Optimizing flexible PVC formulations based on polyol ester plasticizers

PVC Formulation
April 10-12, 2018, Cologne
Anders Magnusson
A leading player with 136 years of expertise

1881
Perstorp was founded by Mr. Wilhelm Wendt

1940’s
Scandinavia’s first modern plastics industry, with more than 10,000 different products

1970’s
World’s largest exporter of decorative high-pressure laminates

1990’s
Refocus on the core business to become a world leading Specialty Chemicals company

1940’s
Scandinavia’s first modern plastics industry, with more than 10,000 different products

2005
PAI acquires Perstorp

2006
Establishes sales office in Shanghai

2008
Acquires a TMP plant in Zibo, China

2008
Acquires the Capa™ business from Solvay Group

2011
Completes major investment to double the Capa™ monomer capacity

2011
Acquires Ashland’s Penta business

2013
Inauguration of new NEO plant in Zibo, China

2013
Acquires Chemko’s calcium formate and penta businesses

2015
Head office moves to Malmo

2015
Acquires Koei’s penta business

2016
Inauguration of a plant for BioFuels in Fredrikstad

2017
Acquires Polialcoli’s TMP and Neo businesses

2017
Acquires Polialcoli’s TMP and Neo businesses

2018
Divestment of Formox to Johnson Matthey and Perstorp Ättika to Kavli Group

2019
Acquires Chemko’s calcium formate and penta businesses

2019
Inauguration of a new Oxo plant in Sweden. Largest investment in company history
Perstorp in the plasticizer industry

- Fully integrated plasticizer producer since 1980’s
- Launched *Emoltene™* 100 (DPHP) in 2009 for durable applications
- Investment announced in 2011 to build a new production platform for new plasticizers
-Exited from DOP business completely early 2012
- Investment completed by Q1 2015
- Launched *Pevalen™* in 2013, a **genuine non-phthalate** based on polyolester
- Storage facilities in UK, Belgium, Germany, Portugal and US
- Member of **European plasticisers**, *VinylPlus* and founding member of *PlasticiserPlus*
Perstorp in brief

- World leader in several sectors of the specialty chemicals market
- Pioneer in formalin chemistry, plastics and surface materials
- Since December 2005 controlled by PAI partners, a leading European private equity company
- Present in 26 countries and production plants in Europe, Asia and North America
- Sales offices in all major markets
PVC Formulation Ingredients

- Heat stabilizers
- Lubricants
- Adhesion promoters
- Hydrocarbon oils
- Antioxidants
- Impact modifier
- Plasticizers
- Pigment
- Blowing agents
- Filler
- Flame retardents
- Viscosity modifier
A jungle of Plasticizer alternatives

- Eastman 168™
- Diplast
- Emoltene™
- Palatinol
- Benzoflex
- Pevalen™
- Flexidone
- Santicizer Platinum
- TOTM
- Mesamoll
- Hexamoll® DINCH
- Polysorb 37
- Drapex Alpha 200
- PLS Green
Changing plasticizer – how hard can it be?

• Easy replacement with no or little reformulation!

• Can substitute traditional phthalates easily!

• One size fits all!

• Quickly and efficiently switch (from classified DOP)!

• Substitution

What is the risk of improper reformulation?
PVC formulation related failure
What to consider when reformulating?

- Compatibility
- Processing
- Viscosity
- Hardness
- Plastisol stability
- Sustainability
- Legislation
Plasticizer Characteristics

Pevalen™ has high calculated compatibility and low volatility.

<table>
<thead>
<tr>
<th>Name</th>
<th>Solubility parameter ($J^{1/2}cm^{3/2}$)</th>
<th>Weight Loss (%)</th>
<th>Viscosity (mPas, 20°C)</th>
<th>Molecular weight (g/mol)</th>
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</thead>
<tbody>
<tr>
<td>PVC</td>
<td>19.40</td>
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<tr>
<td>Pevalen</td>
<td>18.39</td>
<td>11</td>
<td>35</td>
<td>472</td>
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<tr>
<td>DOTP</td>
<td>17.94</td>
<td>15</td>
<td>86</td>
<td>390</td>
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<tr>
<td>DINCH</td>
<td>16.76</td>
<td>19</td>
<td>52</td>
<td>420</td>
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Compatibility

Pevalen™ lower haze is a response to higher compatibility

Haze

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<th>%</th>
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<tr>
<td>Pevalen</td>
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<tr>
<td>DINCH</td>
<td>20</td>
</tr>
<tr>
<td>DINP</td>
<td>25</td>
</tr>
<tr>
<td>DOTP</td>
<td>30</td>
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</tbody>
</table>
Compatibility

Pevalen™ higher weight flow is a response to higher compatibility

Diffusion from P-PVC to U-PVC

Weight Loss, %
Plasticizer absorption time

Pevalen™ has shortest absorption time ➔ faster dry mixing processing, hence less energy required

Time, minutes

- Pevalen
- DINP
- DOTP
- DINCH
Brookfield viscosity 2h and 24h

Pevalen™ yields plastisol with low initial viscosity and keeps its viscosity well over time.
Brookfield viscosity 3 Phr TiO₂ 2h and 24h

Pevalen™ yields plastisol with low initial viscosity and keeps its viscosity well over time.
Solution temperature

Pevalen™ has a higher solution temperature, but...

<table>
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<tr>
<th>Name</th>
<th>Solution Temperature, °C</th>
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<tr>
<td>DOTP</td>
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<tr>
<td>DINCH</td>
<td>135</td>
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<tr>
<td>Pevalen</td>
<td>141</td>
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</tbody>
</table>
Gelation

... Pevalen™ has faster gelation
→ enables high volume manufacturing and energy savings
Hardness

Pevalen™ yields softest material
⇒ less impact on raw material consumption and thereby less environmental impact
Hardness

Pevalen™ yields softest material → less impact on raw material consumption and thereby less environmental impact
**Hardness**

Pevalen™ yields softest material
→ less impact on raw material consumption and thereby less environmental impact
Substitution Factor (S.F) vs DOTP

Pevalen™ yields softest material
→ less impact on raw material consumption and thereby less environmental impact

<table>
<thead>
<tr>
<th>S-PVC K-value 52</th>
<th>E-PVC K-value 69</th>
<th>S-PVC K-value 82</th>
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<tbody>
<tr>
<td>- Shore A 85 + SF 1,12</td>
<td>- Shore A 75 + SF 1,13</td>
<td>- Shore A 85 + SF 1,25</td>
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<td>- Shore A 70 + SF 1,09</td>
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<td>- Shore A 70 + SF 1,09</td>
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</table>
Tensile – S-PVC

Pevalen™ yields softest material and highest strain → enables higher content of filler
Efficiency impacts viscosity

Requires BYK additive to counterbalance increased viscosity

<table>
<thead>
<tr>
<th></th>
<th>Pevikon P2170</th>
<th>100</th>
<th>100</th>
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<td>Dinch</td>
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<td>Viskobyk 5120</td>
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</table>

|                  | Hardness, Shore A | 73 | 74 | 71 | 68 |

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<thead>
<tr>
<th></th>
<th>Viscosity, 0h, cP</th>
<th>2050</th>
<th>2900</th>
<th>1850</th>
<th>1450</th>
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<tr>
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<td>2300</td>
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<td>Viscosity, 168h, cP</td>
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<td>2750</td>
<td>5400</td>
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<td>1950</td>
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PVC grades impacts viscosity

PVC grades is a tool to formulate hardness and viscosity

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<td>Pevalen</td>
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<tr>
<td>Baerostab UBZ 711-1 RF</td>
<td>3</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hardness, Shore A</th>
<th>74</th>
<th>69</th>
<th>69</th>
<th>69</th>
<th>72</th>
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<tbody>
<tr>
<td>Viscosity, 0h, cP</td>
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<td>2851</td>
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<td>5371</td>
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<td>Viscosity, 48h, cP</td>
<td>4850</td>
<td>3945</td>
<td>5905</td>
<td>5142</td>
<td>4276</td>
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</table>
Plastisol stability

Proper formulated yields stable pigmented Pevalen™ plastisol

DOTP  Pevalen  Reformulated Pevalen
Plastisol viscosity

Proper formulated yields retained viscosity

![Graph showing Plastisol containing bonding agent](image)

- Time (h)
- Viscosity (cP)
Carbon footprint

Improved sustainability upon Pevalen™ usage*

*DINCH and DOTP are expected to have a higher Carbon Index than DPHP/Emoltene 100 due to production characteristics
## Legislation

### Classified Plasticisers

<table>
<thead>
<tr>
<th>Included in REACH Candidate List or pending Authorisation</th>
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<tbody>
<tr>
<td>ORTHOPHTHALATES</td>
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<tr>
<td>Low Molecular weight</td>
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<tr>
<td>3-6C</td>
</tr>
<tr>
<td>DEHP</td>
</tr>
<tr>
<td>DBP</td>
</tr>
<tr>
<td>DIBP</td>
</tr>
<tr>
<td>DCHP</td>
</tr>
</tbody>
</table>

### Non-Classified Plasticisers

<table>
<thead>
<tr>
<th>ORTHOPHTHALATES</th>
<th>Terephthalates</th>
<th>Adipates</th>
<th>Alkyl sulfonates</th>
<th>Phosphate</th>
<th>Citrates</th>
<th>Butyrates</th>
<th>Vegetable Oil based</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Molecular weight ≥ 7C</td>
<td>DOTP, DBT</td>
<td>DEHA, DINA, DIDA, DTDA</td>
<td>ASE</td>
<td>TPP</td>
<td>ATBC</td>
<td></td>
<td>Valerates</td>
</tr>
<tr>
<td>DINP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIDP</td>
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<tr>
<td>DPHP</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

- **Sebacates**: DMS, DBS
- **Azelates**: DIDAz

This table is for illustration purposes only. The list of plasticisers is non-exhaustive and box sizes do not accurately represent market volumes.

Source: www.europeanplasticizers.org
Changing plasticizer – how hard can it be?

- Easy replacement with no or little reformulation!
- Can substitute traditional phthalates easily!
- One size fits all!
- Quickly and efficiently switch (from classified DOP)!
- Substitution
Summary

• Different plasticizer molecular structure gives diverse properties

• Pevalen™ structure yields high compatibility improving clarity and the visual appearance

• Pevalen™ has a unique combination of high efficiency and low volatility

• Pevalen™ has an unique property combination of low viscosity and fast gelation

• Pevalen™ will in overall contribute to improved sustainability

→ Proper formulating is essential and collaboration is key to success
One molecule can change everything

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