Karlsruhe Institute of Technology

Institute for Technical Chemistry

Characterisation of inhalable aerosols from carbon fibres

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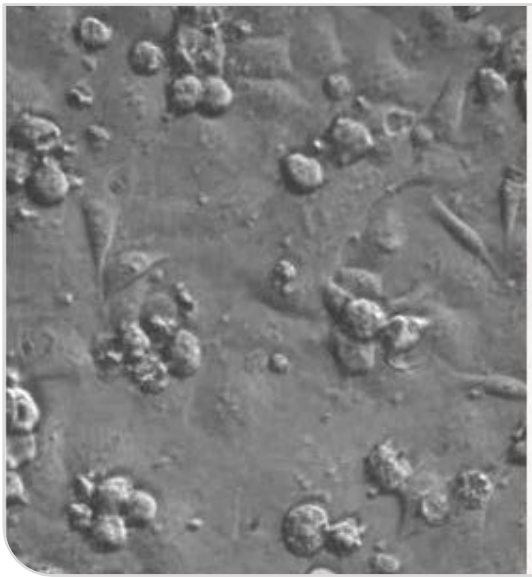
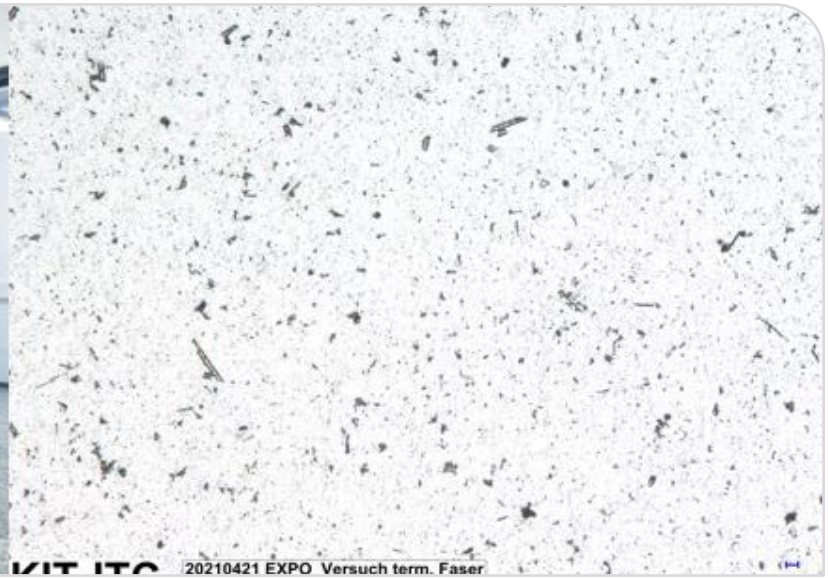
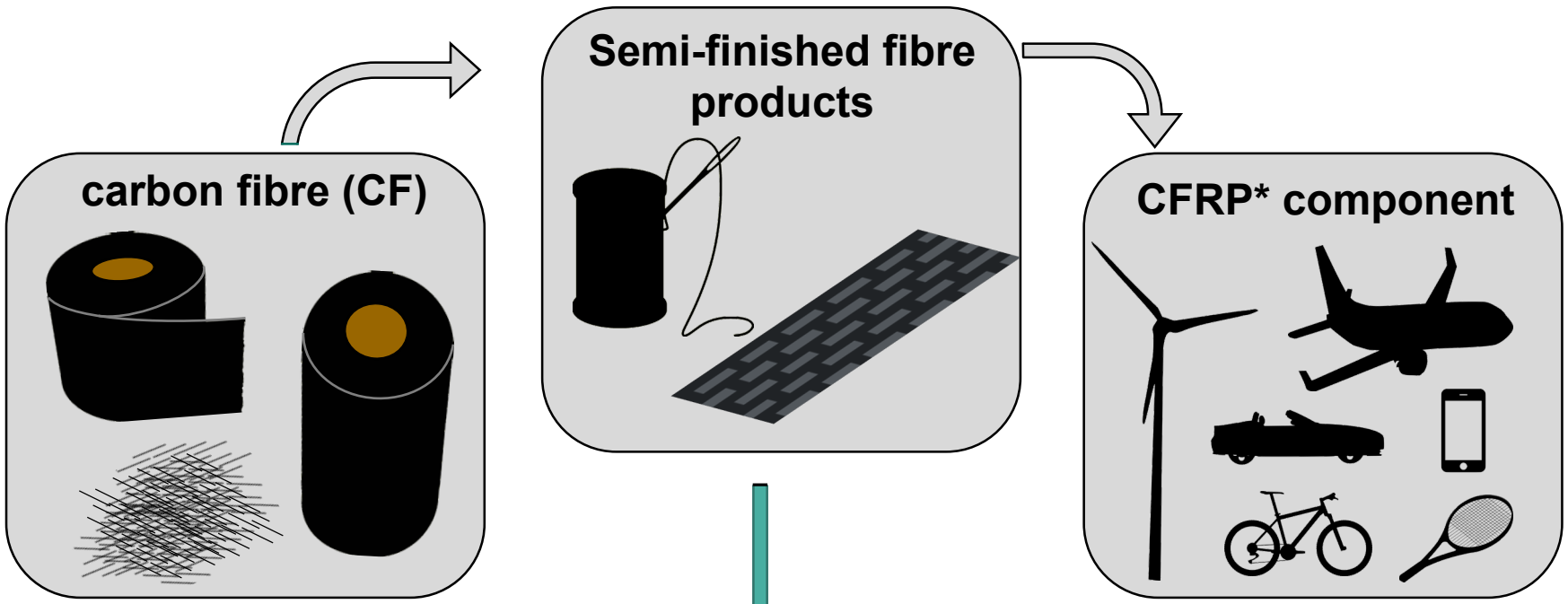




Life cycle of carbon fibres



Processing of CF/CFRP

includes:

- Mechanical processes like
  - Cutting
  - Sawing
  - Grinding
  - …
- Thermal processes like
  - Energetic disassembly
  - Pyrolysis
  - …

➔ **Change of properties possible**
➔ **Release of fibres and fibre fragments possible**

*Carbon fibre reinforced polymer

CFC – Carbon Fibre Cycle

Carbon Fibre Cycle

GEFÖRDERT VOM

Bundesministerium für Bildung und Forschung

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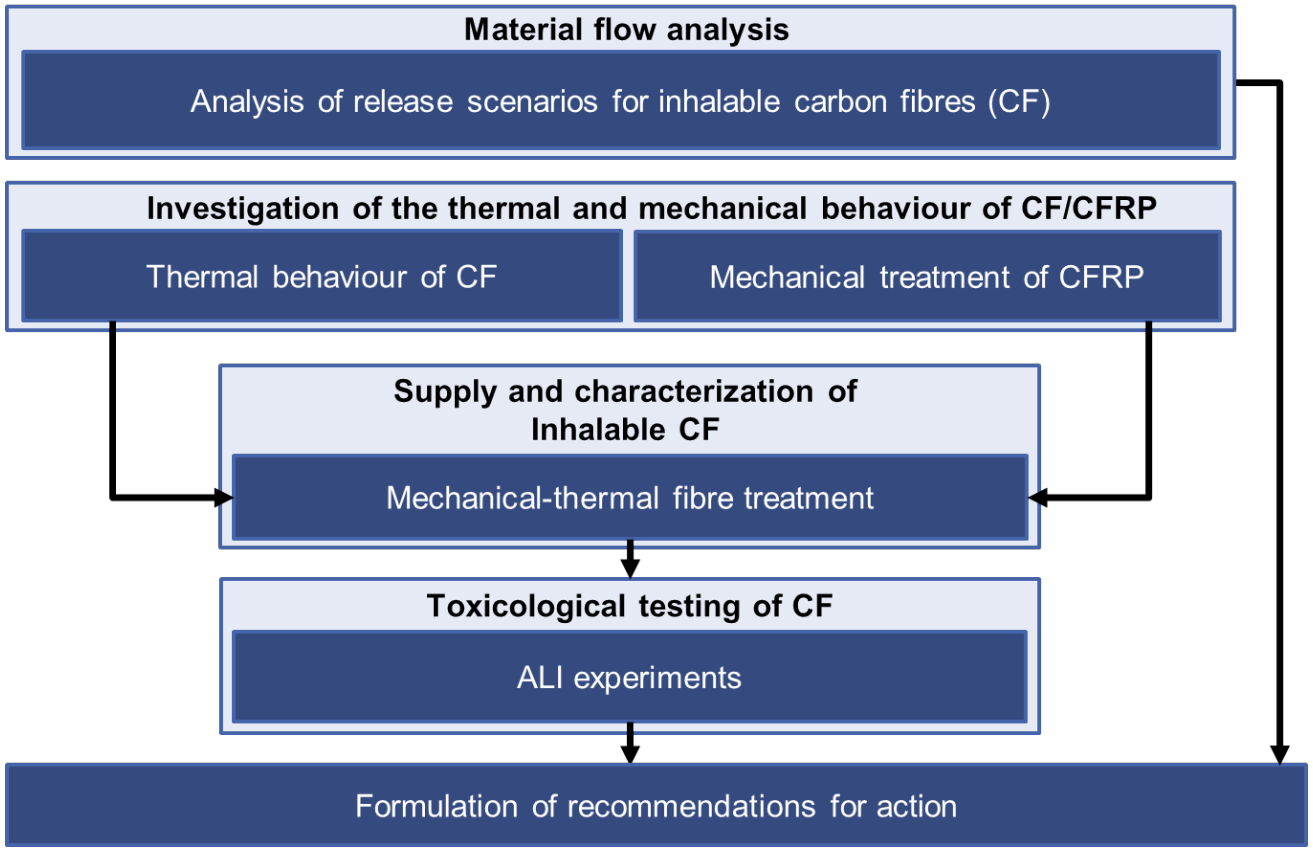
ITC
IBCS-BIP
IAB



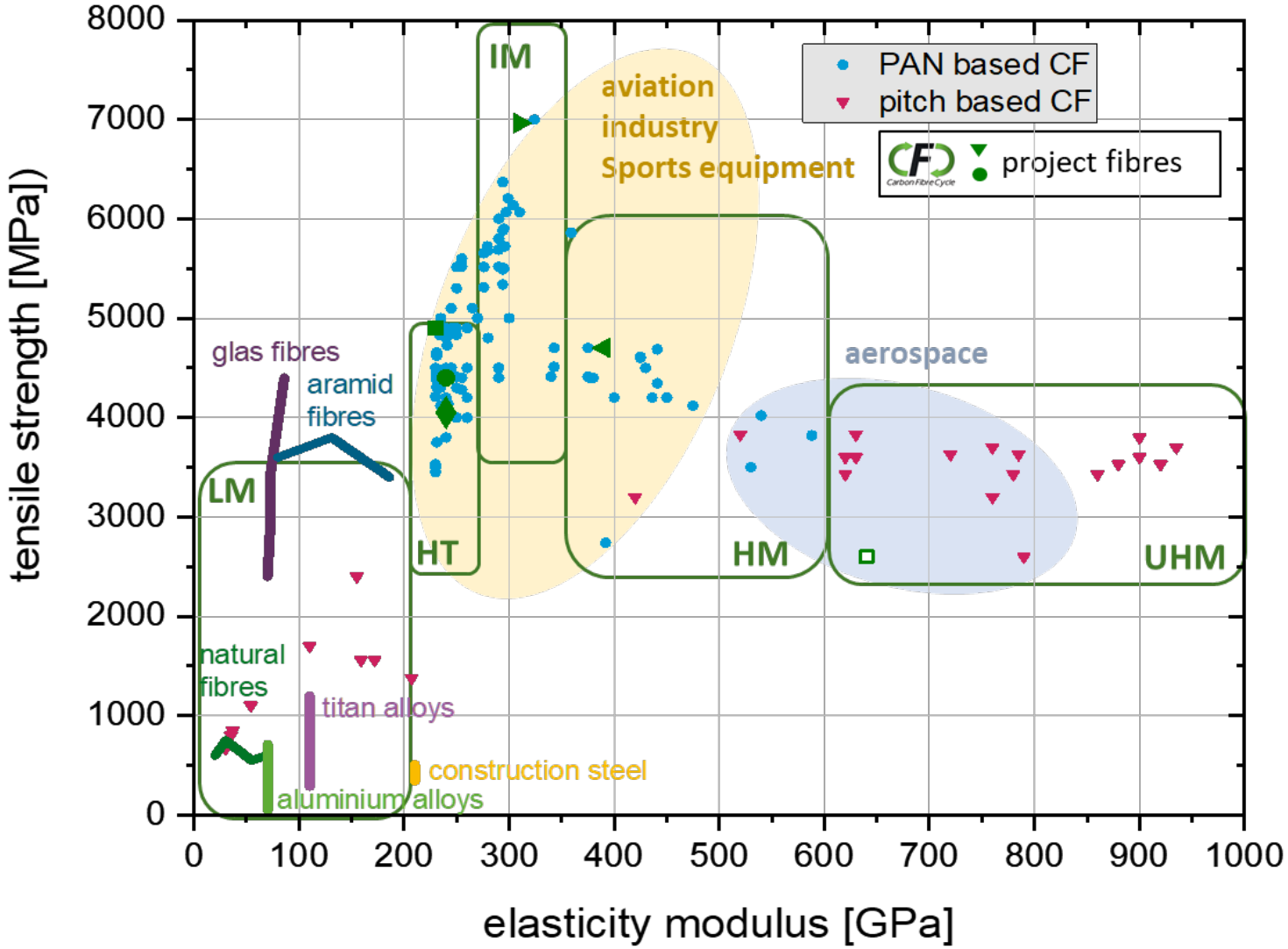
TEER Technologie der Energierohstoffe | RWTH AACHEN UNIVERSITY

Leibniz-Institut für Verbundwerkstoffe

VITROCELL® SYSTEMS

PALAS®

Carbon fibres



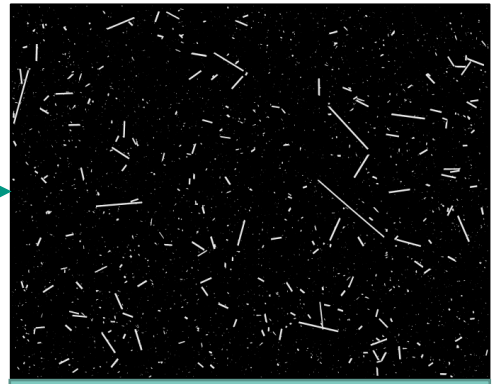
LM	**Low Modulus**
HT	**High Tensile Strength**
IM	**Intermediate Modulus**
HM	**High Modulus**
UHM	**Ultra High Modulus**

Classification based on the Japanese Association of CF Manufacturers

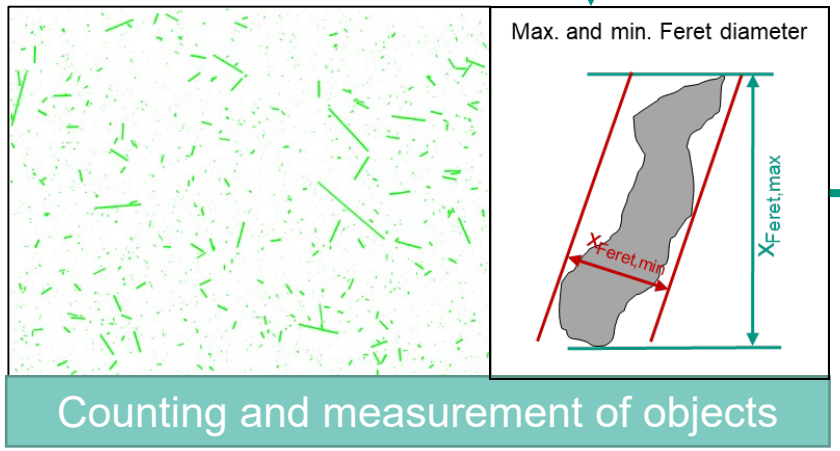
Characterisation of CF and CF fragments

Image analysis of micrographs

micrograph



Binary image



Counting and measurement of objects

Excel macro

Categorisation of objects and evaluation of data

Rejection of agglomerates

Criterium for agglomerates:

- $d_{Objekt} > d_{Rohfaser}$

Classification of objects

- Fibres
- WHO fibres
- particles

Criterium for fibres:

- Length/Diameter $\frac{L_F}{d_F} \geq 3$

Criteria for WHO fibres:

- Fibre diameter $d_F \leq 3\ \mu m$
- Fibre length $L_F \geq 5\ \mu m$
- Length/Diameter $\frac{L_F}{d_F} \geq 3$

Criterium for particles:

Length/Diameter $\frac{L_F}{d_F} < 3$

Statistical evaluation

Inhalable fibres („WHO fibres“)

Definition of World Health Organisation (WHO)

- L > 5 µm
- D < 3 µm
- L:D > 3:1

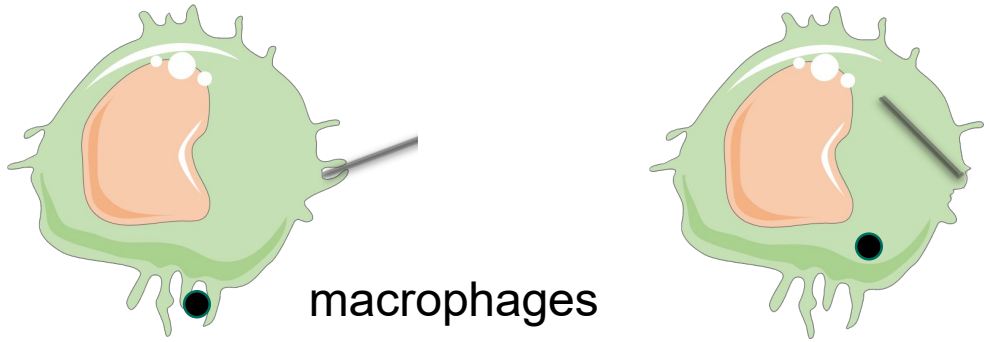
Properties increasing the risk

- biopersistancy
- rigidity

Typical disease patterns

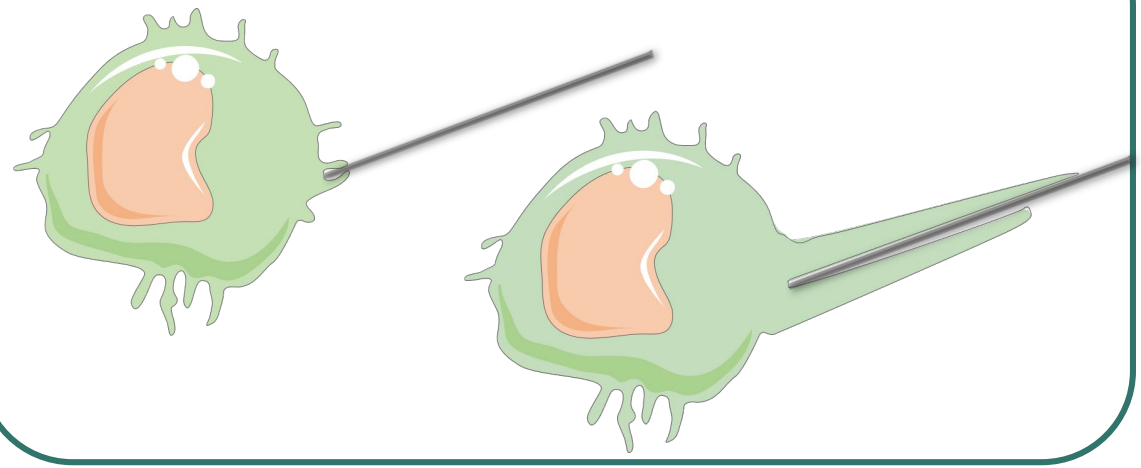
- Asbestosis (lung fibrosis)
- Lung cancer
- Mesotheliomas

Phagocytosis of particles or short fibres



macrophages

Frustrated phagocytosis of critical fibres



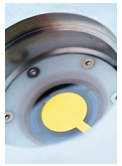
CF aerosols for toxicological testing

Thermal treatment

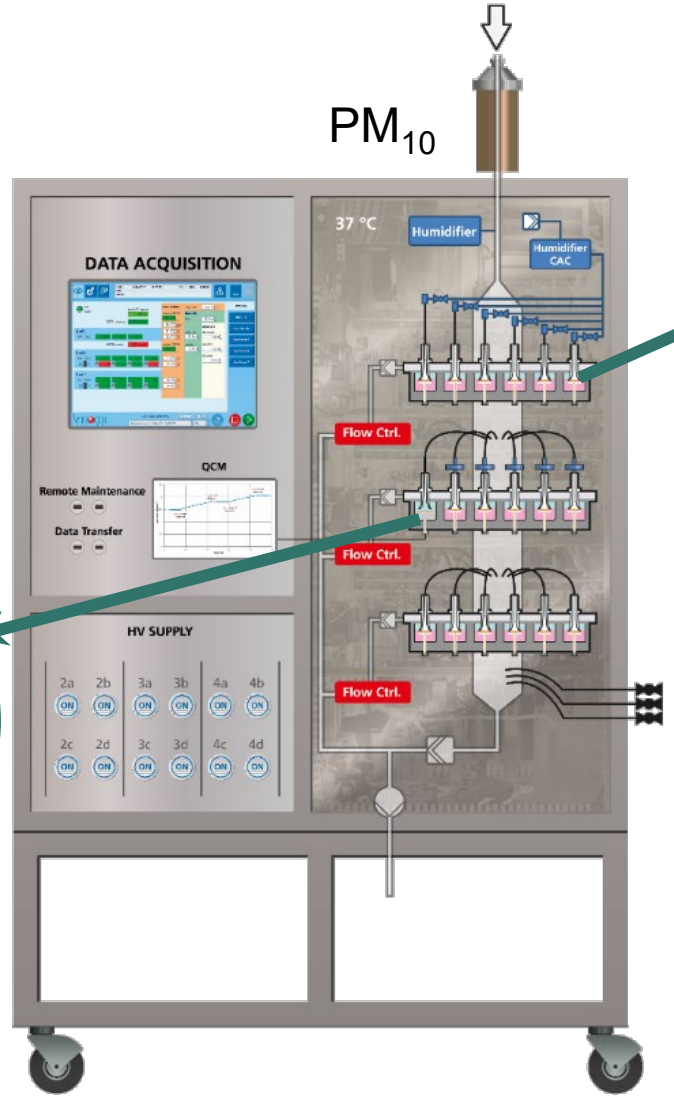
Mechanical treatment

Aerosol generation

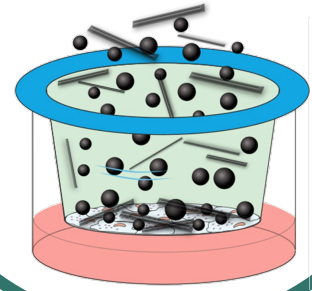
Online dose determination



PM_{10}



Air liquid interface exposure



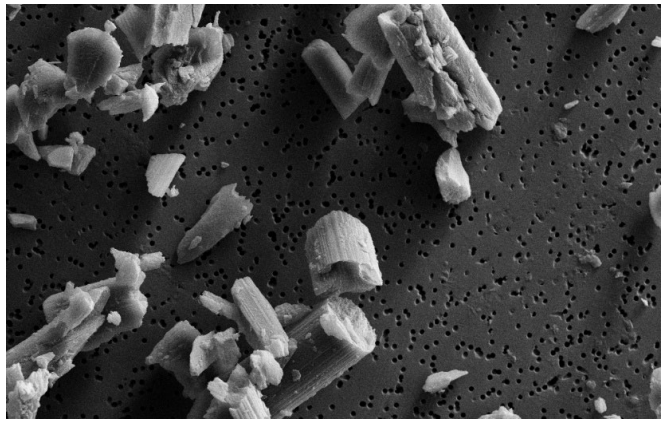
Optical particle counter WELAS

Filter / membrane

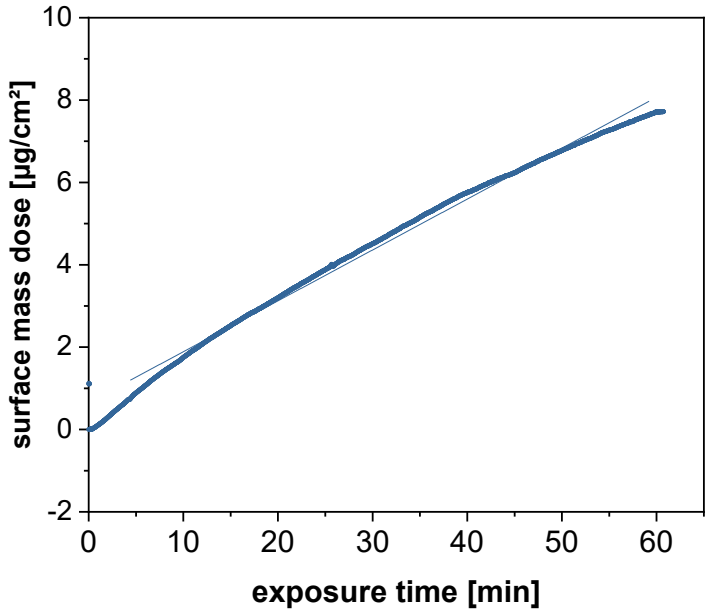
impinger

Microscopy + image evaluation

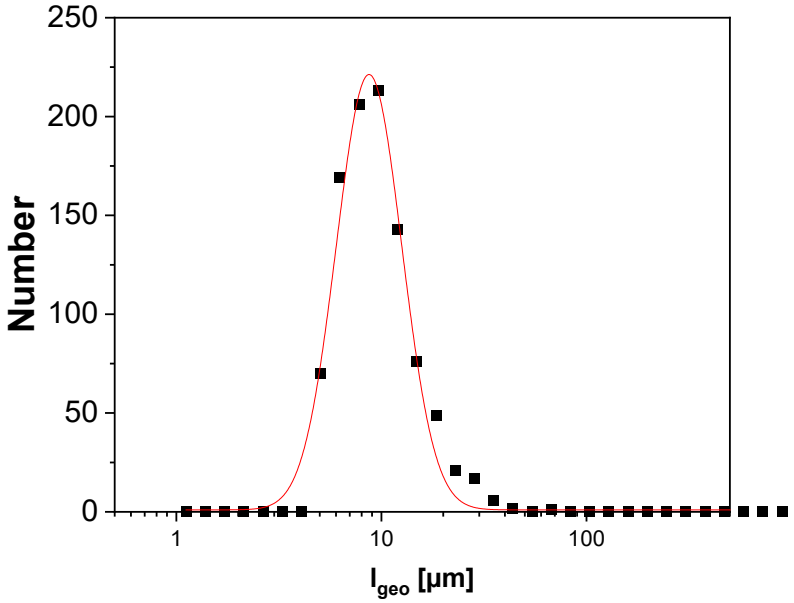
Relevant in–vitro dose of mechanically treated CF



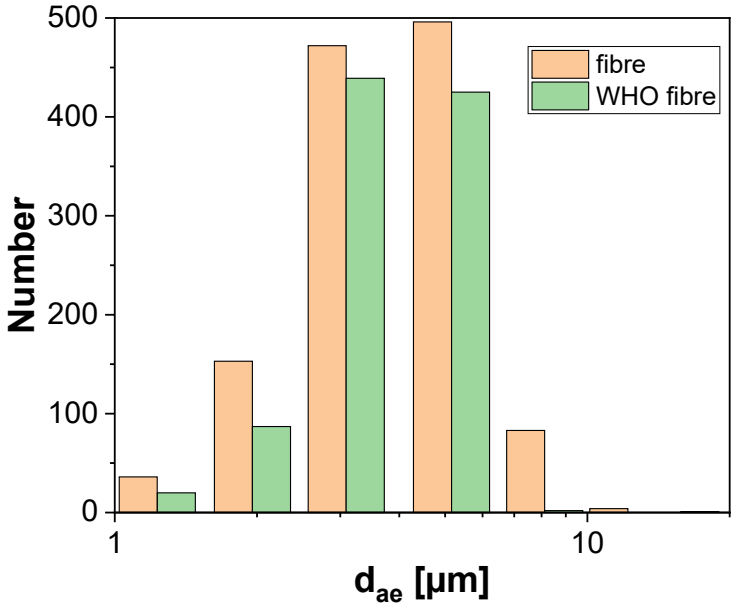
Online measurement using quartz crystal microbalance (QCM)



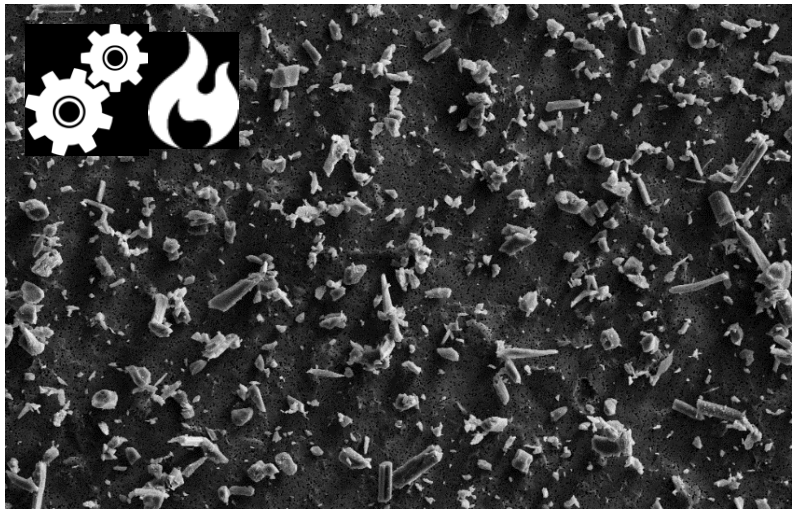
Length distribution of deposited WHO fibres



Aerodynamic equivalent diameter of deposited fibres



Exposure of pulmonary cell culture models to pre-treated carbon fibres (CF)

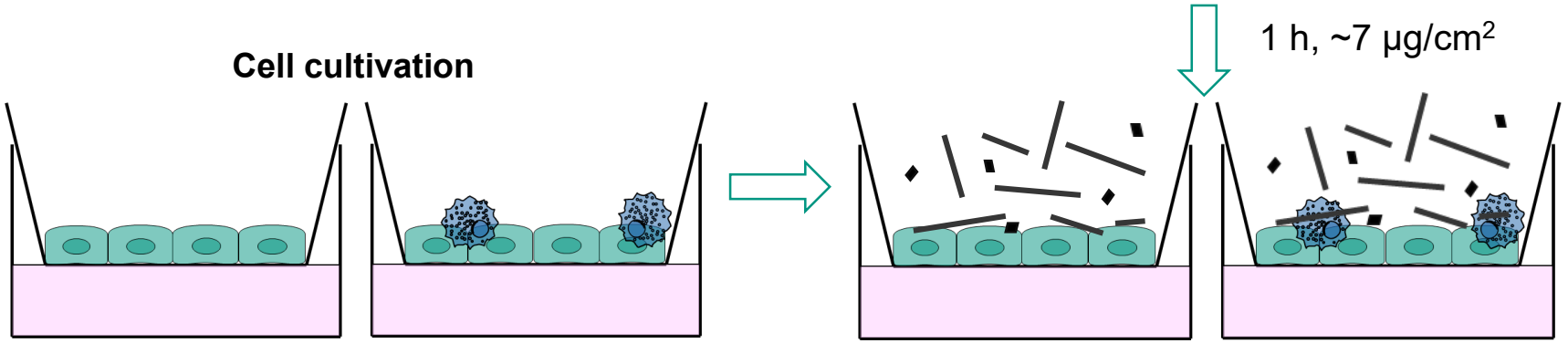


PAN based CF pre treatment

Air liquid interface exposure

Toxicological endpoints

Cell cultivation



BEAS-2B bronchial epithelial cells

dTHP-1 differentiated macrophage-like cells

HT RT-qPCR: high-throughput RT-qPCR
IL-8: interleukin 8

CF cause inflammation depending on pre-treatment

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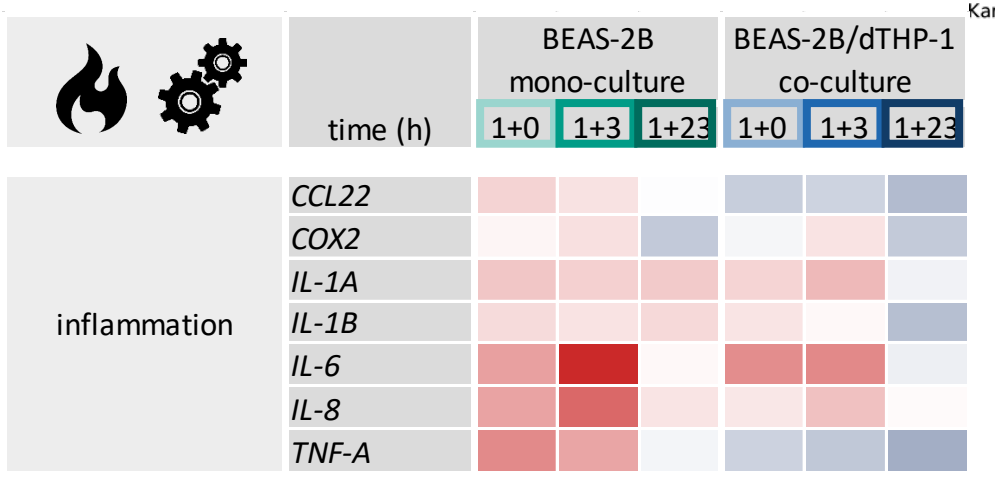
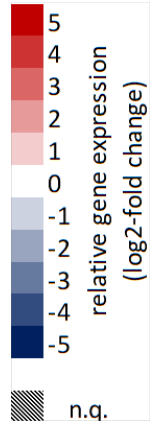
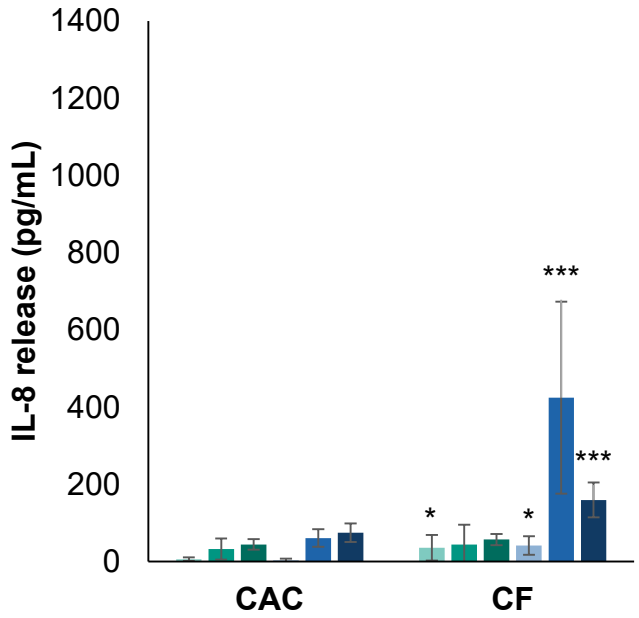
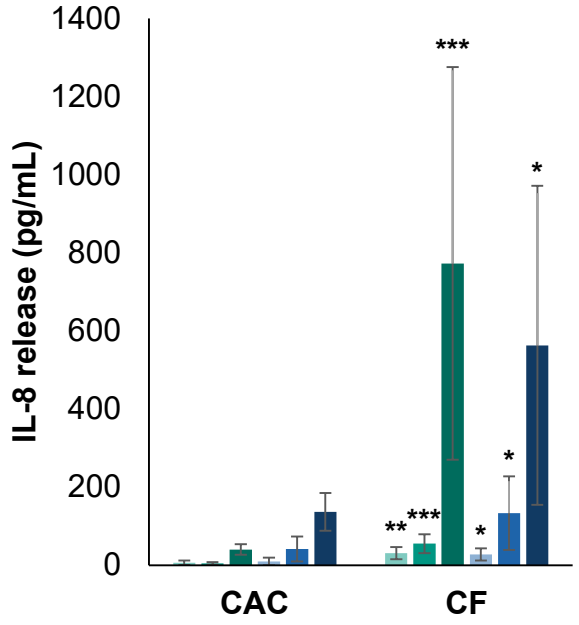
Gene expression





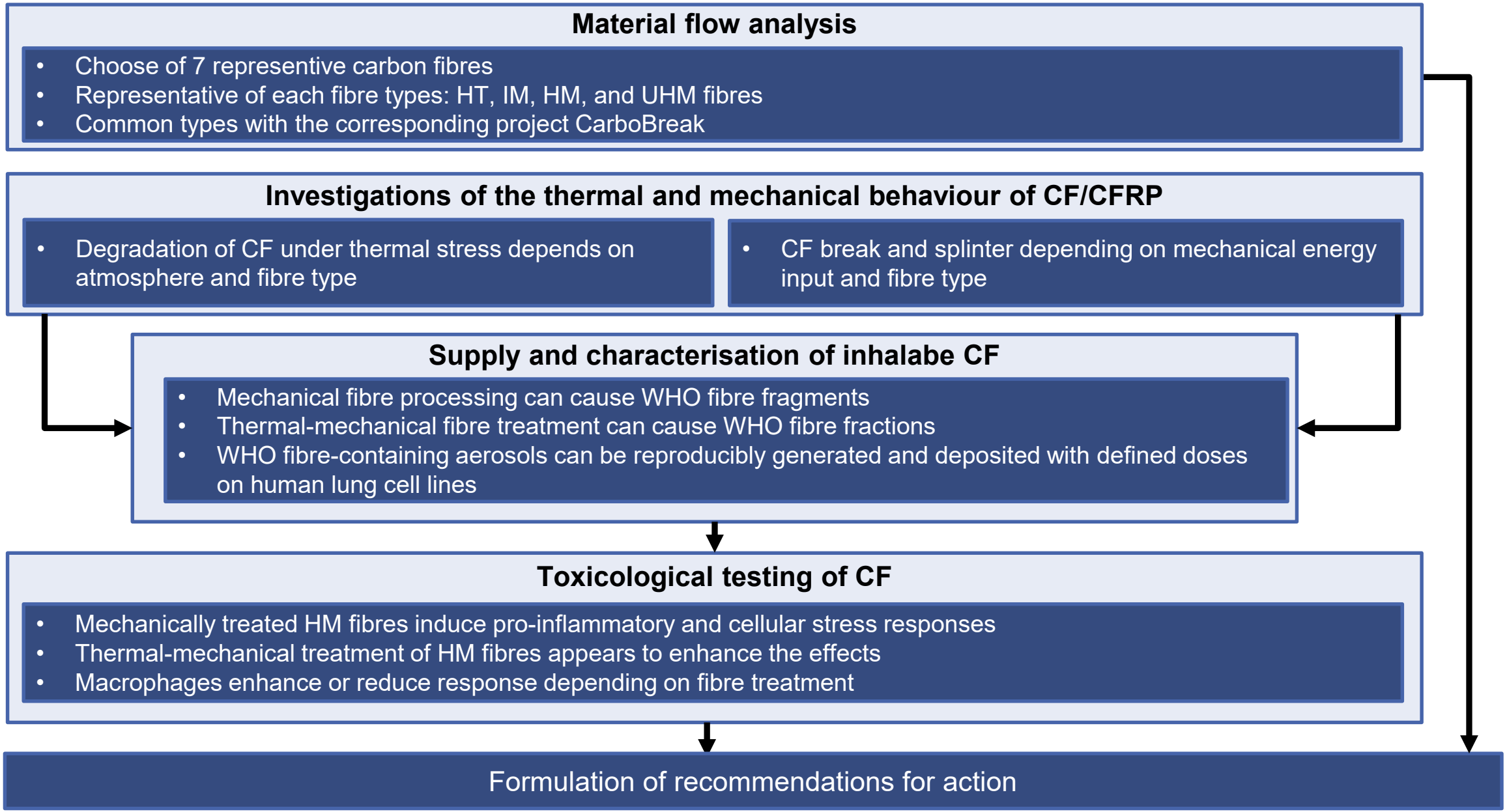
Protein release

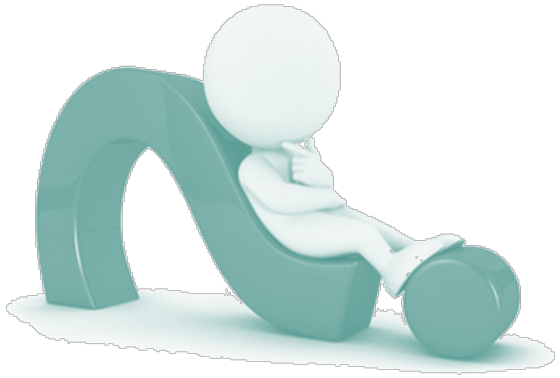




*/**/***: significant changes
(p<0.05/0.01/0.005)

CAC: clean air control
CF: carbon fibre
IL-8: interleukin 8
n.q.: not quantifiable


Material flow analysis
• Choose of 7 representive carbon fibres
• Representative of each fibre types: HT, IM, HM, and UHM fibres
• Common types with the corresponding project CarboBreak
Investigations of the thermal and mechanical behaviour of CF/CFRP
• Degradation of CF under thermal stress depends on atmosphere and fibre type
• CF break and splinter depending on mechanical energy input and fibre type
Supply and characterisation of inhalabe CF
• Mechanical fibre processing can cause WHO fibre fragments
• Thermal-mechanical fibre treatment can cause WHO fibre fractions
• WHO fibre-containing aerosols can be reproducibly generated and deposited with defined doses on human lung cell lines
Toxicological testing of CF
• Mechanically treated HM fibres induce pro-inflammatory and cellular stress responses
• Thermal-mechanical treatment of HM fibres appears to enhance the effects
• Macrophages enhance or reduce response depending on fibre treatment
Formulation of recommendations for action



Questions ?