21st Century EVOH recycling study
2013 Recycling study

In cooperation with Nextek, [www.nextek.org](http://www.nextek.org)

- Nextek is a recognised consulting organisation in the field of recycling

- PP/EVOH/PP and HDPE/EVOH/HDPE recycling study on multilayer sheet and bottles was conducted

- First, Focus on PCR-PP* processing and thermoforming using up-to-date recycle stream

  - Description of the Process
  - Performance
  - Analysis
  - Summary

- Next, Multilayer HDPE/EVOH Packaging influence in Processing and Performance of Recycled HDPE for blow moulded articles was studied

  * PCR = Post-Consumer Recycled
Industrial Scrap

Analysis of multilayer PP/EVOH/PP sheet with 4 to 6% EVOH

<table>
<thead>
<tr>
<th>Structure</th>
<th>(out) PP</th>
<th>Regrind</th>
<th>Adhesive</th>
<th>EVOH</th>
<th>Adhesive</th>
<th>Regrind</th>
<th>PP</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (µm)</td>
<td>287</td>
<td>326</td>
<td>36</td>
<td>82.8</td>
<td>33</td>
<td>442</td>
<td>282</td>
<td>1489</td>
</tr>
<tr>
<td>Thickness (µm)</td>
<td>168</td>
<td>930</td>
<td>33</td>
<td>107.6</td>
<td>33</td>
<td>985</td>
<td>166</td>
<td>2423</td>
</tr>
<tr>
<td>Thickness (µm)</td>
<td>491</td>
<td>668</td>
<td>47</td>
<td>125.0</td>
<td>44</td>
<td>717</td>
<td>419</td>
<td>2511</td>
</tr>
</tbody>
</table>
Collection and Sorting

Thanks to the cooperation of Systech Company

- [www.gruener-punkt.de](http://www.gruener-punkt.de)
- [www.systech-plastics.de](http://www.systech-plastics.de)

**Observation:**

In the region of Germany studied, about **2% of plastic waste** is barrier packaging.

In these 2% barrier packaging:

- 90% is for meat packaging
- The remaining 10% is pâté, ready meals, cheese and fish salad
Collection and Sorting

Market Applications and Percentage of EVOH in Recycling Streams:

- An assessment was made by Nextek based on available market data and material audits to establish a typical and maximum percentage of HDPE barrier packaging in the market.
- Manual sorting bale audit at Viridor Arundel in the UK
Sorting post-consumer waste

Different forms of PP/EVOH waste
Compounding and Decontamination

PCR-PP and 90%PCR-PP + 10% industrial scrap (PCR-pp, evoh)

- PCR-PP was compounded and pelletised on a multi-screw extruder at 260°C and then decontaminated for 6 hours 145°C vacuum in batch reactor.
- Dry blend of 90%PCR-PP + 10% industrial scrap was then compounded on a twin screw extruder for about 3 minutes at 240°C.
- PCR-pp, evoh blend was then decontaminated for 6 Hours at 130 - 140°C using vacuum batch reactor.
- Melt index of the PCR-pp, evoh material suitable for sheet extrusion and thermoforming.

Controlled time / temp / pressure is used during melt and solid phase to provide complete decontamination of PCR-PP and highest quality.

EVAL™
Coextrusion and Thermoforming

EVAL Europe Technical Centre in Antwerp
## PCR-PP, EVOH/EVOH Thermoforming Samples

### Multilayer Sheet PCR-pp, evoh(25)/PP and PCR-pp, evoh(25)/EVOH/PP

<table>
<thead>
<tr>
<th>Structure</th>
<th>Virgin PP</th>
<th>Adhesive</th>
<th>25% PCR-PP/EVOH (white)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (µm)</td>
<td>222</td>
<td>86</td>
<td>479</td>
<td>787</td>
</tr>
</tbody>
</table>

![Magnification 100x](image1)

![Magnification 100x](image2)

<table>
<thead>
<tr>
<th>Structure</th>
<th>Virgin PP</th>
<th>Adhesive</th>
<th>EVOH</th>
<th>Adhesive</th>
<th>25% PCR-PP/EVOH (white)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (µm)</td>
<td>208</td>
<td>37</td>
<td>30.4</td>
<td>29</td>
<td>490</td>
<td>794</td>
</tr>
</tbody>
</table>

![Magnification 100x](image3)

![Magnification 100x](image4)
PCR-PP, EVOH thermoforming samples

0.5/1 and 1/1 samples were produced with monolayer sheet

- Nice trays could be produced without issue
## The Bottles

### Co-EBM HDPE/EVOH

<table>
<thead>
<tr>
<th>trial</th>
<th>Layer 1 (outer)</th>
<th>Layer 2</th>
<th>Layer 3</th>
<th>Layer 4</th>
<th>Layer 5</th>
<th>Layer 6 (inner)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AR</td>
<td>AR</td>
<td>AR</td>
<td>AR</td>
<td>AR</td>
<td>AR</td>
</tr>
<tr>
<td>2</td>
<td>BR</td>
<td>BR</td>
<td>BR</td>
<td>BR</td>
<td>BR</td>
<td>BR</td>
</tr>
<tr>
<td>3</td>
<td>Virgin HDPE</td>
<td>Virgin HDPE</td>
<td>BR</td>
<td>BR</td>
<td>Virgin HDPE</td>
<td>Virgin HDPE</td>
</tr>
<tr>
<td>4</td>
<td>Virgin HDPE</td>
<td>Virgin HDPE</td>
<td>AR</td>
<td>AR</td>
<td>Virgin HDPE</td>
<td>Virgin HDPE</td>
</tr>
<tr>
<td>5</td>
<td>AR</td>
<td>AR</td>
<td>Tie</td>
<td>EVOH F101B</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>6</td>
<td>BR</td>
<td>BR</td>
<td>Tie</td>
<td>EVOH F101B</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>7</td>
<td>Virgin HDPE</td>
<td>Virgin HDPE</td>
<td>Tie</td>
<td>EVOH F101B</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>8</td>
<td>Virgin HDPE</td>
<td>BR</td>
<td>Tie</td>
<td>EVOH F101B</td>
<td>---</td>
<td>Virgin HDPE</td>
</tr>
<tr>
<td>9</td>
<td>Virgin HDPE</td>
<td>AR</td>
<td>Tie</td>
<td>EVOH F101B</td>
<td>---</td>
<td>Virgin HDPE</td>
</tr>
</tbody>
</table>

AR = Recycled HDPE + ± 0.25% EVOH  
BR = Virgin HDPE + ± 0.25%EVOH
Performance of the samples (I)

Overall Migration tests conducted at SMITHERS PIRA

- Overall migration, by filling, into simulants iso-octane; exposure conditions 24 hours at 40ºC as detailed in EU Regulation No 10/2011.

The samples are all OK for packaging food according to EU regulation 10/2011,

EVOH provides efficient way to reduce Overall migration as functional barrier

<table>
<thead>
<tr>
<th>PCR-pp,evo(100) monolayer</th>
<th>PCR-pp,evo(25)/PP</th>
<th>PCR-pp,evo(25)/EVOH/PP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Method</strong></td>
<td><strong>EN 1186-14</strong></td>
<td><strong>EN 1186-15</strong></td>
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<tr>
<td><strong>Replicates</strong></td>
<td><strong>Migration into</strong></td>
<td><strong>Migration into</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Iso-octane</strong></td>
<td><strong>Iso-octane</strong></td>
</tr>
<tr>
<td></td>
<td><strong>mg/dm²</strong></td>
<td><strong>mg/dm²</strong></td>
</tr>
<tr>
<td>1</td>
<td>42.4</td>
<td>8.8</td>
</tr>
<tr>
<td>2</td>
<td>40.1</td>
<td>10.9</td>
</tr>
<tr>
<td>3</td>
<td>42.9</td>
<td>9.9</td>
</tr>
<tr>
<td>Mean result</td>
<td>41.8</td>
<td>9.9</td>
</tr>
<tr>
<td>Limit</td>
<td>#40.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Tolerance</td>
<td>#1.2</td>
<td></td>
</tr>
<tr>
<td><strong>Replicates</strong></td>
<td><strong>(rapid extraction)</strong></td>
<td><strong>(rapid extraction)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>mg/dm²</strong></td>
<td><strong>mg/dm²</strong></td>
</tr>
<tr>
<td>1</td>
<td>8.8</td>
<td>4.8</td>
</tr>
<tr>
<td>2</td>
<td>10.9</td>
<td>4.9</td>
</tr>
<tr>
<td>3</td>
<td>9.9</td>
<td>6.5</td>
</tr>
<tr>
<td>4</td>
<td>10.1</td>
<td>3.9</td>
</tr>
<tr>
<td>Mean result</td>
<td>9.9</td>
<td>5.0</td>
</tr>
<tr>
<td>Limit</td>
<td>10.0</td>
<td></td>
</tr>
</tbody>
</table>

The samples are all OK for packaging food according to EU regulation 10/2011,
Performance of the samples (II)

Mechanical properties of PCR-PP, EVOH with PCR-PP

- Notched Izod Impact strength of Injection moulded PCR-PP, EVOH (25) and PCR-PP pieces were determined; No difference observed (8 KJ/m²)

- Tensile test on 15mm wide strips cut out from the sheet (MD) was conducted. E-Modulus, Strain at Break and Maximum stress were determined.

- No difference with various loading PCR-pp, evoh in monolayer.

![Mechanical parameters graph](image-url)
Summary Recycling Study

EVOH impact on the Performance of Recycled PP and HDPE

- The use of **EVOH** in *multi-layer barrier packaging* for long-time food preservation does not affect the recycling possibilities or opportunities.

- It has now been demonstrated that:
  - **EVOH does not affect the recycling stream of PP and HDPE** (polypropylene).
  - It brings **new opportunities to recycle PCR-PP (or HDPE)** even in the food packaging applications.

- Indeed, the use of **EVOH as functional barrier** certainly opens new doors to the plastic industry.

- Recycling codes used to identify the material from which an item is made, to facilitate easier recycling or other reprocessing:
  - #5 PP is applicable to PP/EVOH.
  - #2 HDPE is applicable to HDPE/EVOH.

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**EVAL™**

**Kuraray**
Plantic™ Organic Recovery
PLANTIC™

✓ PLANTIC™ is a fully biodegradable renewable sheet suitable for thermoforming applications (e.g. for packing foods and goods with water activity of 35% to 70%).
PLANTIC™

PLANTIC™ CF  (PLANTIC™ + BioPBS)

Compost Certifications

Vincotte Certifications:

- PLANTIC™ mono layer

- BioPBS™
Conclusion

Kuraray, with its global presence, supports the circular economy with an advanced product portfolio:

- EVAL™ EVOH resins and monolayer film, ready to be produced from renewable resources and which allows the production of multilayer structures fully recyclable with no impact on polyolefin recycling streams, independently from the converting technologies
  → Recycling Stream value chain

- PLANTIC™ CF films, Bio-sourced, Bio-Plastic, Bio-degradable and barrier film for advanced packaging solutions
  → Organic Waste value chain

- Even more performant materials enabling downgauging, keeping efficiency for use, are being developed.

  EVAL™ and PLANTIC™ for now and the future
Thank You

Special thanks to our partner Nextek (Edward Kosior, Kelvin Davies and Jonathan Mitchell) and to our EVAL Technical Centre colleagues in Antwerp

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</thead>
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