Development of a leaching test to estimate emissions from synthetic sports grounds into soil and ground water under weathering exposure

Volker Wachtendorf, Ute Kalbe, Oliver Krüger, Wolfgang Berger, Anja Geburtig
BAM Federal Institute for Materials Research and Testing, Berlin, Germany
Outline

1. Introduction
2. Experimental
3. Results
4. Conclusions
1. Introduction
2. Experimental
3. Results
4. Conclusions
Introduction

Limits to Service Life

• usually:
  • degradation in essential property:
    • mechanical stability (cracks, delamination)
    • surface erosion (gloss loss)
    • optical properties (transparency, discoloration)
  ► “failure” limits use

• here:
  • emissions of environmental relevance into soil and groundwater due to degradation of polymeric matrix
  ► regulations stop further use.
Introduction

Project

- **Funding:**
  - German Federal Institute for Sports Science (BISp)

- **Participants**
  - BAM, Berlin, Germany: weathering, leaching tests, analysis
  - ECT GmbH, Flörsheim, Germany: eco toxicological effects

- **Term:**
  - 2 years, 2010 - 2011

- **Goal:**
  - reproducible lab test for quantifying release of substances from sports grounds into soil and ground water
1. Introduction

2. Experimental

3. Results

4. Conclusions
Experimental

Materials

1) Running Tracks

---

Elastomeric track
Bound sub-layer
Unbound sub-layer
Materials

1) Running Tracks

- B1: recycled SBR + thin layer of spray coated new EPDM (+PUR binder)
- B2: recycled SBR + (thicker) granulate layer of new EPDM (+PUR binder)
- B3: new EPDM (+PUR binder).
Materials

2) Artificial Turf

- Elastomeric infill (recl. SBR, EPDM, partly PUR coated)
- Quartz sand infill
- Artificial turf (PE, PP)
- Bound sub-layer (SBR+PUR)
- Unbound sub-layer (gravel)

- elasticity
- keep grass upright
Materials

2) Artificial Turf

• Single components
  • turf R2, R3, R4 : PE
  • elastomeric infill:
    • SBR 5 (recycled SBR),
    • SBR 8 (recycled SBR + green PUR coating)
• Complete systems
  • R2 + sand + SBR 5.
### Materials

#### Typical Components of SBR Elastomers:

<table>
<thead>
<tr>
<th>Component</th>
<th>In-organ.</th>
<th>Organic</th>
<th>PAH</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Styrene Butadiene Rubber</td>
<td>X</td>
<td>X</td>
<td></td>
<td>matrix</td>
</tr>
<tr>
<td>ZnO</td>
<td></td>
<td>X</td>
<td></td>
<td>activator</td>
</tr>
<tr>
<td>Stearic acid</td>
<td></td>
<td></td>
<td></td>
<td>activator</td>
</tr>
<tr>
<td>Thiazoles</td>
<td></td>
<td>X</td>
<td>X</td>
<td>accelerators</td>
</tr>
<tr>
<td>Stabilizer</td>
<td></td>
<td>X</td>
<td>X</td>
<td>stabilizes against heat, oxygen, ozone</td>
</tr>
</tbody>
</table>
Artificial Weathering

Weiss company, Global UV-Test 200 (according ISO 4892-3; UVA 340 fluorescence lamps)

- only UV, no VIS, no IR
- no radiation heating of sample: $T_{chambre} = T_{sample}$
- high humidity on sample surface possible

Running Tracks
Vertical orientation

Artificial Turf
Horizontal orientation
Artificial Weathering: Running Tracks

- Vertical sample orientation
- UV-A 340 nm fluorescence lamps (45 W/m² UV)
- Duration: 4200 h (UV equals ≈ 3 years Europe)
- Temperature, controlled humidity, rain
- Every ≈1000 h ozone treatment (externally)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4 h</td>
<td>70 °C</td>
<td>&lt;10 %RH</td>
</tr>
<tr>
<td>4 h</td>
<td>25 °C</td>
<td>rain</td>
</tr>
<tr>
<td>4 h</td>
<td>70 °C</td>
<td>&lt;10 %RH</td>
</tr>
<tr>
<td>4 h</td>
<td>25 °C</td>
<td>rain</td>
</tr>
<tr>
<td>4 h</td>
<td>-15 °C</td>
<td>uncontrolled</td>
</tr>
<tr>
<td>4 h</td>
<td>25 °C</td>
<td>rain</td>
</tr>
</tbody>
</table>

Leaching tests on solid samples
Analysis of recycled rain water
Artificial Weathering: Running Tracks

Experimental

B1 SBR/EPDM

B2 SBR/EPDM

B3 EPDM

0 h 1100 h 2300 h 4200 h weathering

7 d Ozone 14 d Ozone 21 d Ozone 28 d Ozone

Rain water reservoir: recycling of water as long as < 10 µS / cm
Artificial Weathering: Running Tracks

<table>
<thead>
<tr>
<th>B1</th>
<th>SBR/EPDM</th>
<th>0 h</th>
<th>1100 h</th>
<th>2300 h</th>
<th>4200 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>B2</td>
<td>SBR/EPDM</td>
<td>7 d</td>
<td>14 d</td>
<td>21 d</td>
<td>28 d</td>
</tr>
<tr>
<td>B3</td>
<td>EPDM</td>
<td>Ozone</td>
<td>Ozone</td>
<td>Ozone</td>
<td>Ozone</td>
</tr>
</tbody>
</table>

Ozone conc. 0.5 ppm
Temperature 30°C
Humidity 90 %RH
Duration 7 d
Experimental

**Artificial Weathering: Artificial Turf**

- Horizontal sample orientation
- UV-A 340 nm fluorescence lamps, $E_{UV} = 20\ W/m^2$
- Duration: 2700 h (UV equals ≈ 1 year C. Europe)
- Temperature, controlled humidity, rain
- Long contact time granulate / turf with water
- Every 1000 h ozone treatment

<table>
<thead>
<tr>
<th>Dur.</th>
<th>Temp.</th>
<th>Relative Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 h</td>
<td>70 °C</td>
<td>&lt;10 %RH</td>
</tr>
<tr>
<td>15 s</td>
<td>25 °C</td>
<td>rain</td>
</tr>
<tr>
<td>4 h</td>
<td>35 °C</td>
<td>70 %RH</td>
</tr>
<tr>
<td>4 h</td>
<td>70 °C</td>
<td>&lt;10 %RH</td>
</tr>
<tr>
<td>15 s</td>
<td>25 °C</td>
<td>rain</td>
</tr>
<tr>
<td>4 h</td>
<td>35 °C</td>
<td>70 %RH</td>
</tr>
<tr>
<td>4 h</td>
<td>-10 °C</td>
<td>uncontrolled.</td>
</tr>
</tbody>
</table>

samples for diff. stages weathered in parallel

Leaching test on solid samples

Analysis of recycled rain water
Experimental

Artificial Weathering: Artificial Turf

R3

R4

SBR 8 (coated)

R2

SBR 5

R2 + sand + SBR 5

0 h 7d

1000 h 2 x 7d

2000 h 3 x 7d

3000 h 4 x 7d

Weathering Exposure Ozone

100 cm
Artificial Weathering: Artificial Turf: Ozone Test

- Ozone conc: 0.5 ppm
- Temperature: 30 °C
- Humidity: 90 %RH
- Duration: 7 days

<table>
<thead>
<tr>
<th>Time (h)</th>
<th>Ozone Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 h</td>
<td>0 h</td>
</tr>
<tr>
<td>1000 h</td>
<td>14 d ozone</td>
</tr>
<tr>
<td>2000 h</td>
<td>21 d ozone</td>
</tr>
<tr>
<td>2700 h</td>
<td>28 d ozone</td>
</tr>
<tr>
<td>7 d ozone</td>
<td>14 d ozone</td>
</tr>
</tbody>
</table>
Experimental

Leaching Tests

Newly introduced column test carried out in comparison to other established leaching tests like batch tests

• **Batch test:**
  - not realistic, worst case scenarios
  - only for single components

• **Column test:**
  - realistic simulation of the actual percolation process
  - allows to test entire systems
Leaching Behaviour: Column Test

Elution continued until water / solid ratio = 4 l / kg
Analysis of Eluates

- those with special significance
  - Inorganic Ions: Zn + others: by ICP-OES, GF-AAS
  - Total Organic Carbon (TOC): IR detection
  - Polycyclic Aromatic Hydrocarbons (PAH): HPLC-FLD

- additional analyses
  - Total Nitrogen (TN)
  - Elements: by ICP-OES
  - Physical parameters: pH, conductivity, turbidity
  - ...
1. Introduction
2. Experimental
3. Results
4. Conclusions
Results

Artificial Weathering: Running Tracks

B1

Magnification 20x

0h Weathering  4200 h Weathering

B2

Magnification 20x

0h Weathering  4200 h Weathering

8 mm
Artificial Weathering: Running Tracks

Results

- Very high initial conductivity (ion conc.)
- Decrease with exposure duration
- Peaks after ozone tests

Recycled rain water B1 + B2 + B3

Conductivity, mass normalized

Weathering Duration / h

- after 7 d ozone #1
- after 7 d ozone #2
- after 7 d ozone #3
Results

Artificial Weathering: Running Tracks

- Monotone increase with exposure duration
- Slight quantitative difference between different systems
- Bleaching of dyes, yellowing/ageing of elastomeric matrix
Artificial Weathering: Running Tracks

- Increase with exposure duration until 1100 h (B2: 0h)
- Decrease below starting value
- Increase from 2300 h onwards

- 2 diff. ageing processes (saturated, unsaturated bonds)?
Artificial Weathering: Running Tracks

- Low absolute values (solubility)
- Decrease with exposure duration until 1100 h
- Increase from 2300 h onwards
- Ageing of elastomeric matrix > 2300 h accesses new release sites
Results

Artificial Weathering: Running Tracks

- Initial increase after first ozone test
- Decrease with exposure duration until 1100 h
- Increase from 2300 h onwards

Ageing of elastomeric matrix > 2300 h accesses new release sites
Artificial Weathering: Artificial Turf

- Very high initial conductivity (ion conc.)
- Decrease with exposure duration
- Peaks after ozone tests (except 1000 h)

Sum of all components turfs + granulates
Artificial Weathering: Artificial Turf

Results

Artificial Weathering: Artificial Turf

0 h

2700 h

starting fraying
Artificial Weathering: Artificial Turf

SBR 5

- Added cracking after 4200 h

SBR 8

- No changes after 4200 h
Artificial Weathering: Artificial Turf

SBR 5

0 h

4200 h

1 mm
Artificial Weathering: Artificial Turf

- Initial value very low
- Increase up to maximum at 2000 h (lower for coated SBR, SBR in turf)
- Sharp decrease afterwards
- Reflects ageing of elastomeric matrix
**Artificial Weathering: Artificial Turf**

- Initial value very low
- Increase up to maximum at 2000 h
- Sharp decrease afterwards (lower for coated SBR)

► Reflects ageing of elastomeric matrix
Results

Artificial Weathering: Artificial Turf

• Initial value very high for uncoated, low for coated SBR
• Decrease with increasing exposure duration
► Reflects ageing of elastomeric matrix
1. Introduction

2. Experimental

3. Results

4. Conclusions
Conclusions

• Contribution to leaching: rubber >> polyolefins

• Complex leaching behaviour as function of weathering time:
  • each component shows specific ageing behaviour
  • each leached species shows different ageing behaviour
  • each component has different leaching behaviour
  • observed behaviour of sample is sum behaviour of components

• Time/ageing scale of leaching per component
  • unbound material on surface is dissolved
  • recycled/aged material releases in further ageing process more and more blended additives and fillers from newly ageing exposed material

• ozone:
  • unsaturated C=C bonds → ozonolysis
  • saturated C-C bonds → oxidation
Conclusions

Schematics of Ageing Behaviour of Leaching

- UV + oxygen + ozone

0 \hspace{1cm} 1 \hspace{1cm} 2 \hspace{1cm} 3

Exposure Duration

Elastomere
ZnO
PAH

Volker Wachtendorf (BAM)          Service Life Prediction - Vision for the Future, Monterey, CA            3-8 March, 2013
Thanks !