adolphe merkle institute
excellence in pure and applied nanoscience
UNIVERSITY OF FRIBOURG SWITZERLAND

In-vitro genotoxicity of filtered diesel exhausts: impact of filtration and catalysis

S. Steiner

18th ETH-Conference on Combustion Generated Nanoparticles

june 2014

Exhaust toxicity – effects of filtration

Presented two years ago:

Experiment:

Direct exposure of human lung cells to freshly produced diluted diesel exhaust for 6 hours

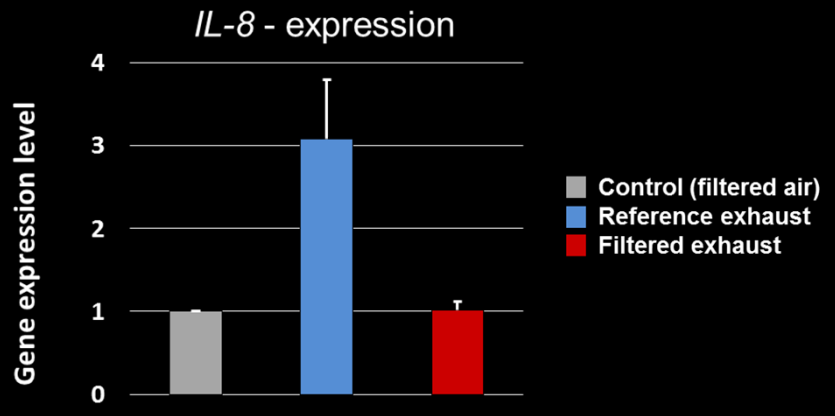
Control: filtered air
Reference: unfiltered exhaust
Filtered: uncoated DPF, no DOC

Core findings:

Particles are eliminated
Effects on gases weaker

Exhaust comp.	REF	DPF	% change
Particles	4.8E+08	1.9E+03	-99.9996
CO (ppm)	33.2	32.6	-1.7
HC (ppm)	11.5	8.8	-23.6
NO_x (ppm)	10.7	11.0	2.8

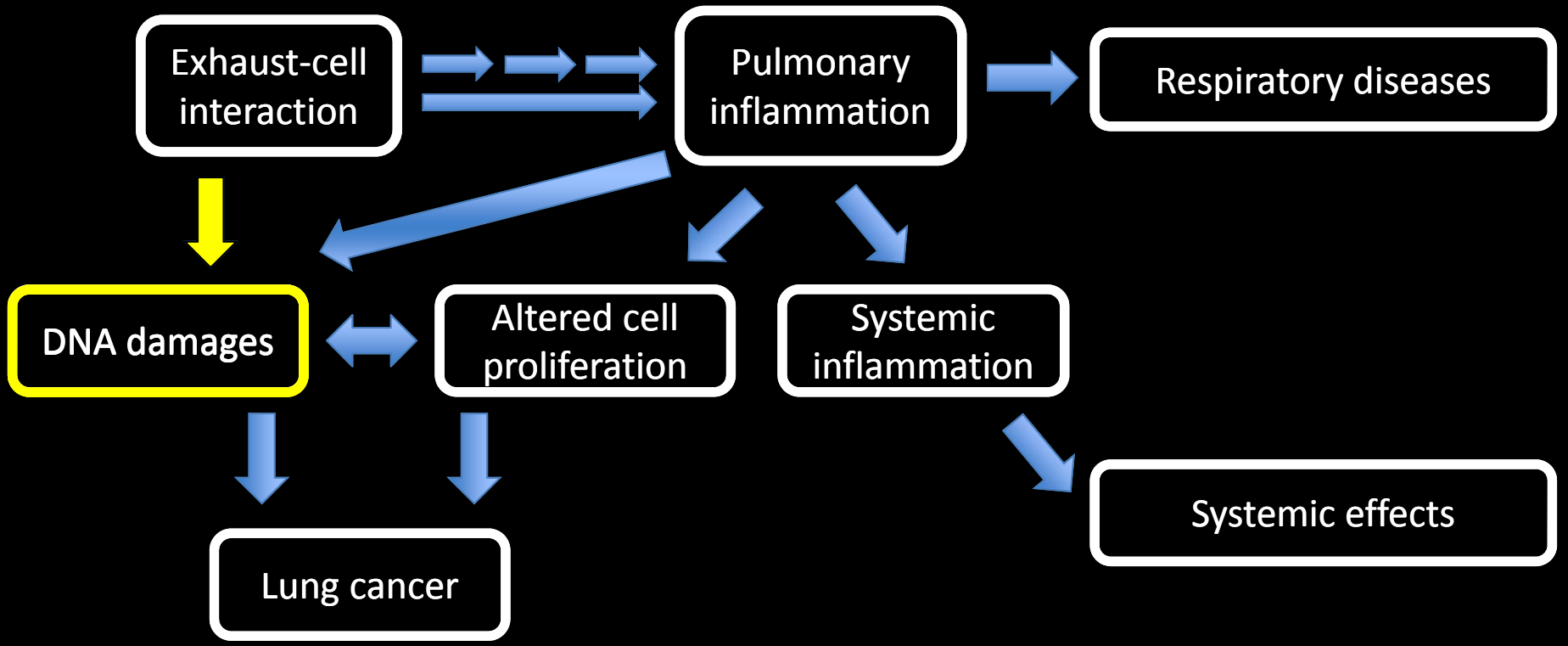
no pro-inflammatory stimulation after filtration



Exhaust toxicity – effects of filtration

Conclusion:

Exhaust filtration may reduce exhaust toxicity…
…but exhaust genotoxicity is yet to be tested

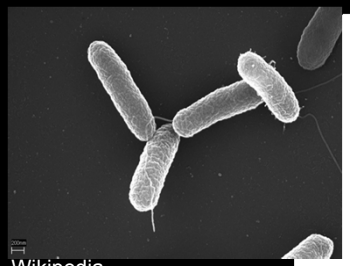


e.g. Pope and Dockery, 2006. Journal of the Air & Waste Management Association 56. Künzli and Tager, 2005. Swiss Medical Weekly 135

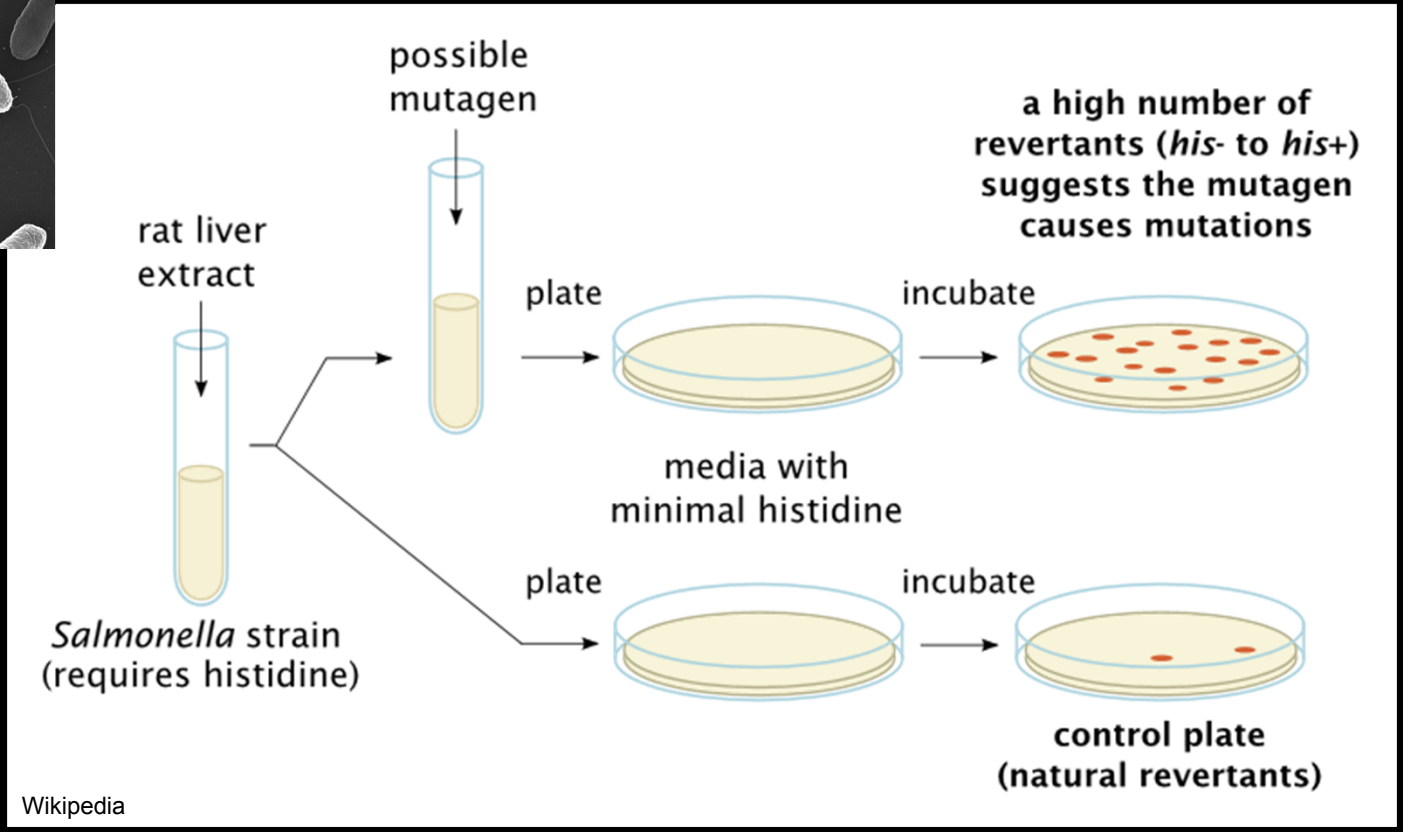
Completing the data on filter effects

Repeat the experiments, but use Ames-test bacteria as test-organism

Salmonella typhimurium



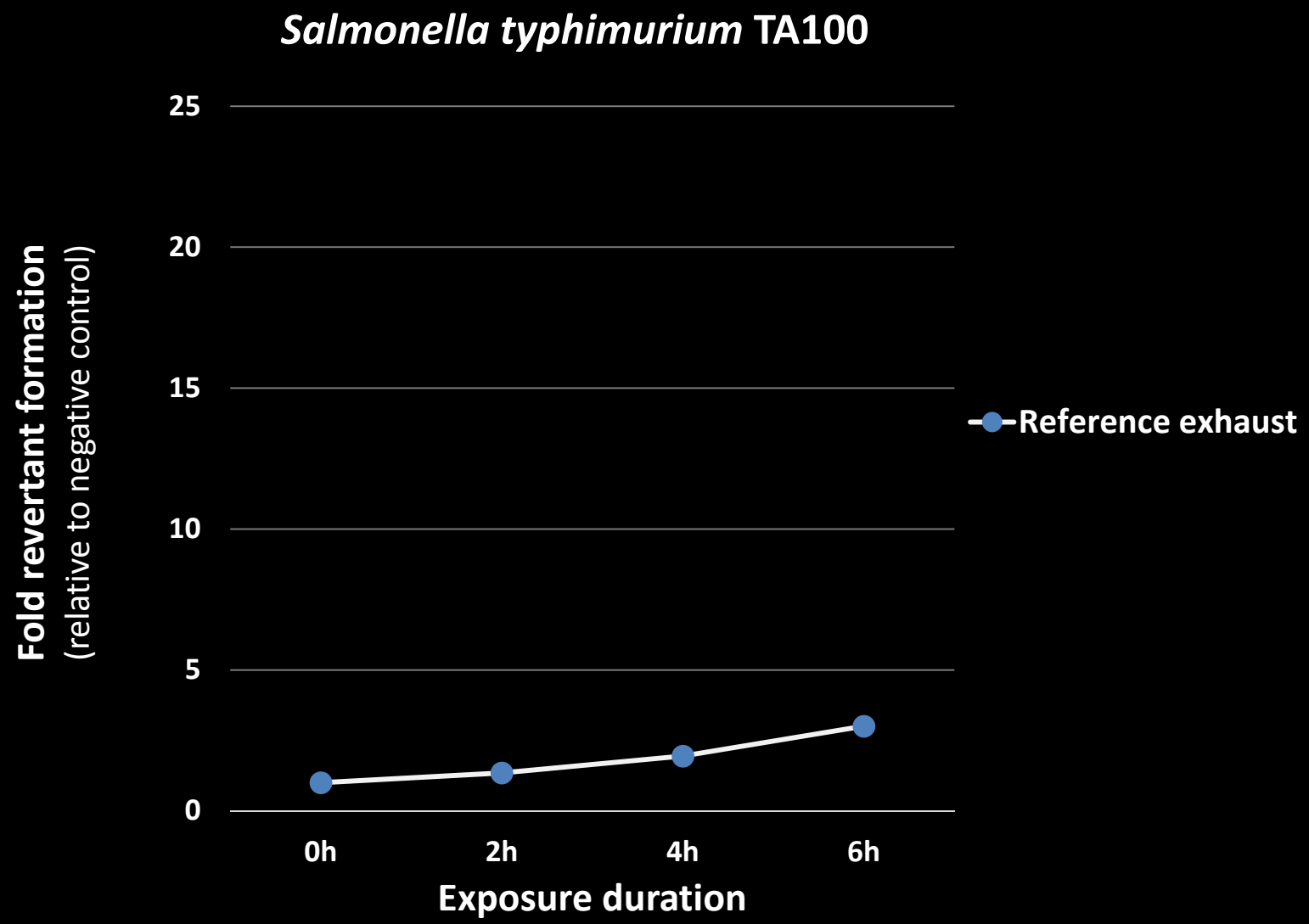
Wikipedia



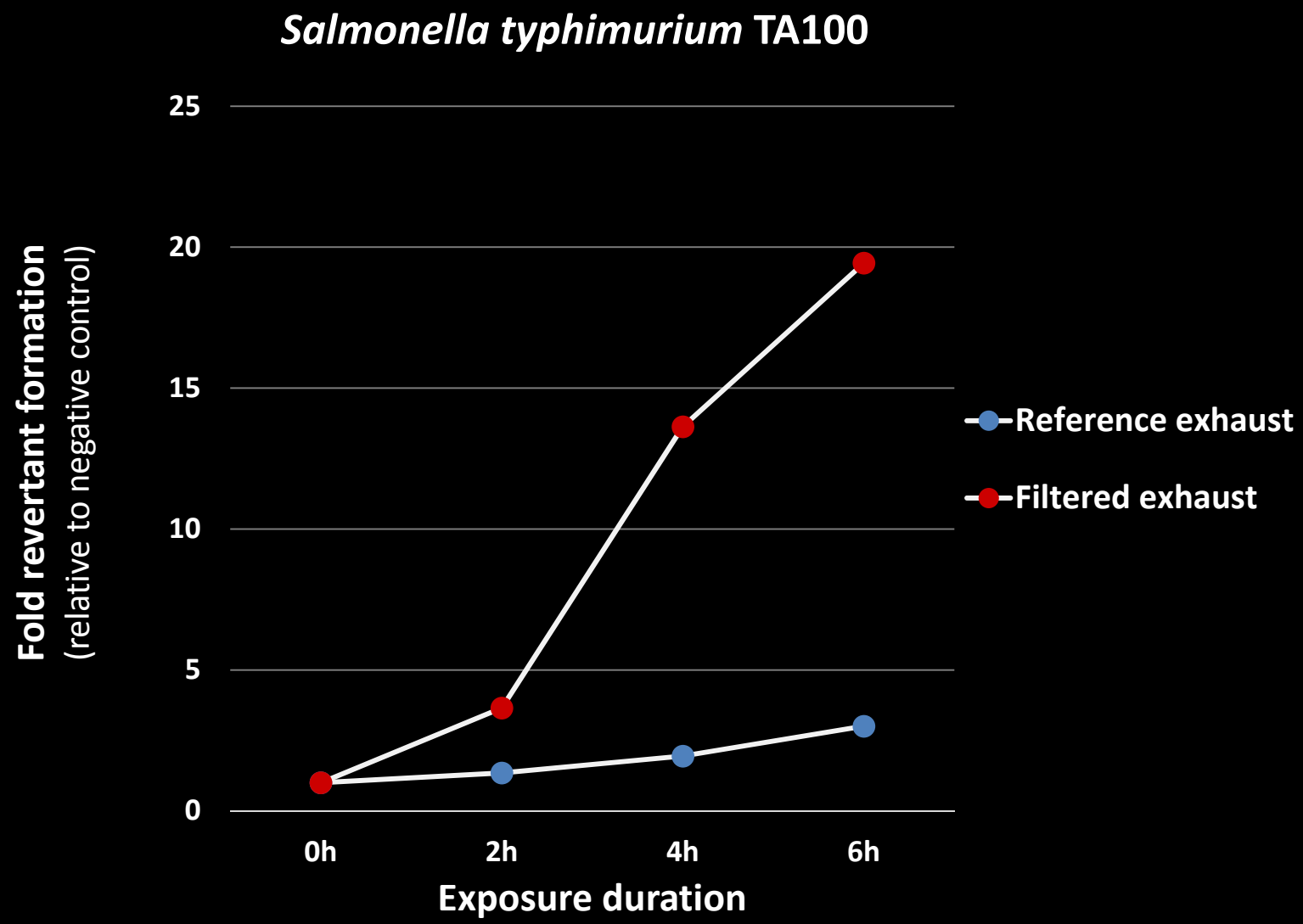
Wikipedia

Exposure to control air / reference exhaust / filtered exhaust for 2, 4, and 6 hours

Completing the data on filter effects



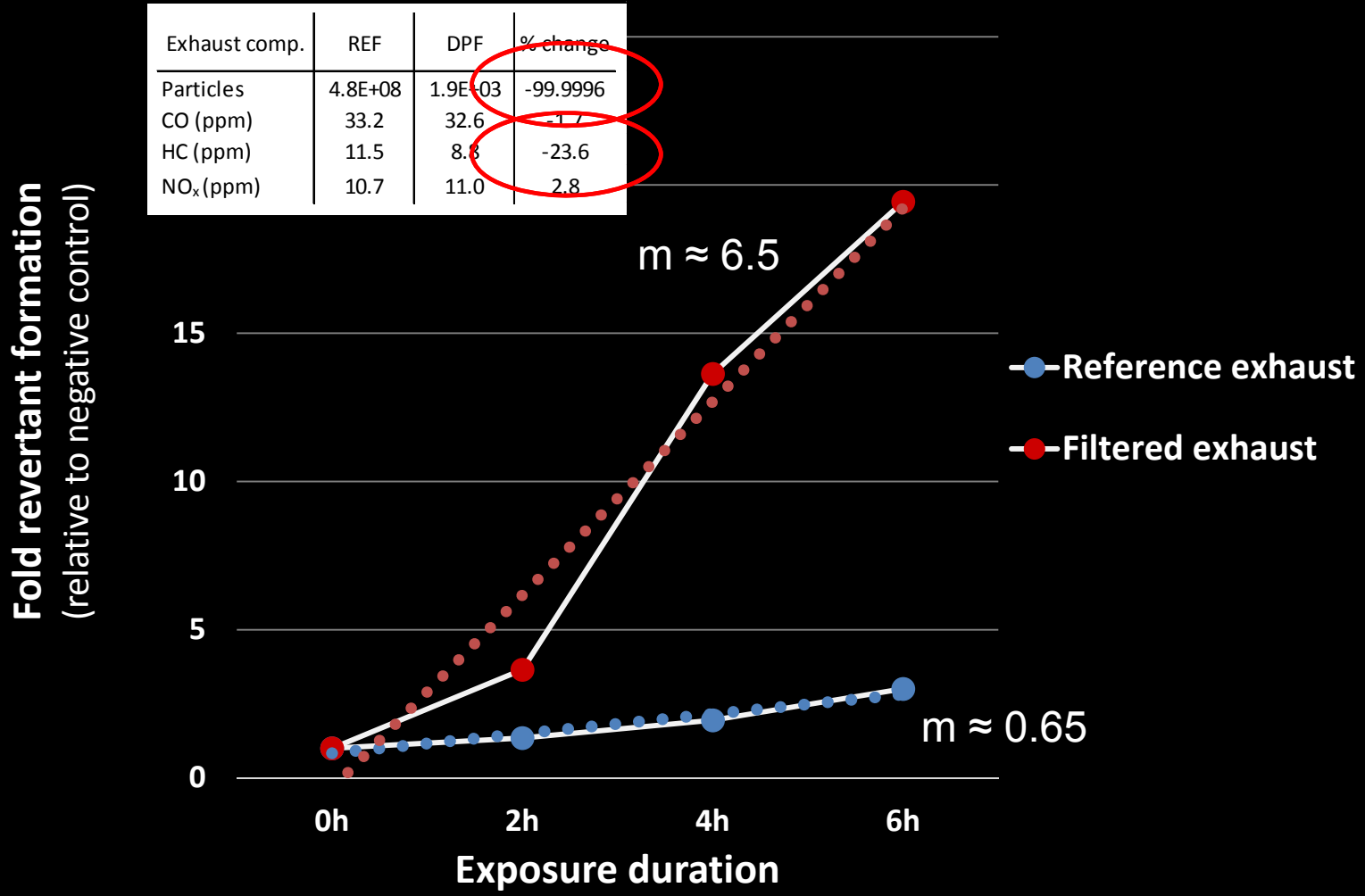
Completing the data on filter effects



Completing the data on filter effects

Salmonella typhimurium TA100

Exhaust comp.	REF	DPF	% change
Particles	4.8E+08	1.9E+03	-99.9996
CO (ppm)	33.2	32.6	-1.7
HC (ppm)	11.5	8.8	-23.6
NO_x (ppm)	10.7	11.0	2.8

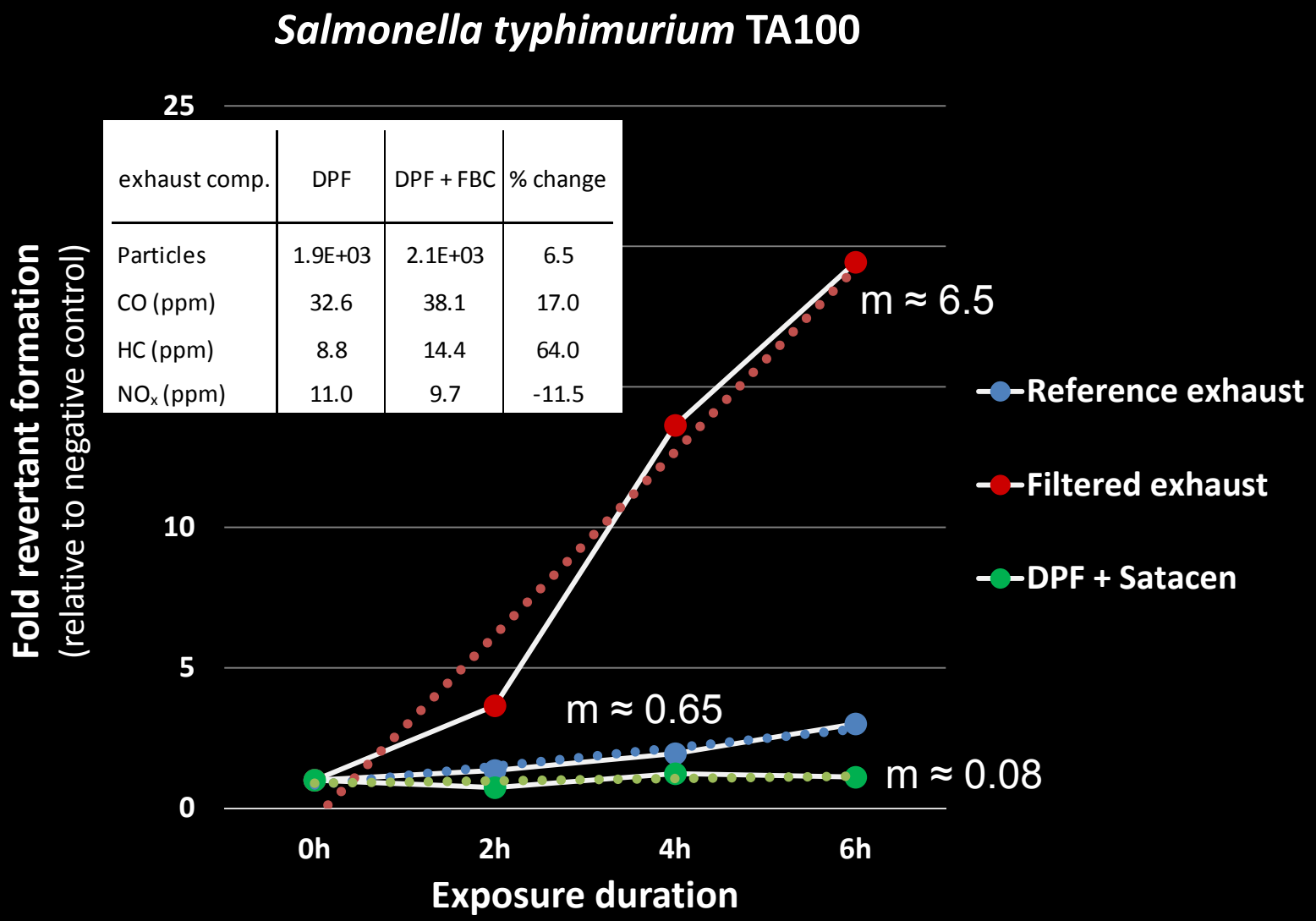


Results and discussion – part I

- **Reference exhaust AND filtered exhaust act mutagenic**
- **Rate of revertant formation: 10 x increased by filtration**
- **→ Particles?**
  - **Lack of nucleation centers downstream the filter**
- **→ HC?**
  - **Known from analytical studies (recall the previous talk):**
    - Filters may act as reactors → secondary emissions
    - Possible formation of highly genotoxic compounds, e.g. NPAHs
    - Highly dependent on catalytic activity in the filter

      (e.g. Heeb et al. 2010, Environmental Science and Technology 44, Heeb et al. 2007, Environmental Science and Technology 41, Heeb et al. 005, SAE 2005-26-014.)
- **→→→ Perform the same experiment with a catalyzed filter**
  - Fuel borne catalyst (FBC) → same filter can be used
  - Satacen®3 (Innospec), 40ppm Fe

Inclusion of a catalyst



exhaust comp.	DPF	DPF + FBC	% change
Particles	1.9E+03	2.1E+03	6.5
CO (ppm)	32.6	38.1	17.0
HC (ppm)	8.8	14.4	64.0
NO_x (ppm)	11.0	9.7	-11.5

Results and discussion - part II

- **Addition of a catalyst eliminates exhaust genotoxicity**
  - Increased HC-concentration
  - Particle number marginally increased
  - More CO, less NO_x
    → most likely cause: HC-composition
  - Penalty towards other effects of the non-catalyzed filter (pro-inflammation, data not shown)

- **This effect is dependent on exhaust filtration**
  - FBC without DPF: genotoxicity = Reference (data not shown)
  - → Retention of HCs on filter is crucial (reactor)

Conclusions

- **DPFs may increase exhaust toxicity**
  - This is a function of the catalytic activity on the filter
- **The toxicological relevance of secondary emissions is strongly supported**
  - Formation of secondary emissions is reported in analytical studies
  - Despite low concentrations, they can increase exhaust toxicity
  - This is not restricted to genotoxicity
- **Balanced filter catalysis and the filter itself are equally important for exhaust de-toxification**

Thank you for your attention

Bern University of Applied Sciences
Engineering and Information Technology

adolphe merkle institute
excellence in pure and applied nanoscience
UNIVERSITY OF FRIBOURG SWITZERLAND

TTM Technik Thermische Maschinen
Andreas C. R. Mayer

EMPA
Materials Science & Technology
Norbert Heeb

UNIVERSITÄT BERN
Peter Gehr
Loretta Müller (former)

Funding:

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Swiss Confederation
Federal Office for the Environment FOEN

VSS lubes

EVIUP ERDÖL-VEREINIGUNG UNION PÉTROLIÈRE

Adolphe Merkle Foundation