BAM
Bundesanstalt für Materialforschung und -prüfung

Sicherheit in Technik und Chemie

04.05.2020

FE 82.0728/2019 „DEVELOPMENT OF TEST FOR TOXICITY ASSESSMENT OF BUS INTERIOR MATERIALS“

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7.5 Technical Properties of Polymer Materials

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Overview

- Bus interior components and materials
- Specimens
- Smoke gas components
- Toxicity tests: SDC, (Vitiated) Cone Calorimeter, DIN tube
- Set-up of the three different tests, parameter
- Advantages / Disadvantages
- Results of Cone experiments with new bus materials
- Preparation of numerical investigations / master theses

Bus interior components

Identified so far:

- **Seats**
- **Ceiling**
- **Walls (cladding)**
- **Dashboard / instrument panels**
- **Moulded parts**

Bus interior materials

- **Polyurethane (PU)**
- **Polyester (PES)**
- **Polyethylene (PE)**
- **Acrylnitril-Butadien-Styrol (ABS)**
- **Polyvinylchloride (PVC)**
- **Wood materials**
- **Polyamid (PA)**
- **Leather / artificial leather**

Glassfibre reinforced plastic:

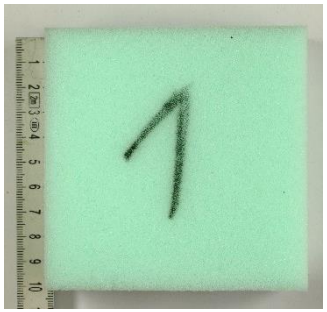
- **Acrylnitril-Butadien-Styrol (ABS)**
- **Polypropylen (PP)**
- **Polyester resin**

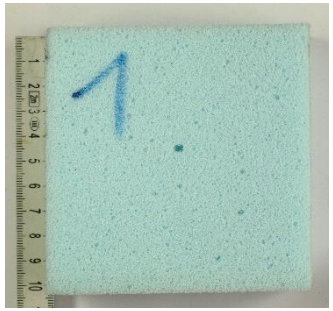
Specimens

textiles				
upper layer	66 % polyester 28 % wool 6 % viscose	polyester/ polyamid	100% polyester	70 % polyester 30 % wool
basic layer/ lamination	60 % polyester 24 % viscose 15 % cotton 1 % elastane	polyethylene fleece	72 % polyester 28 % viscose	50 % polyester 50 % viscose
burning test acc.	UN ECE R 118 Nr. 2	UN ECE-R 118:03	attachment 8 evaluation acc. DIN 5510 - 2 (05.09)	EN 45545- 2:2013 R21, ECE R 118.03

Specimens

upholstery foams





Polyurethane foams

Dashboard –
is there a company in the group which could supply dashboard specimens?

Wall coverings - is there a company in the group which could supply side wall specimens?

Smoke gas components

Identified so far:

- Carbon dioxide (CO_2)
- Carbon monoxide (CO)
- Hydrogen cyanide (HCN)
- Hydrogenchloride (HCl)
- Formaldehyde
- Benzene
- Nitrogene oxides (NO_x)
- HF?
- SO2? to be added?
- SOx?

Toxicity test

Requirements for toxicity testing:

- Measurements of gas components: FTIR (Fourier Transformed Infrared) spectroscopy
- Smoke is not only depending on the material but highly dependent on combustion conditions – temperatures / heat / ventilation / vitiation
- Variation and control of combustion conditions
- Fire load – proper value: mass loss

Three different possible toxicity test

- Smoke Density Chamber

- Cone Calorimeter / Vitiated Cone Calorimeter / Mass Loss Calorimeter

- DIN tube

Smoke Density Chamber (SDC) tests

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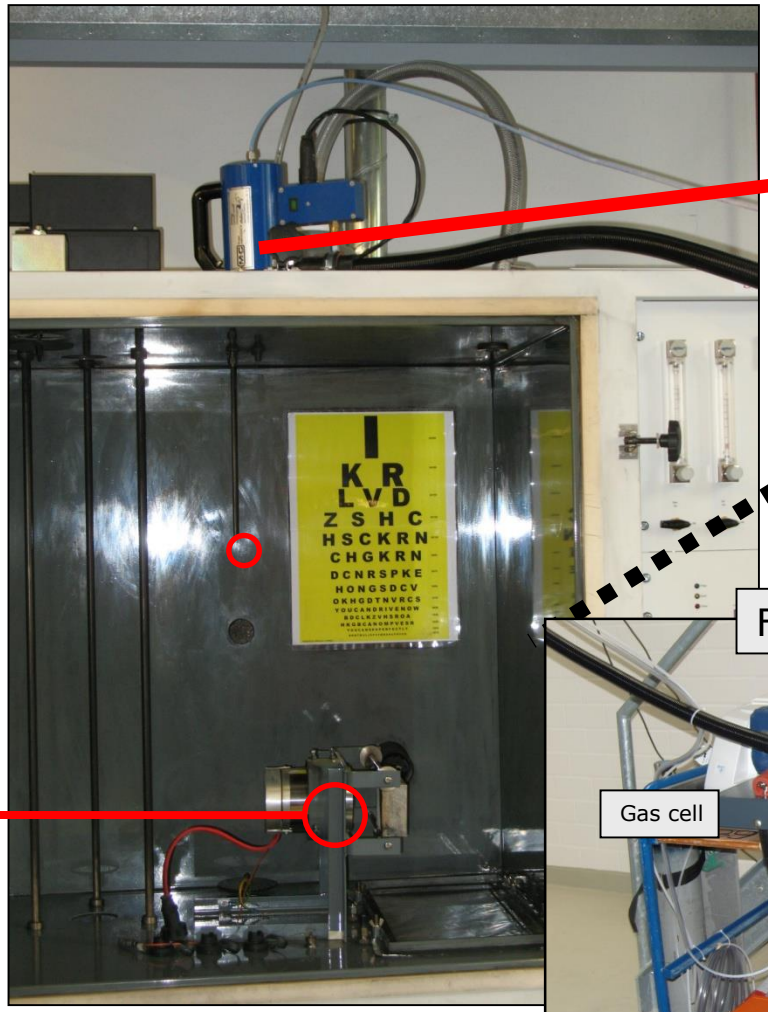
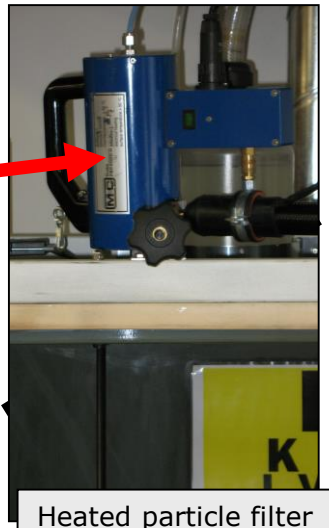
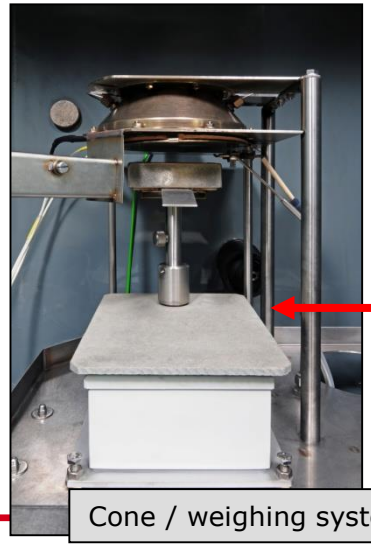
Measured parameters:

- Mass loss
- Transmission
- Specific optical density
- Smoke gas composition

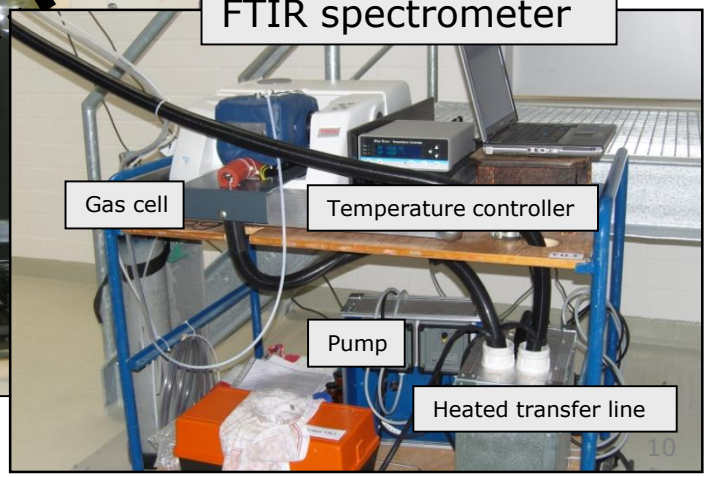




Heated particle filter



Cone / weighing system



Cone Calorimeter tests

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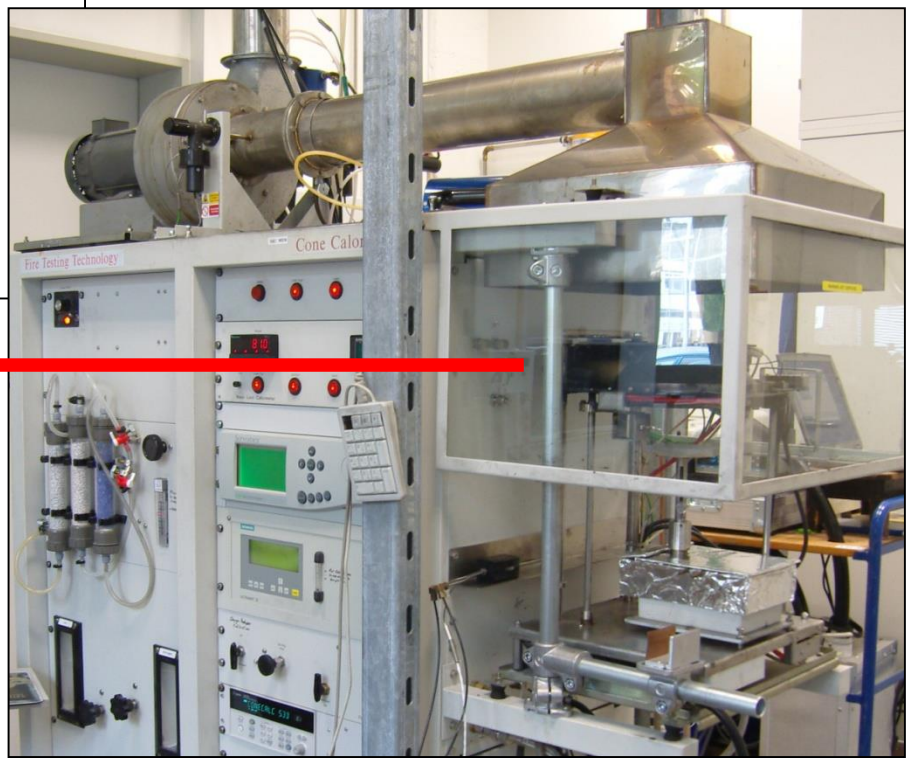
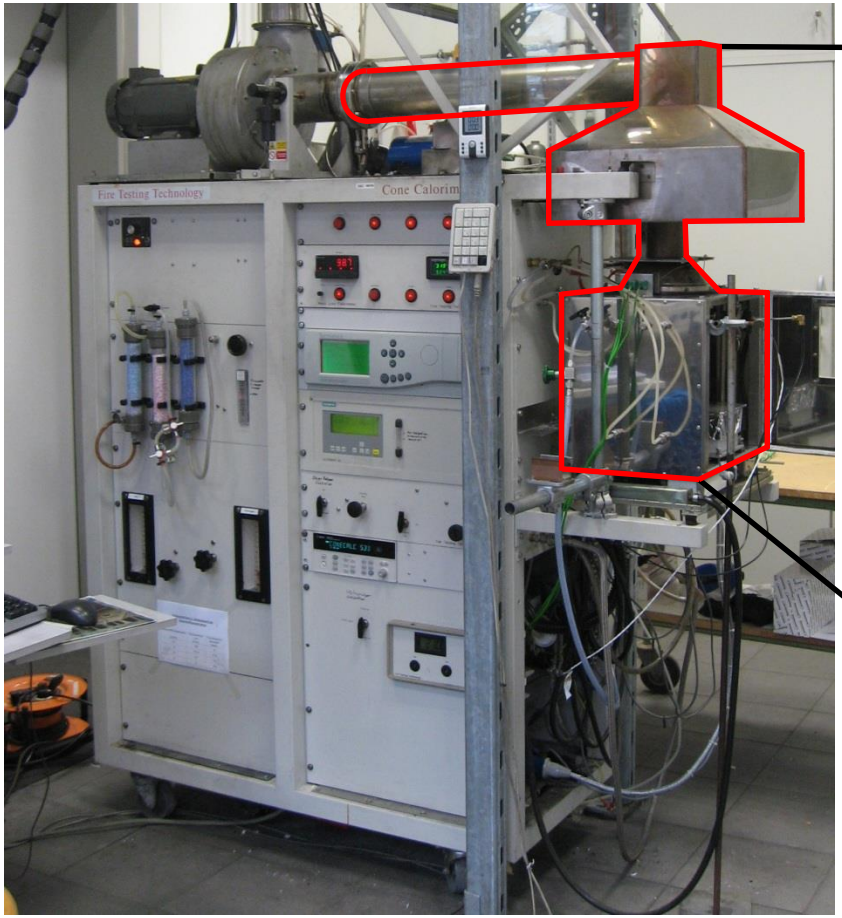
Measured parameters:

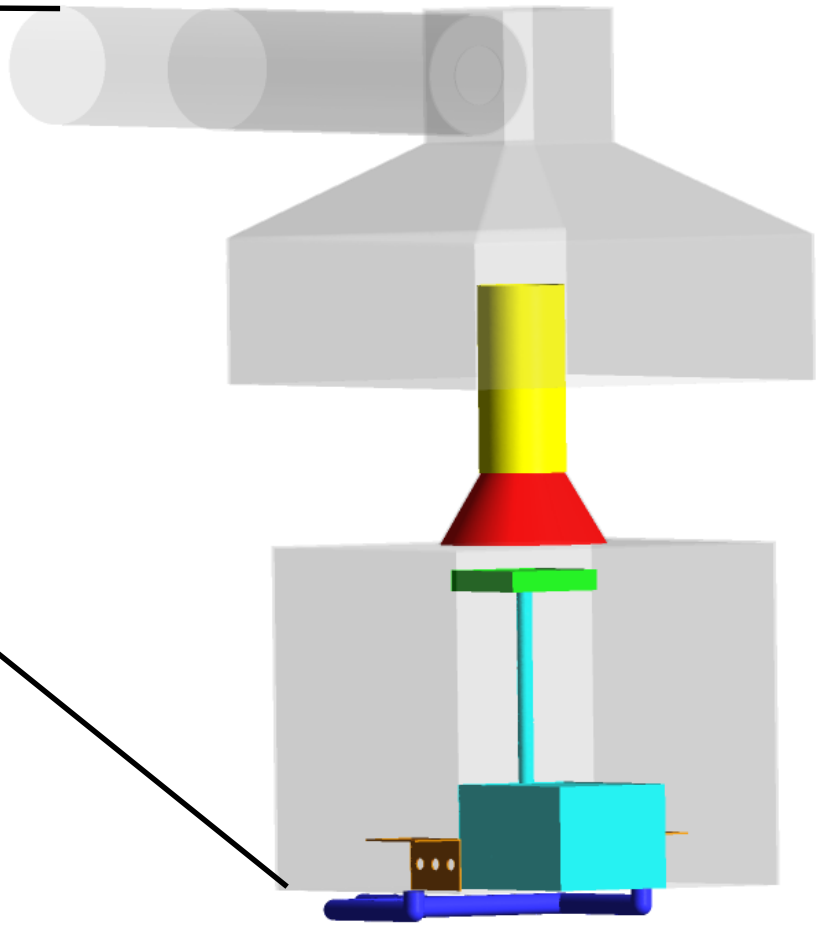
- Mass loss
- Smoke gas components, CO, CO_2, O_2
- Transmission
- Heat release rate
- Time to ignition
- FTIR spectrometer



Cone / weighing system

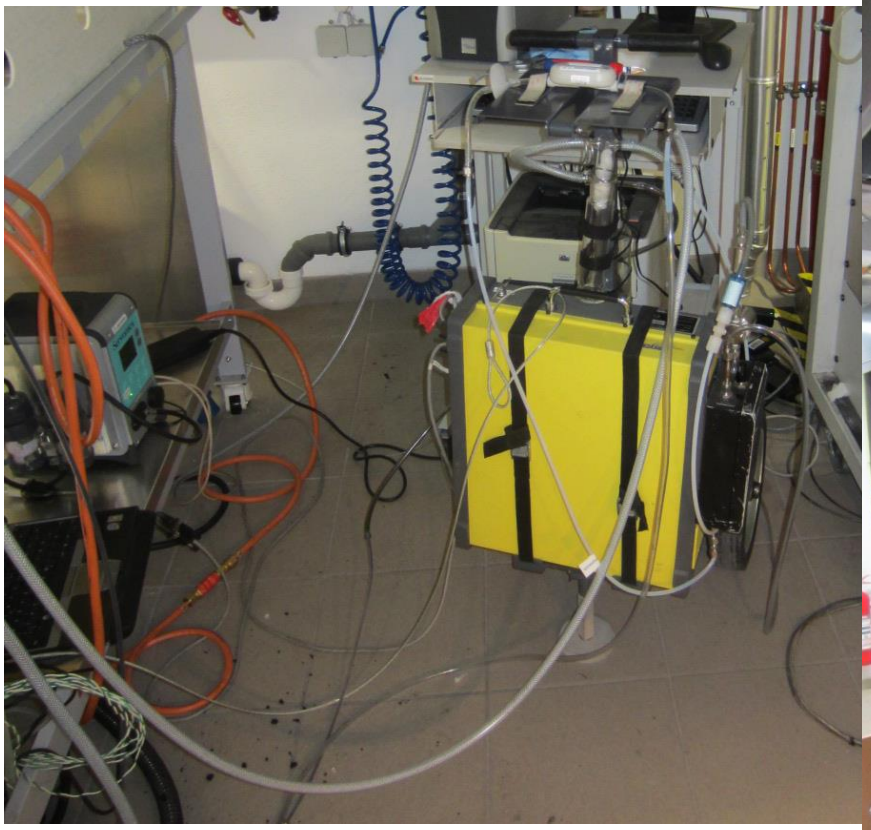
Vitiated Cone Calorimeter tests



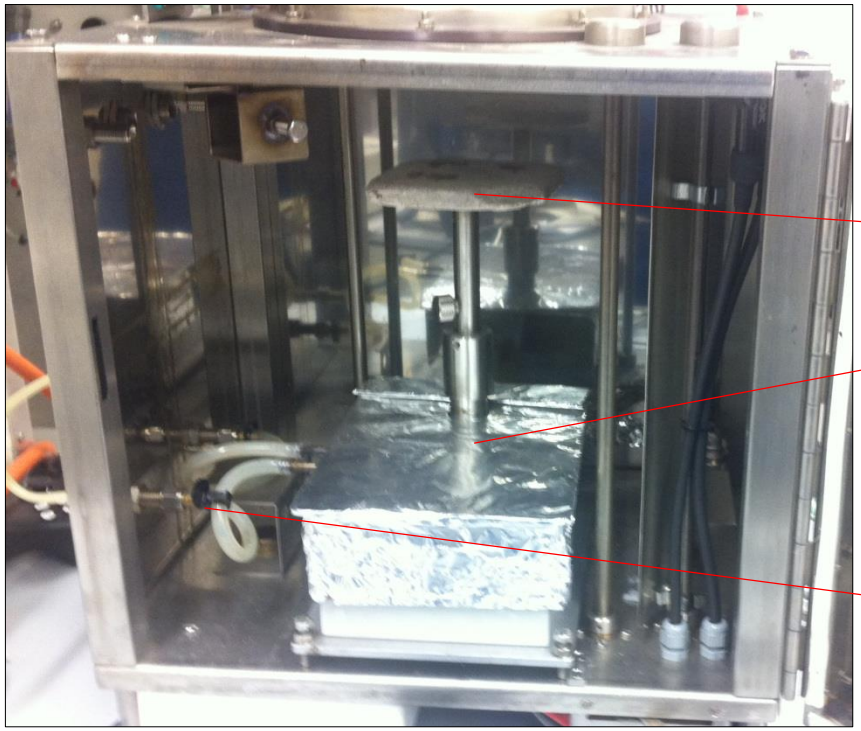


Vitiated Cone Calorimeter (M. Werrel BAM)

Vitiated Mass Loss Calorimeter



Vitiated Mass Loss Calorimeter



Sample holder

Scale

Water cooled

Cone heater

Baffle

Controlled Atmosphere Box

Chimney

Oxygen

FT-IR

T HRR

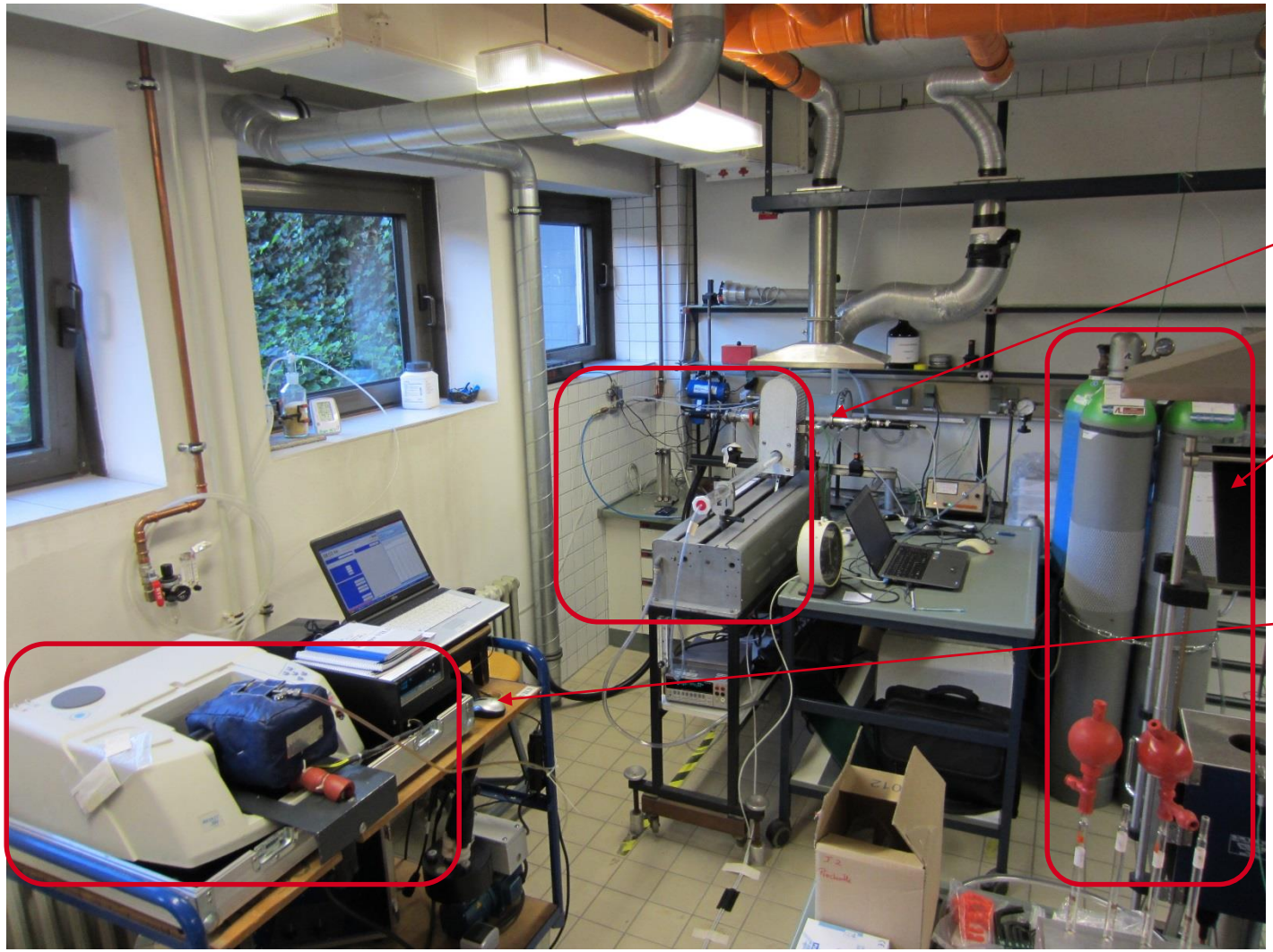
Vitiated Mass Loss Cone Calorimeter

liquid nitrogen and vaporiser

compressed air

mixer

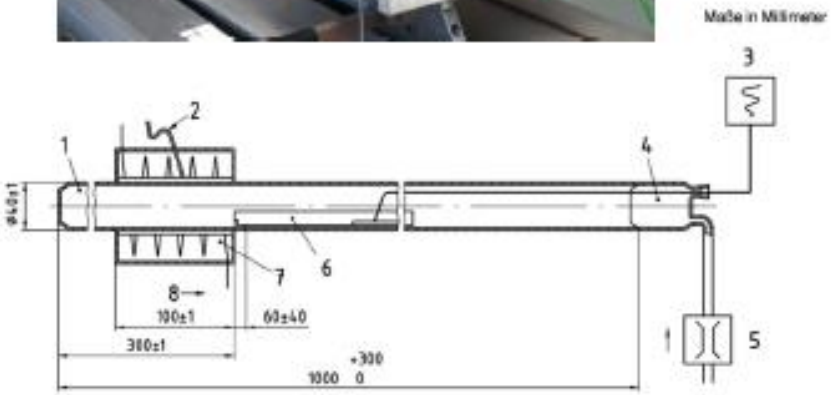
DIN tube



DIN tube – set-up

- Modified DIN 4102/ 53436
- 1.1 m tube
- 0.1 m heater up to 700°C
- Supply air 300 l/h
- Specimen 270*10*10 mm^3
- Linked with a FT-IR-Spectrometer, O_2-sensor

- 3 Parameters
  - Material
  - Oxygen Concentration
  - Temperature



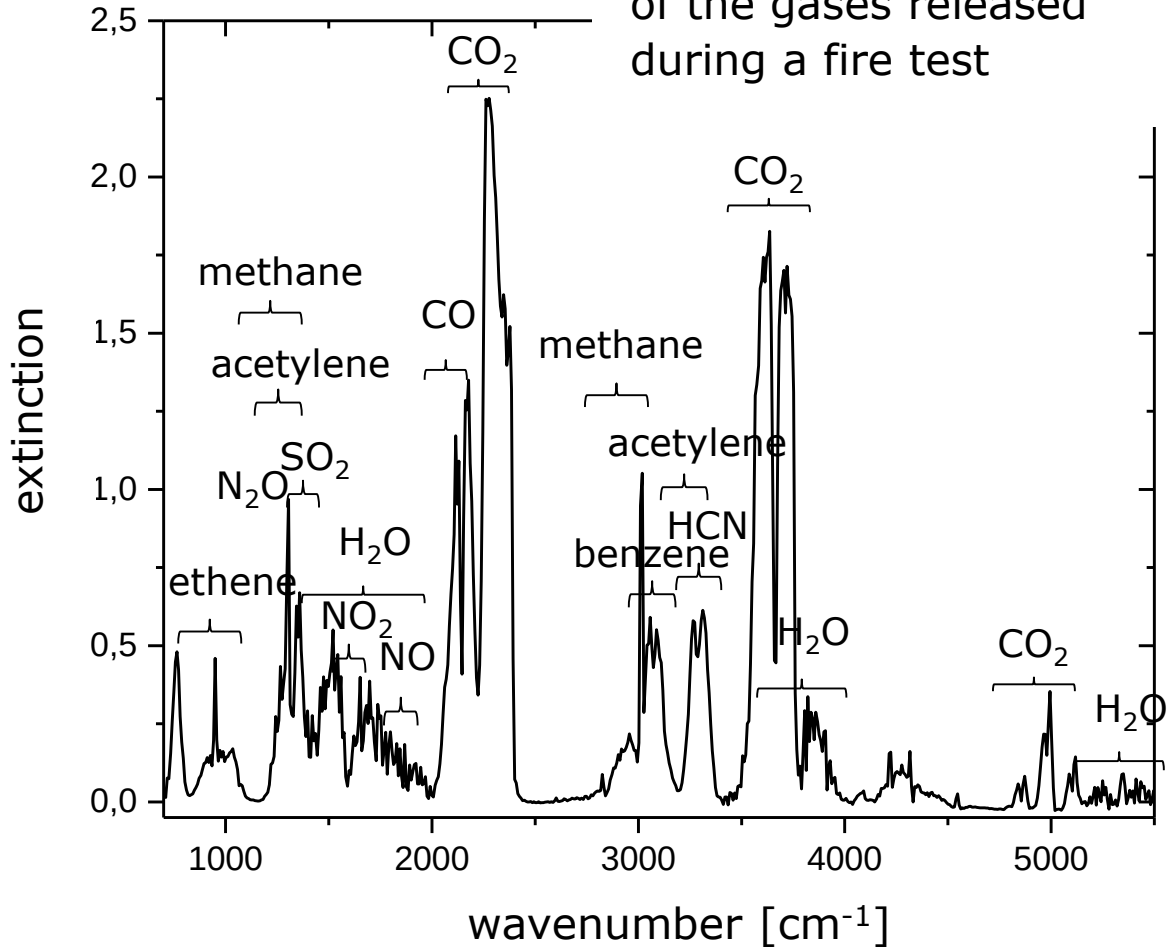
1 quartz tube
2 thermocouple
3 slider
4 connection for supply air
5 flow mater
6 sample holder
7 furnace
8 moving direction

Gas analysis – Fourier Transform Infrared (FTIR) Spectroscopy

Advantages:

- simultaneous analysis of most common fire gases
- connection to all suggested fire test devices possible
- gas analysis includes 25 gas components (adjustable)
- enables continuous measurement of released gases during the fire tests

generic FTIR-spectrum of the gases released during a fire test



Discussion of the three possible toxicity tests

(advantages and disadvantages)

Smoke Density Chamber (SDC)

Advantages

- Existing method, standardised
- Limits and parameters are standardised for different transport sectors (train, ship, aircraft)
- Existing materials on the market
- Different irradiation values
- Spark / no spark
- Mass loss

Disadvantages

- Undefined atmosphere in the chamber after begin of experiment as the material influences the atmosphere (closed box)
- Only accumulative measurements possible
- CIT as an accumulative parameter is not accurate with regard to components and doses

(Vitiated) Cone / Mass Loss Calorimeter

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Advantages

- Existing method, standardised
- Method is used in other transport sectors (not for toxicity)
- Parameters are standardised
- Controlled atmosphere
- Oxygen fraction can be varied
- Different irradiation values
- Spark / no spark
- Toxicity can be assessed continously, FED concept can be applied

Disadvantages

- Limits have to be set
- Materials have to be adapted to new standard

DIN tube

Advantages

- Existing method, standardised
- Parameters are standardised
- Small specimens
- Controlled atmosphere
- Different levels of irradiation
- Different levels of oxygen or flow rate are possible
- Toxicity can be assessed continously, FED concept can be applied

Disadvantages

- Only few laboratories have it (there is a similar French and a similar UK version)
- Mass loss is not measured
- Limits have to be set
- Materials have to be adapted to new standard

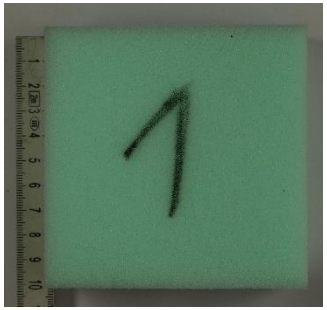
Results from tested new materials

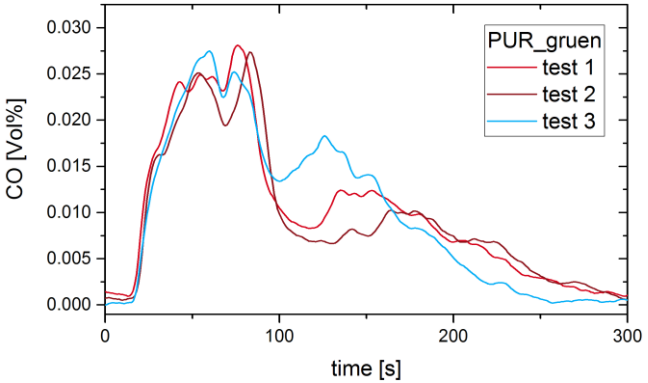
- First results of textiles and foam (new materials) in Cone Calorimeter tests (standard configuration),

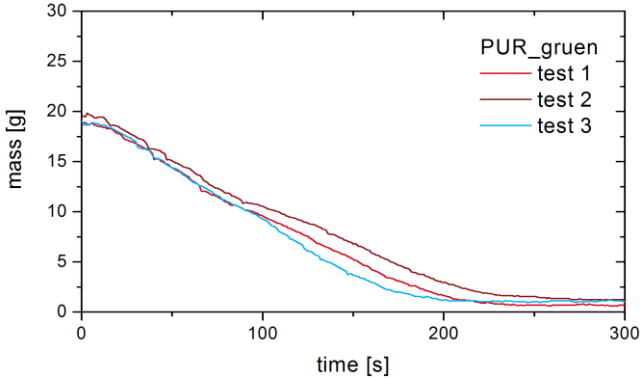
- combined specimens, three textiles each with both PUR foams,

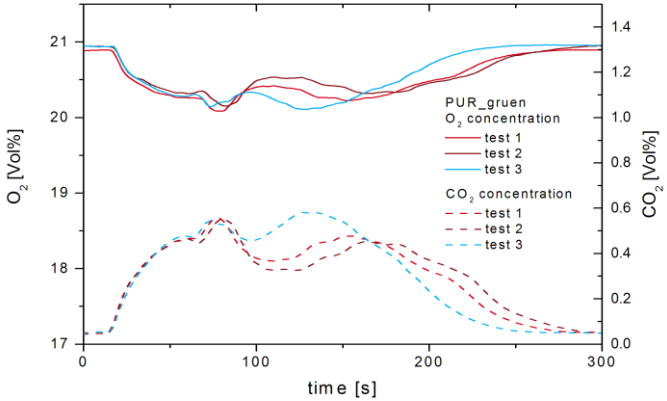
- 25 kW/m² with ignition spark, at least 3 tests with each material, ambient air (normal oxygen fraction)

Cone Calorimeter Tests: PUR foams

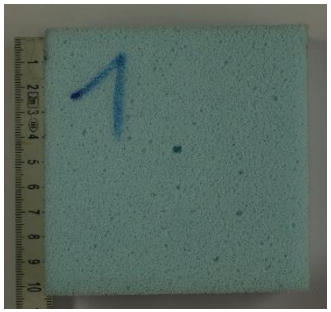


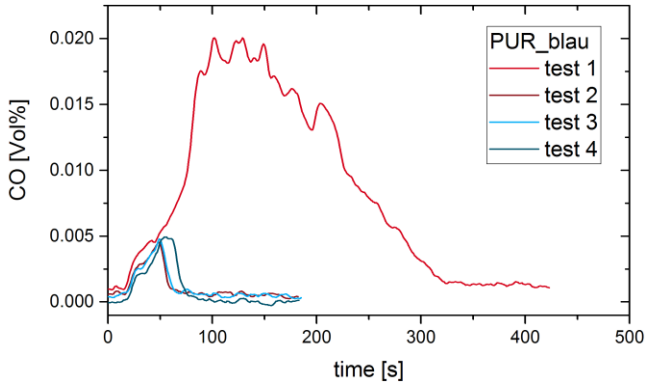


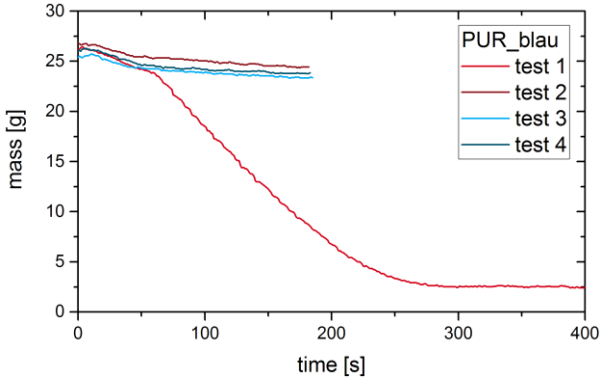


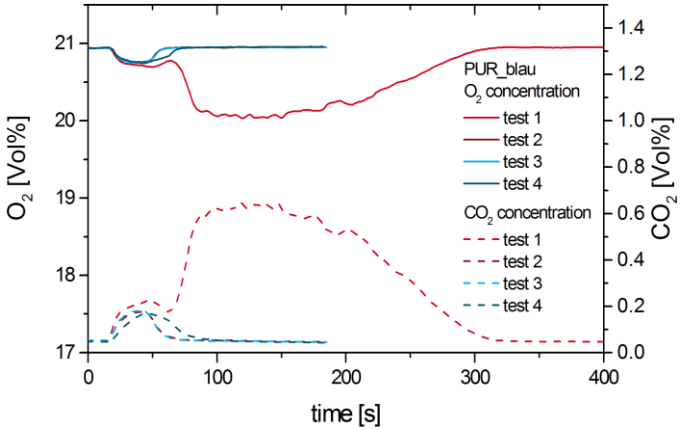


Cone Calorimeter Tests: PUR foams

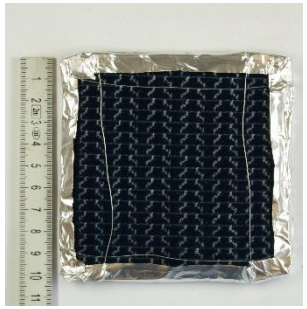


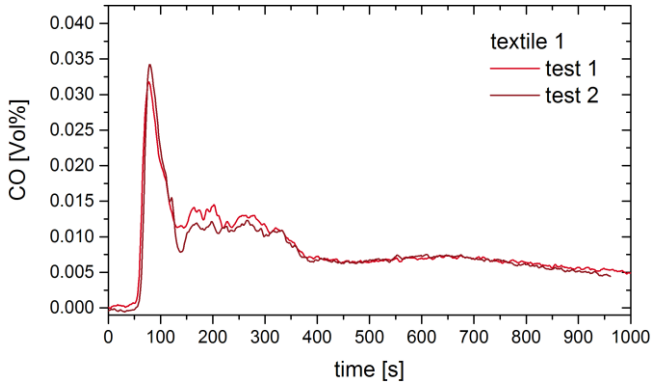


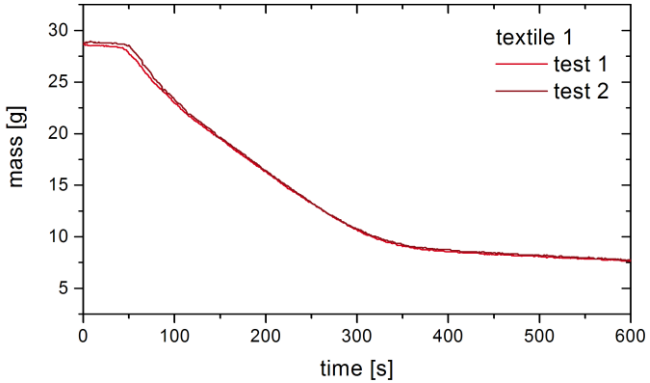


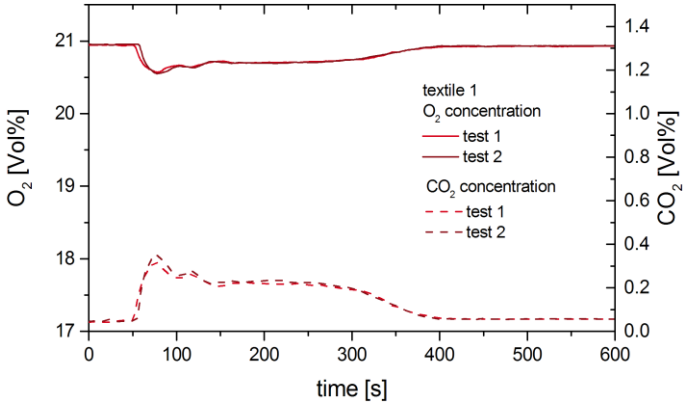


Cone Calorimeter Tests: textiles

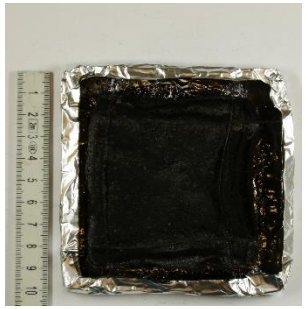


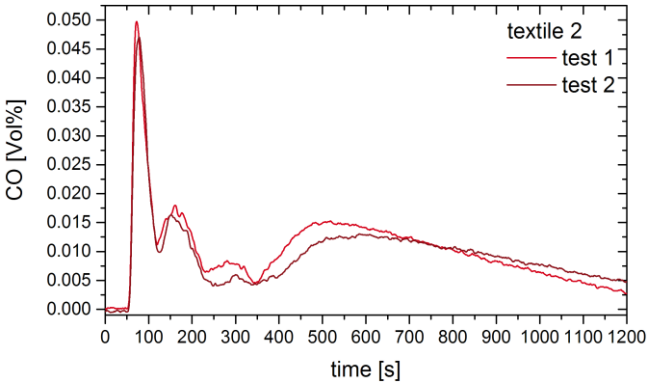


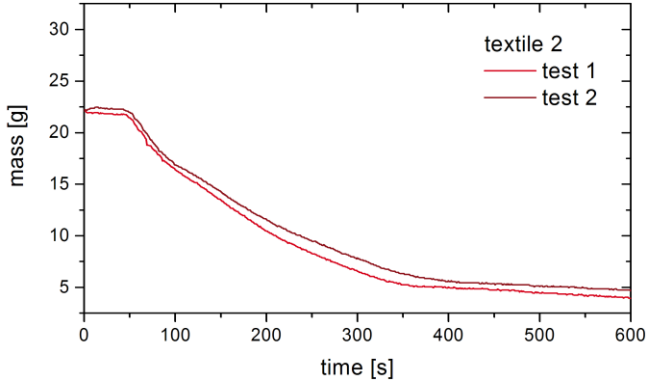


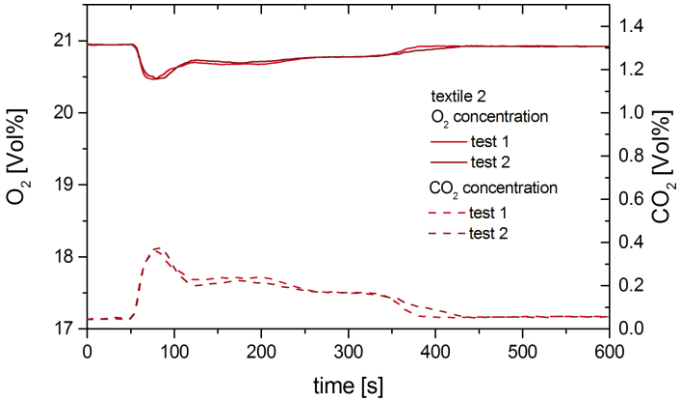


Cone Calorimeter Tests: textiles

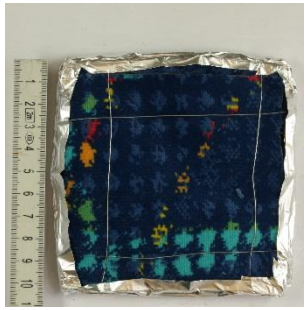


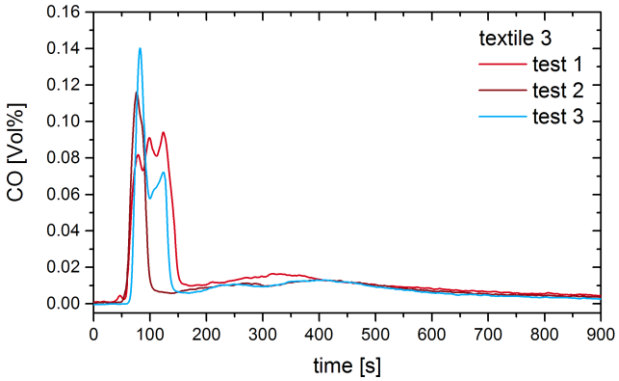


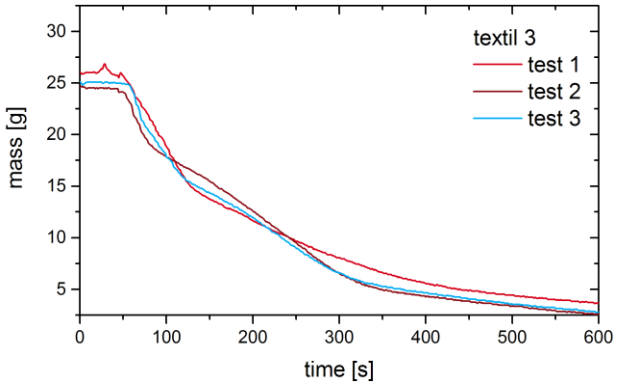


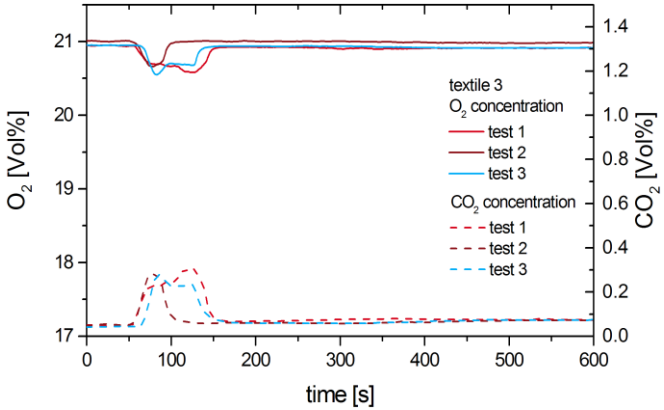


Cone Calorimeter Tests: textiles

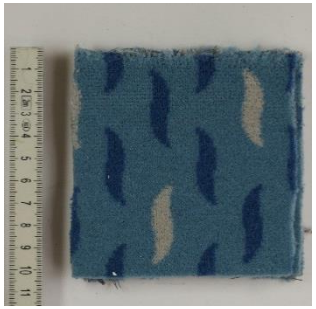


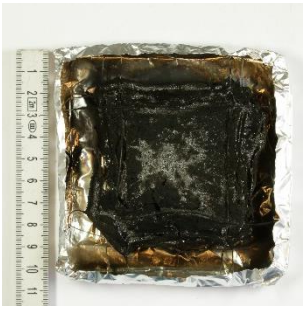


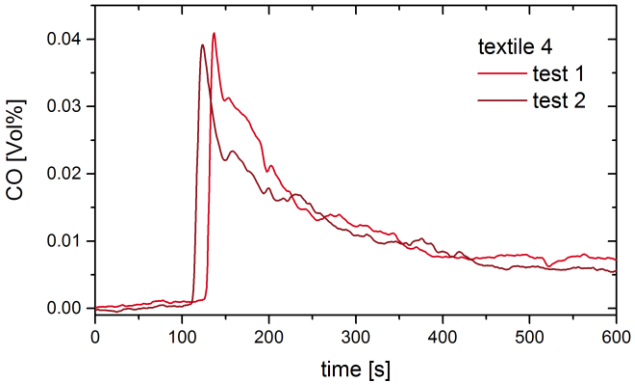


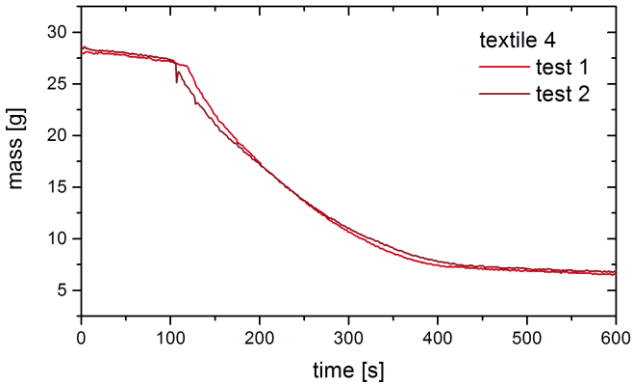


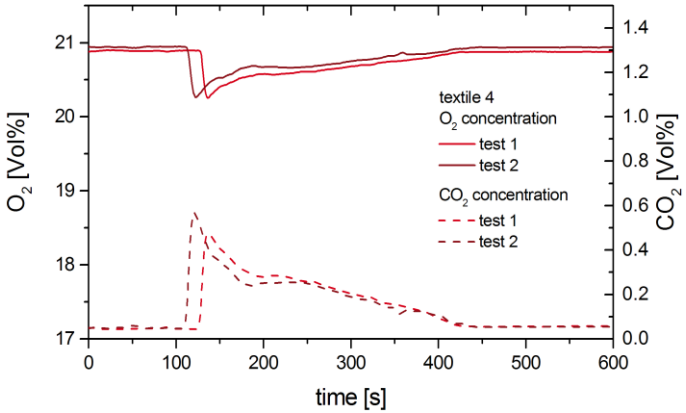
Cone Calorimeter Tests: textiles











Next steps

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Further data evaluation:

- evaluation of the FTIR-spectra collected during all fire tests in the cone calorimeter
- analysis of the gases released during the fire tests of all materials
- assessment of the toxicity of the fire effluents

Further experiments:

- Mass loss calorimeter: textiles and foams, as well as combinations
- smoke density chamber: textiles and foams, as well as combinations
- DIN tube furnace: selected materials
- further materials?
  - side wall coverings
  - dashboards

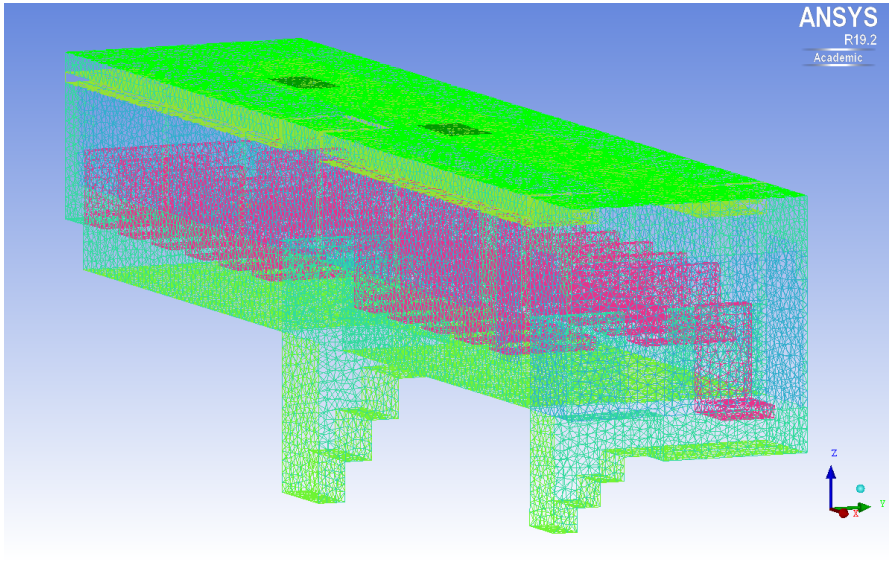
Two Master theses

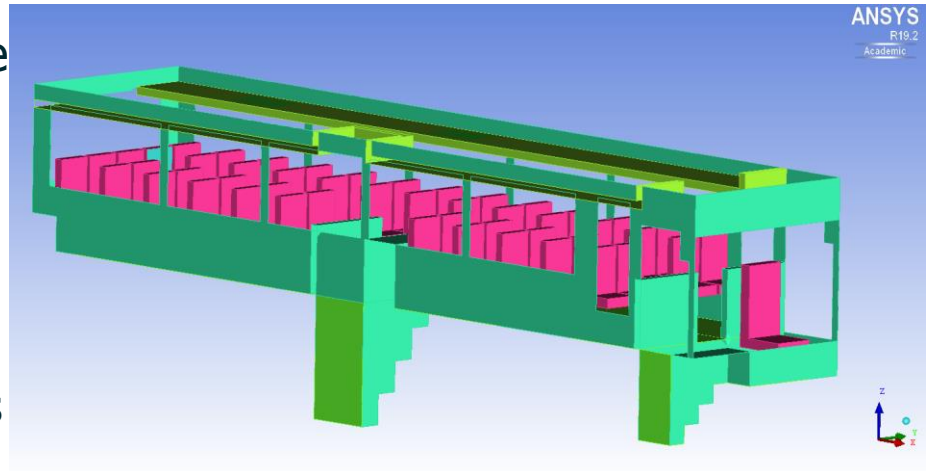
- Experimental investigation of bus interior materials with Cone Calorimter tests
  - to be finished at end of June 2020

- Numerical investigation of smoke gas toxicity of bus materials using numerical modeling

Numerical calculations

- Implementation of bus cabin for numerical calculations in Ansys CFX
- Integration of the gas analysis results from bench-scale fire tests in numerical simulation
- Modelling of a bus fire scenario in Ansys CFX using data from bench-scale tests
- Evaluation of transferability of the small scale test results to real scale fire scenarios
- assessment of the toxicity in real scale fire scenarios
- evaluation of possible limit values





Conclusions

- DIN tube: usage for research – assessing of the relation between small scale test results and prediction of conditions in a bus
- Cone Calorimeter: to be assessed as possible standard test for toxicity
- Smoke Density Chamber: to be assessed in suitability for application to bus toxicity assessment
- Mass Loss Cone Calorimeter / Vitiated Mass Loss Calorimeter: to be assessed as possible standard test for toxicity of bus materials
- Assessment of FED concept for standard use for toxicity of bus materials
- Numerical calculations of a bus cabin with test data as input parameter

Thank you for your attention!