

How does asphalt dust affect our health?

Preventive measures to reduce the adverse health impact of traffic-related air pollution
(PrevenTAP)

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28.03.23

Air pollution particulate matter

A global health issue

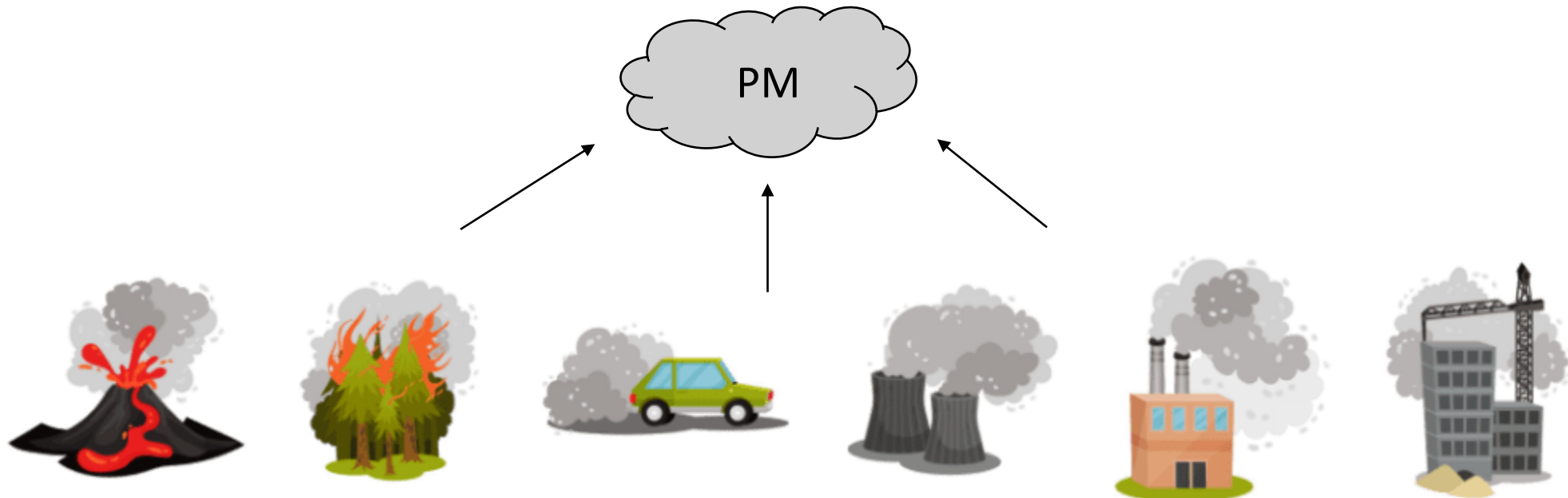
- Particulate matter (PM)
 - PM₁₀ – Particles < 10 µm in aerodynamic diameter
 - PM_{2.5} – Particles < 2.5 µm in aerodynamic diameter
 - UFP - aerodynamic diameter < 0.1 µm
- A leading environmental mortality risk factor
 - Estimated 4.14 million premature deaths in 2019
- Cardiovascular and respiratory diseases
- Wide range of effects throughout the body
 - Metabolic disorders, diabetes, IBD, neurodegenerative disease and neurodevelopment, adverse pregnancy outcomes etc.



Air pollution particulate matter

A global health issue

- Complex mixture of particles from different sources
- Identifying the sources of particles that contributes to adverse health effects is important so that mitigating measures can be implemented



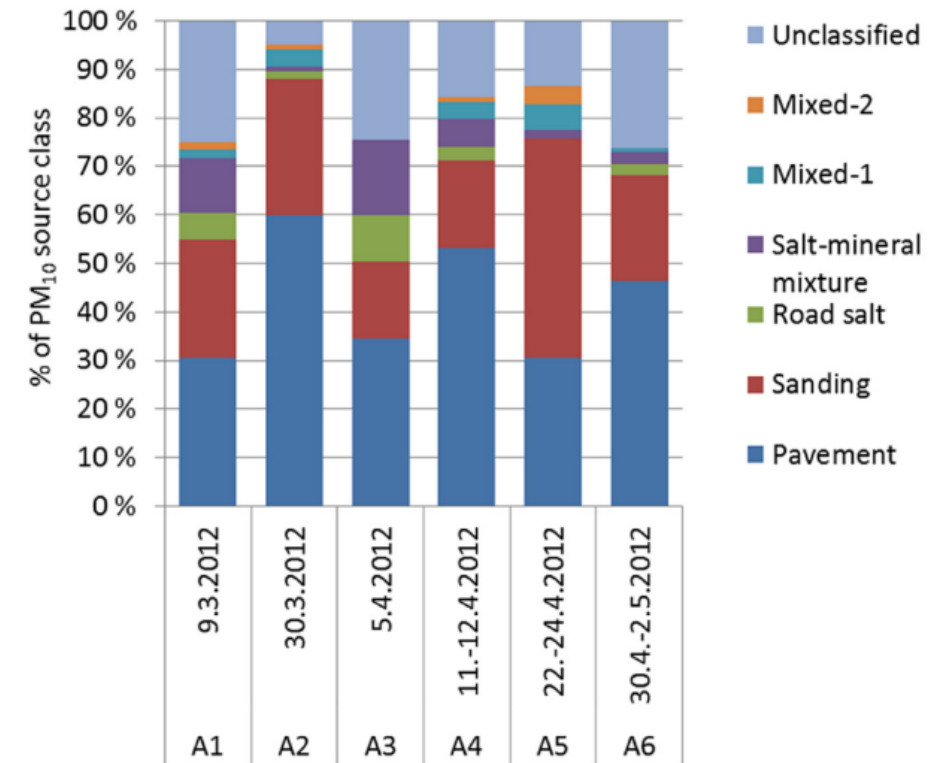
Traffic-related particulate matter

- Consists of a mixture of particles from fuel combustion and non-combustion sources
- Combustion-derived emissions has received a lot of attention
- Wear of tires, brakes and road surface
- Resuspension of road dust



Road wear particles

- Asphalt consists of crushed stone aggregate (94-95%) and bitumen (5-6%)
- Emissions consists primarily of mineral dust from stone aggregate
- Organic fraction in bitumen → PAH
- **Nordic countries:** Large portion of PM_{10} come from stone aggregate due to use of studded tires



PrevenTAP

Project from the Norwegian Council of research (2017-2021) involving Norwegian Institute of Public Health (NIPH), St Olavs Hospital, Norwegian University of Science and Technology (NTNU), Norwegian Public Roads Administration, Geological Survey of Norway (NGU) and different international collaborations

PrevenTAP

- Human exposure chamber study, *in vivo* studies in animals, *in vitro* studies in different cell models, and chemical analysis

Main research questions:

- Which size fractions are most important for the different diseases?
- Which type of sources are most important for health effects?
- Effects of coarse road wear particles
 - How different stone material in pavement affects potential health effects?
 - Tunnels paved with two different stone materials
 - Particle samples of different mineralogical composition
 - Will the combination of road wear PM with exhaust PM give differential effects?
 - Combined exposure to road wear particles and diesel exhaust particles
 - May road wear particles induce other health effects than exhaust particles?

PrevenTAP

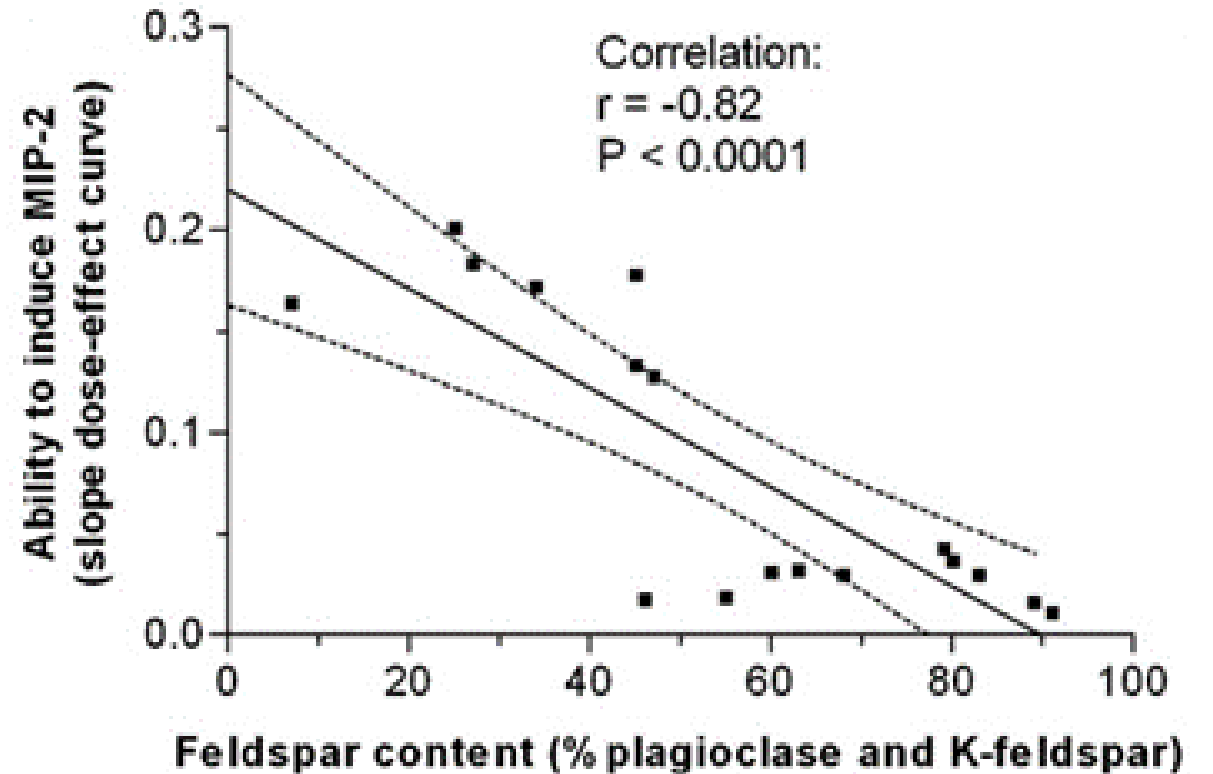
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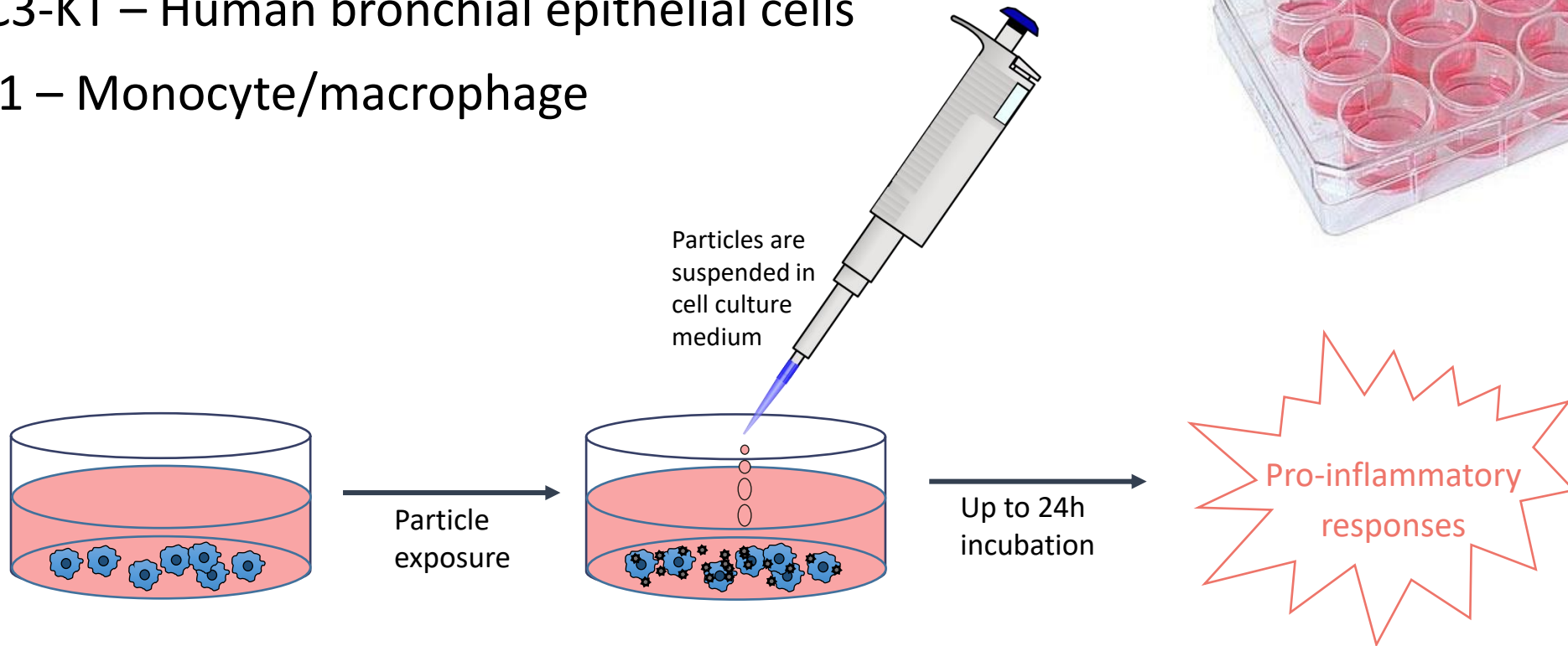


Mineral samples with high content of **feldspar** minerals appear to be **less potent** in inducing inflammatory responses



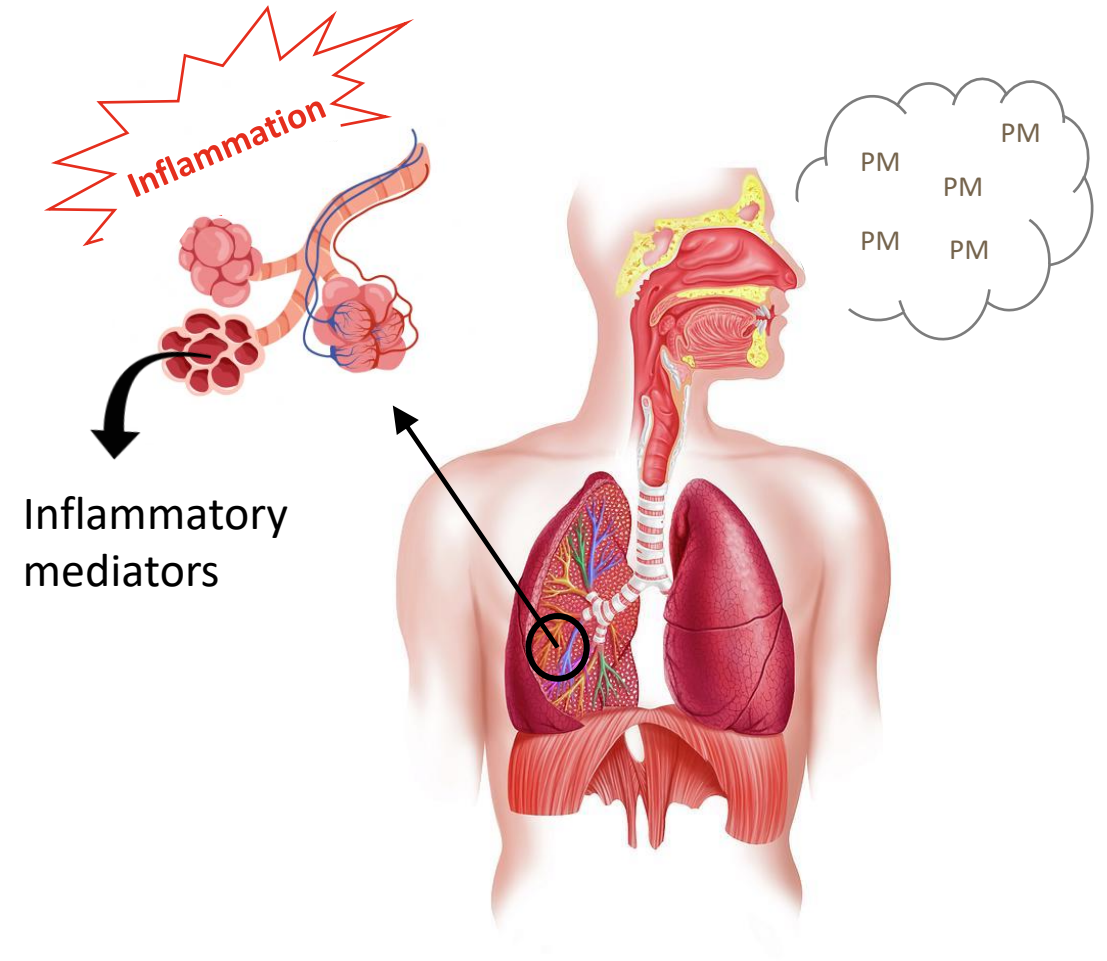
Cell cultures and study design

- HBEC3-KT – Human bronchial epithelial cells
- THP-1 – Monocyte/macrophage



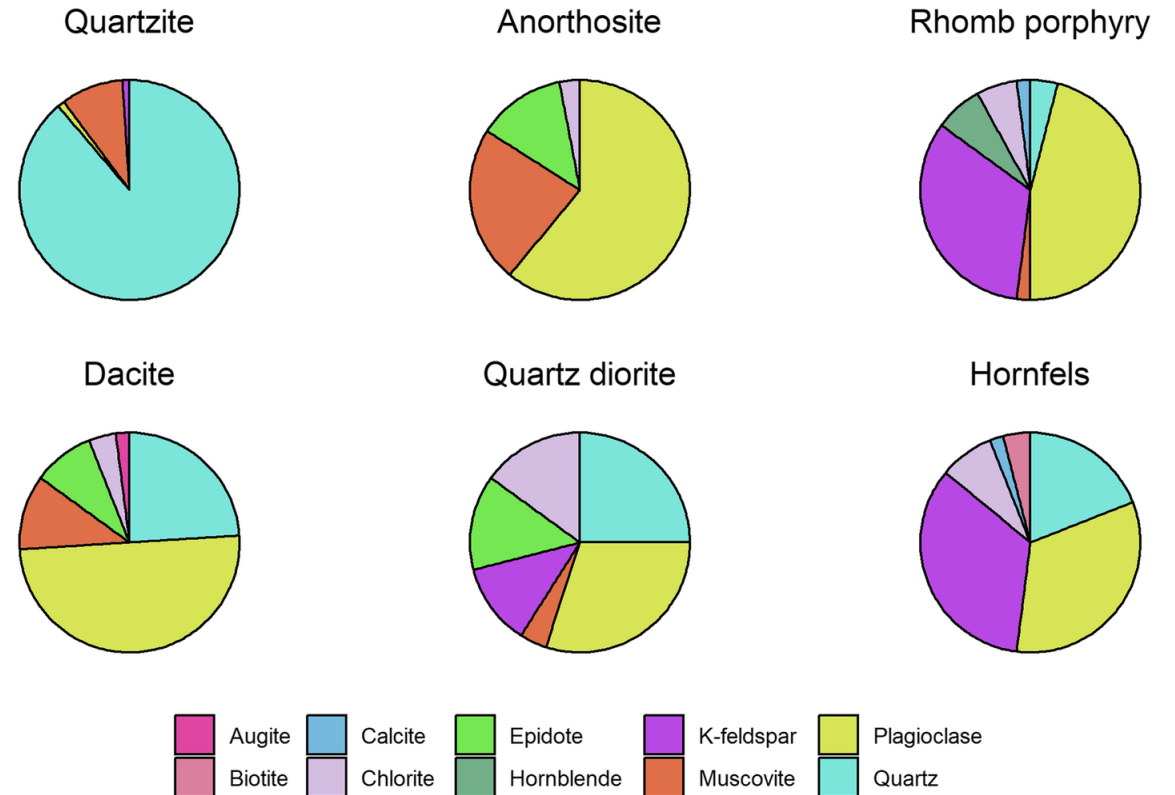
Pulmonary inflammation

- Inflammation and oxidative stress is important for PM-induced health effects
- Activation of cells in the lungs
- Release of pro-inflammatory mediators
 - Cytokines and chemokines (CXCL8, IL-6, IL-1 β , TNF α)
 - Activation of inflammatory response in recipient cells and recruitment of immune cells



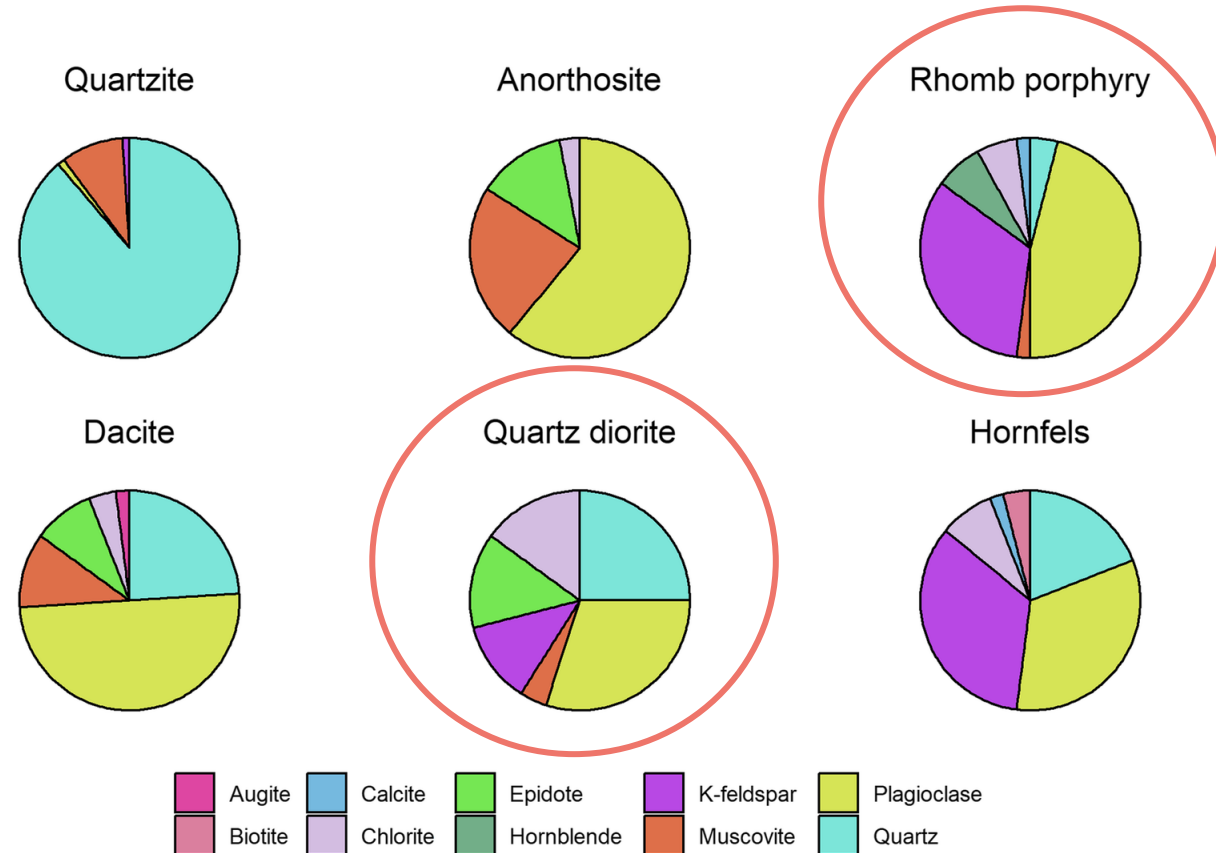
Pro-inflammatory effects of mineral dust

- 6 stone particle samples of different mineralogical composition
 - Crushed with Los Angeles method
 - Fraction below 10 μm was extracted by gravitational settling in water
- 10 mineral samples representing the individual mineral components
 - Na-feldspar, K-feldspar, Ca-feldspar, Biotite, Epidote, Hornblende, Actinolite, Augite, Orthopyroxene Quartz
- Min-U-Sil 5 (α -quartz) for comparison



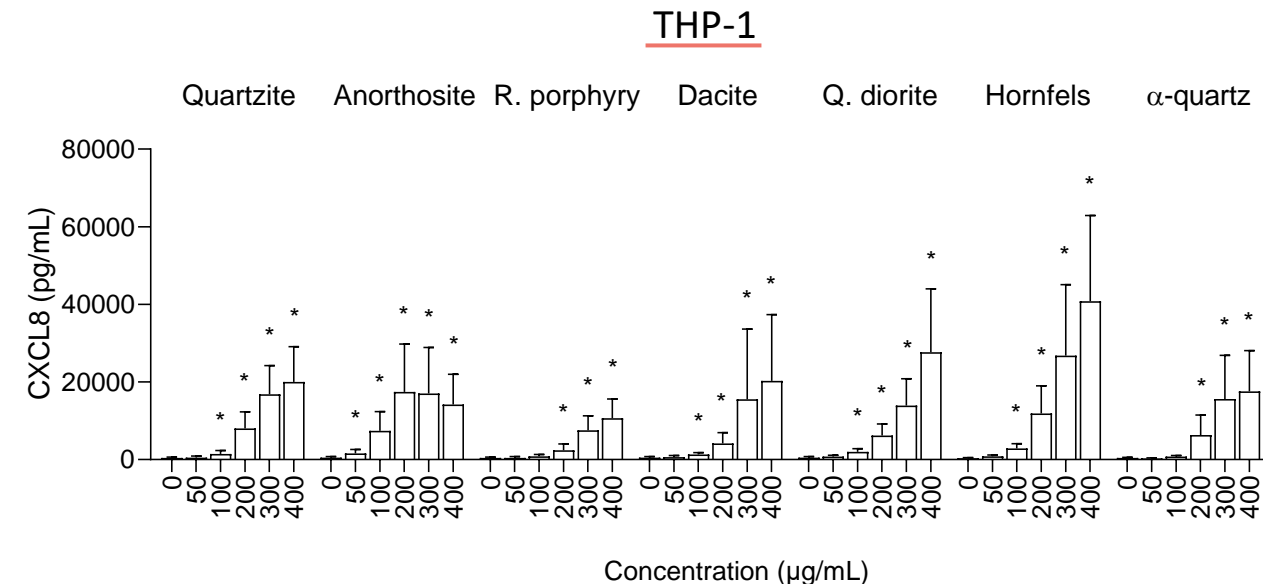
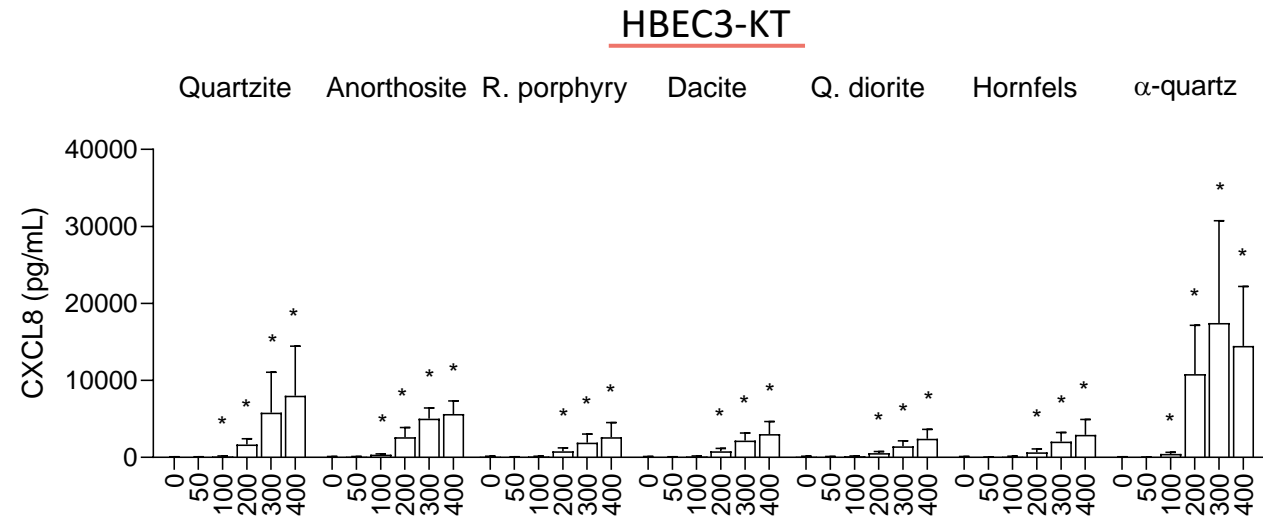
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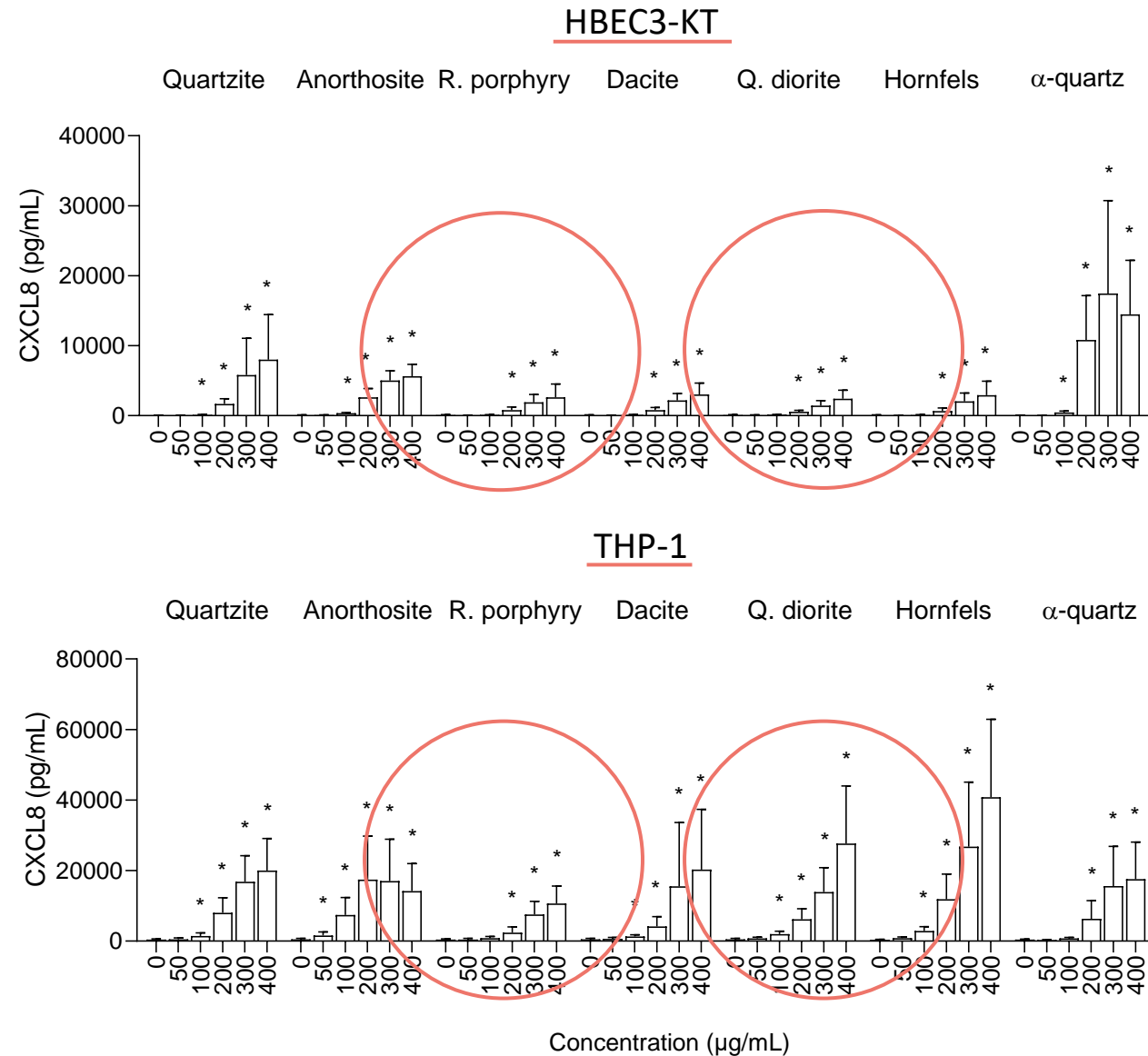
Effects of particles from stone aggregate

- Stone particle samples induce concentration-dependent cytokine release with varying potency
- Anorthosite, quartzite, hornfels and α -quartz the most potent
- Feldspar-rich samples among the most and least potent



Effects of particles from stone aggregate

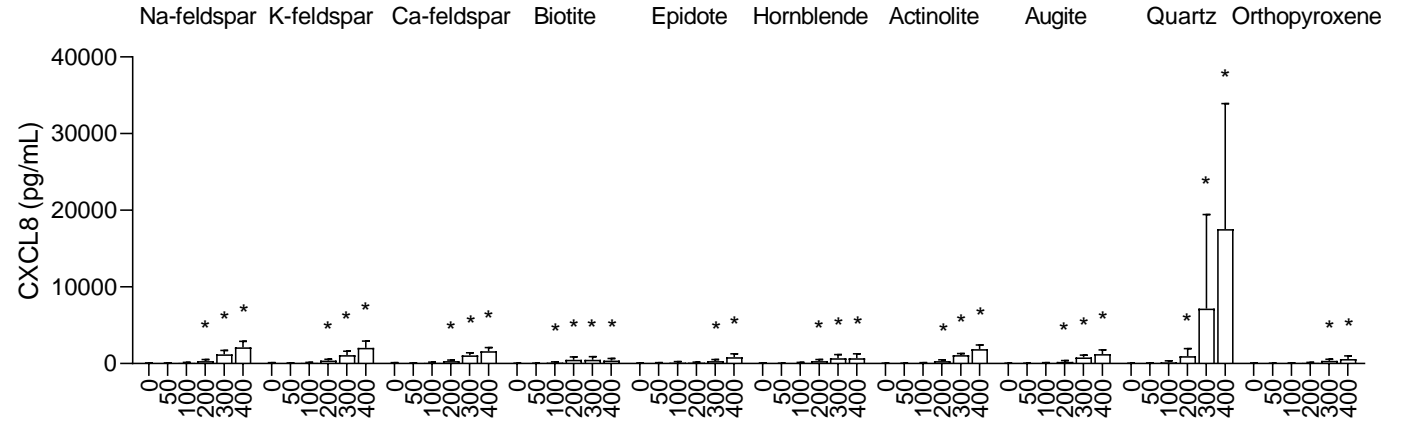
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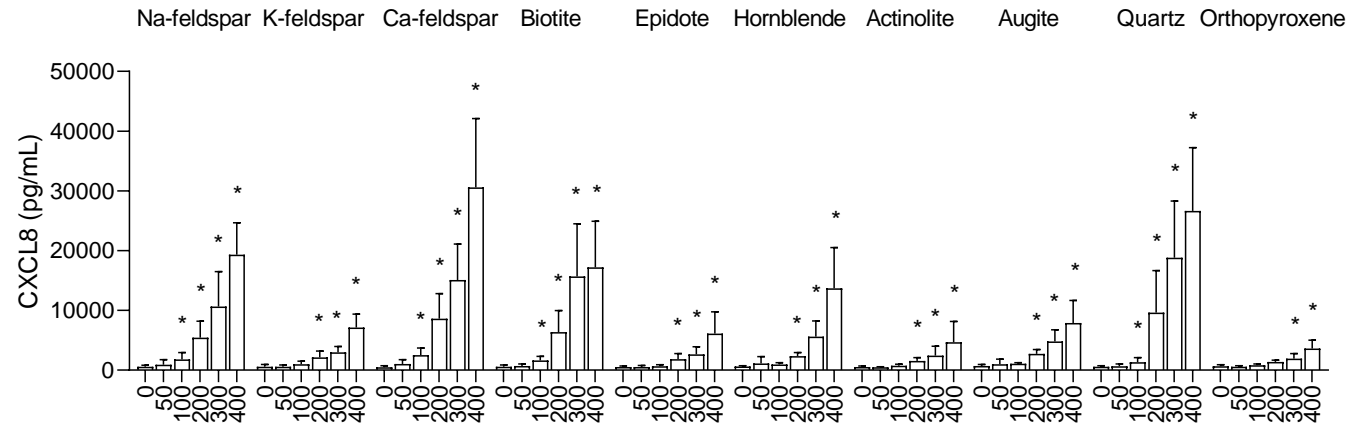
Effects of pure mineral samples

- Stone particle samples induce concentration-dependent cytokine release with varying potency
- Na-feldspar, Ca-feldspar, biotite and quartz are among the most potent
- Feldspar minerals vary in potency

HBEC3-KT



THP-1



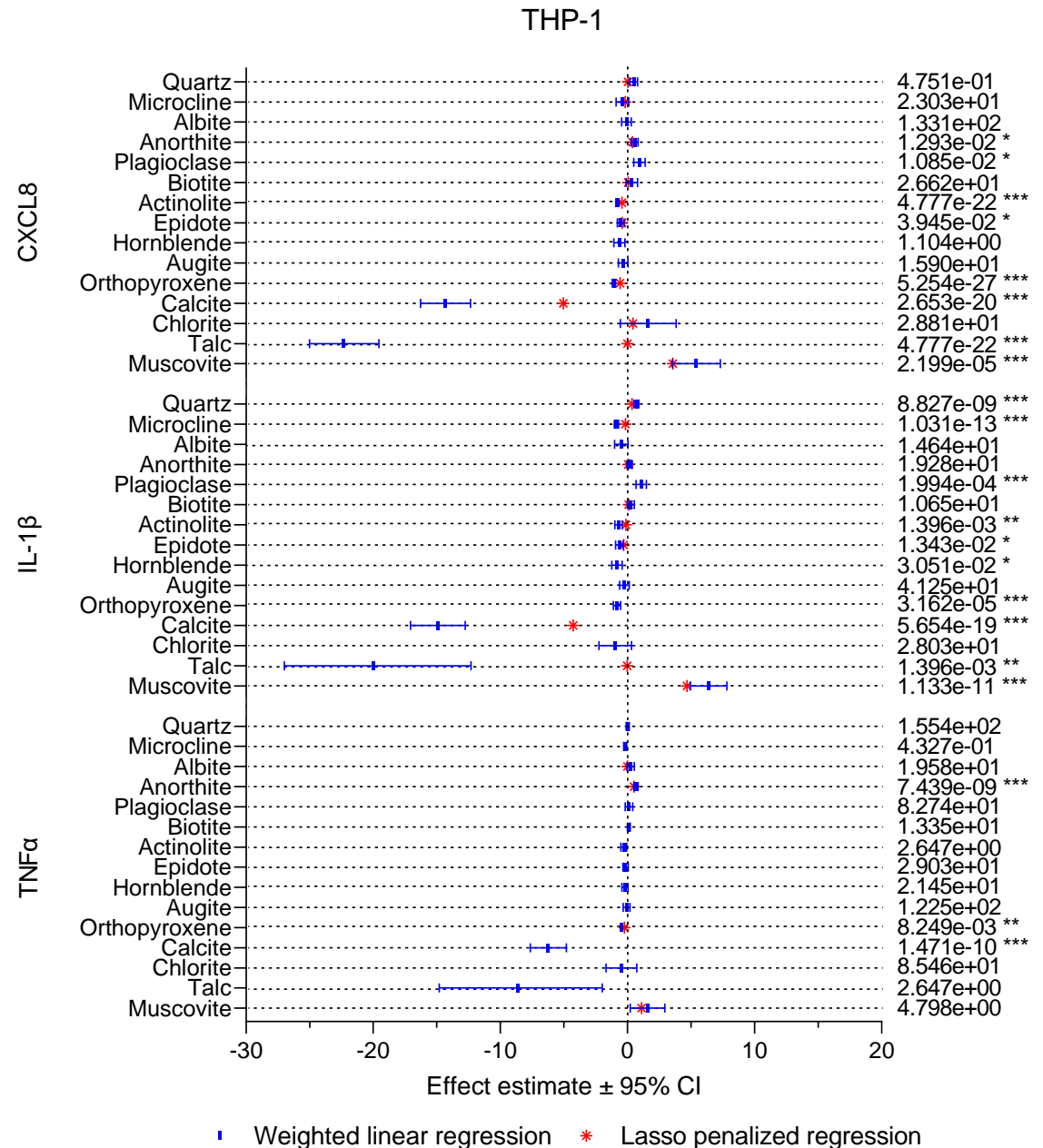
Concentration (µg/mL)

The impact of different mineral constituents

- Linear regression and LASSO regression
- Percent increase in endpoint for one unit increase in mineral component

Particle composition and cytokine release:

- Positive associations detected muscovite, quartz, plagioclase, biotite, anorthite and chlorite
- Negative associations detected for orthopyroxene, calcite, chlorite, orthoclase, actinolite and epidote
- Muscovite was consistently positively associated with cytokine release

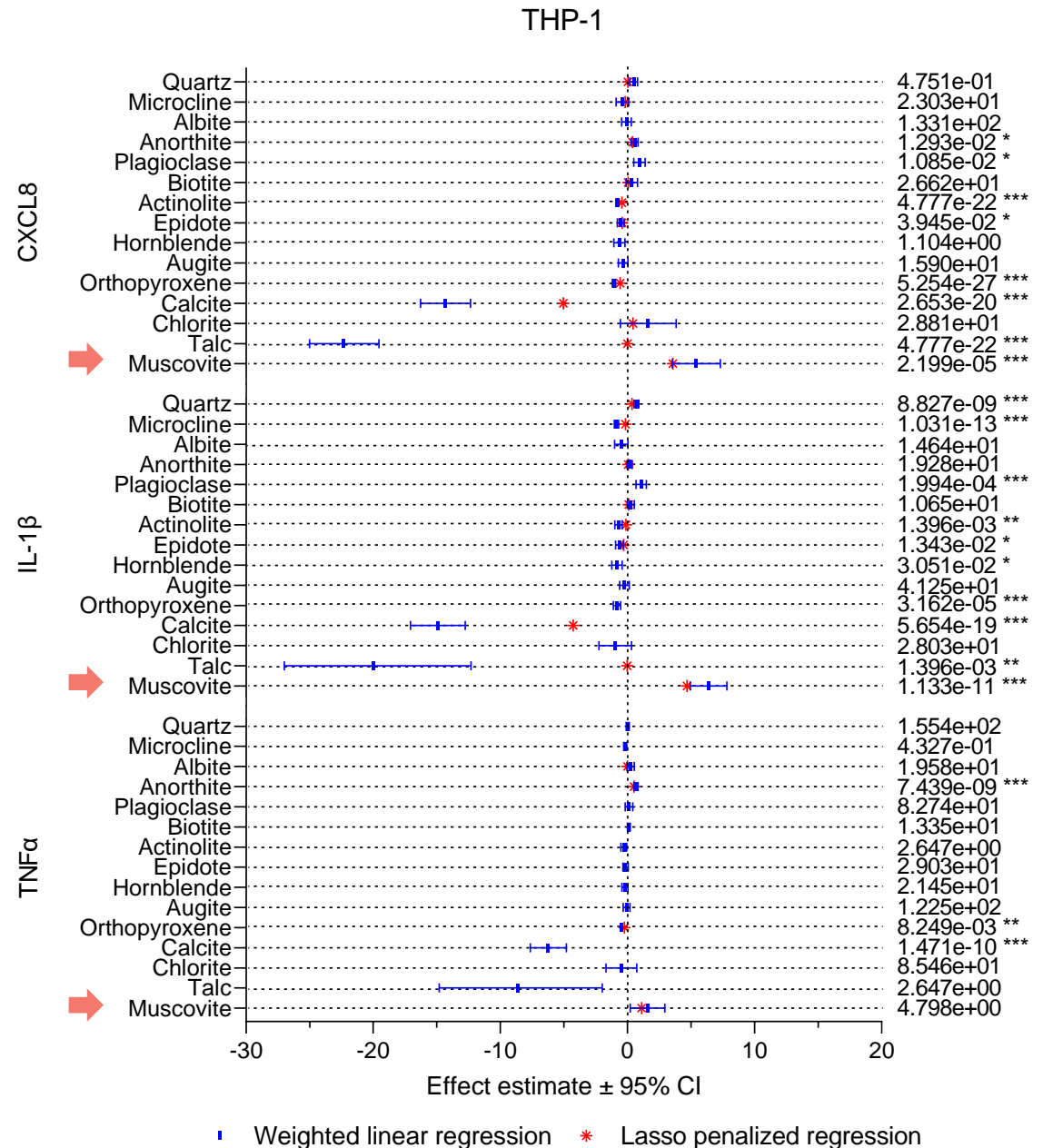


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The potential interaction between road wear particles and diesel exhaust particles

Exposure to wear particles and combustion particles alone and in combination

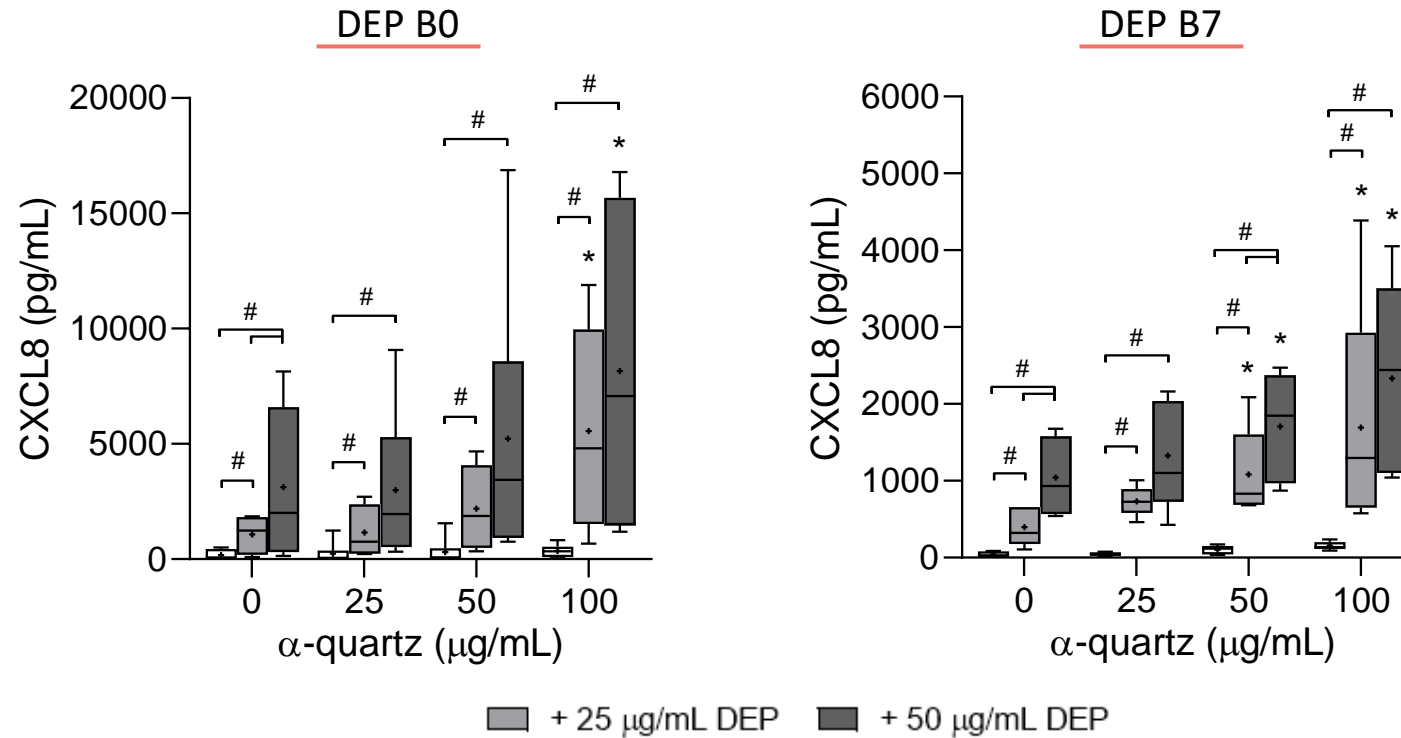
- Mineral dust
 - α -quartz
 - Anorthosite, rhomb porphyry and quartz diorite
- Road wear particles
- Diesel exhaust particles (DEP)
 - DEP_{B0} – High content of organic chemicals
 - DEP_{B7} – Modern biodiesel blend with 7% fatty acid methyl ester (FAME)

$$1 + 1 = 2?$$

$$1 + 1 = 1?$$

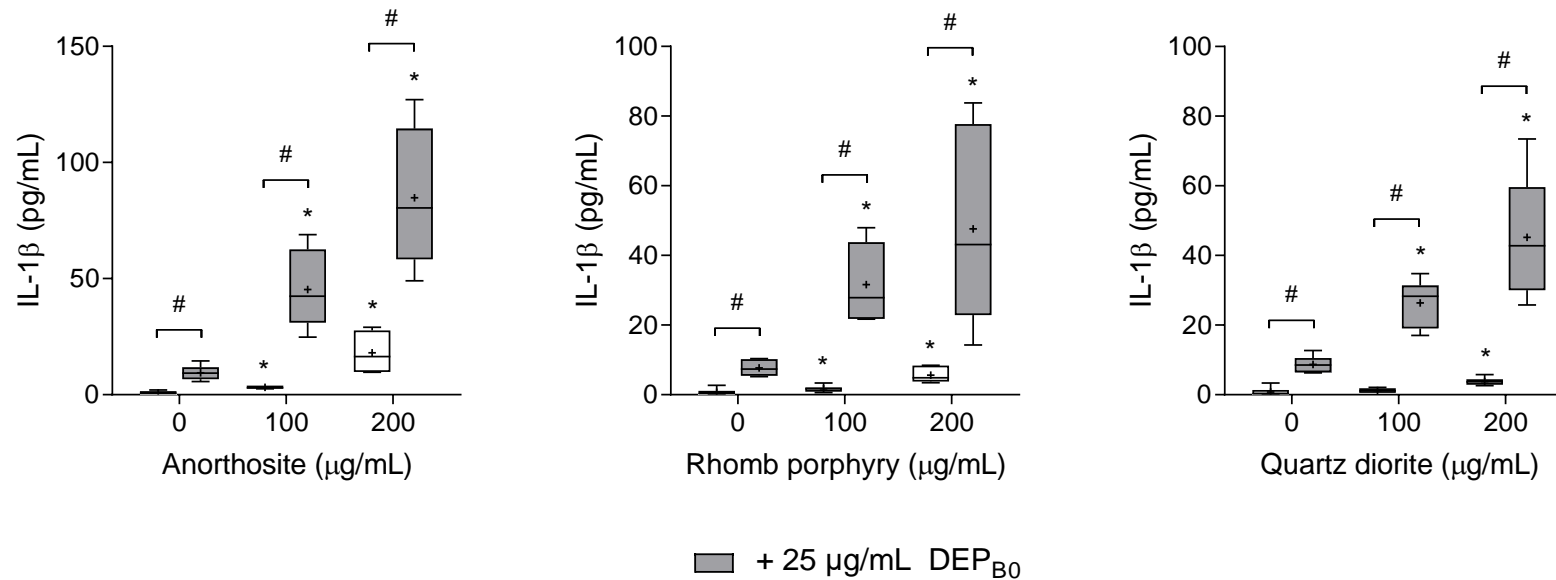
$$1 + 1 = 3?$$

Combined exposure to α -quartz and DEP



Combined exposure to α -quartz and DEP induces higher levels of cytokine release than the individual compounds

Stone particles induce similar responses as α -quartz in combination with DEP



Similar trend for CXCL8 (not significant)

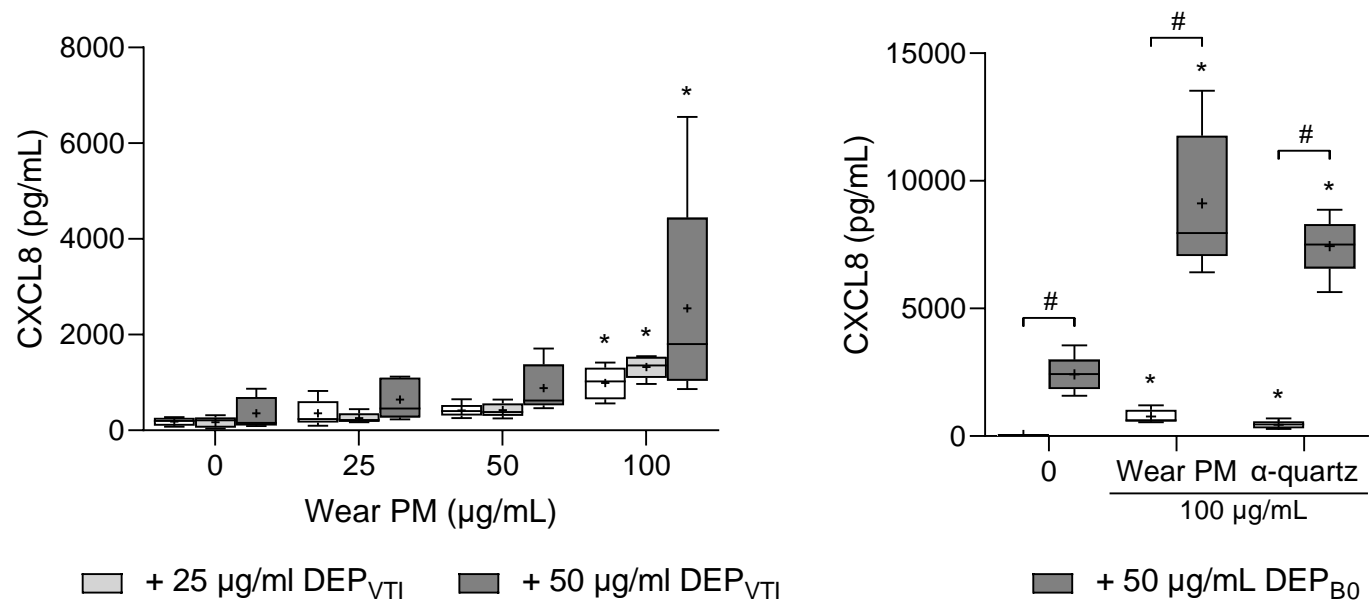
Combined exposure to stone particles and DEP increases cytokine release compared to each sample alone

Road wear PM in combination with DEP

- Particles generated in a road wear simulator at the Swedish National Road and Transport Research Institute (VTI)
- Asphalt and tire wear particles



Road wear PM in combination with DEP



Exposure to road wear PM and DEP in combination induces higher levels of cytokines than the individual compounds.

Does the choice of stone material affect traffic-PM toxicity?

- Two road tunnels in Trondheim was paved with asphalt containing different stone materials
 - **Marienborg:** Rhomb porphyry, primarily feldspar
 - **Hell:** Quartz diorite, mixed mineral composition, 25% quartz
- Sampling in tunnel limits contribution from other sources of PM



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**Is feldspar
associated with
reduced toxicity?**



Sampling of traffic-derived particles

- Coarse (10-2.5 μm), fine (2.5-0.18 μm) and ultrafine (< 0.18 μm)
- Particles were collected on filter using a high-volume cascade impactor sampler
- Sampling was performed in an emergency bay beside the traffic lane
- Dry and humid road surface conditions
- Before and after cleaning the tunnel

For comparison:

- Quartz diorite and rhomb porphyry particles
- DEP_{B7} – Biodiesel blend with 7% fatty acid methyl ester (FAME), without diesel particle filter

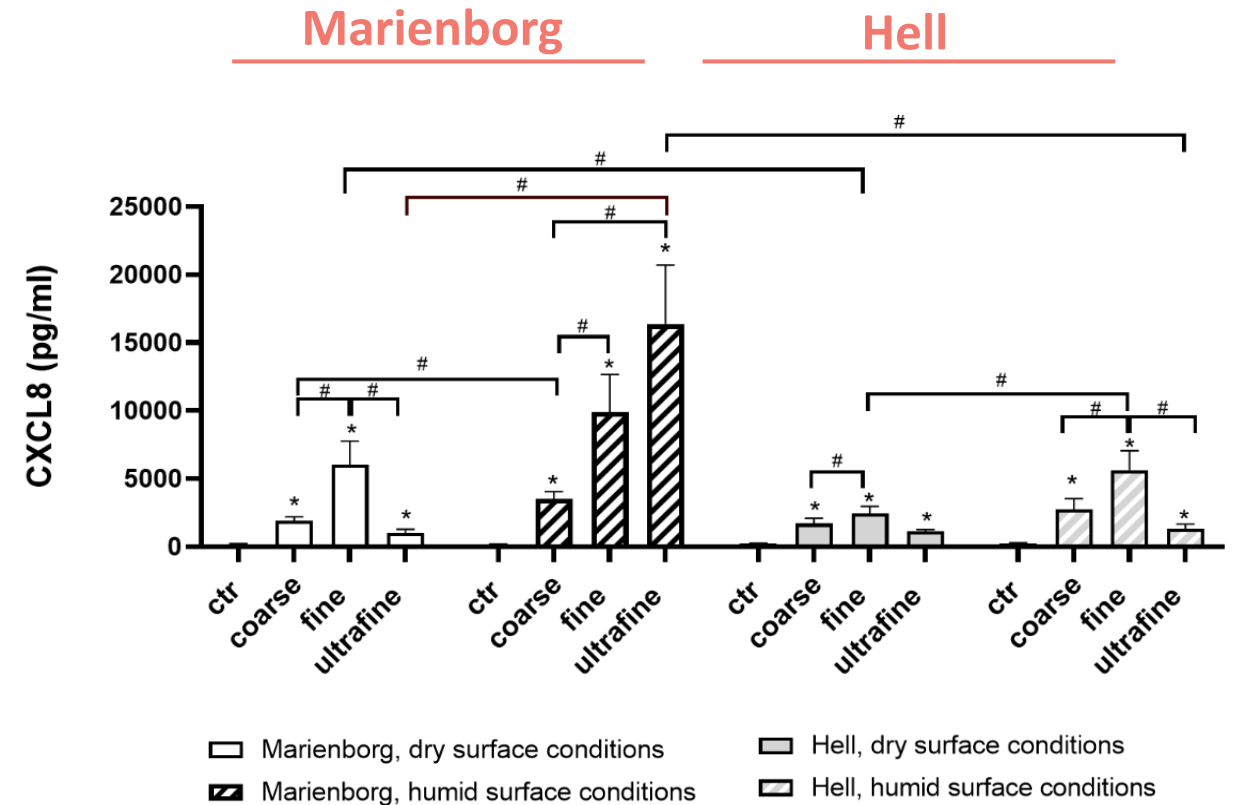


High-volume cascade impactor

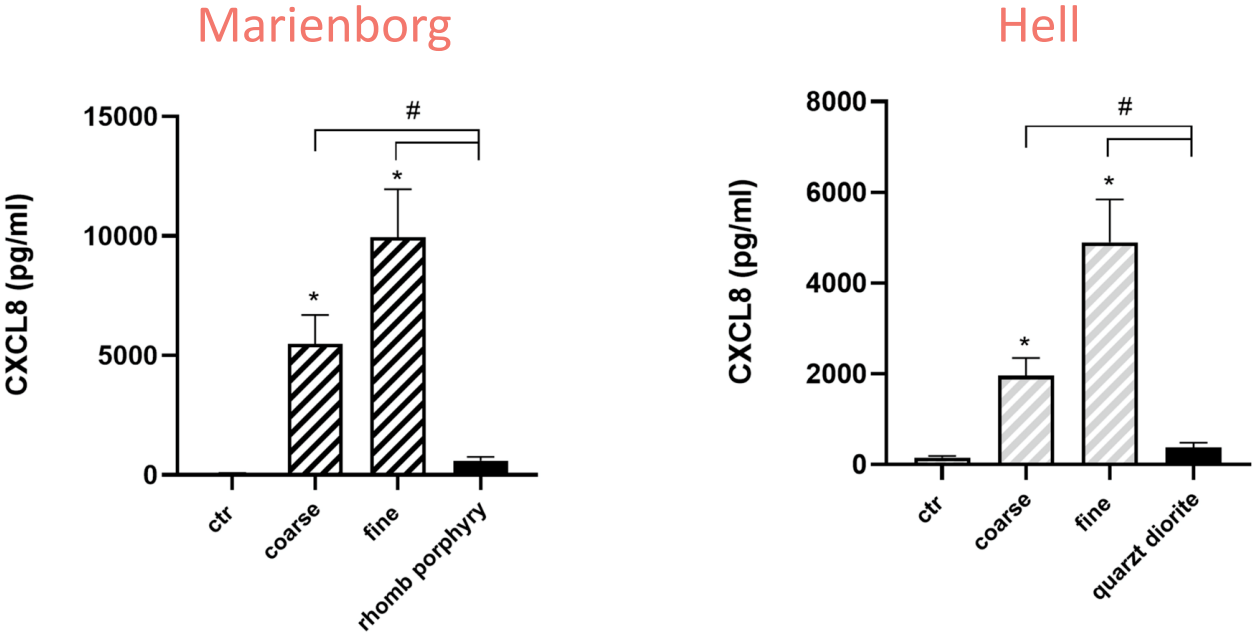
Does the choice of stone material affect traffic-PM toxicity?

- Fine particles appeared to be the most potent in most cases
- Tendency for higher responses for fine and ultrafine particles from Marienborg
- Coarse is similar between tunnels

Feldspar content in the asphalt does not seem to be a major determinant for the toxicity of the particle samples

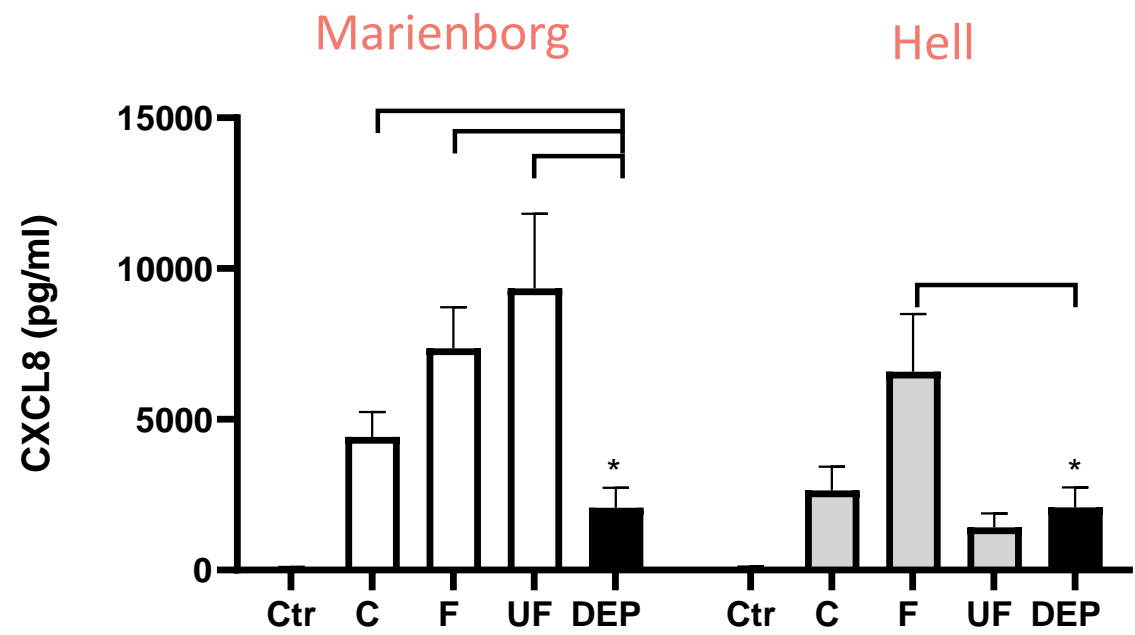


Does the choice of stone material affect traffic-PM toxicity?



The effect of traffic-related PM is higher than particles from the respective stone material used in the asphalt

Does the choice of stone material affect traffic-PM toxicity?



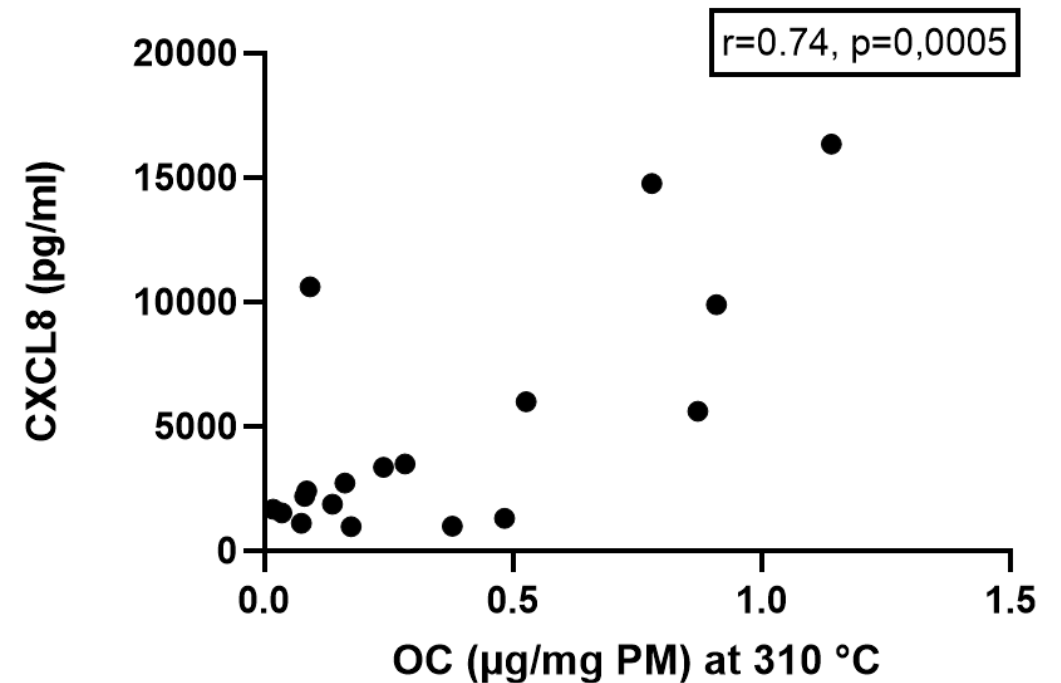
The effect of traffic-related PM is higher than DEP

Which parameters explain PM toxicity?

- Particle size distribution of the three fractions (disc centrifugation method)
- Levels of endotoxin (lipopolysaccharide)
 - Component of the cell wall of gram-negative bacteria
 - Potent pro-inflammatory stimuli
- Generation of reactive oxygen species (ROS) in a cell-free system
 - Dithiothreitol (DTT) and electron spin resonance (ESR)
 - Regarded as a predictor of potential PM health hazard
- Content of organic carbon (OC) and elemental carbon (EC)

Which parameters explain PM toxicity?

- No correlation between cytokine release and particle size distribution, endotoxin content or ability to generate acellular ROS across samples
- Release of cytokines is correlated with content of organic chemicals
- Important role for PAH?



Effects of mineral dust exposure in human volunteers

T. B. Nitter, B. Hilt, K. V. H. Svendsen, M. Buhagen and R. B. Jorgensen Sci Total Environ 2021 Vol. 778
Pages 146309

T. N. Moazami, B. Hilt, K. Soras, K. V. H. Svendsen, H. J. Dahlman, M. Refsnes, et al. Scand J Work Environ
Health 2022 Vol. 48 Issue 5 Pages 410-418

Study population

- 24 healthy non-smoking young adults
- Aged 20-28 years old
- Interviewed about respiratory health problems, chronic inflammatory diseases sleep quality, and lifestyle.
- Avoid alcohol, specific nutrition and challenging exercise 36 h before exposure day



Study design

- Randomized, double-blind, cross-over study design
- Exposed by inhalation to **quartz diorite** or **rhomb porphyry** for 4h
- Lactose was included as placebo dust
- Exercise using step board for 15 min/h
- Exposure concentrations:
 - Respirable dust - 5.4-5.6 mg/m³ median concentration in chamber
 - PM_{2.5} – 4.3-5.1 mg/m³



- **Parameters:** Markers of coagulability and inflammation in blood, pulmonary inflammation and lung function
- Measurements were taken directly before and after exposure and 4 and 24 h post-exposure

Markers of blood coagulability and inflammation

Weak association with markers of coagulability in plasma:

- Non-significant ($p=0.09$) increase in thrombocytes after QD and RP
- Increase in fibrinogen for quartz diorite compared with baseline and a decrease for rhomb porphyry that was significantly different (but not from lactose).

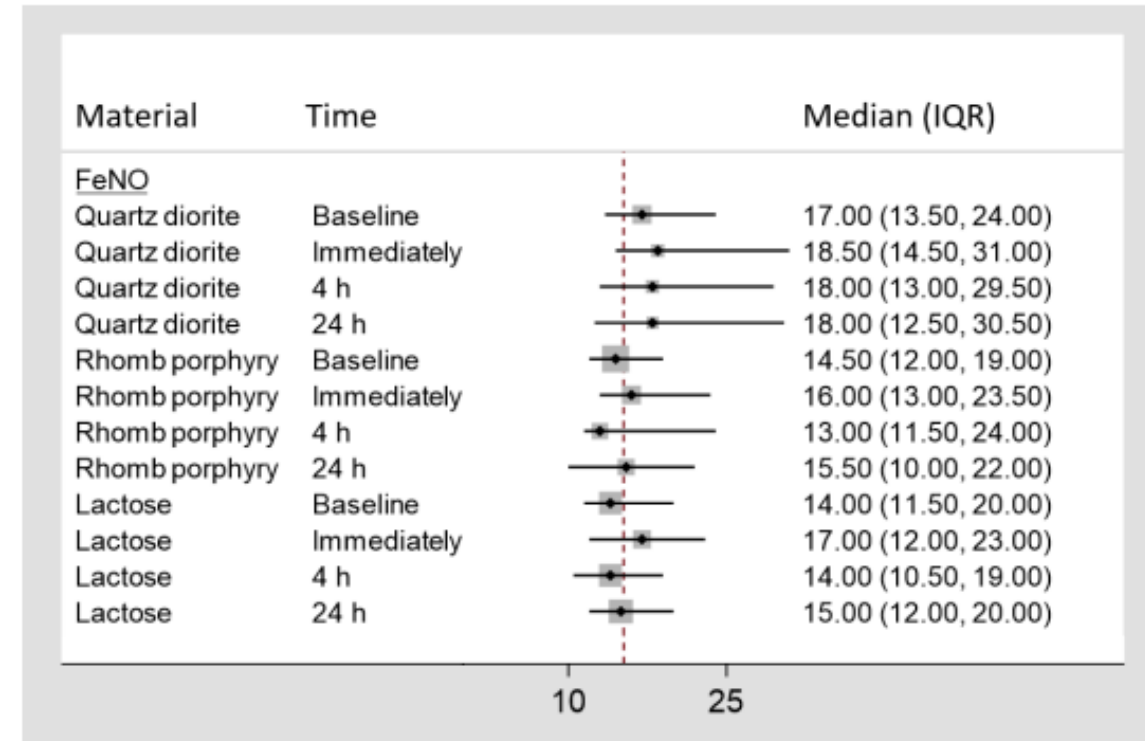
Markers of blood coagulability and inflammation

No acute effect in inflammatory markers in plasma:

- No increase in SP-D, P-selectin or CC16
- Suggestive increase in ICAM-1 for quartz diorite similar to effects on fibrinogen

Effects in the lungs

- Markers of oxidative stress and inflammation in exhaled breath condensate were mostly below detection limits for the assay
- **Fractional exhaled NO (FeNO)** – Significantly higher after quartz diorite exposure compared to rhomb porphyry → increased pulmonary inflammation
- **Lung function** – Rhomb porphyry causes a significant modest decline in FEV₁ and FVC. The effect on FVC was significantly different from quartz diorite



Conclusions and future directions

Mineral particles induce pro-inflammatory responses and the potency vary between samples of different composition

- Particles often considered non-toxic may induce adverse health effects

Mineral dust and road wear particles may increase the pro-inflammatory effects of DEP when administered in combination

- The contribution to the health effects of complex particle mixtures may be greater than assumed from studies on these particles alone
- Could occur for other PM constituents?

The toxicity of particulate matter is likely due to different components and sources

Project partners

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- Jørn Holme
- Tonje Skuland
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Questions?