Leaching characteristic evaluation methodology from soil and waste

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Safety in Technology and Chemistry
Key areas of BAM

Tasks:
Research and Development,
Testing,
Analysis and approval,
Consultation and information

Topics:
- Assessment of soil and groundwater contamination
- Plastics in geotechnical and geoenvironmental engineering
- Waste treatment and recycling processes
Ingredients of solids are released into an aqueous phase

Controlling factors on amount and mechanism of release of substances
- Chemical: pH, redox potential, dissolved organic carbon (DOC)
- Physical: particle size, porosity, pore form, hydraulic conductivity, temperature
- Internal physico-chemical reactions
- Release mechanism: wash-off, dissolution, diffusion
- Field scenario: release kinetic (local equilibrium), Liquid-to-solid ratio (L/S), impact on solid matrix by weathering, erosion, cracking, biological activities
**Leaching**

**Why do we need leaching tests?**

- Information on potential release of contaminants into environment
  - simulation of field conditions
  - test of environmental compatibility of materials in laboratory scale
- Total content – no simple correlation to leaching!

European Hazardous Waste Directive is currently still based on total content for classification of waste

- Materials as residues from thermal processes, where the critical elements are not mobile due to binding in the silicate matrix, may be excluded for beneficial use → consumption of more raw materials

**Classification should be based on actual availability of substances to the environment!**
Leaching

Different impact scenarios to soil and groundwater

- Contaminated sites
- Landfills
- Agriculture
- Reuse of recycling materials (e.g. in road construction)
- Runoff from constructions
- Industrial activities
- ...

Source term determination by laboratory tests

- basis for modelling of contaminant transfer (seepage water prognosis)
- assessment of environmental impact in regulatory context
Application of leaching tests

- **Types of leaching tests:**
  - Compliance testing – comparison with legal threshold values
  - Basic characterization – generic behavior of materials

- **What types of materials are investigated?**
  - Assessment of environmental impact of contaminated sites
  - Characterization of waste / recycling materials intended for reuse (alternative construction products)
  - Assessment of environmental compatibility of construction products
  - Hazardous materials to be landfilled (compliance with acceptance criteria for disposal, prediction of long-term behaviour within landfills)
Application of leaching tests - framework

Assessment of impact to groundwater

Application of leaching tests

Soil

Construction products

Waste

Source term
Seapage water prognosis

Certification
Approvals

Re-Use/Recycling

Landfilling

Classification

Relevant regulations in Germany/Europe

Federal Ordinance on
Soil Protection

DIN 19527/29 (Batch)
DIN 19528 (Column)

ISO TS 21268-1,2 (Batch)
ISO TS 21268-3 (Column)

European CPD

CEN TC 351 WG1
Drafts for harmonized procedures:
CEN TS 16637-1 (Guideline)
CEN TS 16637-2 (Tank test)
CEN TS 16637-3 (Column)

DIN 19528 (Column)

European
Landfill Directive

CEN TC 292 WG2/6
EN 12457-2 (Batch)
prEN 14405 (Column)

DIN 19528 (Column)
Available leaching test procedures

**Batch tests**
“snapshot” at a certain L/S ratio

DIN 19527 and DIN 19529
EN 12457-series
ISO 21268-1,2

**Tank tests**
monolithic materials
and coarse granular materials,
L/S or L/A ratio

**Column percolation tests (up-flow)**
saturated conditions,
time dependent leaching behavior (collection of several fractions at increasing L/S ratios)

DIN 19528
CEN TS 14405
ISO 21268-3

**Lysimeter tests**
larger scale,
unsaturated conditions,
closer to field conditions
not standardized
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size</td>
<td>&lt; 4 mm</td>
<td>&lt; 4 mm</td>
<td>&lt; 32 mm</td>
<td>&lt; 32 mm</td>
</tr>
<tr>
<td>Scope</td>
<td>Soil, soil related materials</td>
<td>Soil, soil related materials</td>
<td>Soil, soil related materials, waste</td>
<td>Soil, soil related materials, waste</td>
</tr>
<tr>
<td>Substances</td>
<td>Inorganics and non-volatile organics</td>
<td>Inorganics and non-volatile organics</td>
<td>Non-volatile organics</td>
<td>Inorganics</td>
</tr>
<tr>
<td>Leachant</td>
<td>Demineralised water or 0,001 mol/l CaCl₂</td>
<td>Demineralised water or 0,001 mol/l CaCl₂</td>
<td>Demineralised water</td>
<td>Demineralised water</td>
</tr>
<tr>
<td>L/S (l/kg)</td>
<td>2 ± 0.04</td>
<td>10 ± 0.2</td>
<td>2 ± 0.05</td>
<td>2 ± 0.05</td>
</tr>
<tr>
<td>Agitation</td>
<td>24 ± 0.5 hours, End over end rotation, 5 - 10 rpm or roller table 10 rpm</td>
<td>24 ± 0.5 hours, End over end rotation, 5 - 10 rpm or roller table 10 rpm</td>
<td>24 ± 0.5 hours, End over end rotation, 5 - 10 rpm,</td>
<td>24 ± 0.5 hours, End over end rotation, 5 - 10 rpm,</td>
</tr>
<tr>
<td>Temperature</td>
<td>20 ± 5 °C</td>
<td>20 ± 2 °C</td>
<td>20 ± 2 °C</td>
<td>20 ± 2 °C</td>
</tr>
<tr>
<td>Liquid/solid separation</td>
<td>Settling 15 ± 5 min, centrifugation at 2000-3000 g for 20 min using glass bottles (screw cap, teflon inlay), vacuum or pressure filtration (centrifugation at 10000-20000 g may be applied</td>
<td>Settling 15 ± 5 min, centrifugation at 2000-3000 g for 20 min using glass bottles (screw cap, teflon inlay), vacuum or pressure filtration (centrifugation at 10000-20000 g may be applied</td>
<td>Settling 15 min, centrifugation to turbidity &lt; 20 FNU at 20000 g for 30 min using appropriate bottles (less intensity at longer duration possible e.g. 2000 g and 300 min), vacuum or pressure filtration</td>
<td>Settling 15 min, centrifugation at 2000-3000 g for 30 subsequent vacuum or pressure filtration</td>
</tr>
<tr>
<td>Filter</td>
<td>Membrane filter 0.45 μm</td>
<td>Membrane filter 0.45 μm</td>
<td>Glasfibre filter without binder ≤ 0.7 μm</td>
<td>Membrane filter 0.45 μm</td>
</tr>
</tbody>
</table>
Available leaching test procedures – Column tests

<table>
<thead>
<tr>
<th>Test name</th>
<th>DIN 19528 (01/2009)</th>
<th>ISO 21268-3 (07/2007)</th>
<th>prEN 14405 (03/2015)</th>
<th>CEN TS 16637-3 (draft 02/2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>Soil, soil related materials, waste</td>
<td>Soil, soil related materials</td>
<td>Waste</td>
<td>Construction products</td>
</tr>
<tr>
<td>Substances</td>
<td>Inorganics/non-volatile organics</td>
<td>Inorganics/non-volatile organics</td>
<td>Inorganics</td>
<td>Inorganics and non-volatile organics</td>
</tr>
<tr>
<td>Particle size</td>
<td>≤ 32 mm (&gt; 32 mm crushing)</td>
<td>95 % ≤ 4 mm</td>
<td>&lt; 4 mm (maximum of 5 % &lt; 10 mm)</td>
<td>≤ 22.4 mm, ≥ 45 % &lt; 4 mm</td>
</tr>
<tr>
<td>Col. diameter/height</td>
<td>5-10 cm (at least 2 x max. particle size)/at least 4 x diameter</td>
<td>5 and 10 cm/30±5 cm</td>
<td>5 and 10 cm/30±5 cm</td>
<td>at least 5 cm (3 x max. particle size)/30±5 cm</td>
</tr>
<tr>
<td>Leachant</td>
<td>Demineralised water</td>
<td>Demineralised water or 0.001 mol/l CaCl₂</td>
<td>Demineralised water</td>
<td>Demineralised water</td>
</tr>
<tr>
<td>Temperature</td>
<td>20 ± 2 °C</td>
<td>20 ± 5 °C</td>
<td>19-25 °C</td>
<td>19-25 °C</td>
</tr>
<tr>
<td>Pre-equilibration</td>
<td>Saturation 2h, direct start</td>
<td>at least two days</td>
<td>recirculation allowed, 72 h</td>
<td>4 to 6 h</td>
</tr>
<tr>
<td>L/S (l/kg)</td>
<td>basic characterization: 0.3±0.05, 1±0.2, 2±0.4, 4 ± 0.8 compliance test: cum. 2± 0.05</td>
<td>0.1±0.02, 0.2±0.04, 0.5±0.08, 1±0.15, 2±0.3, 5±0.4, 10±0.1</td>
<td>m</td>
<td>0.1, 0.2, 0.5, 1, 2, 5, 10± 0.5, modification for specific scenarios possible</td>
</tr>
<tr>
<td>Flow rate</td>
<td>calculation of flow rate based on bulk density and fixed contact time</td>
<td>flow velocity 15 cm/d 5 cm column: 0.2 ml/min 10 cm column: 0.8 ml/min</td>
<td>Flow velocity 15 cm/d 5 cm column: 0.4 ml/min 10 cm column: 1.6 ml/min</td>
<td>empty bed flow velocity 30 ± 4 cm/d</td>
</tr>
<tr>
<td>Contact time</td>
<td>5 h</td>
<td>variable</td>
<td>variable</td>
<td>variable</td>
</tr>
<tr>
<td>Liquid/solid separation</td>
<td>Organics: no filtration, Centrifugation for turbidity ≥100 FNU Inorganics: 0.45 µm filtration if needed</td>
<td>Organics and inorganics: centrifugation 30 min at 20000-30000g or 5h at 2000-2500g Inorganics: Filtration 0.45 µm</td>
<td>Filtration 0.45 µm</td>
<td>Organics: centrifugation for turbidity ≥100 FNU (30 min at 20000-30000g or 5h at 2000-2500g) Inorganics: 0.45 µm filtration</td>
</tr>
</tbody>
</table>
**Available leaching test procedures – Tank tests**

**Principle**
- Monolithic samples
- Different leachant renewal schemes
- Leachant: demineralized water, L/A 8 ml/cm²
- Result: flux or release as a function of time

**Tank tests with periodic leachant renewal**
- prEN15863 (waste)
- CEN TS 16637-2 (construction products)

**Tank tests with continuous leachant renewal**
- prEN15863 (waste)

Tank test of complete solar panels at BAM
Standardization of procedures – CEN specific

EC – Mandates for harmonization of procedures on European level
   ▶ removal of technical obstacles to trade e.g. in construction products

Specific requirements of European standards (EN)
   ▶ Member states have to adopt full EN standards
   ▶ Member states are not allowed to elaborate own standards during preparation of an EN
   ▶ Member states must withdraw own standards with the same purpose and scope after release of an EN

European Regulations
   ▶ if there are currently no European regulations - member states are allowed to keep their own assessment approach and threshold values so far
Standardization of procedures – Course of actions

1. **New Work Item Proposal (NWIP)**
   - Elaboration of a draft - Technical specification
   - Collection of comments
   - Revision of the draft

2. **Robustness testing**
   - Demonstration of suitability of the procedure for its intended purpose
   - Determination of sensitivity to changes in test conditions
   - Revision of the draft

3. **Validation**
   - Determination of accuracy and precision of the specified procedure (performance characteristics)
   - Organization and evaluation of interlaboratory comparisons (ring tests)
   - Final draft and final vote

4. **Confirmation of the procedure as fully validated standard**
   - Precondition to be citable in regulations
Example: Batch test and column test for organic substances

Problem:

- analysis of eluates for organic substances need more elaboration
- crucial step for batch test: liquid/solid separation after agitation
Robustness study – Example DIN 19527

Current stipulations in German leaching procedures:

Batch tests (DIN 19527, L/S 2 l/kg)

- Agitation using end-over-end tumbler: 24 h at 5-10 rpm
- Sedimentation of suspended solids for 15 min, decantation, centrifugation at 20000 g for 30 min (min. 2000 g for 300 min) followed by filtration using 0.7 µm glass fiber filter → turbidity < 20 FNU

No membrane filtration – sorption of organics on filter materials!

Variation of conditions:

- Agitation frequency: 3, 7, 15 rpm
- Agitation duration: 2, 5, 25 h at frequency of 7 rpm
- Centrifugation: 30 min and 20000 g for agitation frequency of 3, 7, 15 rpm
  72 min and 8000 g for agitation frequency of 7 rpm
  300 min and 2000 g for agitation frequency of 7 rpm

For comparison: Column tests (DIN 19528)

- Eluates can mostly be measured without pre-treatment
- Turbidity > 100 FNU → centrifugation required (at least 2000 g)
**Robustness study – Example DIN 19527**

Test material processing: Uncontaminated reference soils with different characteristics

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Grain size distribution [% by weight]</th>
<th>C&lt;sub&gt;org&lt;/sub&gt; [%]</th>
<th>pH [-]</th>
<th>CEC&lt;sub&gt;eff&lt;/sub&gt; mmol/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>TL</td>
<td>Gravel: 21.6</td>
<td>Sand: 53.4</td>
<td>Silt: 25.0</td>
<td>Clay: 3.52</td>
</tr>
<tr>
<td>MS</td>
<td>Gravel: 7.68</td>
<td>Sand: 91.5</td>
<td>Silt: 0.79</td>
<td>Clay: 0.64</td>
</tr>
</tbody>
</table>

TL = clayey loam (top soil), MS = medium sand (small amount of CD waste)

Mixing with contaminated soils to the desired typical concentration levels

<table>
<thead>
<tr>
<th>Test material</th>
<th>PAH Σ&lt;sub&gt;15&lt;/sub&gt; [mg/kg]</th>
<th>TPH [mg/kg]</th>
<th>Phenols Σ&lt;sub&gt;6&lt;/sub&gt; [mg/kg]</th>
<th>PCB Σ&lt;sub&gt;6&lt;/sub&gt; [mg/kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C&lt;sub&gt;10&lt;/sub&gt;-C&lt;sub&gt;40&lt;/sub&gt;</td>
<td>C&lt;sub&gt;10&lt;/sub&gt;-C&lt;sub&gt;22&lt;/sub&gt;</td>
<td>C&lt;sub&gt;22&lt;/sub&gt;-C&lt;sub&gt;40&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>TL - PAH/PCB</td>
<td>7.43</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MS - PAH/PCB</td>
<td>8.77</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TL - Phenols/TPH/PAH</td>
<td>57.8</td>
<td>1999</td>
<td>540</td>
<td>1459</td>
</tr>
<tr>
<td>MS - Phenols/TPH/PAH</td>
<td>71.0</td>
<td>1928</td>
<td>522</td>
<td>1406</td>
</tr>
</tbody>
</table>

Sources of contaminated soils

- PAH railway sleeper impregnation site
- TPH military site
- PCB garden plot
- Phenols tar works site

Two further soil types were used for the robustness study: Leaching behaviour corresponds strongly to characteristics of the soil matrix – similar concentrations in solid matter but different concentration in the eluates.
Robustness study – Batch test - Agitation

Variation of duration and frequency of agitation, centrifugation at 20000g

- no distinct trend of influence of duration and frequency of agitation due influence of the soil matrix on the PAH elution
  (different PAH distribution patterns of the eluates in comparison to the solid matter)

### Influence of duration of agitation on PAH concentration

- TL
  - 24 h
  - 5 h
  - 2 h

- MS
  - 24 h
  - 5 h
  - 2 h

### Influence of duration of agitation on TPH concentration

- TL
  - 24 h
  - 5 h
  - 2 h

- MS
  - 24 h
  - 5 h
  - 2 h

### Influence of agitation frequency on PAH concentration

- TL
  - 3 r.p.m.
  - 7 r.p.m.
  - 15 r.p.m.

- MS
  - 3 r.p.m.
  - 7 r.p.m.
  - 15 r.p.m.
Robustness study – Batch test - Centrifugation

Variation of acceleration of centrifugation

Influence of centrifugation acceleration on PCB concentration

- TL-PCB
- MS-PCB

- 30 min x 20.000g
- 75 min x 8.000g
- 300 min x 2.000g

Influence of centrifugation acceleration on PCB concentration

- TL
- MS

- 30 min x 20.000g
- 75 min x 8.000g
- 300 min x 2.000g

Influence of centrifugation acceleration on PAH concentration

- TL
- MS

- 2000 g
- 8000 g
- 20000 g

- mostly higher concentration at lower centrifugation speed due to higher turbidity → at lower acceleration a higher duration of centrifugation has to be applied! (higher acceleration and shorter duration is preferred)
- higher turbidity of eluates - cannot be compensated by subsequent filtration!
- maximum duration has to be stipulated
Comparison of column and batch tests at L/S 2 l/kg

**Σ_{15} PAH**

- **Σ_{15} PAH**

**Σ_{6} phenols**

- **Σ_{6} phenols**

**Σ_{7} PCB**

- **Σ_{7} PCB**

**TPH**

- **TPH**
Comparison of column and batch tests (L/S 2 l/kg)

Validation - Performance characteristics (ISO 5725-2, software ProLab 2011, quo data)

<table>
<thead>
<tr>
<th></th>
<th>Reference Solution</th>
<th>Test material</th>
<th>Batch test DIN 19527</th>
<th>Column test DIN 19528</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X [µg/L]</td>
<td>CV_r [%]</td>
<td>CV_r [%]</td>
<td>X [µg/L]</td>
</tr>
<tr>
<td>PAH</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Σ_{15}</td>
<td>1.382</td>
<td>59.7</td>
<td>18.2</td>
<td>13.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>88.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>385.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>468.5</td>
</tr>
<tr>
<td>PCB</td>
<td>1.158</td>
<td>16.3</td>
<td>5.4</td>
<td>0.460</td>
</tr>
<tr>
<td>Σ_{7}</td>
<td></td>
<td></td>
<td></td>
<td>1.569</td>
</tr>
<tr>
<td>Phenols</td>
<td>227.6</td>
<td>31.5</td>
<td>5.1</td>
<td>2055</td>
</tr>
<tr>
<td>Σ_{6}</td>
<td></td>
<td></td>
<td></td>
<td>5966</td>
</tr>
<tr>
<td>TPH</td>
<td>444.4</td>
<td>45.9</td>
<td>8.5</td>
<td>411.9</td>
</tr>
<tr>
<td>C_{10-22}</td>
<td></td>
<td></td>
<td></td>
<td>589.8</td>
</tr>
<tr>
<td>TPH</td>
<td>501.4</td>
<td>65.9</td>
<td>6.3</td>
<td>602.2</td>
</tr>
<tr>
<td>C_{10-40}</td>
<td></td>
<td></td>
<td></td>
<td>704.9</td>
</tr>
</tbody>
</table>

X = Mean value of all labs (set as reference value)
CV_r = Relative reproducibility standard deviation
CV_r = Relative repeatability standard deviation

Number of participating laboratories
PAH: 13–16, PCB: 12-14, phenols: 7, TPH: 10-13
Comparison of column and batch tests (L/S 2 l/kg)

<table>
<thead>
<tr>
<th>pH</th>
<th>Test material</th>
<th>Batch test DIN 19527</th>
<th>Column test DIN 19528</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>X [-]</td>
<td>CV_R [%]</td>
</tr>
<tr>
<td>pH</td>
<td>TL - PAH/PCB</td>
<td>7.61</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>MS-PAH/PCB</td>
<td>7.09</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>TL-phenols/TPH/PAH</td>
<td>8.09</td>
<td>4.3</td>
</tr>
<tr>
<td></td>
<td>MS-phenols/TPH/PAH</td>
<td>7.87</td>
<td>6.7</td>
</tr>
</tbody>
</table>

\[X = \text{Mean value of all labs (set as reference value)}\]

\[CV_R = \text{Relative reproducibility standard deviation}\]

\[CV_r = \text{Relative repeatability standard deviation}\]
Results of robustness study and validation

DIN 19527 (batch test) and DIN 1958 (column tests) for organic substances

- No systematic differences between both procedures
- Tests are applicable and provide reliable results for the investigation of organic substances using the stipulated conditions
  - good repeatability
  - good to acceptable reproducibility (partly poor – in particular at low concentration levels)
  - high measurement uncertainty has partly to be considered
- Potential for improvements:
  - analytical performance
  - eluate conservation to prevent biodegradation
  - ...

We know where we are in daily practice!
Example: Grain size of samples within column test CEN TS 16637-3

Problem: Test condition of the sample

- Grain size reduction < 4 mm
- Basic characterisation/Research
- Desired for subsequent geochemical speciation modelling „worst-case scenario“ (leaching test in combination with pH dependence test)

Testing in the condition of intended use
Compliance testing/Routine analysis

- Higher probability that finer particles ensure local equilibrium conditions during the test
- Crushing changes the surface area and may lead to a pH change → Influence on leaching behaviour
- e.g. for some materials such as residues of thermal processes: carbonation leads to increasing pH → less metal release but higher release of oxanions
Robustness study – Example CEN TS 16637-3

Tested condition:

- Influence of grain size distribution

Sulfate in crushed masonry at flow velocity of 15 cm/day
Tested condition:

- Influence of grain size distribution

Cr in crushed masonry at flow velocity of 15 cm/day
Tested condition:

- Influence of grain size distribution

V in crushed masonry at flow velocity of 15 cm/day
Setting parameters for leaching procedures

Example: Grain size of samples within column test CEN TS 16637-3

Decision: maximum grain size 22.4 mm and ≤ 45 % < 4mm

Request for larger columns – not agreed due to less practicability
(20 cm diameter/ 60 cm height)

- up to 3 month test duration
- long durations between sampling of fractions
  (biodegradation possible)
- high sample mass required, huge sample volumes to handle
  (i.e. steelworks slag 35 kg, leads to 350 l eluate up to L/S 10 l/kg)
Setting parameters for leaching procedures (3)

Example: Flow rate within column test CEN TS 16637-3

Problem: Higher probability that finer particles ensure local equilibrium conditions during the test?

Stop-flow tests at flow velocity of 15 cm/day and two grain size distributions, Test material: crushed masonry

Chloride

Chromium
Example: Flow rate within column test CEN TS 16637-3

Based on further tests on the influence on flow rate for several materials: no consistent conclusions could be drawn

Decision: Flow velocity was changed from 15 cm/day to 30 cm/day to make the test more practicable

For the specification of test parameters compromises have to be accepted!
Development of leaching procedures for synthetic turf systems containing scrap tire granules

- Advantages of synthetic turf systems of outdoor sports facilities in comparison to natural turf (resist more frequent use, independent to weather conditions, less maintenance, less risk of getting injured)

- Application of scrap tire granules (SBR) as turf infill and within elastic support layers or athletic running tracks or newly fabricated rubber granules as turf infill
  - Release of contaminants and transfer to soil and groundwater - mainly Zn and PAHs derived from vulcanization accelerators or softening agents
Leaching procedures for synthetic turf systems

Typical installation scheme of synthetic turf systems

- synthetic turf (filled/unfilled)
- elastic layer
- bound base layer (e.g. porous asphalt)
- unbound base layer (≥ 20 cm)
- foundation

Usage of scrap tire granules
Leaching procedures for synthetic turf systems

Requirements regarding environmental compatibility (FIFA/FIH/UEFA, DIN SPEC 18035-7 2011-06, CEN TC 217 WG 10)

Leaching tests

- Application of standard leaching tests (batch test, column test) to synthetic turf and athletic tracks? - designed for single components

- Legislation thresholds?

- Leachate of top layers passes a complex construction consisting of different materials – Consideration of the whole system necessary! lysimeter or column tests?

  DIN SPEC 18035-7 2011-06: Batch test only for single components

  prTS of CEN TC 217 WG 10: Special lysimeter for synthetic turf and infill materials, shock absorbtion layers
Leaching procedures for synthetic turf systems

**Batch tests:**
investigation of single components at L/S 2 l/kg

**Column tests:**
investigation of complete synthetic turf systems and single components in accordance to DIN 19528
Leaching procedures for synthetic turf systems

- special procedure for assembling of the columns for complete turf systems

  bound elastic support layer
  (preparation in plastic piping of the same diameter or by punching from pre-fabricated layers)
fixed contact time - calculating of flow rate based on estimated bulk density (porosity) of the specimen in the column

collection of eluates up to L/S 4 l/kg (four fractions) as basic characterization test or as compliance test up to L/S 2 l/kg (one fraction)
  - Zn, Cd, Pb, other elements, PAHs, Benzothiazole and Mercaptobenzothiazole
**Leaching procedures for synthetic turf systems**

Batch tests SBR granules L/S 2 l/kg (triplicates)

- Varying concentrations of Zn und PAH (between and within different granules)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Zn [mg/l]</th>
<th>St. dev. [%]</th>
<th>PAH * [µg/l]</th>
<th>St. dev. [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBR 1</td>
<td>3,59</td>
<td>9,5</td>
<td>n.d.</td>
<td></td>
</tr>
<tr>
<td>SBR 2</td>
<td>0,90</td>
<td>63</td>
<td>1,42</td>
<td>13</td>
</tr>
<tr>
<td>SBR 3</td>
<td>1,31</td>
<td>32</td>
<td>1,39</td>
<td>36</td>
</tr>
<tr>
<td>SBR 4</td>
<td>0,69</td>
<td>45</td>
<td>1,49</td>
<td>8,9</td>
</tr>
<tr>
<td>SBR 5</td>
<td>4,52</td>
<td>3,7</td>
<td>0,68</td>
<td>25</td>
</tr>
<tr>
<td>SBR 6</td>
<td>0,12</td>
<td>22</td>
<td>0,36</td>
<td>53</td>
</tr>
<tr>
<td>SBR 7</td>
<td>129</td>
<td>23</td>
<td>0,41</td>
<td>12</td>
</tr>
<tr>
<td>SBR 8 (PUR)</td>
<td>0,08</td>
<td>42</td>
<td>1,18</td>
<td>4,9</td>
</tr>
</tbody>
</table>

* Sum of 15 EPA-PAH (HPLC)
Comparison of Zn concentration of SBR granules in solid matter and batch test eluates

- no correlation

<table>
<thead>
<tr>
<th>SBR 3</th>
<th>SBR 5</th>
<th>SBR 6</th>
<th>SBR 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zn in solid matter *</td>
<td>Zn in eluate L/S 2 l/kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[g/kg]</td>
<td>[mg/l]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18,1</td>
<td>1,31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21,6</td>
<td>4,52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23,3</td>
<td>0,12</td>
<td></td>
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</tr>
<tr>
<td>16,8</td>
<td>129</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Microwave digestion  HNO\textsubscript{3}/H\textsubscript{2}O\textsubscript{2}
Column test on SBR

- Partly delayed release of Zn and PAH

![Graph showing concentration of Zn and PAH over L/S ratio](image)
Results – Column tests on complete systems

Leaching procedures for synthetic turf systems

<table>
<thead>
<tr>
<th>Legend</th>
<th>PE monofilament fibres of approx. 0.3 mm thickness, 4 cm pile height</th>
<th>PE monofilament fibres of approx. 0.3 mm thickness, 4 cm pile height</th>
<th>SBR/EPDM bed coated, prefabricated (type B)</th>
<th>SBR/EPDM spray coated, fabricated on-site (type A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of synthetic turf or surface</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of infill granule</td>
<td>SBR + sand</td>
<td>TPE + sand</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Type of bound elastic layer</td>
<td>SBR + binder</td>
<td>SBR + binder</td>
<td>SBR + binder + mineral aggregates</td>
<td>SBR + binder + mineral aggregates</td>
</tr>
<tr>
<td>Unbound base layer</td>
<td>0/8 mm</td>
<td>0/8 mm</td>
<td>0/8 mm</td>
<td>0/8 mm</td>
</tr>
</tbody>
</table>

![Graph showing leaching procedures for synthetic turf systems](chart.png)
Leaching procedures for synthetic turf systems

Results – Column tests on complete systems

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<th>Type of infill granule</th>
<th>Type of bound elastic layer</th>
<th>Unbound base layer</th>
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<td>SBR + binder</td>
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<td>SBR + binder</td>
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</tr>
<tr>
<td></td>
<td>SBR/EPDM bed coated, prefabricated (type B)</td>
<td>-</td>
<td>SBR + binder + mineral aggregates</td>
<td>0/8 mm</td>
</tr>
<tr>
<td></td>
<td>SBR/EPDM spray coated, fabricated on-site (type A)</td>
<td>-</td>
<td>SBR + binder + mineral aggregates</td>
<td>0/8 mm</td>
</tr>
</tbody>
</table>

Sum PAHs [µg/L] vs. L/S [L/kg]
Conclusions

- **Column tests** on complete synthetic turf systems (incl. sub-base layer) are feasible and robust with the experimental boundary conditions used.

  - advantage:
    - time-dependent behavior and interaction of single components can be evaluated
    - more realistic results in comparison to batch tests on single components
    - Data as a basis for further modelling – derivation of threshold values

- **Batch tests** are suitable for application during quality monitoring of production (but difficult for elastic layer materials).
Thank you for your attention!

Team of BAM 4.3 “Contaminant transfer and environmental technologies”