PREDICTION OF EMISSIONS AND EXPOSURE TO MICRO- AND NANOPARTICLES IN INDUSTRIAL ENVIRONMENTS

CASE STUDY IN THE CERAMIC INDUSTRY

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OUTLINE

- Scope
- Methodology
- Results:
  - Spatial variability
  - Exposure assessment as a function of:
    - Material
    - Operating conditions
    - Air extraction system
- Conclusions

SCOPE

Ceramic industry

Impacts on workers exposure → Coarse particles

Motivation: also potential impact on nanoparticle exposure (process-generated nanoparticles)

Dry powders different nature

Respiratory related disease

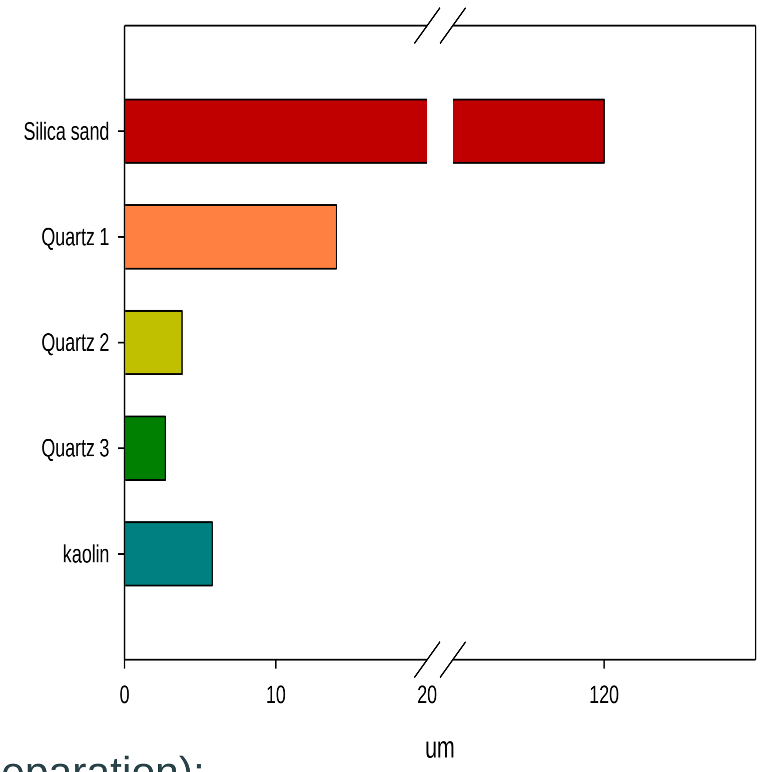
Milling: mechanic process to reduce materials particle size

Used in traditional ceramic production processes and ceramic pigments manufacturing. Dry process for mixing and material preparation. Frequent process!

GOAL → To quantify how particle emissions and workplace exposure are affected by material properties and process conditions during a mechanic process (milling)

METHODOLOGY

Materials	Shape	Uses	d50 (µm)
Silica sand	Spherical	Ceramics production	120
Quartz 1	Spherical	Materials preparation, forming, glazing or firing.	14
Quartz 2	Spherical	Pigment production for the colouration of glazes.	3.8
Quartz 3	Spherical	Used in rubber compounds.	2.7
Kaolin	Laminar	Traditional ceramics production. Cement and metallurgical industries	5.8



Process conditions (aspiration, milling speed, particle separation):

High energy conditions

Low energy conditions

Frequently used!

METHODOLOGY

Device	Information	Range	Image
CPC butanol	Number concentration	4-1500 nm	
NanoScan	Number concentration/Size	10-420 nm	
DiSCmini	Number concentration/Size	10-700 nm	
Grimm	Mass	0.25-32 µm	
Cassette (Au TEM grids)	Particles image	<10µm	

METHODOLOGY

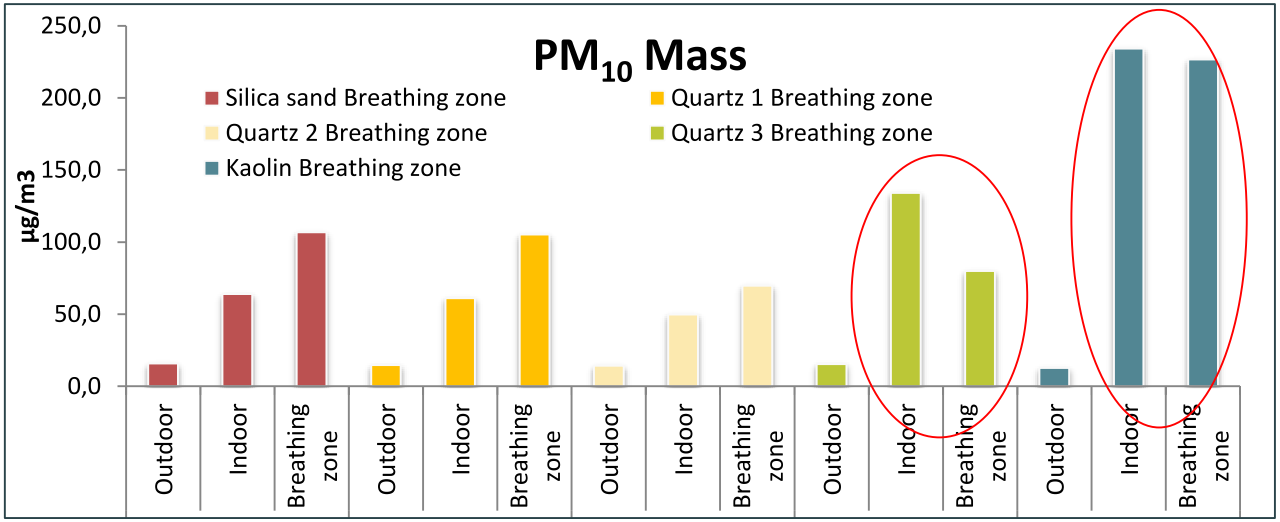
-Grimm
-DiSCmini
-Cassette
-CPC
-NanoScan

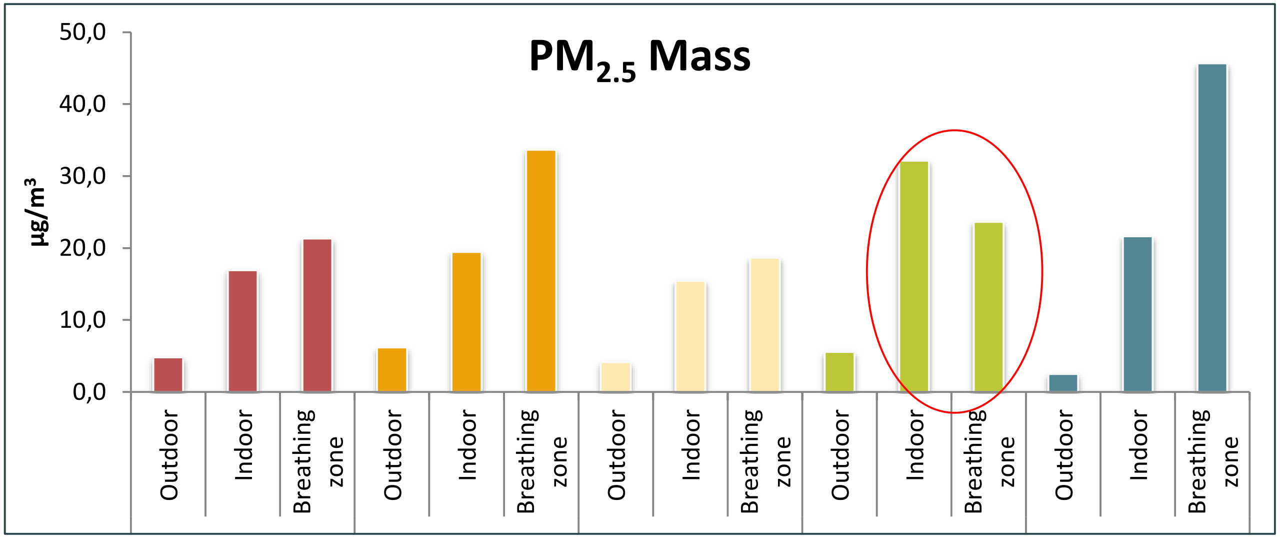
Breathing Zone :1m from the floor and 50 cm from the emission source

-Grimm
-DiSCmini
-Cassette

-Grimm
-DiSCmini

Spatial variability

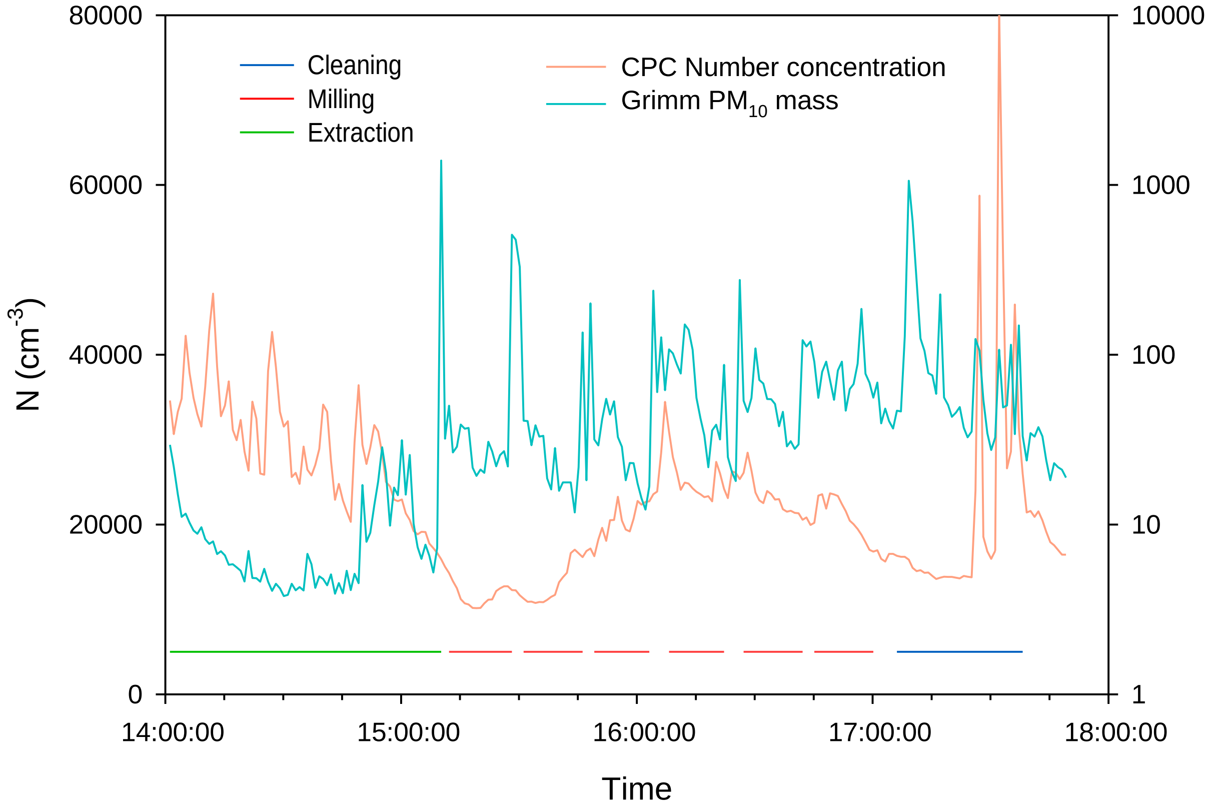




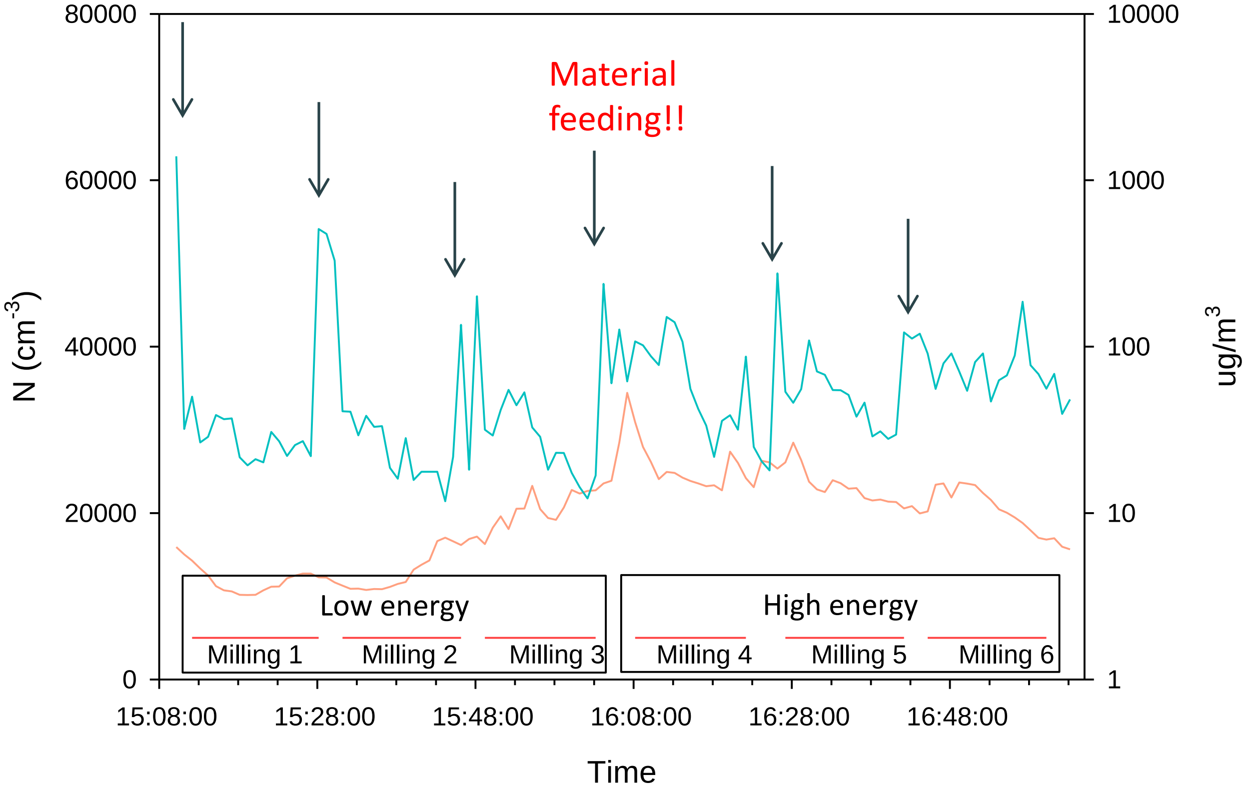
Particle exposure generally higher in the breathing zone

Temporal background: minimum 15-20 minutes prior measurements

Temporal series for Quartz 2



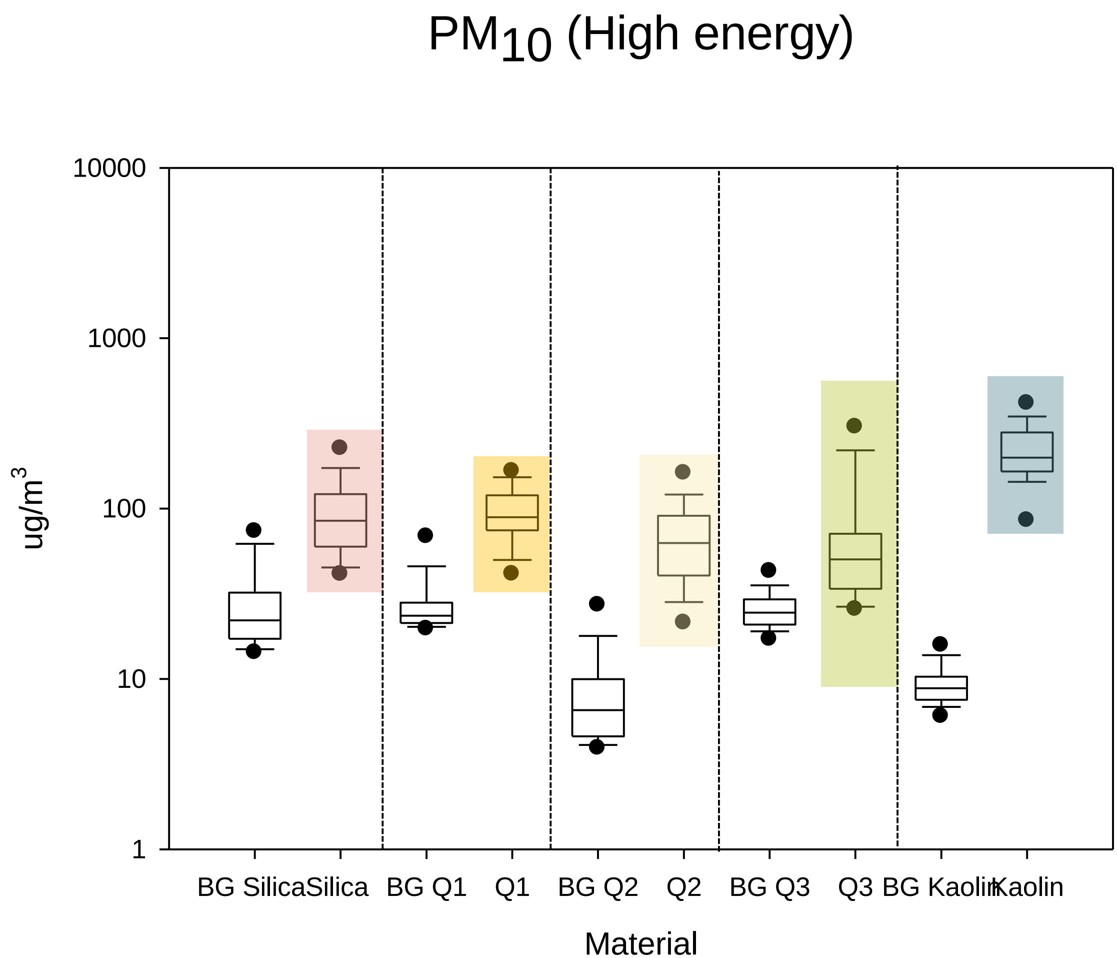
Log scale for mass!



- Milling increases coarser particles as expected (marked cycles)
- Lower impact on ultrafine particles, not negligible (seems to suggest accumulation)

Low: increase and decrease
High: more constant levels

Influence of input material

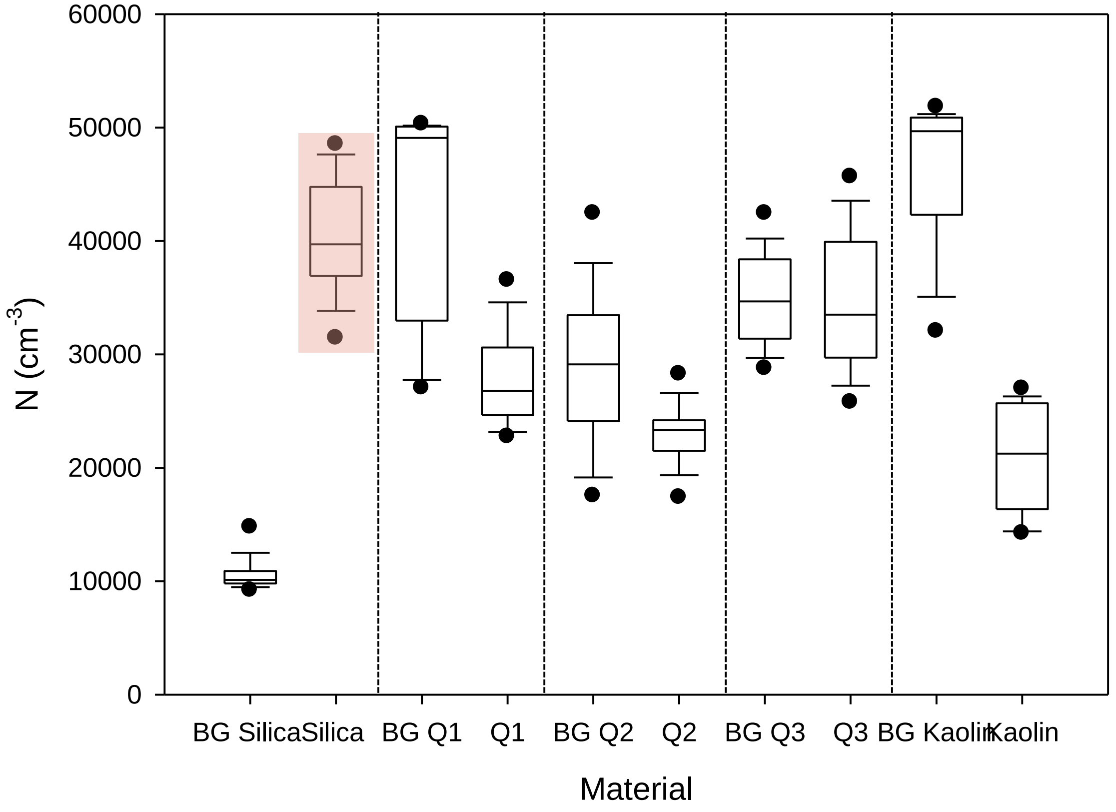


Significant increase for all materials!

Significant if :
Exposure > 3σ+BG

$PM_{2.5}$ and PM_1 only significant for Silica and kaolin!

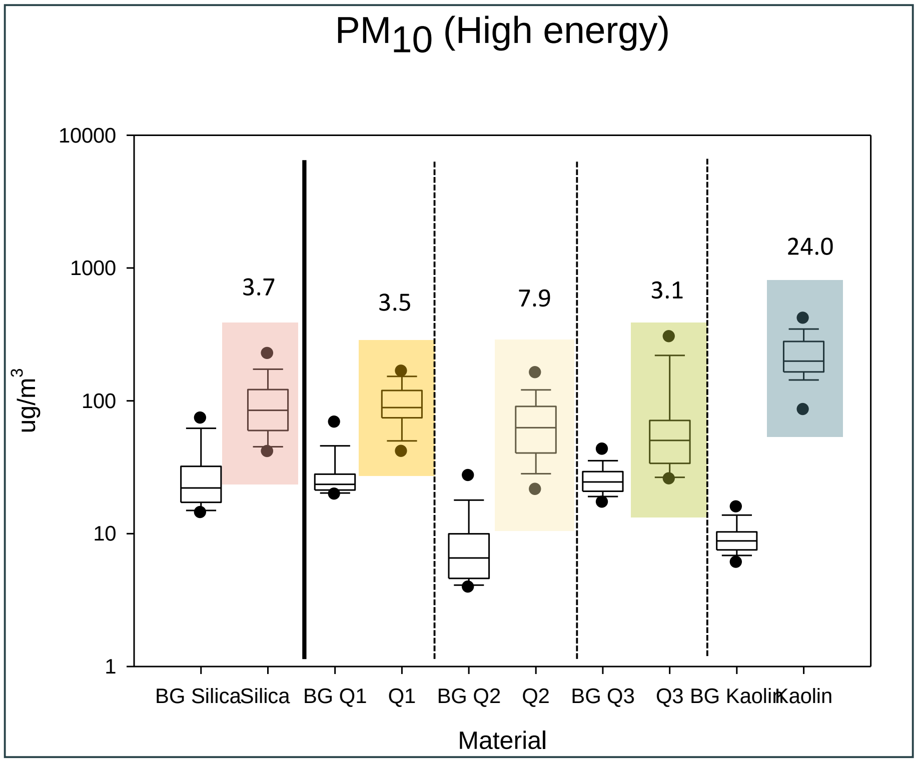
Number concentration (High energy)

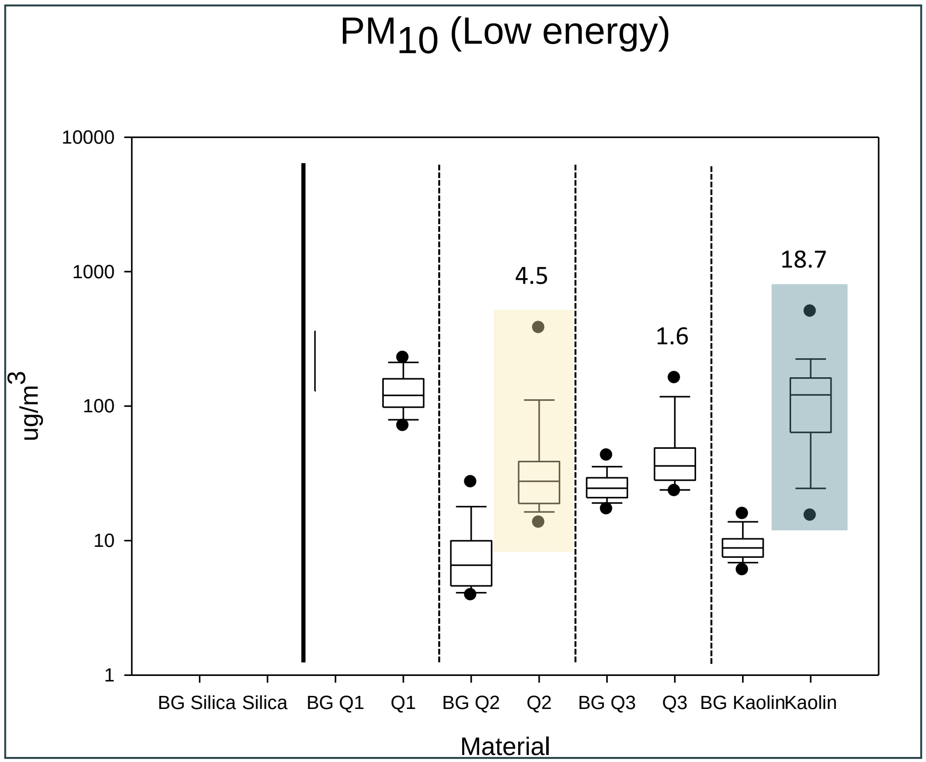


High increase of nanoparticle exposure for Silica

Influence of operating conditions

Mass concentrations

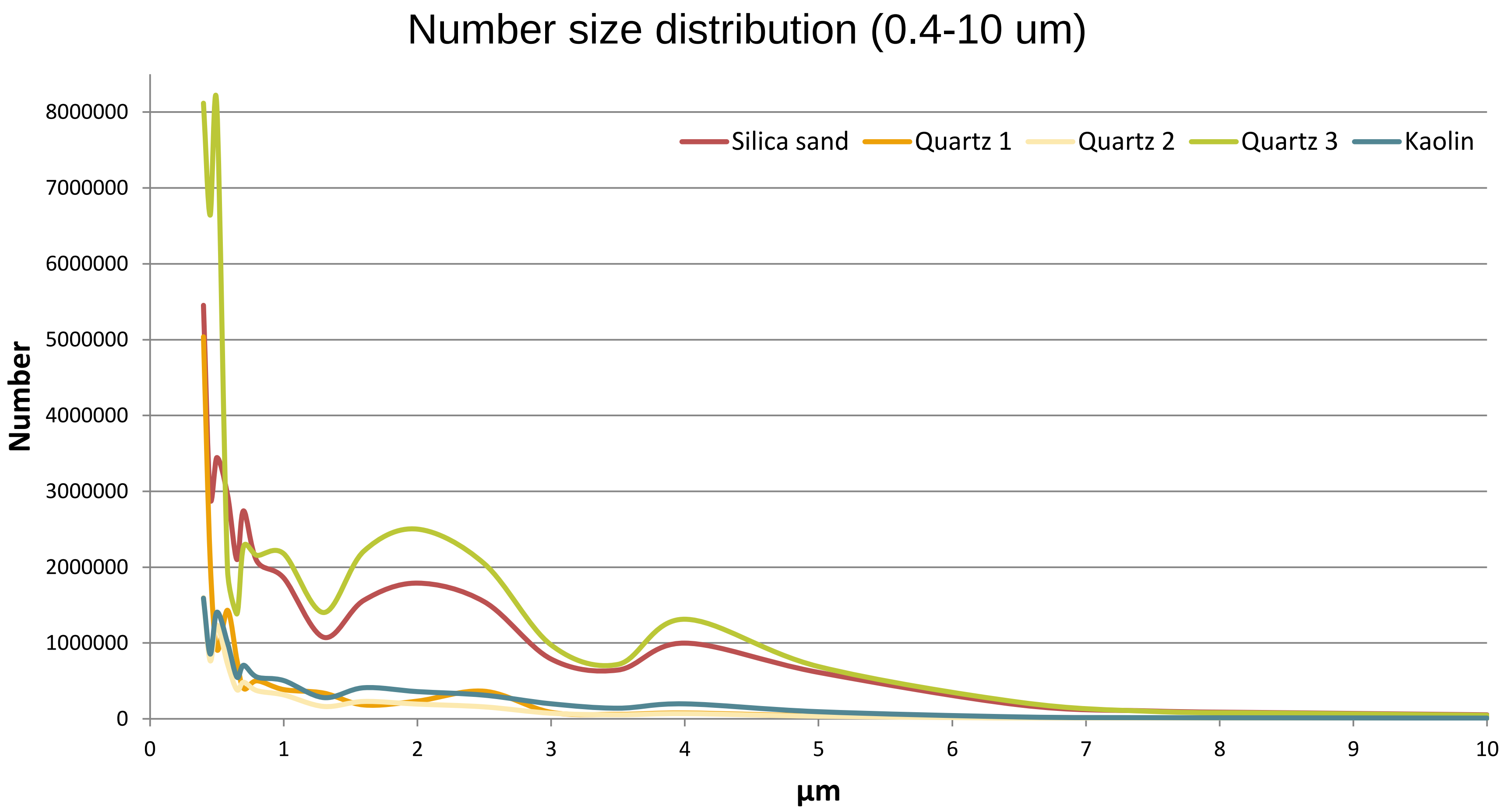




Higher particle emission with high energy conditions

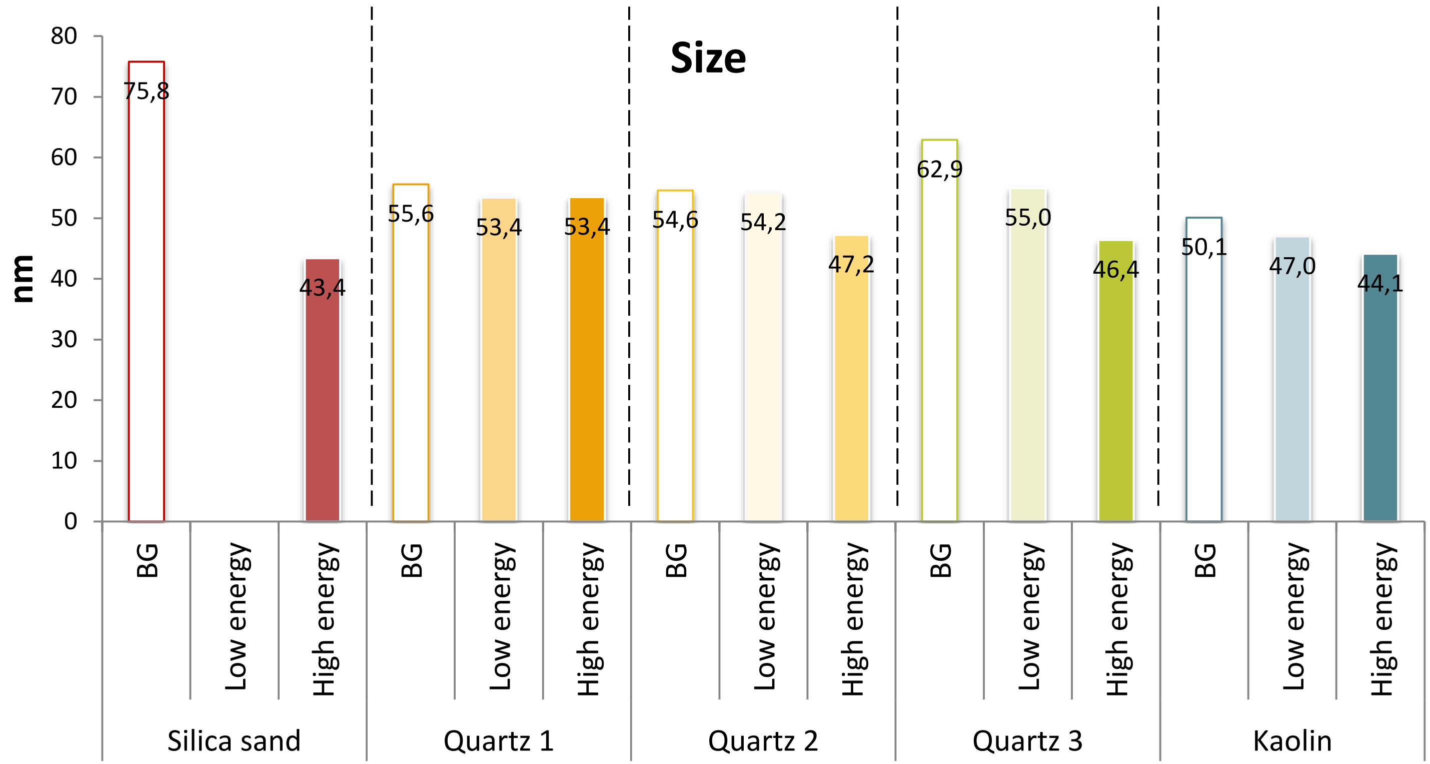
Workers exposure can be reduced changing operating conditions

Influence of input material



Influence of operating conditions

Size

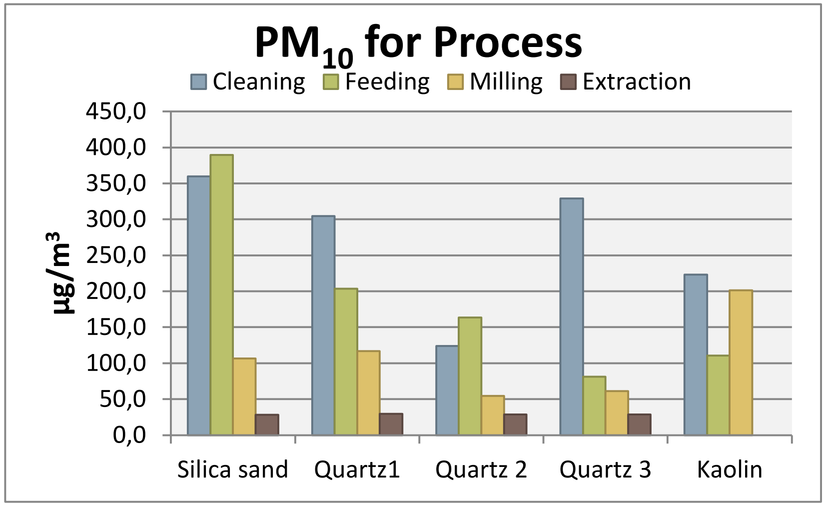


- General reduction of mean particle size (BG)
- Silica and Kaolin the smallest values
- Highest reductions for Silica and Q3

Impact on mean nanoparticle diameter

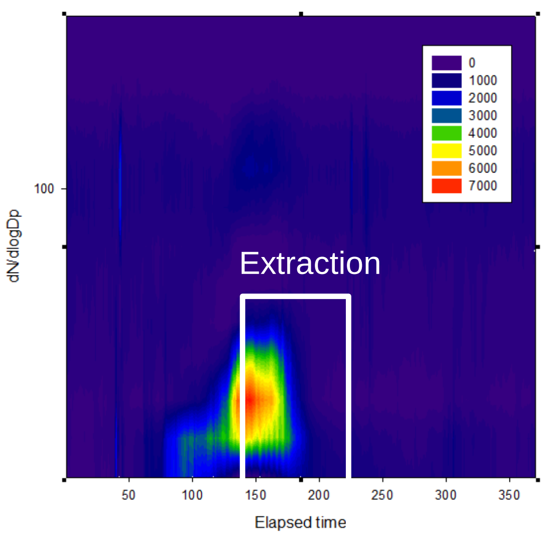
RESULTS

Air extraction system

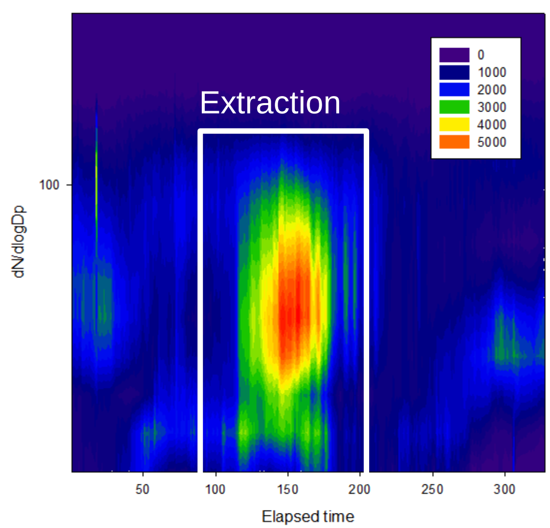


Reduction of coarser particle concentrations

10.10.2016



11.10.2016



Increase of particles between 20-50 nm

Extraction ON!

No reduction of nanoparticle exposure!

CONCLUSIONS

- Impact on mass concentrations, significant for all materials (PM_{10}=69-226, $PM_{2.5}$=18-45, PM_1=5-12 µg/m^3)
- Impact on particle number concentrations, significant for one material (30713-49155 cm^{-3})
- Operating conditions influence particle exposure and diameter
- Mean diameters detected (<420 nm): 43-53 nm
- Size distribution = trimodal (diameters 0.4-0.5/2/4 µm)
- Extraction had a positive impact on particle mass concentrations reduction, but negative on particle number concentration

- Further studies:
  - to compare with dustiness laboratory tests (ongoing)
  - to see the potential impact on exposure of the increase in operating time due to the use of lower energy conditions

ACKNOWLEDGEMENTS

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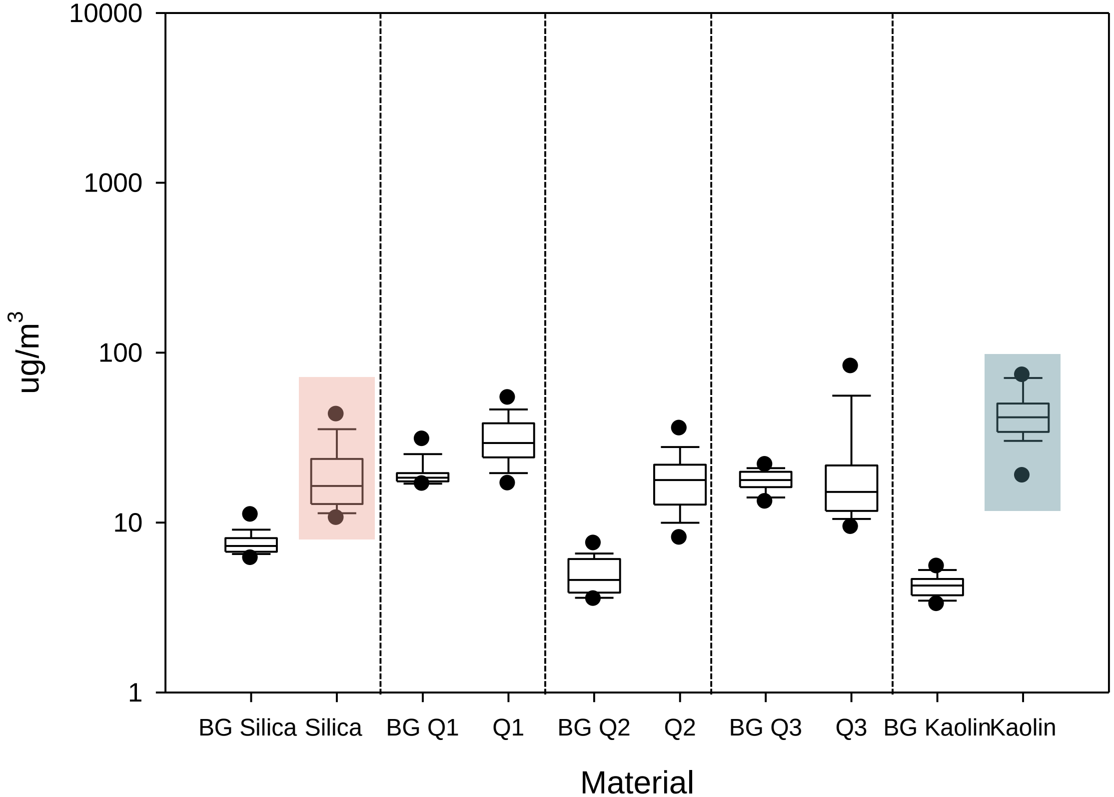
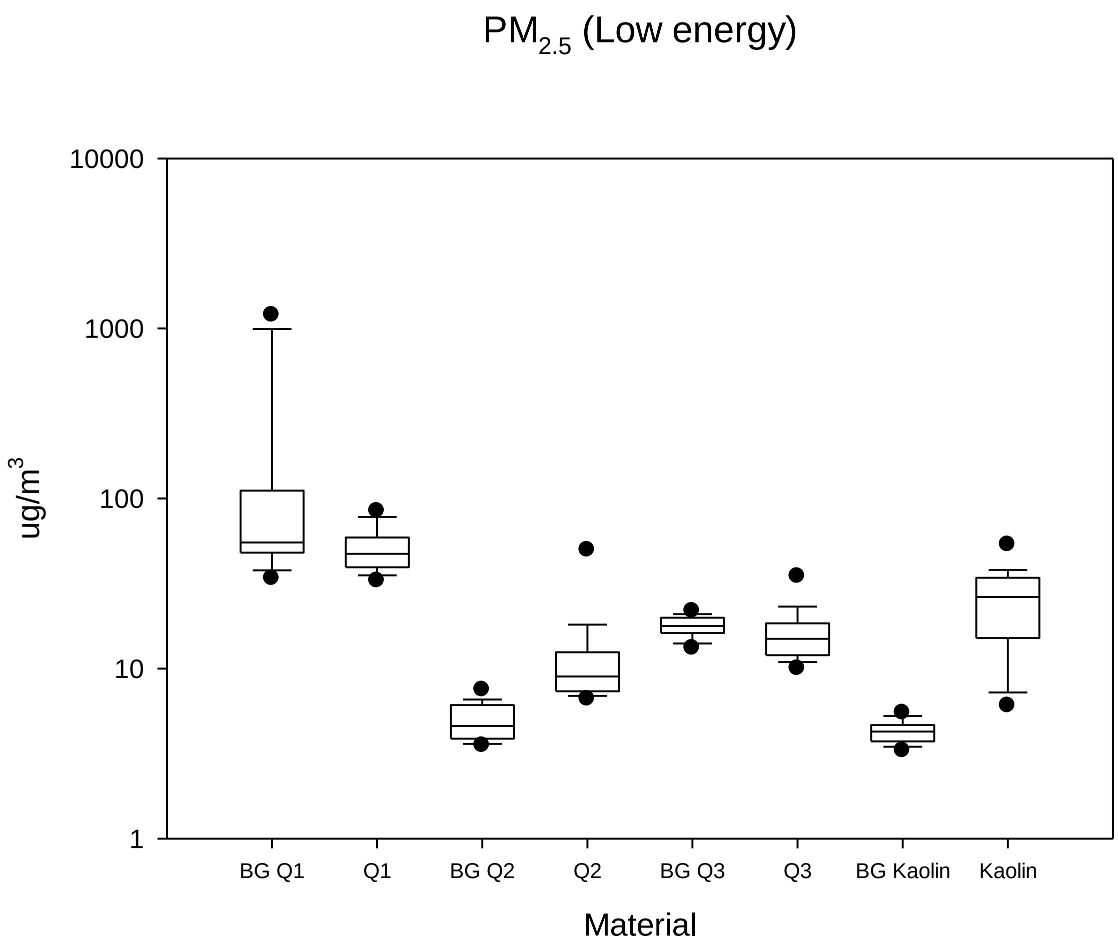
- ITC technical staff
- SIINN ERA-NET and the European Commission

Thank you for your attention

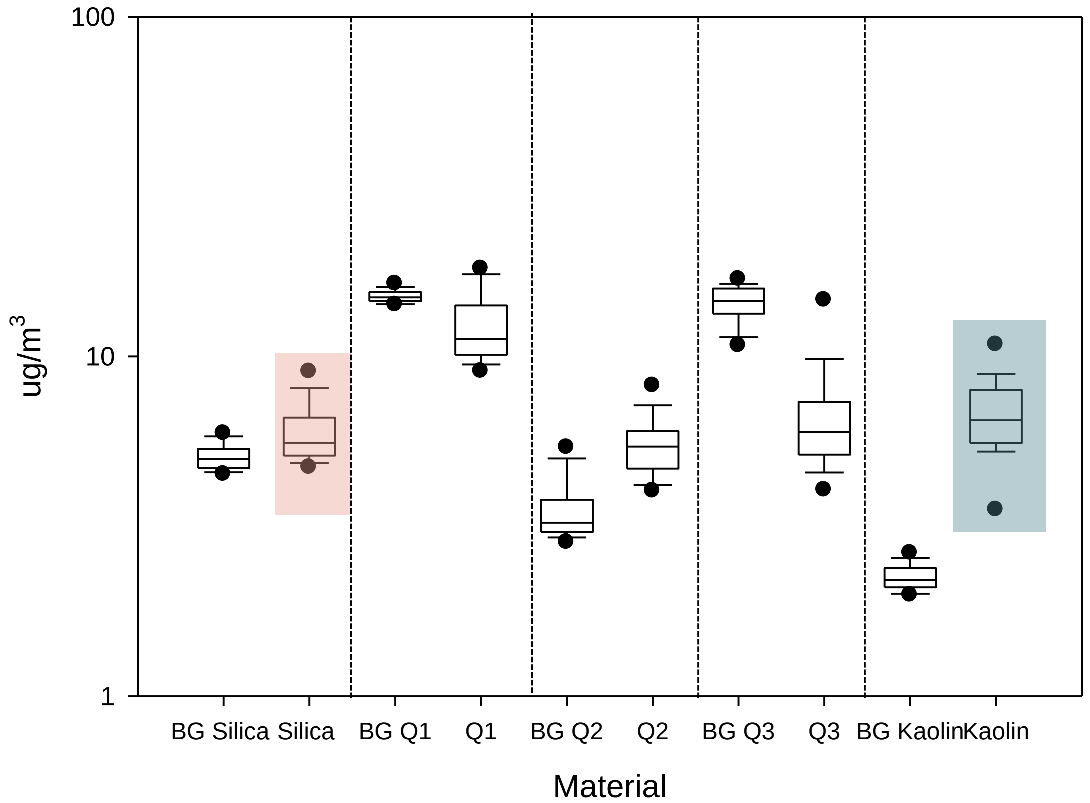
PM2.5 (High energy)



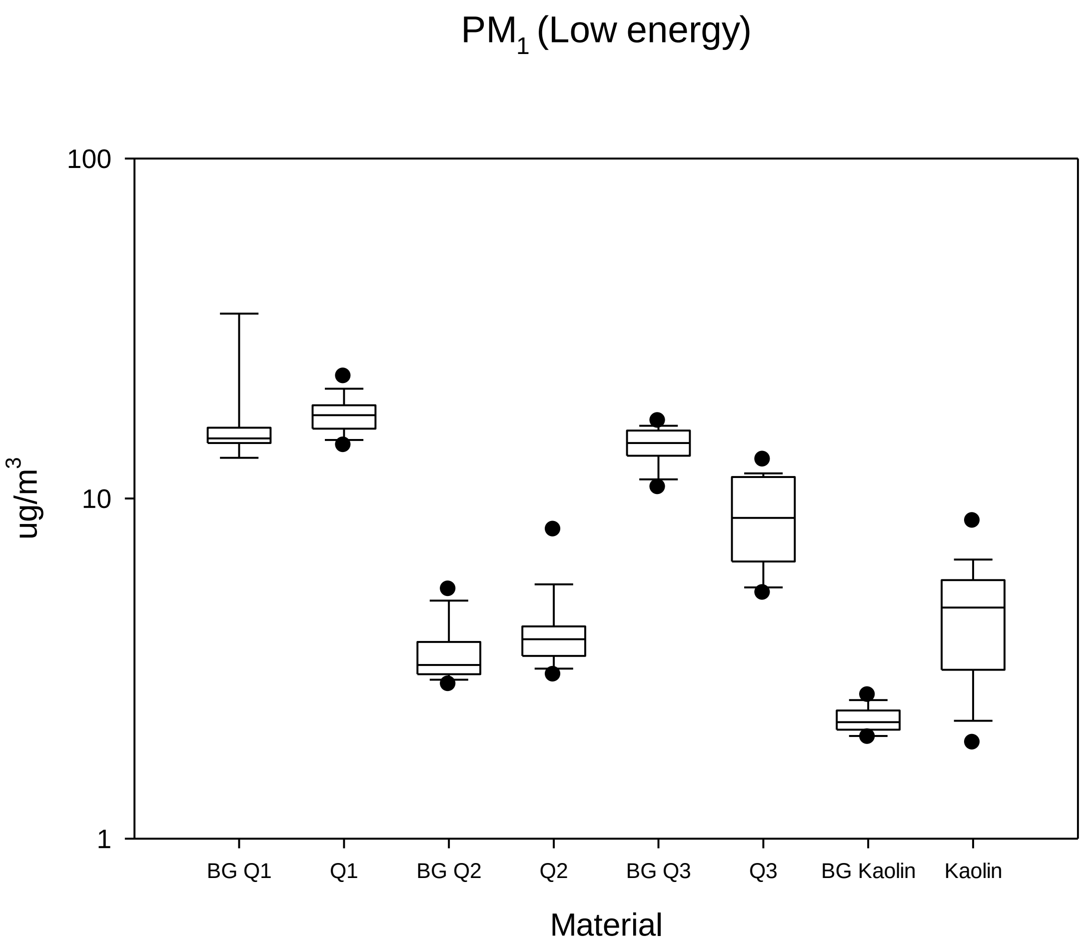
RESULTS


PM2.5 (Low energy)
10000
1000
100
10
1
ug/m3
BG Q1
Q1
BG Q2
Q2
BG Q3
Q3
BG Kaolin
Kaolin
Material

PM₁ (High energy)



RESULTS



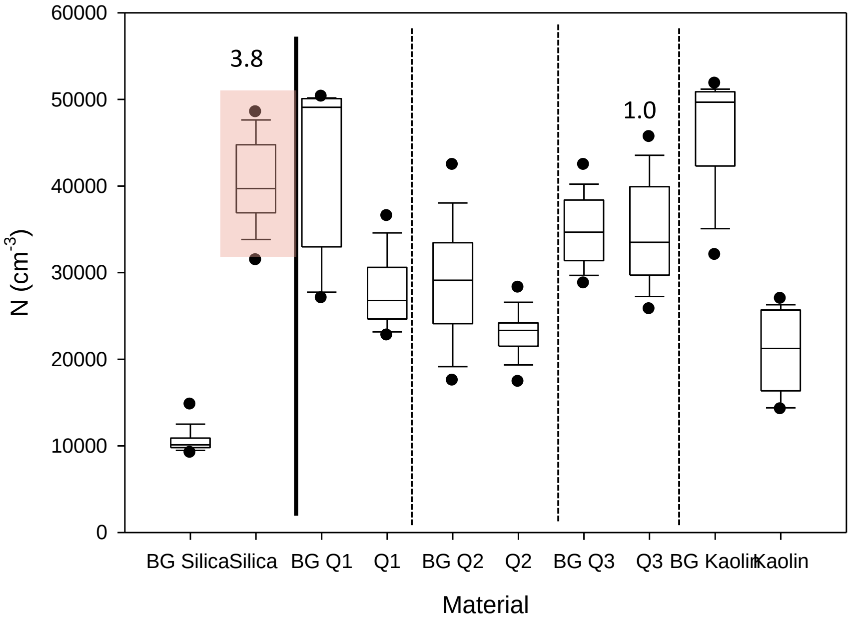
PM1 (Low energy)
100
10
1
ug/m3
BG Q1
Q1
BG Q2
Q2
BG Q3
Q3
BG Kaolin
Kaolin
Material

RESULTS

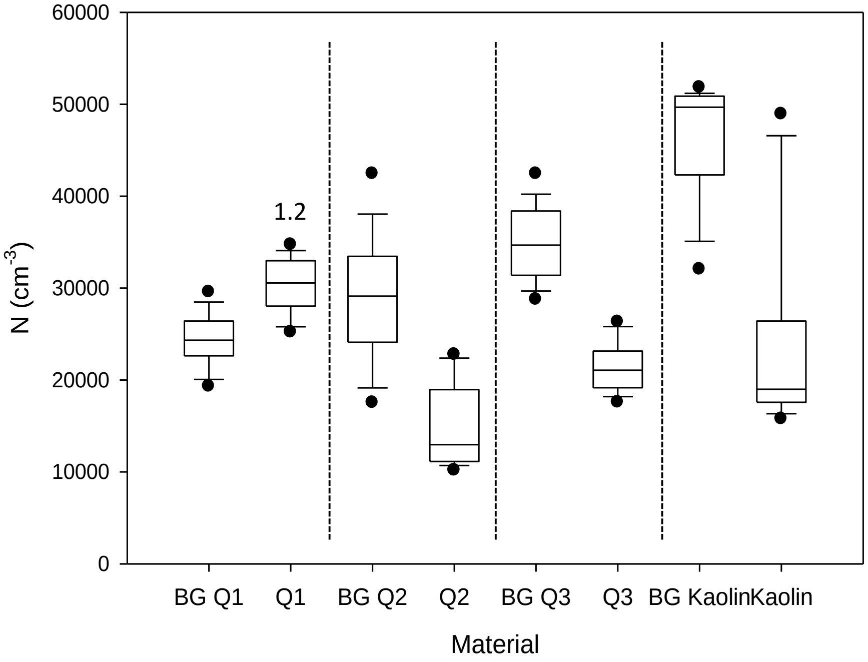
Influence of operating conditions

Particle number

Number concentration (High energy)



Number concentration (Low energy)



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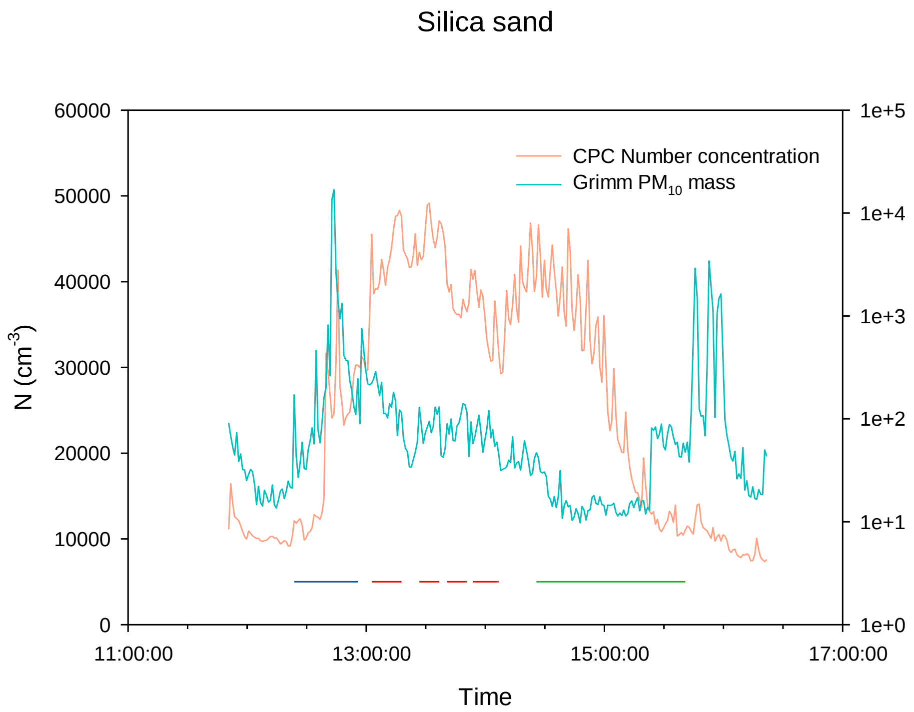
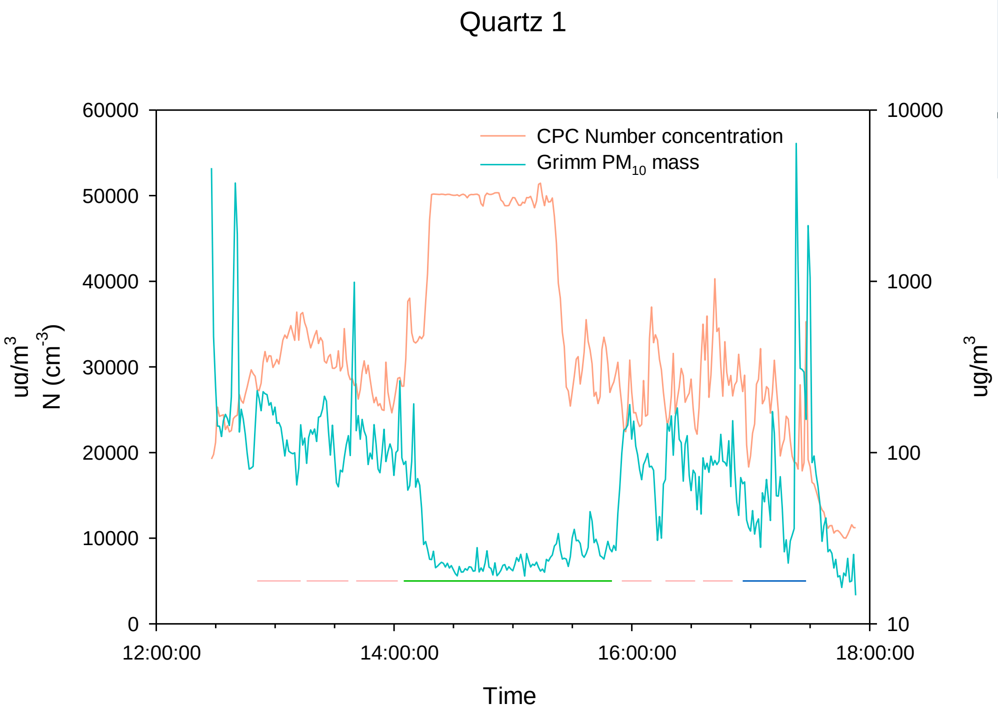
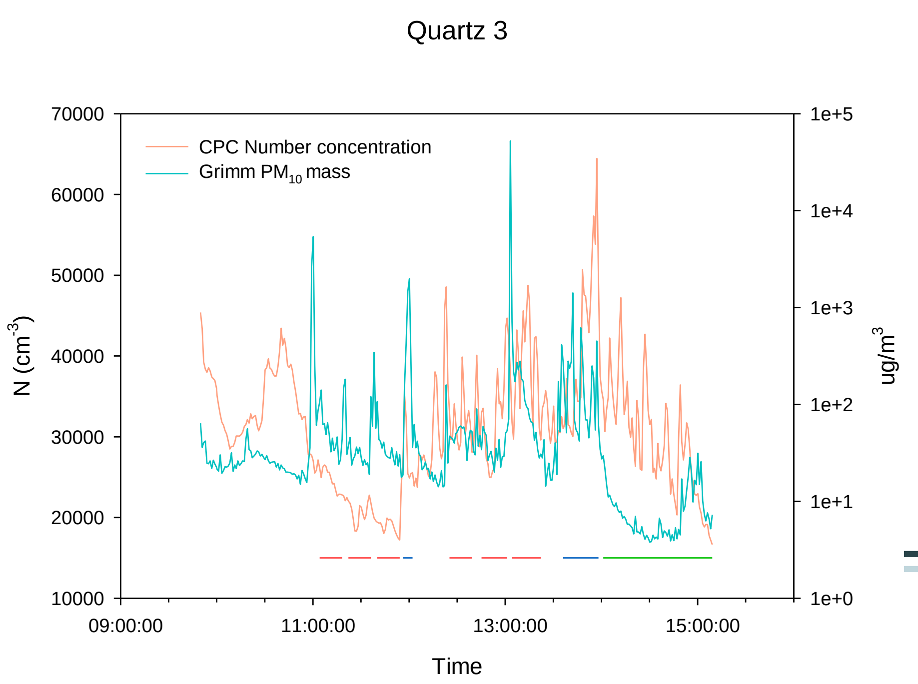


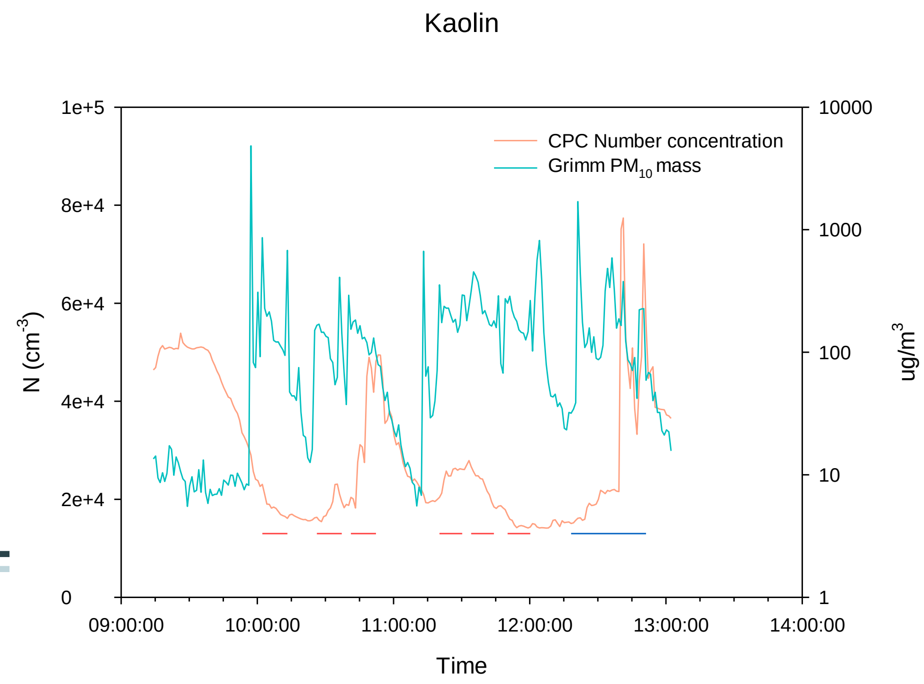
Silica sand
CPC Number concentration
Grimm PM10 mass
N (cm-3)
ug/m3
Time
0
10000
20000
30000
40000
50000
60000
1e+0
1e+1
1e+2
1e+3
1e+4
1e+5
11:00:00
13:00:00
15:00:00
17:00:00



Quartz 1
CPC Number concentration
Grimm PM10 mass
N (cm-3)
ug/m3
Time
0
10000
20000
30000
40000
50000
60000
10
100
1000
10000
12:00:00
14:00:00
16:00:00
18:00:00



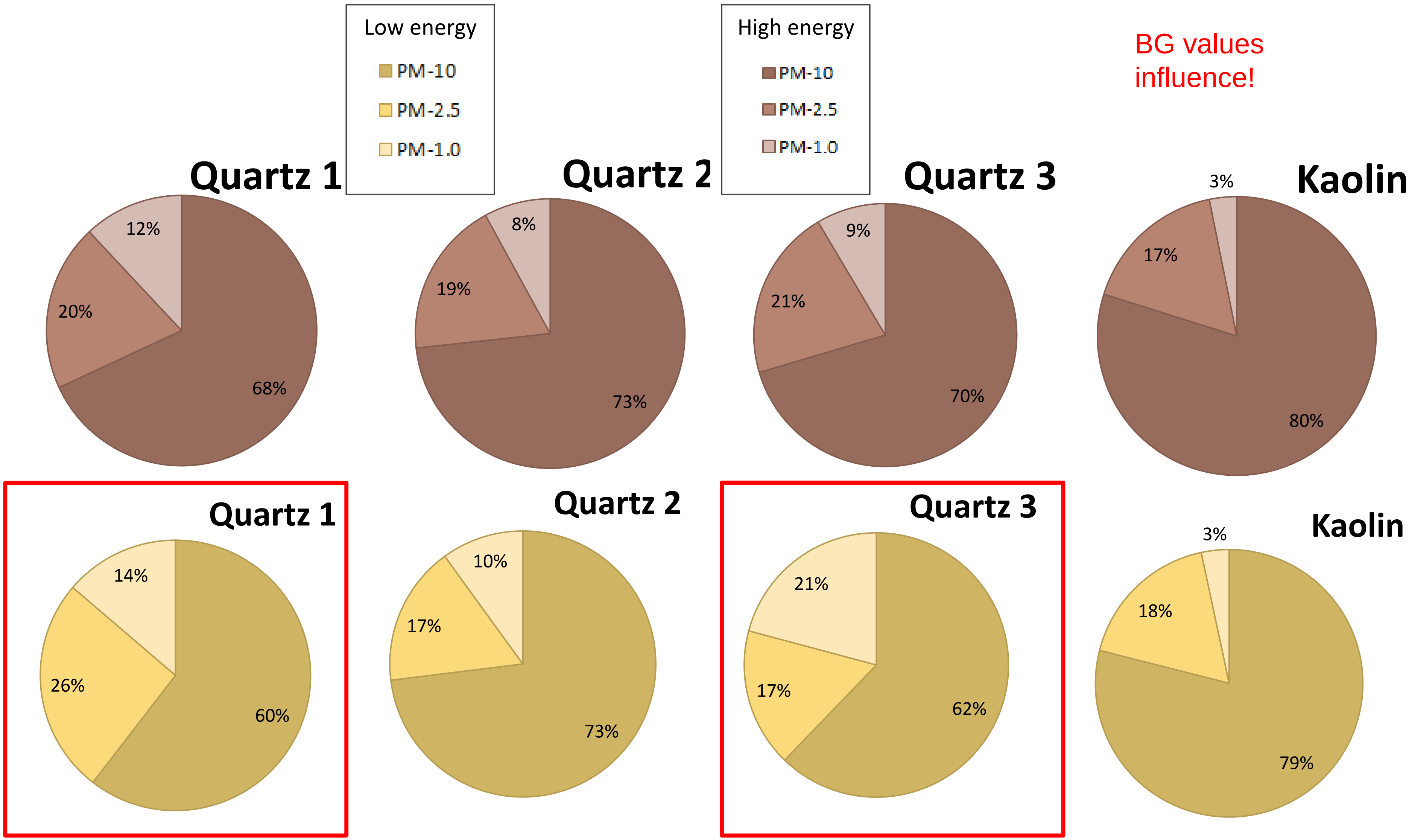
Quartz 3
CPC Number concentration
Grimm PM10 mass
N (cm-3)
ug/m3
Time
10000
20000
30000
40000
50000
60000
70000
1e+0
1e+1
1e+2
1e+3
1e+4
1e+5
09:00:00
11:00:00
13:00:00
15:00:00



Kaolin
CPC Number concentration
Grimm PM10 mass
N (cm-3)
ug/m3
Time
0
2e+4
4e+4
6e+4
8e+4
1e+5
1
10
100
1000
10000
09:00:00
10:00:00
11:00:00
12:00:00
13:00:00
14:00:00

Influence of operating conditions

Mass concentrations



RESULTS

high energy	Number	PM10	PM2.5	PM1.0
Silica-1	2.9	1.9	2.8	1.3
Silica-2	3.0	1.1	1.7	1.0
Silica-3	2.5	1.1	1.8	1.0
Silica-4	2.4	0.8	1.3	0.8
Silica-TOT	**2.7**	**1.3**	**1.9**	**1.0**
QS60-4	0.4	1.2	1.1	0.9
QS60-5	0.4	1.2	1.0	0.7
QS60-6	0.4	1.0	0.8	0.6
QS60-TOT	**0.4**	**1.1**	**0.9**	**0.7**
QI01-4	0.5	2.6	0.3	0.3
QI01-5	0.5	2.0	0.3	0.3
QI01-6	0.4	2.8	0.4	0.3
QI01-TOT	**0.5**	**2.5**	**0.4**	**0.3**
QEL01-4	0.7	1.0	0.6	0.3
QEL01-5	0.7	0.7	0.5	0.3
QEL01-6	0.8	3.0	1.7	0.4
QEL01-TOT	**0.7**	**1.6**	**0.9**	**0.3**
kolin-4	0.1	5.8	2.7	0.8
kaolin-5	0.1	7.2	3.1	0.9
kaolin-6	0.1	5.1	2.3	0.7
kaolin-TOT	**0.1**	**6.0**	**2.7**	**0.8**

low energy	Number	PM10	PM2.5	PM1.0
Silica sand	-	-	-	-
QS60-1	0.98	0.55	0.66	0.88
QS60-2	0.98	0.45	0.58	0.97
QS60-3	0.84	0.40	0.52	0.97
QS60-TOT	**0.93**	**0.47**	**0.58**	**0.94**
QI01-1	0.23	2.00	0.21	0.37
QI01-2	0.26	1.14	0.19	0.38
QI01-3	0.41	1.04	0.21	0.44
QI01-TOT	**0.30**	**1.39**	**0.21**	**0.40**
QEL01-1	0.52	1.07	0.85	0.60
QEL01-2	0.43	0.69	0.56	0.45
QEL01-3	0.39	0.73	0.47	0.30
QEL01-TOT	**0.45**	**0.83**	**0.63**	**0.45**
kolin-1	0.28	14.61	9.00	2.93
kaolin-2	0.28	8.34	4.38	1.62
kaolin-3	0.54	7.57	4.73	1.65
kaolin-TOT	**0.37**	**10.17**	**6.04**	**2.07**