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A lab scale measurement technique for the air-liquid interface exposure of human lung cell cultures towards particulate emissions from combustion processes

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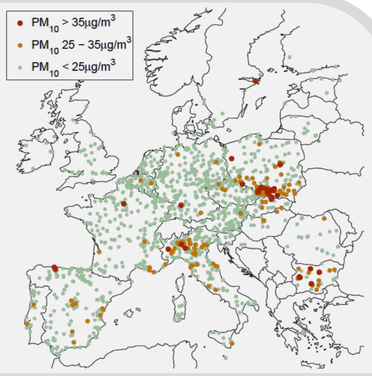
Background

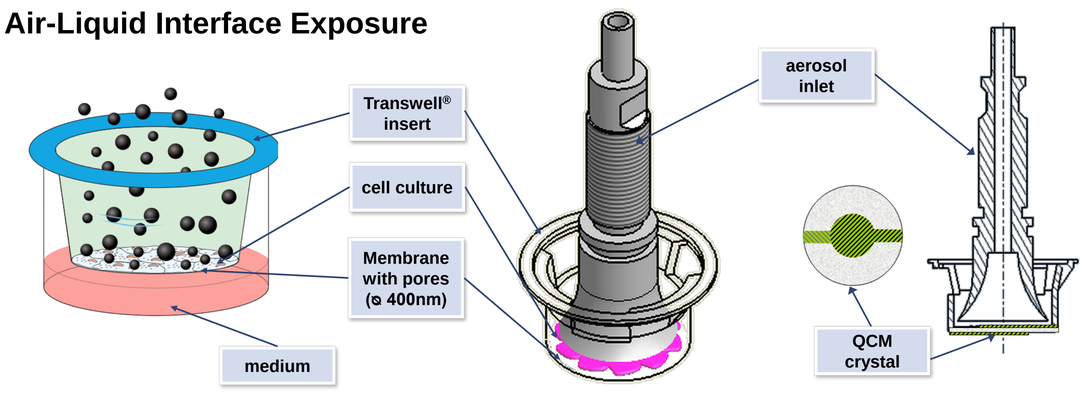
Numerical simulations by Kiesewetter et al. [1] show: also in 15 years the European limits for PM_{10} immissions will not be complied.

figure: predicted PM_{10} concentrations in 2030 [1]

➔ **New assessment methods for biological responses of immissions are required.**



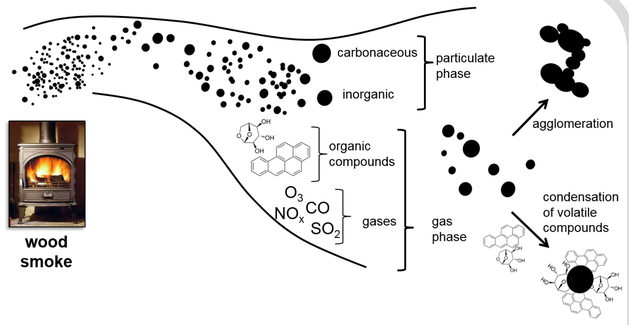
Air-Liquid Interface Exposure



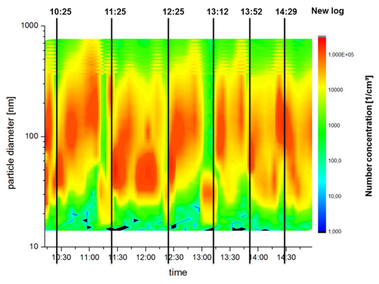
Scheme of a cell culture exposure at the air-liquid interface towards airborne nanoparticles led towards the surface by the aerosol inlet and on the sensor of a quartz crystal microbalance for online monitoring of dose.

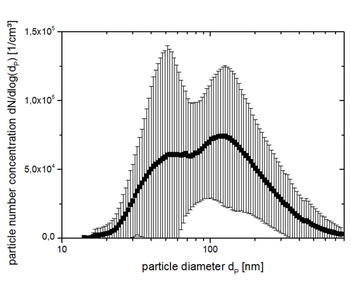
Aerosol characterization

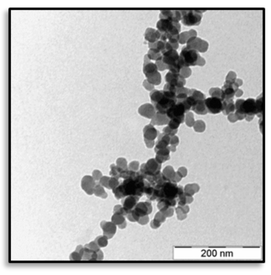
- Wood combustion aerosol is a complex particle collective with varying properties.
- The particle size distribution (determined by SMPS in the Exposure System) changes depending on the burning phase.



wood smoke







Number size distributions of wood smoke aerosol, measured with SMPS (TSI3071) in the exposure system with a dilution factor of 10. Single measurements over time (left) and the mean ± standard deviation of all measurements (middle). The TEM image shows a typical soot agglomerate (right).

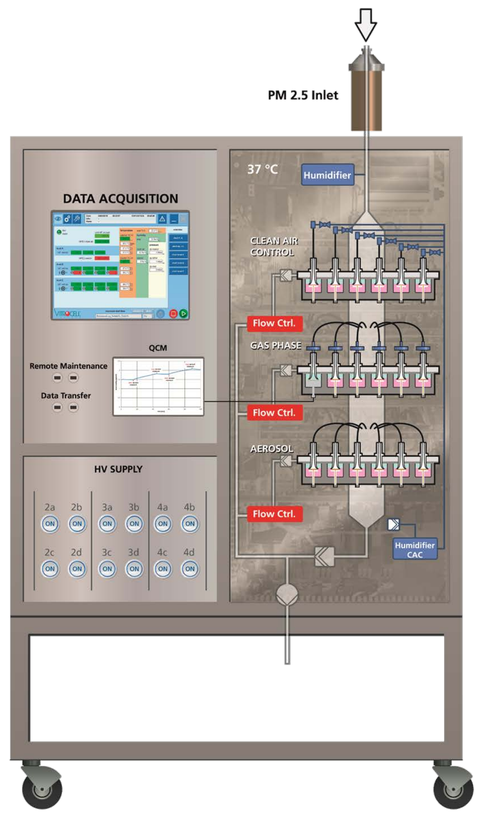
A survey of successively applied and analyzed aerosols, cell cultures, and biological effects

aerosols	**industrial nanoparticles**	titanium dioxide, silicon dioxide, silver, platinum
	combustion aerosols	emissions from wood stoves, marine diesel engines, wood-fired boilers, pellet boilers, municipal waste incinerators
cell cultures	**human lung epithelial cells**	A549, BEAS-2B, SK-MES-1
	macrophages	THP-1, RAW264.7
	human endothelial cells	HUVEC
		co-cultures from epithelial cells and macrophages and/or endothelial cells
biological effects	**markers for inflammatory processes**	release of IL-8, IL-6, MCP-1, expression of ICAM-1
	markers for cytotoxicity	release of LDH, reduction of AlamarBlue
	markers for oxidative stress	expression of HMOX-1
	markers for metabolism of foreign substances	expression of CYP1A1

Karlsruhe Exposure System

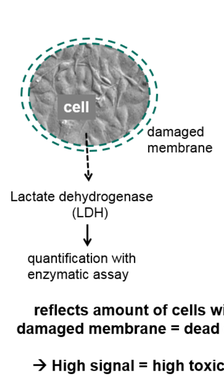
The Karlsruhe Exposure System is a lab scale measurement system for the air-liquid interface exposure of human lung cell cultures towards airborne nanoparticles under well defined conditions.

Specification	
Cell exposure	Up to 24 cell cultures: 4 VITROCELL® 6/6 CF stainless steel modules of 6 well format
Aerosol	• Direct aerosol sampling via size selective inlet: $PM_{2,5}$ inlet with 1 m^3/h • Aerosol conditioning to 37°C and 85 % relative humidity.
Negative control	Humidified synthetic air
Dose enhancement	Electrostatic deposition by applying a potential of up to 1500 Volts is optional for each cell culture separately
Dose monitoring	• Online surface dose monitoring by a Quartz Crystal Microbalance (QCM) in µg/cm². • Integrated sampling probes in the reactor for aerosol measurements a for example SMPS, FTIR, filter …
Automatization / Quality insurance	Integrated standard routines for leak tests, exposure experiments and more with comprehensive data acquisition
Dimensions	2187 x 1124 x 623 mm (H x B x T)



Scheme of the Karlsruhe Exposure System for toxicity measurements of airborne nanoparticles.

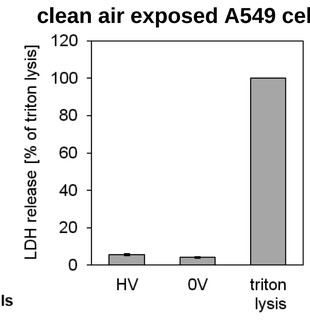
Biological responses: LDH release for cytotoxicity assessment



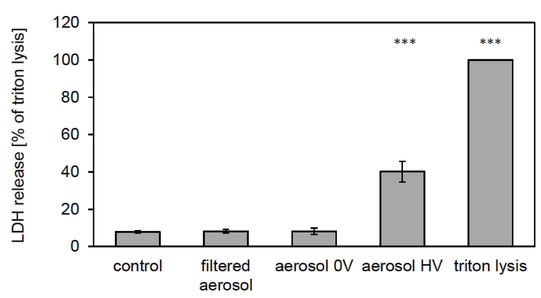
reflects amount of cells with damaged membrane = dead cells

→ High signal = high toxicity

Influence of the electrical field to clean air exposed A549 cells



Cytotoxicity induced by combustion aerosol



particle dose [µg/cm²]	0	0	0.30±0.10 - 0.34±0.12	1.18±0.40 - 1.33±0.29	-

- Electrostatic deposition does not induce toxicity
- Higher particle dose of wood smoke aerosol leads to acute toxicity

Conclusion

- We developed a lab scale measurement system for the air-liquid interface exposure of human lung cell cultures towards airborne nanoparticles.
- Air-liquid interface exposure is the method of choice to investigate in-vitro the biological effects of ultrafine particle emissions.
- Emissions from biomass burners can cause cytotoxicity at elevated dose.
- Further endpoints as multi omics are under investigation within the Helmholtz Virtual Institute HICE

Acknowledgement
This work was supported by the KIT-Seed-Fonds and by the Helmholtz Association within the virtual institute HICE.
Further Information: www.hice-vi.eu
The work is also part of the European projects Quality-Nano and NanoMILE.

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