Meet the team

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Raina Kasera - BS Chemical Biology, Conc. Computational Chemistry, Minor Public Policy
Presentation Overview

**Background**
- The Problem
- Challenge Statement
- Worker Exposure
- Health Performance of Existing Methods

**Performance Criteria**
- Component Functions
- Target Properties of ideal nail polish

**Our Strategies**
- Zein-based formulation
- Water-Based Solvents
- Drop-In Plasticizer Alternative

**Recommendations**
- Challenge Statement
- Worker Exposure
- Health Performance of Existing Methods
<table>
<thead>
<tr>
<th>Background</th>
<th>Performance Criteria</th>
<th>Our Strategies</th>
<th>Strategy 1</th>
<th>Strategy 2</th>
<th>Strategy 3</th>
<th>Recommendations</th>
</tr>
</thead>
</table>
Nail salon workers are routinely exposed to toxic chemicals

Background

Performance Criteria

Our Strategies

Strategy 1

Strategy 2

Strategy 3

Recommendations

Nail salon workers exposed to high levels of toxic chemicals, new study reveals

Colorado nail salon workers face chronic air pollution, elevated cancer risk

Toxic products in California nail salons under renewed scrutiny

Toxic chemicals threaten beauty care workforce with adverse health effects
The Challenge: Safer, non-petroleum based nail polish formulations

**Partners**

L’Oréal & the Department of Toxic Substances Control (DTSC)

**Goals**

- Identify a range of non-petroleum based alternatives to existing solvents that achieve comparable technical performance
- Consider solvents, plasticizers, and film-formers that can be synthesized without petroleum products, or safer alternatives

---

**Background**

**Performance Criteria**

**Our Strategies**

**Strategy 1**

**Strategy 2**

**Strategy 3**

**Recommendations**
There are 3 key components of nail polish formulation

<table>
<thead>
<tr>
<th>Component</th>
<th>Function in formula</th>
<th>Current chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film-former</td>
<td>Binds components together</td>
<td>- Nitrocellulose</td>
</tr>
<tr>
<td></td>
<td>Main component in formulation</td>
<td></td>
</tr>
<tr>
<td>Solvent</td>
<td>Dissolves solutes</td>
<td>- Toluene</td>
</tr>
<tr>
<td></td>
<td>Lowers the viscosity of final formulation</td>
<td>- Butyl acetate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Ethyl acetate</td>
</tr>
<tr>
<td>Plasticizer</td>
<td>Increase flexibility by softening the polymer (film former)</td>
<td>- Dibutyl phthalate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Triphenyl Phosphate (TPhP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Di(ethylhexyl) terephthalate (DEHT)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Diisononyl hexahydrophthalate (DINCH)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Triethyl citrate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Acetyl tributyl citrate</td>
</tr>
</tbody>
</table>

*Red* = current primary bad actors

**Background**  | **Performance Criteria**  | **Our Strategies**  | **Strategy 1**  | **Strategy 2**  | **Strategy 3**  | **Recommendations**
--- | --- | --- | --- | --- | --- | ---
Nail salon workers experience adverse health outcomes from workplace exposures.

**Background**

- Poor Ventilation
- Long Hours + Chronic Exposure

**Strategies**

- **Strategy 1**
  - Performance Criteria
- **Strategy 2**
  - Our Strategies
- **Strategy 3**
  - Strategy 1
  - Strategy 2
  - Strategy 3
- **Recommendations**

**Outcomes**

- Cancer
- Reproductive + Developmental Toxicity
- Potential Endocrine Disruption

**Exposure**

- Toluene
- Triphenyl Phosphate
- Dibutyl Phthalate

**Emissions**

- Toluene
- Dibutyl Phthalate
- Triphenyl Phosphate
Primary bad actors are hazardous to human health

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Carcinogenicity</th>
<th>Genotoxicity/Mutagenicity</th>
<th>Reproductive Toxicity</th>
<th>Developmental Toxicity</th>
<th>Endocrine Activity</th>
<th>Systemic Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toluene</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H - M</td>
<td>M</td>
</tr>
<tr>
<td>Plasticizer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dibutyl Phthalate</td>
<td>M</td>
<td>L</td>
<td>H</td>
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<td>L</td>
</tr>
<tr>
<td>Triphenyl Phosphate</td>
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<td>M</td>
<td>L</td>
</tr>
</tbody>
</table>

Sources: IARC, Prop-65, EU GHS, Pharos

Data Gap

Very Low Hazard

Low Hazard

Medium Hazard

High Hazard

Very High Hazard

Background  Performance Criteria  Our Strategies  Strategy 1  Strategy 2  Strategy 3  Recommendations
Primary bad actors are hazardous to human health

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Carcinogenicity</th>
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<tr>
<td>Toluene</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H - M</td>
<td>M</td>
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<tr>
<td></td>
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</tr>
<tr>
<td>Plasticizer</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Dibutyl Phthalate</td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>L</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triphenyl Phosphate</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>M</td>
<td>L</td>
</tr>
</tbody>
</table>

- **Data Gap**
- **Very Low Hazard**
- **Low Hazard**
- **Medium Hazard**
- **High Hazard**
- **Very High Hazard**

Sources: IARC, Prop-65, EU GHS, Pharos
Secondary bad actors are “safer” than primary bad actors

<table>
<thead>
<tr>
<th>Plasticizer</th>
<th>Carcinogenicity</th>
<th>Develop/Reprod Tox</th>
<th>Genotoxicity/Mutagenicity</th>
<th>Skin/Eye Irritation</th>
<th>Endocrine Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Di(ethylhexyl) terephthalate (DEHT)</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>DG</td>
</tr>
<tr>
<td>Diisononyl hexahydrophthalate (DINCH)</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>M</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Carcinogenicity</th>
<th>Develop/Reprod Tox</th>
<th>Acute/Systemic Toxicity</th>
<th>Skin/Eye Irritation</th>
<th>Endocrine Activity</th>
<th>Neurotoxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butyl Acetate</td>
<td>L</td>
<td>M-L</td>
<td>M</td>
<td>H</td>
<td>DG</td>
<td>M-L</td>
</tr>
<tr>
<td>Ethyl Acetate</td>
<td>L</td>
<td>M-L</td>
<td>M</td>
<td>H</td>
<td>DG</td>
<td>M</td>
</tr>
</tbody>
</table>

References: ECHA, GHS Japan, GHS Korea, Pharos
Performance Criteria
Technical specifications for nail polish formulation

General Performance Goals for Nail Polish

- Excellent film forming properties
- Good adhesion
- Good shine properties
- Good mechanical properties
- Easy removal with non-acetone removers

<table>
<thead>
<tr>
<th>Property</th>
<th>Goal / Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film forming</td>
<td>At room temperature</td>
</tr>
<tr>
<td>Hardness</td>
<td>Persoz Hardness between 50-70 oscillations</td>
</tr>
<tr>
<td>pH</td>
<td>4-8</td>
</tr>
<tr>
<td>Adhesion</td>
<td>&gt; 4 for ASTM standard cross hatch tape test</td>
</tr>
<tr>
<td>Gloss</td>
<td>&gt; 60 GU (gloss units) on Byk Gardner gloss meter</td>
</tr>
</tbody>
</table>

Source: L'Oreal
## Performance criteria for each component

<table>
<thead>
<tr>
<th>Component</th>
<th>Function in formula</th>
<th>Max amount in % weight of component in formulation</th>
<th>Target Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Film-former</strong></td>
<td>Binds components together when dried and thickens formulation. Main component in formulation</td>
<td>50%</td>
<td>- Forms a film at room temperature (between 68-74 degrees Fahrenheit)</td>
</tr>
<tr>
<td>Solvent</td>
<td>Dissolves solutes. Lowers the viscosity of final formulation</td>
<td>90%</td>
<td>- Low volatility (low vapor pressure)</td>
</tr>
<tr>
<td>Plasticizer</td>
<td>Increase flexibility by softening the polymer (film-former)</td>
<td>15%</td>
<td>- Ability to dissolve film-former and plasticizer</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Molecular weight based on compatibility with film-former</td>
</tr>
</tbody>
</table>

All components should also be non-petroleum based and vegan

Sources: L’Oreal, Development of a nail polish with minerals as caring ingredients
Our Strategies
3-tiered approach to building out safer formulations

Component 1

Zein as a **Film-former**

Component 2

Water as a **Solvent**

Component 3

Bio-based **Plasticizer**

Alternative Formulation

<table>
<thead>
<tr>
<th>Background</th>
<th>Performance Criteria</th>
<th><strong>Our Strategies</strong></th>
<th>Strategy 1</th>
<th>Strategy 2</th>
<th>Strategy 3</th>
<th>Recommendations</th>
</tr>
</thead>
</table>
Our 3 strategies target each major component of nail polish formulation

1. Building Out a Formulation from Zein as a **Film-former**

2. Water as a **Solvent** Alternative to Toluene

3. Bio-based **Plasticizer** Drop-in Replacements
Strategy 1  Building Out a Formulation from Zein as a Film-former
Inspiration: Zein emulates properties of the natural resin shellac

Chemical structure of shellac.

Zein monomeric unit.

Laccifer lacca (aka Tachardia lacca).

Sample shellac colors.
Zein is hydrophobic, vegan, and biodegradable

Zein monomeric unit.

Chemical Properties
- High proportion of non-polar amino acids (leucine, alanine, proline)
- Hydrophobic (poor water solubility, alcohol-soluble)
- Film forms through hydrogen and limited disulfide bonds between zein chains

Additional Properties of Zein
- Zein films are brittle - need plasticizers to make them soft and “permanently flexible”
- Low water vapor permeability
- High fatty acid-binding capacity
- Vegan
- Biodegradable

Zein films from different processes.
Plasticizer was selected based on compatibility with zein and existing formulations

**Existing Formulations**

Acetyl tributyl citrate is already used in ~7% of nail polish formulations as a plasticizer.

**Zein Compatibility**

(Shi. K et al., 2012) found zein mixed with 10% tributyl citrate can achieve an ideal level of flexibility and toughness in high humidity and water.
Solvent selection was driven by the GSK Solvent Selection Guide and zein extraction methods

- (Li et al., 2012) zein has been shown to dissolve well in 70% ethanol and commercially extracted using 88% isopropanol
- Both solvents can be produced in a bio-based manner

<table>
<thead>
<tr>
<th>Classification</th>
<th>Solvent Name</th>
<th>CAS Number</th>
<th>Composite Colour</th>
<th>Boiling Point (°C)</th>
<th>Indecination</th>
<th>Recycling</th>
<th>Biotreatment</th>
<th>VOC Emissions</th>
<th>Aquatic Impact</th>
<th>Air Impact</th>
<th>Health Hazard</th>
<th>Exposure potential</th>
<th>Flammability &amp; Explosion</th>
<th>Reactivity &amp; Stability</th>
<th>Life Cycle Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohols</td>
<td>1-Heptanol</td>
<td>111-70-6</td>
<td>178</td>
<td>9</td>
<td>8</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>4</td>
<td>10</td>
<td>7</td>
<td>9</td>
<td>10</td>
<td>10</td>
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<tr>
<td></td>
<td>Ethylene glycol</td>
<td>107-21-1</td>
<td>197</td>
<td>4</td>
<td>5</td>
<td>5</td>
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<td>8</td>
<td>7</td>
<td>10</td>
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<tr>
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<td>1-Octanol</td>
<td>111-87-5</td>
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<td>4</td>
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<td>9</td>
<td>10</td>
<td>10</td>
<td>10</td>
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<tr>
<td></td>
<td>1-Butanol</td>
<td>71-36-3</td>
<td>118</td>
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<td>7</td>
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<td></td>
<td>Ethanol</td>
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<td>5</td>
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<td>8</td>
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<td>10</td>
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<td></td>
<td>2-Propanol</td>
<td>67-63-0</td>
<td>82</td>
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<td>7</td>
<td>10</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>4</td>
<td>10</td>
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<tr>
<td></td>
<td>t-Butanol</td>
<td>75-65-0</td>
<td>82</td>
<td>5</td>
<td>5</td>
<td>3</td>
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<td>7</td>
<td>7</td>
<td>5</td>
<td>6</td>
<td>10</td>
<td>10</td>
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<td></td>
<td>IMS (ethanol, denatured)</td>
<td>64-17-5</td>
<td>78</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>9</td>
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<td>10</td>
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<td></td>
<td>Methanol</td>
<td>67-56-1</td>
<td>65</td>
<td>4</td>
<td>7</td>
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<td>6</td>
<td>5</td>
<td>10</td>
<td>10</td>
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</tbody>
</table>
Zein has low toxicity endpoints

Zein has low toxicity endpoints in categories such as Carcinogenicity, Genotoxicity/Mutagenicity, Develop/Reprod Tox, Skin/Eye Irritation, Skin/Resp Sensitization, and Endocrine Activity. The details are shown in the diagram with symbols indicating the level of hazard:

- **Carcinogenicity**: L (Low Hazard)
- **Genotoxicity/Mutagenicity**: DG (Data Gap)
- **Develop/Reprod Tox**: L (Low Hazard)
- **Skin/Eye Irritation**: vL (Very Low Hazard)
- **Skin/Resp Sensitization**: vL (Very Low Hazard)
- **Endocrine Activity**: DG (Data Gap)

Sources: EPA, PubChem, IARC
Acetyl tributyl citrate shows similar hazard endpoints to primary bad actor plasticizers.

<table>
<thead>
<tr>
<th></th>
<th>Carcinogenicity</th>
<th>Genotoxicity/ Mutagenicity</th>
<th>Develop/ Reproduct Tox</th>
<th>Skin/Eye Irritation</th>
<th>Endocrine Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetyl Tributyl Citrate</td>
<td>L</td>
<td>VL</td>
<td>L</td>
<td>vL-M</td>
<td>M</td>
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<tr>
<td>Current Plasticizer**</td>
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<td></td>
</tr>
<tr>
<td>Di(ethylhexyl) terephthalate (DEHT)</td>
<td>L</td>
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<td>L</td>
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<td>DG</td>
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<tr>
<td>Diisononyl hexahydrophthalate (DINCH)</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>M</td>
</tr>
</tbody>
</table>

**both are phthalates

Data Gap | Very Low Hazard | Low Hazard | Medium Hazard | High Hazard | Very High Hazard

Sources: EPA; PubChem; IARC; Johnson, 2002; Sheikh and Beg, 2019

Background | Performance Criteria | Our Strategies | Strategy 1 | Strategy 2 | Strategy 3 | Recommendations
Ethanol and isopropanol are less hazardous than current “safe” solvents

<table>
<thead>
<tr>
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<th>Carcinogenicity</th>
<th>Genotoxicity/ Mutagenicity</th>
<th>Develop/ Reproduct Tox</th>
<th>Skin/Eye Irritation</th>
<th>Endocrine Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanol</td>
<td>L</td>
<td>L</td>
<td>M-L</td>
<td>H-L</td>
<td>DG</td>
</tr>
<tr>
<td>Isopropanol</td>
<td>L</td>
<td>L</td>
<td>M</td>
<td>H-M</td>
<td>DG</td>
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</table>

<table>
<thead>
<tr>
<th>Current Solvents</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Butyl Acetate</td>
<td>L</td>
<td>M-L</td>
<td>M</td>
<td>H</td>
<td>DG</td>
</tr>
<tr>
<td>Ethyl Acetate</td>
<td>L</td>
<td>M-L</td>
<td>M</td>
<td>H</td>
<td>DG</td>
</tr>
</tbody>
</table>

Data Gap: Very Low Hazard, Low Hazard, Medium Hazard, High Hazard, Very High Hazard

Sources: EPA, PubChem, IARC

Background, Performance Criteria, Our Strategies, Strategy 1, Strategy 2, Strategy 3, Recommendations
Sample zein-based formulation shows promising technical performance with room for improvement

**Film-former**

**Plasticizer**

**Solvent**

- **Zein**
- **Acetyl Tributyl Citrate**
- **Ethanol**
- **Isopropanol**

**Future Directions**

**Improving current formulation**
- Solvent mixtures (ethanol & isopropanol)
- Antioxidants (carotenoids, vitamin E/C, ...)
- Blue-colored chemical to neutralize yellow

**Developing other formulations**
- Different solubility guides (Pfizer, Sanofi, ...)
- Solubility parameters (Hansen, Hildebrand, ...)
- Other hydrophobic solvents (non-alcohols)

---

**Strategy 1**

**Strategy 2**

**Strategy 3**

**Recommendations**
Strategy 2 Water as a Solvent Alternative to Toluene
## Strategy 2: Water as a solvent alternative

<table>
<thead>
<tr>
<th>Component</th>
<th>Function in formula</th>
<th>Max amount in % weight of component in formulation</th>
<th>Current Chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Film-former</strong></td>
<td>Binds components together when dried and thickens formulation</td>
<td>50%</td>
<td>- Nitrocellulose</td>
</tr>
<tr>
<td></td>
<td>Main component in formulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Solvent</strong></td>
<td>Dissolves solutes</td>
<td>90%</td>
<td>- Toluene</td>
</tr>
<tr>
<td></td>
<td>Lowers the viscosity of final formulation</td>
<td></td>
<td>- Butyl acetate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Ethyl acetate</td>
</tr>
<tr>
<td><strong>Plasticizer</strong></td>
<td>Increase flexibility by softening the polymer (film-former)</td>
<td>15%</td>
<td>- Dibutyl phthalate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Triphenyl Phosphate (TPhP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Di(ethylhexyl) terephthalate (DEHT)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Diisononyl hexahydrophthalate (DINCH)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Triethyl citrate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Acetyl tributyl citrate</td>
</tr>
</tbody>
</table>

*Red = current primary bad actors*
## Water has no known hazards

<table>
<thead>
<tr>
<th></th>
<th>Carcinogenicity/ Mutagenicity</th>
<th>Develop/ Reproduct Tox</th>
<th>Endocrine Activity</th>
<th>Skin/Eye Irritation</th>
<th>Acute/Systemic Toxicity</th>
<th>Neurotoxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Toluene</strong></td>
<td>L</td>
<td>H</td>
<td>H-M</td>
<td>H</td>
<td>M</td>
<td>M-L</td>
</tr>
<tr>
<td><strong>Butyl Acetate</strong></td>
<td>L</td>
<td>M-L</td>
<td>DG</td>
<td>H</td>
<td>M</td>
<td>M-L</td>
</tr>
<tr>
<td><strong>Ethyl Acetate</strong></td>
<td>L</td>
<td>M-L</td>
<td>DG</td>
<td>H</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td><strong>Water</strong></td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
</tbody>
</table>

**Sources:** IARC, Prop-65, EU GHS, New Zealand GHS, Pharos, EWG Skin Deep, REACH
Many water-based formulations use acrylates copolymers as film-formers

<table>
<thead>
<tr>
<th>Brand</th>
<th>Film-former</th>
<th>Plasticizer</th>
<th>Full Ingredient List</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquarella</td>
<td>Acrylates Copolymer</td>
<td>N/A</td>
<td>Aqua, Styrene Acrylates Copolymer, Acrylates Copolymer. Pigments</td>
</tr>
<tr>
<td>Honeybee Gardens No Nasties</td>
<td>Acrylates Copolymer</td>
<td>N/A</td>
<td>Water (aqua), acrylics copolymer. Pigments</td>
</tr>
<tr>
<td>(peelable)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miniso</td>
<td>Polyurethane-1</td>
<td>propylene glycol</td>
<td>Polyurethane-1, water, propylene glycol, stearalkonium bentonite</td>
</tr>
</tbody>
</table>

Source: My List of Water Based, Peelable & Odourless Non-Toxic Nail Polish
Syntran 5620 CG is a film-former developed for water-based nail enamels

**Styrene/acrylates/ammonium methacrylate copolymers are made up of 3 components**

Syntran 5620 CG* is a specific version of this copolymer:

- 42% solids
- Miscible with water
- pH of 7-8
- Flammable at >120°C

*Syntran 5620 CG is an updated version of Syntran PC 5620 without the methylisothiazolinone (MIT) preservative

**Background**

**Performance Criteria**

**Our Strategies**

**Strategy 1**

**Strategy 2**

**Strategy 3**

**Recommendations**
Water-based formulations are slower drying than their solvent counterparts.
### Acrylates copolymers have concerning health endpoints

<table>
<thead>
<tr>
<th></th>
<th>Styrene</th>
<th>Methacrylate ester</th>
<th>Ammonium methacrylate copolymers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acute Exposure</strong></td>
<td>- Mucous membrane &amp; Eye irritant</td>
<td>- Skin, eye, and nose irritant</td>
<td>- Skin and eye irritant</td>
</tr>
<tr>
<td></td>
<td>- Gastrointestinal effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Chronic Exposure</strong></td>
<td>- Central nervous system</td>
<td>- Development of skin allergy</td>
<td>- Skin and eye irritant</td>
</tr>
<tr>
<td></td>
<td>- Hearing loss</td>
<td>- Itching</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Peripheral neuropathy</td>
<td>- Skin rash</td>
<td></td>
</tr>
<tr>
<td><strong>Reproductive/Developmental Toxicity</strong></td>
<td>- No increase in developmental effects</td>
<td>- Data Gap</td>
<td>- Data Gap</td>
</tr>
<tr>
<td></td>
<td>- Increase in spontaneous abortions</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Decrease in sperm concentration</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Carcinogenicity</strong></td>
<td>- Group 2B</td>
<td>- Not classifiable to cause cancer</td>
<td>- Not classifiable to cause cancer</td>
</tr>
</tbody>
</table>

References: IARC, EPA, ASTDR, ECHA
Various natural film-formers also dissolve well in water

Pullulan

Alginates (e.g. sodium alginate)

Chitosan
**Pros**

- Eliminates bad actor chemicals
- Odorless
- Non-flammable

**Cons**

- Dries top-down
- Long dry time
- Absorbs water
- Bacterial growth

**Solutions**

- Instructions to apply 2-3 thin coats
- Allow 15 mins to dry between coats
- Let cure for 6+ hours overnight
- Antibacterial agents

**Future Directions**

- Less toxic film-formers
- Solubility of plasticizers with proposed Syntran 5620 CG
- Properties of proposed natural water-soluble film-former
- Applicability of water-based properties of cosmetics to nails
Strategy 3 Bio-based Plasticizer Drop-in Replacements
## Strategy 3: Drop-in plasticizer alternatives

<table>
<thead>
<tr>
<th>Component</th>
<th>Function in formula</th>
<th>Max amount in % weight of component in formulation</th>
<th>Current Chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Film-former</strong></td>
<td>Binds components together when dried and thickens formulation</td>
<td>50%</td>
<td>- Nitrocellulose</td>
</tr>
<tr>
<td></td>
<td>Main component in formulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Solvent</strong></td>
<td>Dissolves solutes</td>
<td>90%</td>
<td>- Toluene&lt;br&gt;- Butyl acetate&lt;br&gt;- Ethyl acetate</td>
</tr>
<tr>
<td><strong>Plasticizer</strong></td>
<td>Increase flexibility by softening the polymer (film-former)</td>
<td>15%</td>
<td>- Dibutyl phthalate&lt;br&gt;- Triphenyl Phosphate (TPhP)&lt;br&gt;- Di(ethylhexyl) terephthalate (DEHT)&lt;br&gt;- Diisononyl hexahydropthalate (DINCH)&lt;br&gt;- Triethyl citrate&lt;br&gt;- Acetyl tributyl citrate</td>
</tr>
</tbody>
</table>

Red = current primary bad actors
Many companies are developing alternative plasticizers to shift away from phthalates.

**Epoxidized oils** (Vernonia Oils)

![Epoxidized oils structure]

**Cross-linked polyesters**

\[
\begin{align*}
\text{CH}_2\text{-CO-}R_1 \\
\text{HO-}C\text{-CO-}R_2 \\
\text{CH}_2\text{-CO-}R_3
\end{align*}
\]

**Sulfonamides**

\[
\text{Ar}\text{-SO}_2\text{-N}\text{R}_1\text{R}_2
\]

**Vernonia galamensis** (Ironweed)

Sources:
- Patents: FR2785531; 5,578,297; 5,882,636; US 8,187,576 B2
Natural carbonates are plasticizers that can be prepared in bio-based manners.

Generic carbonates:

\[ R_1 \text{OCOOR}_2 \]

Where:

1. \( R_1 \) and \( R_2 \) are equivalent
2. \( R_1 \) and \( R_2 \) form an alkyl chain with 2 or 3 carbon atoms and one or more hydroxy or hydroxy(C\(_1\)–C\(_3\)) alkyl groups

**Strategy 1**

**Performance Criteria**

**Strategy 2**

**Strategy 3**

**Recommendations**

Glycerol carbonate has good plasticizing properties for nail polish

- Chemically stable
- **Non-flammable** (Flash Point >204°C)
- **Water-soluble**
- Biodegradable
- Low volatility (Boiling Point 110–115°C at 0.1 mmHg)
- **High renewable content** (76 - 100% depending on synthesis route)

Sources: Patent No.: US 8,187,576 B2
Clemson, 2003
Glycerol carbonate has better plasticizing properties than the commercial plasticizer.

**Effect of the plasticizers on the Persoz hardness**

- **Formulation**
  - Ingredient | % Composition |
  - Solvents* | 59.1 |
  - Nitrocellulose | 17.9 |
  - Polyester resin | 13.3 |
  - Plasticizer | 9.9 |
  - *mixture of ethyl acetate, butyl acetate, and isopropanol

**Results**
- Moderate plasticizing effect for dilauryl carbonate and diisoamyl carbonate
- Glycerol carbonate had better plasticizing properties than the commercial plasticizer

Source: de Caro et al., 2019
Glycerol carbonates can be synthesized in a variety of ways.

Different conversion routes for synthesis of glycerol carbonate.

Synthesis of glycerol carbonate from dimethylcarbonate (DMC) and glycerol (an alcohol).

Source: de Caro et al., 2019
Glycerol carbonates interact strongly with nitrocellulose

- Hydrogen bonds between hydroxyl groups of glycerol carbonate and NO$_2$ groups of nitrocellulose
- Large and well-distributed free volume between nitrocellulose chains $\rightarrow$ high plasticizing effect
- Glycerol carbonate can be reduced below 10% to meet specifications of nail polish
The hazard assessment of plasticizer alternatives indicates notable data gaps

<table>
<thead>
<tr>
<th>Plasticizer</th>
<th>Carcinogenicity/ Mutagenicity</th>
<th>Develop/ Reproductive Tox</th>
<th>Skin/Resp Sensitization</th>
<th>Skin/Eye Irritation</th>
<th>Endocrine Activity</th>
<th>Systemic Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diisoamyl carbonate 2050-95-5</td>
<td>DG</td>
<td>M</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
</tr>
<tr>
<td>Dilauryl carbonate 6627-45-8</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
<td>vH</td>
<td>DG</td>
<td>DG</td>
</tr>
<tr>
<td>Glycerol carbonate 96-49-1</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
<td>vH</td>
<td>DG</td>
<td>M</td>
</tr>
<tr>
<td>Acetyl tributyl citrate 77-90-7</td>
<td>L-vL</td>
<td>L</td>
<td>vL</td>
<td>M-vL</td>
<td>M</td>
<td>DG</td>
</tr>
</tbody>
</table>

None of these plasticizers are considered hazardous by the 2012 OSHA Hazard Communication Standard (29 CFR 1910.1200)

Sources: 29 CFR 1910.1200, Pharos, Johnson, Sheikh and Beg, 2019, EU GHS
Drop-in bio-based plasticizers show strong technical performance but lack information regarding health endpoints

<table>
<thead>
<tr>
<th>Technical Performance</th>
<th>Health Endpoints</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Natural carbonates can be synthesized via multiple pathways</td>
<td>● ATBC outperforms glycerol carbonate</td>
</tr>
<tr>
<td>● Glycerol carbonate outperforms ATBC in terms of plasticizing effects</td>
<td>● Glycerol carbonate (GC)</td>
</tr>
<tr>
<td></td>
<td>- Systemic toxicity</td>
</tr>
<tr>
<td></td>
<td>- Acute Toxicity</td>
</tr>
</tbody>
</table>

**Future Directions**

- Other glycerol esters (glycerol triacetate, glyceroltriocanatoate, glyceroltribenzoate, …)
- Related classes to carbonates (diols, glycols, …)
- Non-glycerol related substitutes (adipates, pentaerythrityltetrazenoate, 2,2,4-trimethyl-1,3-pentanedioldisobutyrate, …)

**Future Directions**

- Preference for ATBC as used in Strategy 1
Recommendations
## Comparison of proposed strategies

<table>
<thead>
<tr>
<th></th>
<th>Pros</th>
<th>Cons</th>
<th>Notes</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Zein-based formulation</strong></td>
<td>● Hydrophobic</td>
<td>● Requires alcohol for removal</td>
<td>● Includes safer solvent alternative current actors</td>
<td>● Is there an antioxidant that can be used with zein to prevent the color change?</td>
</tr>
<tr>
<td></td>
<td>● Biodegradable</td>
<td>● Remains skin and eye irritant</td>
<td>● Zein has no known toxic endpoints</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Flexible formulation</td>
<td></td>
<td>● New approach to bring to market</td>
<td></td>
</tr>
<tr>
<td><strong>Water as an alternative solvent</strong></td>
<td>● Easily removed</td>
<td>● Requires additive to increase hardness + reduce bacterial growth</td>
<td>● Reduced need for hazard communication - safer for workers</td>
<td>● What is the ability of the formulas to suspend the pigments? Do we need an additive?</td>
</tr>
<tr>
<td></td>
<td>● Water = no toxic health endpoints</td>
<td>● Slow dry time</td>
<td>● Inexpensive</td>
<td></td>
</tr>
<tr>
<td><strong>Bio-based drop-in plasticizer replacement</strong></td>
<td>● Developed in in many ways</td>
<td>● Difficult application instructions</td>
<td>● Soy-based remover</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Well-researched compatibility between formulation components</td>
<td>● Many data gaps regarding health endpoints</td>
<td>● Existing formulations already on market</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>● This method will require additional testing prior to use to see interactions with other compounds</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>● How do we classify compounds that are both plasticizers and film formers?</td>
<td></td>
</tr>
</tbody>
</table>

### Background
- Strategy 1
- Performance Criteria
- Our Strategies
- Strategy 1
- Strategy 2
- Strategy 3
- Recommendations
Final recommendation: further research on zein-based formulations

- Zein-based formulation has potential to achieve similar results to Shellac
  - Inexpensive, Vegan, Bio-inspired

- Water-based formulations may not achieve long-lasting results
  - Customer reviews report dissatisfaction
  - Additives must be considered

- Consider alternative plasticizers in formulations
  - Many data gaps regarding potential plasticizer alternatives
  - L’Oreal and DTSC should explore alternatives to evaluate use

All strategies eliminate bad actors. Zein-based formulation offers a new and inexpensive approach to create vegan, clean-beauty nail polishes.
Thank you for joining us today

& a special thank you to our partners at L’Oreal and DTSC.
References

1. **Frontiers** | Recent Progress in Synthesis of Glycerol Carbonate and Evaluation of Its Plasticizing Properties (frontiersin.org)
2. §339. The Hazardous Substances List.
8. Zein as biodegradable material for effective delivery of alkaline phosphatase and substrates in biokits and biosensors - ScienceDirect
9. Implications of Protein- and Peptide-Based Nanoparticles as Potential Vehicles for Anticancer Drugs - ScienceDirect
10. Enhanced enteric properties and stability of shellac films through composite salts formation
12. Safety Assessment of Acetyl Trialkyl Citrates as Used in CosmeticsSafety Assessment of Acetyl Trialkyl Citrates as Used in Cosmetics
13. U.S. corn-based ethanol worse for the climate than gasoline, study finds
15. Zein: Structure, Production, Film Properties and Applications
1. GSK Solvent Selection Guide.
2. A one-step approach for esterification of zein with methanol
4. Understanding the Dissolution of α-Zein in Aqueous Ethanol and Acetic Acid Solutions
5. Formulation And Characterization Of Natural Biodegradable Chewing Gum
6. Development of New Method for Extraction of α-Zein from Corn Gluten Meal Using Different Solvents
7. Measurement and correlation of solubility of D-sorbitol in different solvents
8. Ingredient Feature: Acetyl Tributyl Citrate
10. CPSC Staff Statement on University of Cincinnati Report “Toxicity Review for Acetyl Tri-n-butyl Citrate (ATBC)
11. Improved Mechanical Property and Water Resistance of Zein Films by Plasticization with Tributyl Citrate
12. Two fraction extraction of α-zein from DDGS and its characterization
13. Sigma Aldrich Zein SDS
14. Effect of plasticizing sugars on rheological and thermal properties of zein resins and mechanical properties of zein films
15. “Shellac” How Products Are Made Encyclopedia
16. Development of a nail polish with minerals as caring ingredients
17. Additives for water-based nail polish
References (cont.)

1. Measurement of Sixty-Degree Specular Gloss
2. Plasticizer of Natural Origin for Nail Polish
3. Phthalate free nail polish enamel composition
4. Nail varnish composition comprising a crosslinked polyester
5. Cosmetic composition containing an epoxidized oil as plasticizer
6. Recent Progress in Synthesis of Glycerol Carbonate and Evaluation of Its Plasticizing Properties
7. YIKES: Acrylates Copolymer in Beauty Products
8. Water-based nail-polish composition
9. Polymer for water-based nail polish SYNTRAN® PC 5620
10. My List of Water Based, Peelable & Odourless Non-Toxic Nail Polish
11. Working the Nail Polish, Acquarella
12. Green Science Alliance Has Developed Water Base 100% Nature Biomass Nail Polish, Nail Color Which Does Not Come Off Even After Washing
14. PULLULAN BASED FILM FORMING COSMETIC COMPOSITIONS
15. Design of Sodium Alginate/Gelatin-Based Emulsion Film Fused with Polylactide Microparticles Charged with Plant Extract
16. Chitosan Films in Food Applications. Tuning Film Properties by Changing Acidic Dissolution Conditions
17. Ciclopirox Hydroxypropyl Chitosan (HPCH) Nail Lacquer: A Review of Its Use in Onychomycosis
18. DeWolf Chem: Film Former
References (cont.)

1. Sheen: REF. 707 PENDULUM HARDNESS ROCKER
2. Two fraction extraction of α-zein from DDGS and its characterization
3. How is gloss measured?, Rhopoint Instruments
4. Tools and techniques for solvent selection: green solvent selection guides
5. Gras Dossier. GENERALLY RECOGNIZED AS SAFE (GRAS) NOTIFICATION FOR BASIC METHACRYLATE COPOLYMER
6. Summary of Classification and Labelling 2-Propenoic acid, 2-methyl-, ammonium salt (1:1), homopolymer
7. Comp Tox Ammonium methacrylate
9. US EPA, Methyl Methacrylate Hazard Summary
10. CDC, Health Effects of Styrene
11. US EPA, Styrene Hazard Summary
12. European Commission, SCIENTIFIC COMMITTEE ON TOXICITY, ECOTOXICITY AND THE ENVIRONMENT (CSTEE) Opinion on the toxicological characteristics and risks of certain citrates and adipates used as a substitute for phthalates as plasticisers in certain soft PVC products
<table>
<thead>
<tr>
<th>Background</th>
<th>Performance Criteria</th>
<th>Our Strategies</th>
<th>Strategy 1</th>
<th>Strategy 2</th>
<th>Strategy 3</th>
<th>Recommendations</th>
</tr>
</thead>
</table>
How hazard assessments were conducted

- **Literature**
  - IARC
  - IRIS
  - European Commission: Scientific Committee on Toxicity, Ecotoxicity and the Environment
  - EPA
  - Consumer Product Safety Commission
  - PubChem
  - Agency for Toxic Substances and Disease Registry (ATSDR)
  - U.S. Department of Health and Human Services
  - CDC

- **Screening tools**
  - Pharos
  -
# Hazard Assessment Primary Bad Actors

<table>
<thead>
<tr>
<th></th>
<th>Carcinogenicity</th>
<th>Genotoxicity/Mutagenicity</th>
<th>Develop/Reprod Tox</th>
<th>Skin/Eye Irritation</th>
<th>Endocrine Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Toluene</strong></td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>M - H</td>
</tr>
<tr>
<td><strong>Formaldehyde</strong></td>
<td>H</td>
<td>M</td>
<td>DG</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td><strong>Dibutyl Phthalate</strong></td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td><strong>Triphenyl Phosphate</strong></td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>M</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Background</th>
<th>Performance Criteria</th>
<th>Our Strategies</th>
<th>Strategy 1</th>
<th>Strategy 2</th>
<th>Strategy 3</th>
<th>Recommendations</th>
</tr>
</thead>
</table>

- **Formaldehyde**: Carcinogenicity: H, Genotoxicity/Mutagenicity: M, Develop/Reprod Tox: DG, Skin/Eye Irritation: M, Endocrine Activity: M
- **Triphenyl Phosphate**: Carcinogenicity: M, Genotoxicity/Mutagenicity: L, Develop/Reprod Tox: L, Skin/Eye Irritation: L, Endocrine Activity: M

The table above provides a comprehensive overview of the hazard assessment for primary bad actors, detailing their classification across various biological and toxicological criteria.
## Strategy 1: Alternative Solution Hazards

<table>
<thead>
<tr>
<th></th>
<th>Carcinogenicity</th>
<th>Genotoxicity/Mutagenicity</th>
<th>Develop/Reprod Tox</th>
<th>Skin/Eye Irritation</th>
<th>Skin/Resp Sensitization</th>
<th>Endocrine Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Zein</strong></td>
<td>L</td>
<td>DG</td>
<td>L</td>
<td>vL</td>
<td>vL</td>
<td>DG</td>
</tr>
<tr>
<td><strong>Acetyl Tributyl Citrate</strong></td>
<td>L</td>
<td>vL</td>
<td>L</td>
<td>vL-M</td>
<td>vL</td>
<td>M</td>
</tr>
<tr>
<td><strong>Ethanol</strong></td>
<td>L</td>
<td>L</td>
<td>M-L</td>
<td>H-L</td>
<td>L</td>
<td>DG</td>
</tr>
<tr>
<td><strong>Isopropanol</strong></td>
<td>L</td>
<td>L</td>
<td>M</td>
<td>H-M</td>
<td>M</td>
<td>DG</td>
</tr>
</tbody>
</table>

### Data Gap
- Very Low Hazard
- Low Hazard
- Medium Hazard
- High Hazard
- Very High Hazard

**Sources:** EPA, PubChem, IARC, Pharos

---

**Background**

**Performance Criteria**

**Our Strategies**

**Strategy 1**

**Strategy 2**

**Strategy 3**

**Recommendations**
# Hazard Assessment of Film-formers in Existing Water-Based Formulations

## Background

- **Strategy 1**
- **Performance Criteria**
- **Our Strategies**
- **Recommendations**

## Performance Criteria

<table>
<thead>
<tr>
<th>Film-former:</th>
<th>Carcinogenicity/ Mutagenicity</th>
<th>Develop/ Reproductive Tox</th>
<th>Skin/Resp Sensitization</th>
<th>Skin/Eye Irritation</th>
<th>Endocrine Activity</th>
<th>Systemic Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acrylates Copolymer</strong>&lt;br&gt;25133-97-5</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
</tr>
<tr>
<td><strong>Acrylates Copolymer</strong>&lt;br&gt;25035-69-2</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
</tr>
<tr>
<td><strong>Acrylates Copolymer</strong>&lt;br&gt;25212-88-8</td>
<td>DG</td>
<td>DG</td>
<td>H</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
</tr>
<tr>
<td><strong>PEG-150/Decyl/Alcohol/SDMI Copolymer</strong>&lt;br&gt;193487-42-2</td>
<td>L</td>
<td>L</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
</tr>
</tbody>
</table>

- **Data Gap**
- **Very Low Hazard**
- **Low Hazard**
- **Medium Hazard**
- **High Hazard**
- **Very High Hazard**
Water-based formulations with Syntran PC 5620 showed high film hardness.
Benzoflex™ 9-88 and Dowanol PnB can provide plasticizing properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Benzoflex™ 9-88</th>
<th>Dowanol™ PnB Glycol Ether</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW (g/mol)</td>
<td>474.59</td>
<td>132.2</td>
</tr>
<tr>
<td>Water solubility (g/L) @ RT</td>
<td>-</td>
<td>52</td>
</tr>
<tr>
<td>Viscosity (mPa•s) @ 25°C</td>
<td>105</td>
<td>2.8</td>
</tr>
<tr>
<td>Flash point (°C)</td>
<td>182</td>
<td>63</td>
</tr>
</tbody>
</table>

---

**Background**

**Strategy 1**

**Performance Criteria**

**Our Strategies**

**Strategy 1**

**Strategy 2**

**Strategy 3**

**Recommendations**
Acrylates copolymer has high toxicity

<table>
<thead>
<tr>
<th>Film-former:</th>
<th>Carcinogenicity/ Mutagenicity</th>
<th>Develop/ Reproductive Tox</th>
<th>Skin/Resp Sensitization</th>
<th>Skin/Eye Irritation</th>
<th>Endocrine Activity</th>
<th>Systemic Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylates Copolymer</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>M-L</td>
<td>DG</td>
<td>DG</td>
</tr>
<tr>
<td>PEG-150/Decyl/Alcohol/SDMI Copolymer</td>
<td>L</td>
<td>L</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
</tr>
</tbody>
</table>

Data Gap | Very Low Hazard | Low Hazard | Medium Hazard | High Hazard | Very High Hazard

<table>
<thead>
<tr>
<th>Background</th>
<th>Performance Criteria</th>
<th>Our Strategies</th>
<th>Strategy 1</th>
<th>Strategy 2</th>
<th>Strategy 3</th>
<th>Recommendations</th>
</tr>
</thead>
</table>
**Strategy 2: Water-based Nail Polish Formulation**

<table>
<thead>
<tr>
<th><strong>Typical Formulation</strong></th>
<th><strong>Water-Based Alternative</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Film Former</td>
<td>Acrylates Copolymer</td>
</tr>
<tr>
<td>Solvent</td>
<td>Water</td>
</tr>
<tr>
<td>Plasticizer</td>
<td>Drying Retarder</td>
</tr>
<tr>
<td>Pigments</td>
<td>Pigments</td>
</tr>
</tbody>
</table>

**Pros**
- Eliminates bad actor chemicals,
- Odorless, Non-flammable

**Cons**
- Dries top-down, Long dry time,
- Absorbs water, Bacterial growth

**Solution**
- Include application instructions to apply 2-3 thin coats and allow 15 mins to dry between coats, Let cure for 6+ hours overnight
# Hazard Assessment of Plasticizers in Existing Water-Based Formulations

## Plasticizer:

<table>
<thead>
<tr>
<th>Plasticizer</th>
<th>Carcinogenicity/ Mutagenicity</th>
<th>Develop/ Reproductive Tox</th>
<th>Skin/Resp Sensitization</th>
<th>Skin/Eye Irritation</th>
<th>Endocrine Activity</th>
<th>Systemic Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neem Oil (Melia azadirachta) 947173-77-5</td>
<td>L</td>
<td>L</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
<td>DG</td>
</tr>
<tr>
<td>PPG-2 Methyl Ether 88917-22-0</td>
<td>DG</td>
<td>pC</td>
<td>pC</td>
<td>pC</td>
<td>DG</td>
<td>DG</td>
</tr>
<tr>
<td>Propylene glycol 57-55-6</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>DG</td>
<td>DG</td>
<td>M</td>
</tr>
</tbody>
</table>

- **Data Gap**: Not available
- **Very Low Hazard**: Not relevant
- **Low Hazard**: Relevant but not critical
- **Medium Hazard**: Requires monitoring
- **High Hazard**: Needs immediate action
- **Very High Hazard**: Imminent danger

### Performance Criteria

- **Background**
- **Performance Criteria**
- **Our Strategies**
- **Strategy 1**
- **Strategy 2**
- **Strategy 3**
- **Recommendations**
Other Plasticizers of Natural Origin

Plasticizer Properties

- Remain in polish film
- Flash point > 30°C

Phthalate-free nail polish enamel composition substitutions:

Adipates

Pentaerythritol tetrabenozoate

Carbonates

- Prepared by reaction of Dimethyl Carbonate (DMC)
- Glycerol carbonate

2,2,4-trimethyl-1,3-pentanediol diisobutyrate
Current Plasticizer of Natural Origin

**Dimethyl Carbonate Synthesis**

**Diisoamyl Carbonate**

\[
\text{DMC} + \text{Isoamyl alcohol} \xrightleftharpoons[K_2CO_3]{K_2CO_3} \text{Diisoamyl carbonate} + \text{CH}_3\text{OH}
\]

**Glycerol Carbonate**

\[
\text{Glycerol} + \text{MeO} \xrightarrow[K_2CO_3]{K_2CO_3} \text{Glycerol carbonate}
\]

---

**Background** | **Performance Criteria** | **Our Strategies** | **Strategy 1** | **Strategy 2** | **Strategy 3** | **Recommendations**
---|---|---|---|---|---|---

65
Current Plasticizer of Natural Origin

Dimethyl Carbonate Synthesis

Dilauryl Carbonate

\[
\begin{align*}
&\text{DMC} + \text{Lauryl alcohol} \\
&\text{K}_2\text{CO}_3 \\
&\text{Dilauryl carbonate} + \text{MeOH}
\end{align*}
\]
- **Dimethyl carbonate transesterification base catalysis**
  - Green chem
  - Catalyst: potassium carbonate (K2CO3)

- **Dmc**
  - Non-toxic
  - Manufactured to a clean process
  - Replaces toxic and hazardous reagents

- **Synthesis of diisoamyl, dilauryl & glycerol carbonates**
  - Rxn of DMC with isoamyl alcohol, dodecanol, or lauryl alcohol, and glycerol
### Background

<table>
<thead>
<tr>
<th>Criteria 1</th>
<th>Criteria 2</th>
<th>Criteria 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zein-based formulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water as an alternative solvent</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Bio-based drop-in plasticizer replacement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Additional references not in folders

1. Measurement of Sixty-Degree Specular Gloss
2. Plasticizer of Natural Origin for Nail Polish
3. Phthalate free nail polish enamel composition
4. Nail varnish composition comprising a crosslinked polyester
5. Cosmetic composition containing an epoxidized oil as plasticizer
6. Recent Progress in Synthesis of Glycerol Carbonate and Evaluation of Its Plasticizing Properties
7. YIKES: Acrylates Copolymer in Beauty Products
8. Water-based nail-polish composition
9. Polymer for water-based nail polish SYNTRAN® PC 5620
10. My List of Water Based, Peelable & Odourless Non-Toxic Nail Polish
11. Working the Nail Polish, Acquarella
12. Green Science Alliance Has Developed Water Base 100% Nature Biomass Nail Polish, Nail Color Which Does Not Come Off Even After Washing
14.
15.