Verifying the Impermeability of GRP
Regarding Hydrocarbons

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• Comparison to other plastics
• Direct proof of suitability for GRP pipes
• General proof of suitability for GRP pipes
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VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

• Motivation (about 7 years ago)

Grundwasser von Söhlingen vergiftet?


Die Behörden wollen nun die möglichen Ursachen für die erhöhten Giftkonzentrationen suchen, erklärte Klaus Söntgerath vom Landesamt.

VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

• Incident: oil field Söhlingen, 7 years ago

- pipe trench
- old steel pipe
- leak-tight PE-tube
- transporting reservoir fluids
- diffusion!
- pollution of soil and groundwater
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

- Preface

adsorption

high BTEX concentration

inside

reservoir fluid

BTEX

PE-Wall

diffusion

PE-Wall

low BTEX concentration

outside

concentration gradient

polyethylene pipeline

soil / groundwater

BTEX
Official directives of the LBEG

  (Nachweis der Eignung von Kunststoffrohren bei Verwendung als Feldleitung in Erdöl- und Erdgasbetrieben bzgl. des sicheren Einschlusses des zu transportierenden Mediums (keine messbare Permeation) im Sinne des § 49, Abs. 1, BVOT mittels wiederkehrender Prüfungen durch Analysen von Boden- und Wasserproben, ggf. alternativer Verfahren im Einvernehmen

- **Bescheid L1.5/L67911-06/2016-0002 vom 07.11.2016**
  (Einvernehmen bzgl. Anwendung Genereller Eignungsnachweis für GFK)

LBEG: Landesamt für Bergbau, Energie und Geologie (*mining authority*) für die Länder Schleswig-Holstein, Hamburg, Bremen und Niedersachsen
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

• Preface

- Soil samples 0 – 10 mm and 100 mm
- Water samples
- Reference sample
- Reservoir fluid
- Pipeline
- Pipe trench

„indirect proof of suitability“
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

• Preface

"indirect proof of suitability"

documentation

sample taking of soil for BTEX analysis

excavating a trench

soil samples BTEX

soil samples
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

• Preface

emission measuring cell → evaluating the permeation rate (difficulty: tight sealing)
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

• Preface

Used PE pipeline (transported reservoir fluid for over 1.5 years, BTEX ≤ 3.000 µg/l)

10 mg/m·d BTEX

Permeation measuring cell

→ Permeation: 10 mg/m·d (4”, 10 mm PE wall)
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

• Analytical method

Material tests

➢ Used plastic tube + brand new tube (reference sample)

➢ Cut sample out of tube (sawing)

➢ Chip layers on a turning lathe (≥ 0,1 mm/layer)

➢ Extract lathe turnings with methanol

➢ Analyse extract using gas chromatography

BTEX as main parameter for hydrocarbons

➢ Evaluate concentration profiles in tube wall matrix [µg/kg BTEX]
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

• Analytical method

„direct proof of suitability“

GFK material tests with used GFK pipelines … unfortunately a destructive process
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

• Analytical method

Chipping layers off of a tube wall on a turning lathe (lathe turnings in methanol)

„direct proof of suitability“
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

- Analytical method
  Evaluation of gas chromatogram from 10 tube wall layers

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- Analytical method
  Evaluation of gas chromatogram from 10 tube wall layers
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

- Comparison to other plastics used PE pipeline
  (transported reservoir fluids for over 1,5 years, BTEX ≤ 3,000 µg/l)
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

• Comparison to other plastics used PE-ALU composite pipeline (transported reservoir fluids for over 1 year, BTEX ≤ 1.000 µg/l)

LaWa: reservoir fluid

„direct proof of suitability“

LaWa, ≤ 1.000 µg/l BTEX

NO PERMEATION!
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

- Comparison to other plastics used PE-ALU composite pipeline
  (transported reservoir fluids for over 1 year, BTEX ≤ 1.000 µg/l)

„direct proof of suitability“
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

- Comparison to other plastics

**PE-ALU** composite pipeline in a laboratory test at DBI-GUT
(18 month, 10% Toluol, 90% n-alkenes at 30°C, 8 bar)

„direct proof of suitability“
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

- Comparison to other plastics
  - PA12 pipeline in a field test (2,5 years)
  - PVC pipeline in an oil field (36 years)

Reservoir fluids with ≤ 3.000 µg/l BTEX both cases

"direct proof of suitability"

NO PERMEATION!
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

- Direct proof of suitability for GRP pipes
  Evaluation of BTEX penetration in GRP matrix
  BTEX concentration profiles within the GRP tube wall [µg/kg]
  used GRP pipeline, transported cut oil for over 30 years

„direct proof of suitability“

used GRP pipeline
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

- Direct proof of suitability for GRP pipes
  Evaluation of BTEX penetration in GRP matrix
  BTEX concentration profiles within the GRP tube wall [µg/kg]
  brand new GRP pipeline from inventory stock (reference sample)

brand new GRP pipeline

BTEX source: epoxy resin
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

- Direct proof of suitability for GRP pipes

Evaluation of BTEX penetration in GRP matrix
BTEX concentration profiles within the GRP tube wall [µg/kg]

NO PERMEATION!

BTEX-source: epoxy resin

used GRP pipeline

brand new GRP pipeline
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

- Direct proof of suitability for GRP pipes

BTEX concentration profiles within the GRP tube wall [µg/kg] used 12“GRP pipeline, transported reservoir fluids for over 50 years

Source of BTEX/VOC: epoxy or vinyl ester resin
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

• Direct proof of suitability for GRP pipes
  BTEX concentration profiles within the GRP tube wall [µg/kg]
  used GRP pipeline, transported reservoir fluids for over 17 years

no BTEX detectable in epoxy resin matrix (< 300 µg/kg)
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

- Direct proof of suitability for GRP pipes

**Statistical data**

- **GRP pipelines - direct proof of suitability** (61 samples)
  - none with any indication for diffusion or permeation

<table>
<thead>
<tr>
<th>GRP pipelines in oil / gas fields Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRP type</td>
</tr>
<tr>
<td>----------------------------</td>
</tr>
<tr>
<td>GRP-EP (epoxy resin)</td>
</tr>
<tr>
<td>GRP-VE (vinylester resin)</td>
</tr>
<tr>
<td>GRP-PE (polyester resin)</td>
</tr>
<tr>
<td>GRP overall</td>
</tr>
</tbody>
</table>

- **GRP pipelines - indirect proof of suitability** (91 samples)
  - additional 91 from 458 = 19,9 % (only „negative“ findings)
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

• Direct proof of suitability for GRP pipes

Variable

- Producer
- Resin / curing agent
- Wall thickness 2 mm (min.)
- Inner diameter 300 mm (max.)
- Temperature 60 °C (max.)
- Pressure 60 bar (max.)
- Transfer rate 2,000 m³/h (max.)
- Operating time 50 years (max.)
- Oil / gas field
- Fluid type (reservoir fluid, cut oil, oil, gas condensate)
- BTEX concentration in fluid (1,000 up to 75,000,000 µg/l)

No measurable influence on permeation observed
## VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

- Direct proof of suitability for GRP pipes (61 pipe samples)

<table>
<thead>
<tr>
<th>variable</th>
<th>variance</th>
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</thead>
<tbody>
<tr>
<td><strong>producer</strong></td>
<td>Future Pipe In. NOV-FGS</td>
</tr>
<tr>
<td>quantity</td>
<td>16</td>
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<tr>
<td><strong>curing agent</strong></td>
<td>arom. Amines</td>
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<tr>
<td>quantity</td>
<td>19</td>
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<tr>
<td><strong>wall thickness</strong></td>
<td>up to 2,5 mm</td>
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<tr>
<td>quantity</td>
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</tr>
<tr>
<td><strong>inside diameter</strong></td>
<td>DN 50</td>
</tr>
<tr>
<td>quantity</td>
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<td><strong>fluid temperature</strong></td>
<td>up to 20 °C</td>
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<td>quantity</td>
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<tr>
<td><strong>operating pressure</strong></td>
<td>up to 5 bar</td>
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<td>quantity</td>
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<td><strong>operating time</strong></td>
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<tr>
<td>quantity</td>
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<td><strong>oil / gas field</strong></td>
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<td>quantity</td>
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<td><strong>fluid type</strong></td>
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<td>quantity</td>
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<tr>
<td>BTEX concentration in fluid</td>
<td>up to 5 mg/l</td>
</tr>
<tr>
<td>quantity</td>
<td>21</td>
</tr>
</tbody>
</table>
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

• General proof of suitability for GRP pipes

✓ Old facilities
  ❖ 50 years overall running time

✓ New construction of GRP pipes:
  ❖ ≤ 65 °C fluid temperature
  ❖ Operating pressure → BVEG-manual
  ❖ Epoxy resin *or* vinyl ester resin
  ❖ ≥ 65 mass-% glass fibre content
  ❖ ≥ 105°C glass transition temperature
  ❖ ≥ 4,0 mm wall thickness
  ❖ Permeation tight for 50 years (general proof, no periodic inspections regarding permeation)
VERIFYING THE IMPERMEABILITY OF GRP REGARDING HYDROCARBONS

• Future prospects

General proof of impermeability of GRP Pipes regarding hydrocarbons

➢ Approval by authorities

➢ Expand permissible temperature range

➢ Apply findings to other fields of application
GLASS FIBRE REINFORCED PIPELINES (GRP) …

… are impermeable to hydrocarbons