Basics on permeation and EVOH

• What is permeation?
  – Permeation is the movement from gases, vapours and liquids through a solid material

• When does permeation occur?
  – In case the partial pressure of the permeant between both sides is different
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- Permeation proceeds mainly in three steps:
  - Absorption
  - Diffusion
  - Desorption

\[ P_1 > P_2 \]
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Permeation consequences

- Permeation of water vapour
  - Chemical reaction
    - e.g.: Isocyanate

- Permeation of oxygen
  - Oxidation (e.g. edible oil)
  - Vitamin deterioration
  - Growth of micro organisms

- Permeation of solvents
  - Changing composition / quality
  - Creating Ex-Zones
    - e.g.: Inks, Resins

- Permeation of nitrogen

- Permeation of aroma and fragrances
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EVOH permeation barrier

• EVOH is a co-polymer of ethylene and vinyl alcohol

\[ \text{CH}_2-\text{CH}_2 (\text{CH}_2-\text{CH})_n \text{OH} \]

An excellent barrier against:
• Solvents
• Gasoline, oil
• Aroma
• Gases

Where is EVOH commonly used?
• Packaging of foodstuffs
• Packaging of cosmetics
• Plastic fuel tanks
• Bottles for crop protection products
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EVOH material composition

a copolymer of Ethylene and Vinyl Alcohol

$(\text{CH}_2-\text{CH}_2)_m(\text{CH}_2-\text{CH})_n\text{OH}$

- thermoplastic
- hydrophobic
- flexible
- barrier
- soluble in water

kuraray
# Basics on permeation and EVOH

## EVOH application market

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive</td>
<td>Emission standards, ISO TS16494 qualified.</td>
</tr>
<tr>
<td>Pipe/Tube</td>
<td>Copper replacement, sanitary and floor heating.</td>
</tr>
<tr>
<td>Coating</td>
<td>Aluminium replacement, sterilisation.</td>
</tr>
<tr>
<td>Bottle</td>
<td>Barrier PET, IBCs, juice, value-added milk</td>
</tr>
<tr>
<td>Form</td>
<td>PVDC replacement, deep-draw, glass replacement</td>
</tr>
<tr>
<td>Flexible</td>
<td>Shrink film, stand-up pouch, MAP, AI replacement</td>
</tr>
<tr>
<td></td>
<td>Deep/Clear forming, Medical, Sterilisation</td>
</tr>
</tbody>
</table>
Basics on permeation and EVOH

Permeation comparison: EVOH vs. HDPE

<table>
<thead>
<tr>
<th>Material</th>
<th>Permeation of d-Limonene at 20 °C (g x mm/m² x day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDPE</td>
<td>24.39</td>
</tr>
<tr>
<td>EVOH</td>
<td>0.0008</td>
</tr>
</tbody>
</table>

* Source: Kuraray Company Ltd

Wall thickness: 1 µm  (equivalent 10000 µm = 10 mm)

**EVOH**

d-Limonene barrier:  + 30,000 times
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SCHÜTZ development: 6-layer technology

- Inner layer: HDPE, new material
- Adhesive
- **EVOH permeation barrier**
- Adhesive
- Intermediate layer: HDPE regrind
- Outer layer
  - conductive, anti-static,
  - additional UV protection for filling good
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SCHÜTZ development: IBCs with EVOH

ECOBULK MX-EV

HDPE
Chemical resistance
Mechanical properties
Water vapour barrier

EVOH
Gas barrier
Solvent barrier
Flavour barrier
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ECOBULK MX-EV 1000 – UN approval

![UN Label](image)

<table>
<thead>
<tr>
<th>Standard fluid</th>
<th>Density (kg/liter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1.9</td>
</tr>
<tr>
<td>Hydrocarbon mixture (white spirit)</td>
<td>1.4</td>
</tr>
<tr>
<td>Detergent solution</td>
<td>1.6</td>
</tr>
<tr>
<td>n-Butyl Acetate</td>
<td>1.4</td>
</tr>
<tr>
<td>with n-butyl acetate saturated detergent solution</td>
<td></td>
</tr>
<tr>
<td>Nitric acid 55%</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Pfl-Fr 2344 and Pfl-Fr 2323
Model fluids for crop protection products

Tested using the same criteria
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Permeation comparison: MX-EV 1000 vs. MX 1000

- Water vapour

**WVTR (g/IBC day) @RT**

<table>
<thead>
<tr>
<th>Water vapour transmission rate (WVTR)</th>
<th>MX-EV 1000 (6-layer technology)</th>
<th>MX 1000 (without barrier)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>0.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

WVTR: water vapour transmission rate

**MX-EV 1000**

Water barrier: comparable to the barrier of MX 1000
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Permeation comparison: MX-EV 1000 vs. MX 1000

- **Gases**

<table>
<thead>
<tr>
<th>Gases</th>
<th>GTR (ccm/IBC day) @RT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>O₂</strong></td>
<td>0.19</td>
</tr>
<tr>
<td><strong>CO₂</strong></td>
<td>0.74</td>
</tr>
<tr>
<td><strong>N₂</strong></td>
<td>0.15</td>
</tr>
</tbody>
</table>

- **MX-EV 1000** (6-layer technology)

- **MX 1000** (without barrier)

- Oxygen barrier: + 150 times
- CO₂ barrier: + 200 times
- Nitrogen barrier: + 160 times

GTR: gas transmission rate
Basics on permeation and EVOH

Permeation comparison: MX-EV 1000 vs. MX 1000

- Solvent

### Toluene

<table>
<thead>
<tr>
<th>Solvent</th>
<th>TR (g/IBC day) @RT</th>
</tr>
</thead>
<tbody>
<tr>
<td>MX-EV 1000 (6-layer technology)</td>
<td>4*</td>
</tr>
<tr>
<td>MX 1000 (without barrier)</td>
<td>102*</td>
</tr>
</tbody>
</table>

* Computed values for a IBC including a screw cap DN150 and outlet valve DN50

TR: transmission rate
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Permeation comparison

- Permeation of benzene, toluene, and xylene starting from a mixture of these solvents*

*Test performed with 1l bottles