
• Measured ER of 3.62. This is close to the published MEK ER 4.0
• May have slightly less solvent power than MEK in the above epoxy formula. This may vary dependent upon formulation and other factors.
0 VOC MEK Replacement Results

- Substituting the MEK with 0 VOC MEK Sub resulted in a minor 2 – 3 KU (Kreb Units) increase in viscosity.
- 0 VOC MEK Sub works well as a replacement for MEK in epoxy formulas.
- Moisture content is well below 500 ppm, making it suitable for use in 1 and 2K polyurethane systems.
# Green Solvent Alternative

## 0 VOC Toxicity Comparison

<table>
<thead>
<tr>
<th></th>
<th>MEK</th>
<th>0 VOC MEK Sub</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oral Toxicity (LD$_{50}$ Rat mg/kg)</strong></td>
<td>2700</td>
<td>&gt;5500</td>
</tr>
<tr>
<td><strong>Dermal Toxicity (LD$_{50}$ Rabbit mg/kg)</strong></td>
<td>6480</td>
<td>&gt;20,000</td>
</tr>
<tr>
<td><strong>Long Term Organ Damage</strong></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Central Nervous System Damage</strong></td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Green Solvent Alternative

0 VOC Replacement for Acetone

A safe, effective, efficient and cost effective replacement for Acetone

• Benzene-free
• Non-carcinogenic
• No hazardous air pollutants (HAPs)
• No ozone-depleting or creator chemicals
• Considered an Ultra-Low VOC Solvent (LVOC) in SCAQMD and CARB, zero VOC in 49 states
• EPA Test Method 24: 2.82 g/l VOC
• Boeing Spec 5750 - approved for Aerospace Cleaning
A 0 VOC Acetone Sub can be used in or as:
  • paint formulations and cleaning
  • ink and marker formulations and cleaning
  • adhesive formulations and cleaning
  • hard surface cleaning
  • lubricating greases and oils
  • aerospace cleaning applications
  • automotive chemicals
  • nail polish and polish remover
  • TergoSol can also be used as a:
    • surface preparation and precision cleaner
    • general purpose surface wipe cleaner
    • general and heavy duty degreasing
    • laboratory and equipment wipe solvent
BTEX Solvents are Toxic

Benzene, Toluene, Ethyl Benzene, Xylene (BTEX)

• Proven to be serious risks to human health: asthma, lower birth weights, hearing loss and permanent damage to Central Nervous System.

• BTEX solvents are major emitters of Volatile Organic Compounds (VOCs) which create smog.

• BTEX solvents pollute soil and groundwater.
Green Solvent Alternative

0 VOC replacement for Xylene

A safe, efficient, effective and cost-effective replacement for Toluene and Xylene, Parachlorobenzotrifluoride (PCBTF) and Tertiary Butyl Acetate (TBAc).

A 0 VOC Xylene Replacement:
• is formulated to be benzene-free.
• is non-carcinogenic.
• does not contain hazardous air pollutants.
• is environmentally hazardous ingredients.
• has no ozone depleters or creators.
• is 0 VOC and NPRI-exempt (SCAQMD Ultra low VOC 1.13 g/l).
Green Solvent Alternative

0 VOC replacement for Xylene

<table>
<thead>
<tr>
<th>Designed for a variety of uses and purposes.</th>
<th>Can also be used as a chemical diluent for:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can be used as a diluent for:</td>
<td>• printing ink</td>
</tr>
<tr>
<td>• paints</td>
<td>• adhesives</td>
</tr>
<tr>
<td>• coatings</td>
<td>• lacquers</td>
</tr>
<tr>
<td>• adhesives</td>
<td>• plastics</td>
</tr>
<tr>
<td>• resins</td>
<td>• perfumes</td>
</tr>
<tr>
<td>• silicones</td>
<td>• pesticides</td>
</tr>
<tr>
<td>• sealants</td>
<td>• leather tanning</td>
</tr>
<tr>
<td></td>
<td>• paraffin wax</td>
</tr>
<tr>
<td>Physicochemical Property</td>
<td>0 VOC Xylene Sub</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Specific Gravity (@ 25 °C)</td>
<td>1.00</td>
</tr>
<tr>
<td>Flashpoint (Tag Closed Cup (TCC) °C)</td>
<td>4.00</td>
</tr>
<tr>
<td>Boiling Point °C</td>
<td>70-90</td>
</tr>
<tr>
<td>Appearance</td>
<td>Clear liquid</td>
</tr>
<tr>
<td>Viscosity @ 20 °C (CentiPoise Cp)</td>
<td>0.44</td>
</tr>
<tr>
<td>$\delta$ (Hansen solubility parameter) Hildebrand = 1 cal$^{1/2}$ cm$^{-3/2}$</td>
<td>9.18</td>
</tr>
<tr>
<td>$\delta$D (Dispersion) cal$^{1/2}$ cm$^{-3/2}$</td>
<td>7.76</td>
</tr>
<tr>
<td>$\delta$P (Polar) cal$^{1/2}$ cm$^{-3/2}$</td>
<td>3.42</td>
</tr>
<tr>
<td>$\delta$H (Hydrogen bonding) cal$^{1/2}$ cm$^{-3/2}$</td>
<td>3.46</td>
</tr>
<tr>
<td>Surface tension (dynes/cm at 20 °C)</td>
<td>25.03</td>
</tr>
<tr>
<td>Evaporation rate (n-butyl acetate = 1)</td>
<td>5.14</td>
</tr>
<tr>
<td>MIR (gO3/g VOC)</td>
<td>0.076</td>
</tr>
<tr>
<td>Solvency (Kb value)</td>
<td>90.30</td>
</tr>
</tbody>
</table>
Green Solvent Alternative

0 VOC Replacement for Xylene

Experimental Data:

• a clear liquid with a mild fruity, non-offensive odour
• has a specific gravity of 1.004.
• evaporated faster than Xylene by a factor of 1.63-1.65
• has a pronounced “tail” at end
• Aids in flow and leveling and helps prevent unwanted dry spray
Green Solvent Alternative

0 VOC Replacement for Xylene

0 VOC Solvent and Xylene
Clear Tint Base
Chain Stop Alkyd Formulation

<table>
<thead>
<tr>
<th>Properties</th>
<th>Control Formula</th>
<th>Formula With 0 VOC Xylene Sub</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight Solids, %</td>
<td>33.31</td>
<td>31.97</td>
</tr>
<tr>
<td>Volume Solids%</td>
<td>24.82</td>
<td>24.82</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>0.942</td>
<td>0.982</td>
</tr>
<tr>
<td>Viscosity, KU</td>
<td>95.2</td>
<td>58.1</td>
</tr>
<tr>
<td>Gloss 20⁰ / 60⁰</td>
<td>86.0 / 96.6</td>
<td>82.5 / 95.8</td>
</tr>
<tr>
<td>VOC g/l minus exempt solvent</td>
<td>628</td>
<td>543</td>
</tr>
<tr>
<td>Dust Free, mins</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Tack Free, mins</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Hard Dry, mins</td>
<td>30</td>
<td>20</td>
</tr>
</tbody>
</table>
Green Solvent Alternative

Solvency Comparisons

0 VOC solvent has better solvency and solubility than Xylene and its conventional substitutes.

Comparison based on Epon 828, DER 331 Epoxy Resin
# Green Solvent Alternative

## Toxicity Comparison

<table>
<thead>
<tr>
<th></th>
<th>Xylene</th>
<th>0 VOC Xylene Sub</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral Toxicity ($LD_{50}$ Rat mg/kg)</td>
<td>2119</td>
<td>&gt;6000</td>
</tr>
<tr>
<td>Dermal Toxicity ($LD_{50}$ Rabbit mg/kg)</td>
<td>1700</td>
<td>&gt;5,000</td>
</tr>
<tr>
<td>Long Term Organ Damage</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Central Nervous System Damage</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Green Solvent Alternative
0 VOC Replacement for Xylene

Conclusions

• Improved odor
• Improved solubility
• Improved viscosity control
• Reduced overall VOC content
• No negative effect on:
  (i) Gloss
  (ii) Flow
  (iii) Tack
  (iv) Film appearance
• Improved dry time
Summary

Issues:
- Greenwashing
- Toxicity
- Long Term chronic exposure
- Problems with alternative “green” solvents

Regulations:
- Tightly revised Regulations in Massachusetts and CARB coming
- MIR Value of Solvents becoming increasingly important
- Overall VOC content of finished goods decreasing
## Summary

<table>
<thead>
<tr>
<th>Product</th>
<th>Replacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>EkaSol™</td>
<td>0 VOC replacement for MEK</td>
</tr>
<tr>
<td>TergoSol™</td>
<td>0 VOC replacement for Acetone</td>
</tr>
<tr>
<td>ZemaSol™</td>
<td>0 VOC replacement for Xylene, Toluene, TBAc, PCBTF</td>
</tr>
</tbody>
</table>
A good executive is known by the company he keeps solvent.