Ranges in respirable and inhalable dustiness and dustiness kinetics of NM powders as determined by the prototype small rotating drum – priority parameters for exposure assessment

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Definition of dustiness

- **Definition**
  - The propensity of powders to release dust as airborne particles during a standardized agitation procedures.
- **Measurands**
  - Dustiness Index in mg/kg powder in toxicologically relevant size-fractions (DI_{inh}, DI_{tho}, DI_{resp})
- **Methods**
  - Several methods exist, but only two methods are currently accepted in standards: EN15051 (rotating drum and continuous drop method)

The two EN15051 methods

- The rotating drum (35 cm^3 powder; agitation for 1 min. in 50%RH air).
- The continues drop (≥500 cm^3 powder; drop until powder used, in 50%RH air)

1 m

1.2 m

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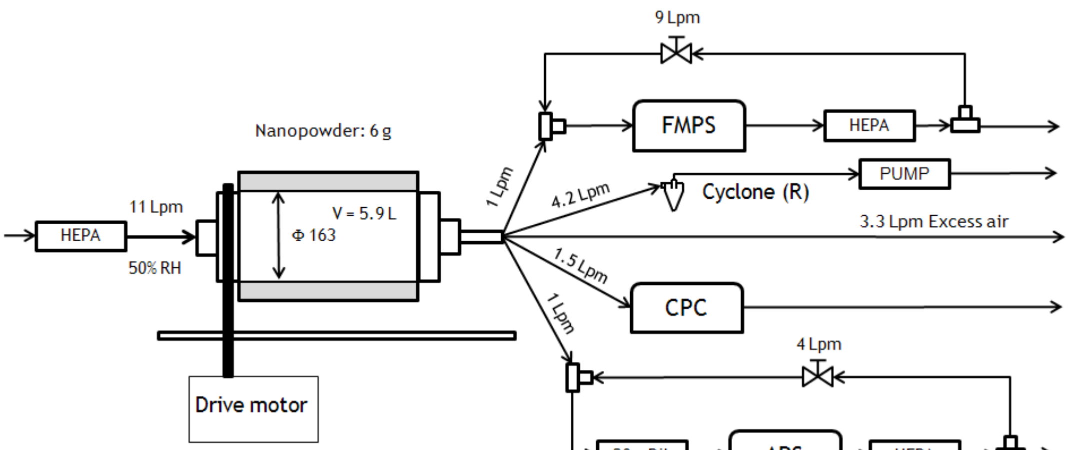
Small rotating drum developed for safer testing of small amounts of “nanopowders”

- 1/5’th the volume of the EN15051 drum; ; agitation for 1 min. in 50%RH air)
- Use <6 g powder (consideration of standard volume instead)
- Simoultaneous online measurement with different aerosol monitors and PM.



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(Schneider and Jensen, 2008); Jensen et al., 2009; Levin et al., 2014…)

Measurands

- **Original Purpose in EN15051**
  - Relatively rank powder dustiness in mg/kg powder for assessent of release potential (importance for processing, design and risk management)

- **New additional aims**
  - More specific test methods
  - Data for more quantitatíve exposure assessment and prioritization in material selection (nano-focus)

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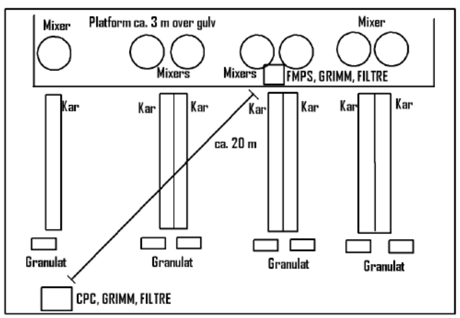
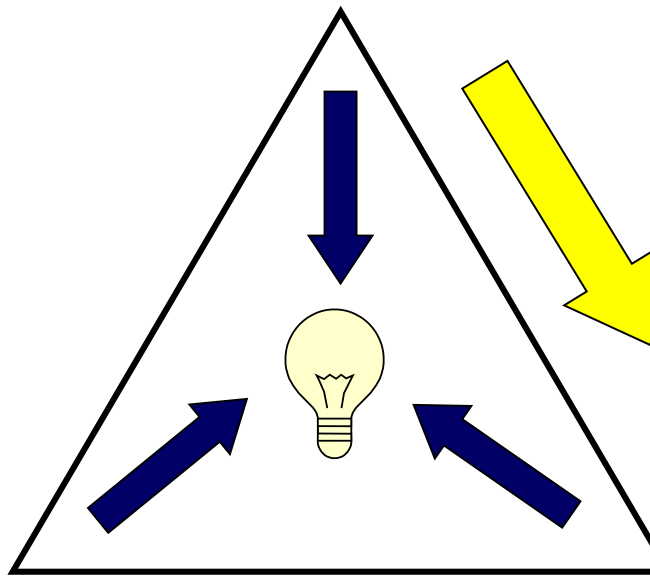
Dustiness data already used for technical evaluation and exposure assessment



Emission Potential
Simulated work processes

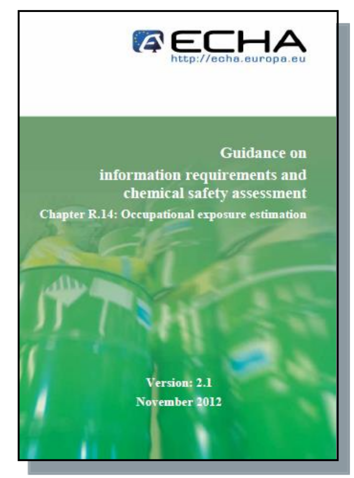


Akut eksponering i nærområdet (15 minutter)

Toxicitet / Eksponering	0,76 - 1,00	0,51 - 0,75	0,26 - 0,50	0,00 - 0,25
> 1,00				
0,51 - 1,00				
0,26 - 0,50				
0,11 - 0,25				★
< 0,10				

Akut eksponering i arbejdslokalet (15 minutter)

Toxicitet / Eksponering	0,76 - 1,00	0,51 - 0,75	0,26 - 0,50	0,00 - 0,25
> 1,00				
0,51 - 1,00				
0,26 - 0,50				
0,11 - 0,25				
< 0,10				★



Workplace Measurement

Exposure (Risk) Modelling

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Exposure scaling/estimation in several Control Banding tools

Probability factor	Maximum points	Maximum probability score
Estimated amount of nanomaterial	25	100
Dustiness/mistiness	30	
Number of employees with similar exposure	15	
Frequency of operation	15	
Duration of operation	15	

Example: US CB NANOTOOL (Paik et al., 2008)

Probability

Severity	Extremely Unlikely (0-25)	Less Likely (26-50)	Likely (51-75)	Probable (76-100)
Very High (76-100)	RL 3	RL 3	RL 4	RL 4
High (51-75)	RL 2	RL 2	RL 3	RL 4
Medium (26-50)	RL 1	RL 1	RL 2	RL 3
Low (0-25)	RL 1	RL 1	RL 1	RL 2

Control bands:

RL 1: General Ventilation

RL 2: Fume hoods or local exhaust ventilation

RL 3: Containment

RL 4: Seek specialist advice

Intrinsic part of dustiness classes in some REACH R.14 recommended tools

ECETOC-TRA

Table R.14-5: Help on fugacity selection criteria

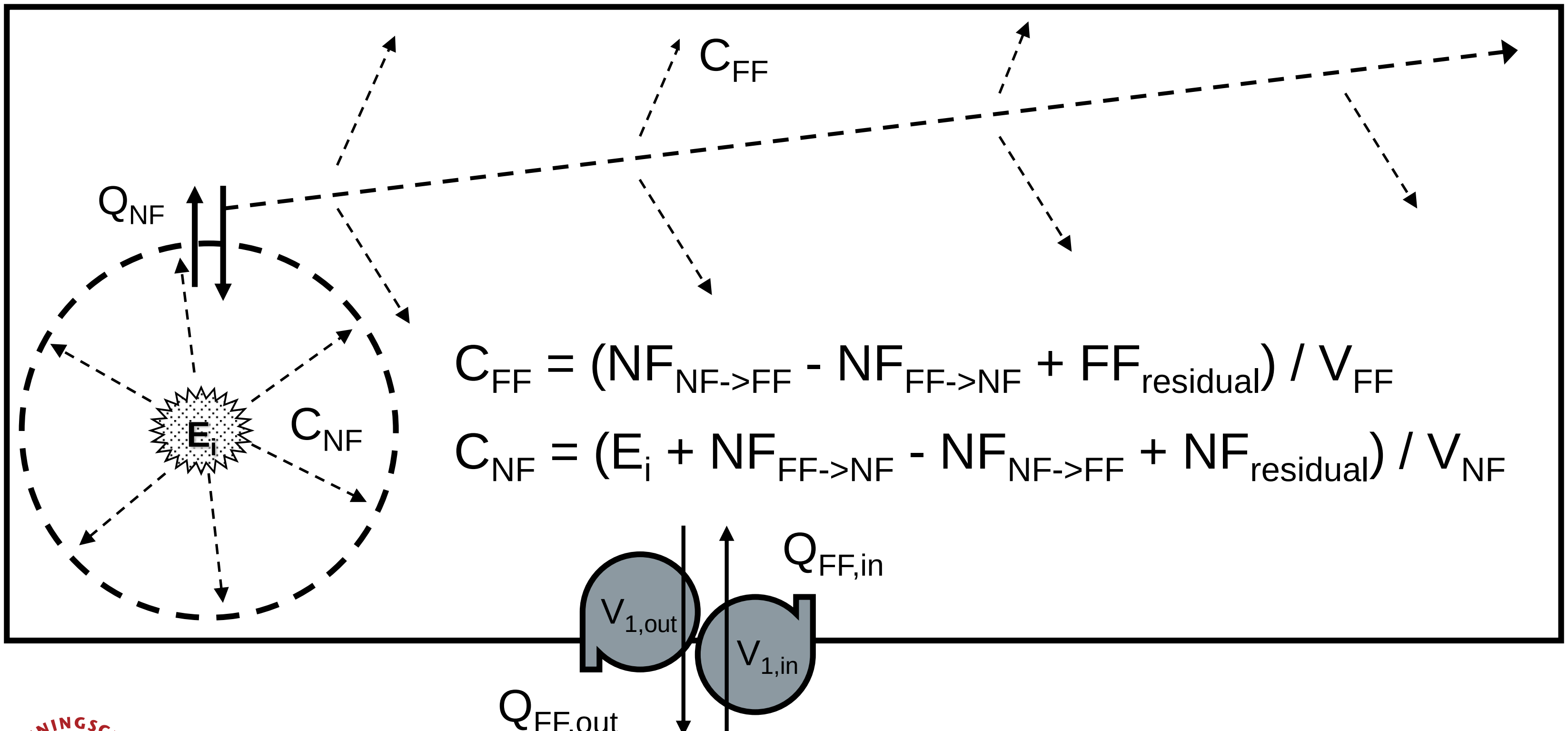
General description	Relative dustiness potential	Typical materials	TRA Selection Value
Not dusty	1	Plastic granules [a], pelleted fertilisers	**Low**
Slightly dusty	10 - 100 times dustier	Dry garden peat, sugar, salt	**Low /Medium** [c]
Dusty	100 - 1,000 times dustier	Talc, graphite	**Medium**

EMKG-EXPO

Table R.14-10: Definition of dustiness bands

High	Fine, light powders. When used, dust clouds can be seen to form and remain airborne for several minutes. For example: cement, titanium dioxide, photocopier toner
Medium	Crystalline, granular solids. When used, dust is seen, but it settles quickly. Dust is seen on the surface after use. For example: soap powder, sugar granules
Low	Pellet-like, non friable solids. Little evidence of any dust observed during use. For example: PVC pellets, waxes

First order estimation of NF and FF NOAA dust exposure potential (e.g., NanoSafer algorithm)



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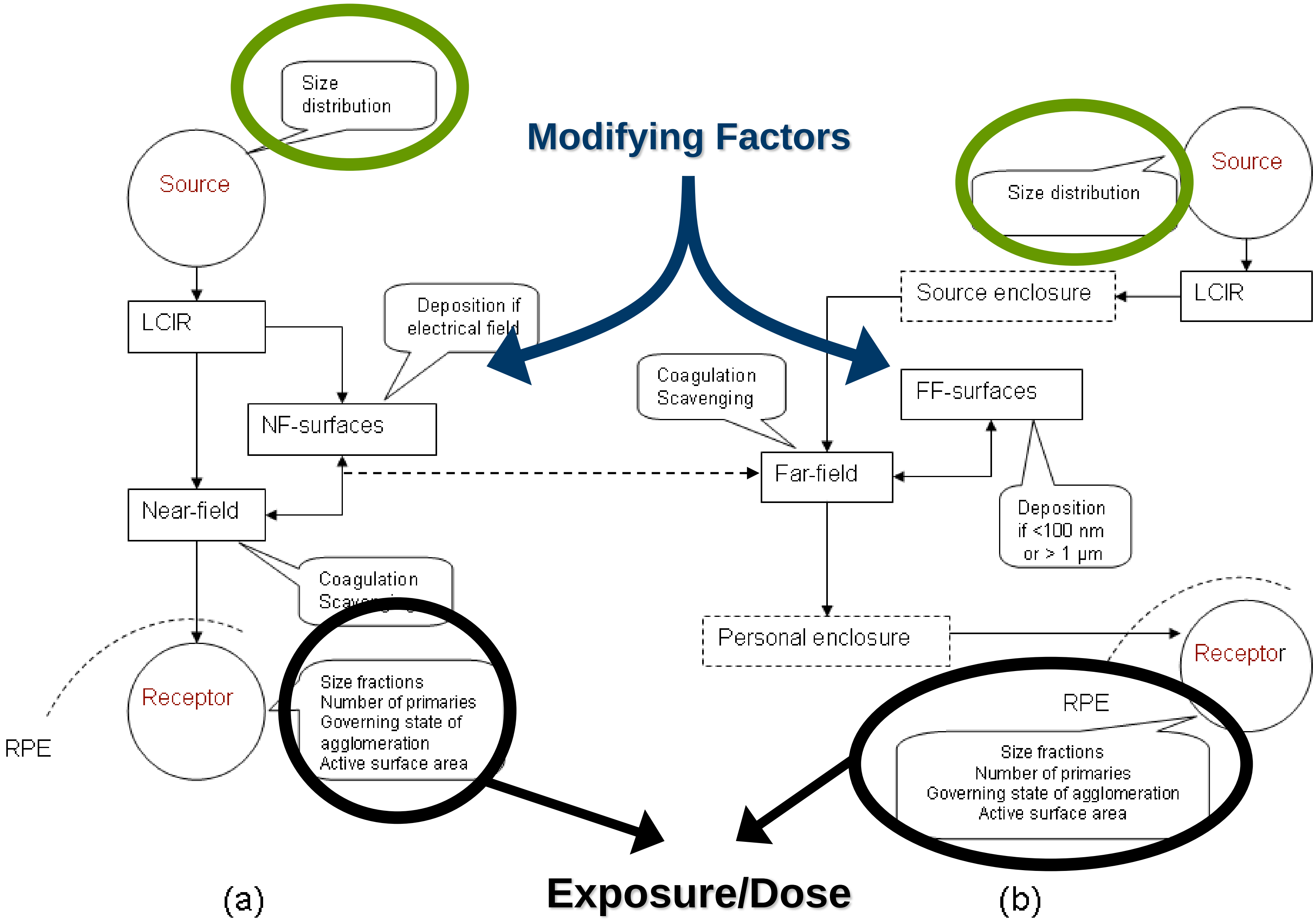
Kristensen et al. (2010); decay functions based on Schneider et al. AE (2004)

Conceptual Exposure Assessment Model for NOAA



LCIR: Local Control Influence Region

Schneider et al. (2009; 2011)

Applicability of Dustiness ranges for NOAA: EN15051 Rotating Drum systems

ECETOC-TRA

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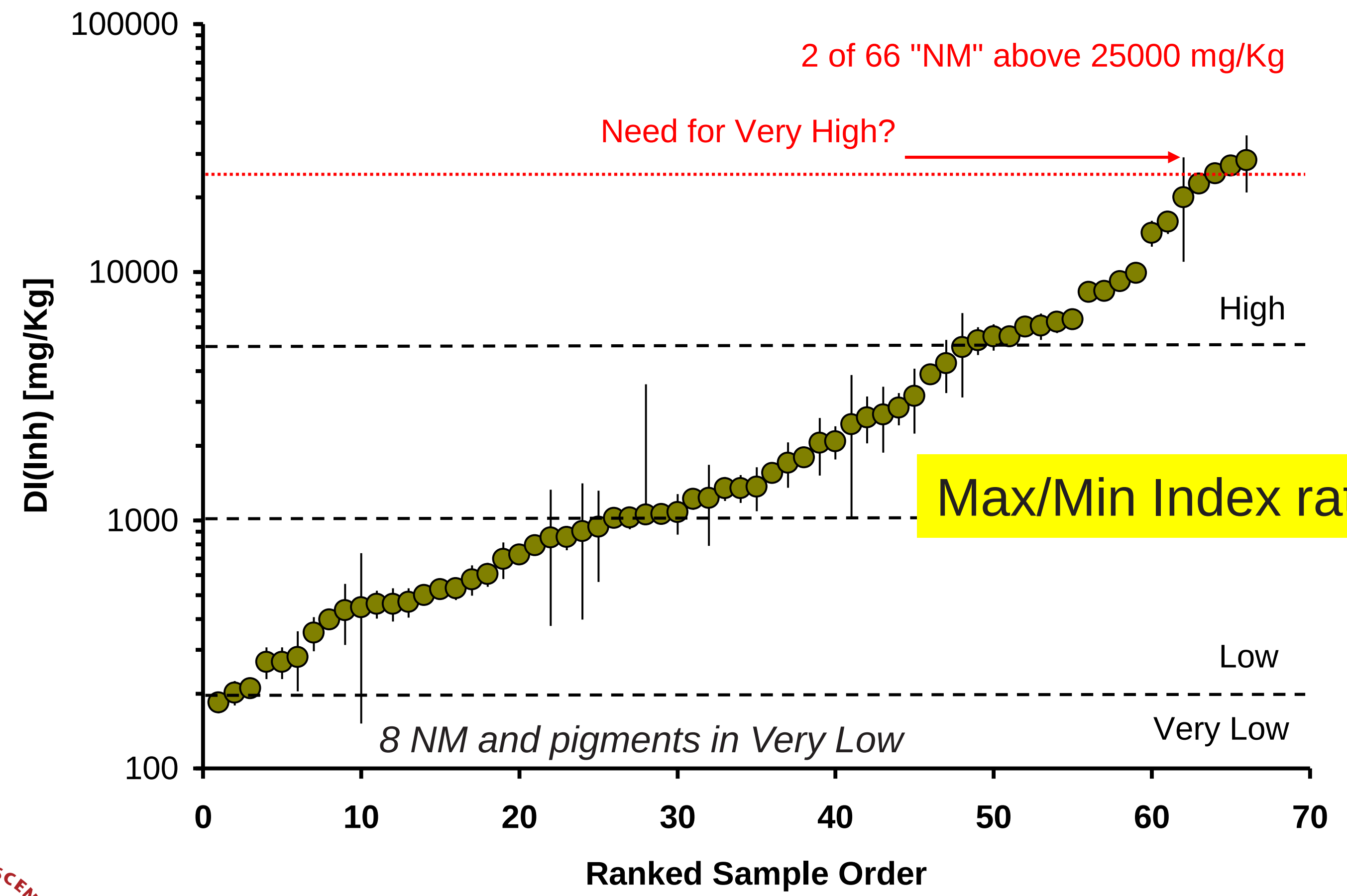
Max/Min Index ratio ≥ 100

EN15051

Dustiness class	DI(resp)	DI(inh)
High	>250 mg/Kg	5000 mg/Kg
Moderate	250 mg/Kg	1000 – 5000 mg/Kg
Low	50 mg/Kg	200 – 1000 mg/Kg
Very Low	10 mg/Kg	< 200 mg/Kg

Max/Min Index ratio ≥ 25

Variation Inhalable dustiness indices of fine pigments and “nanopowders”?



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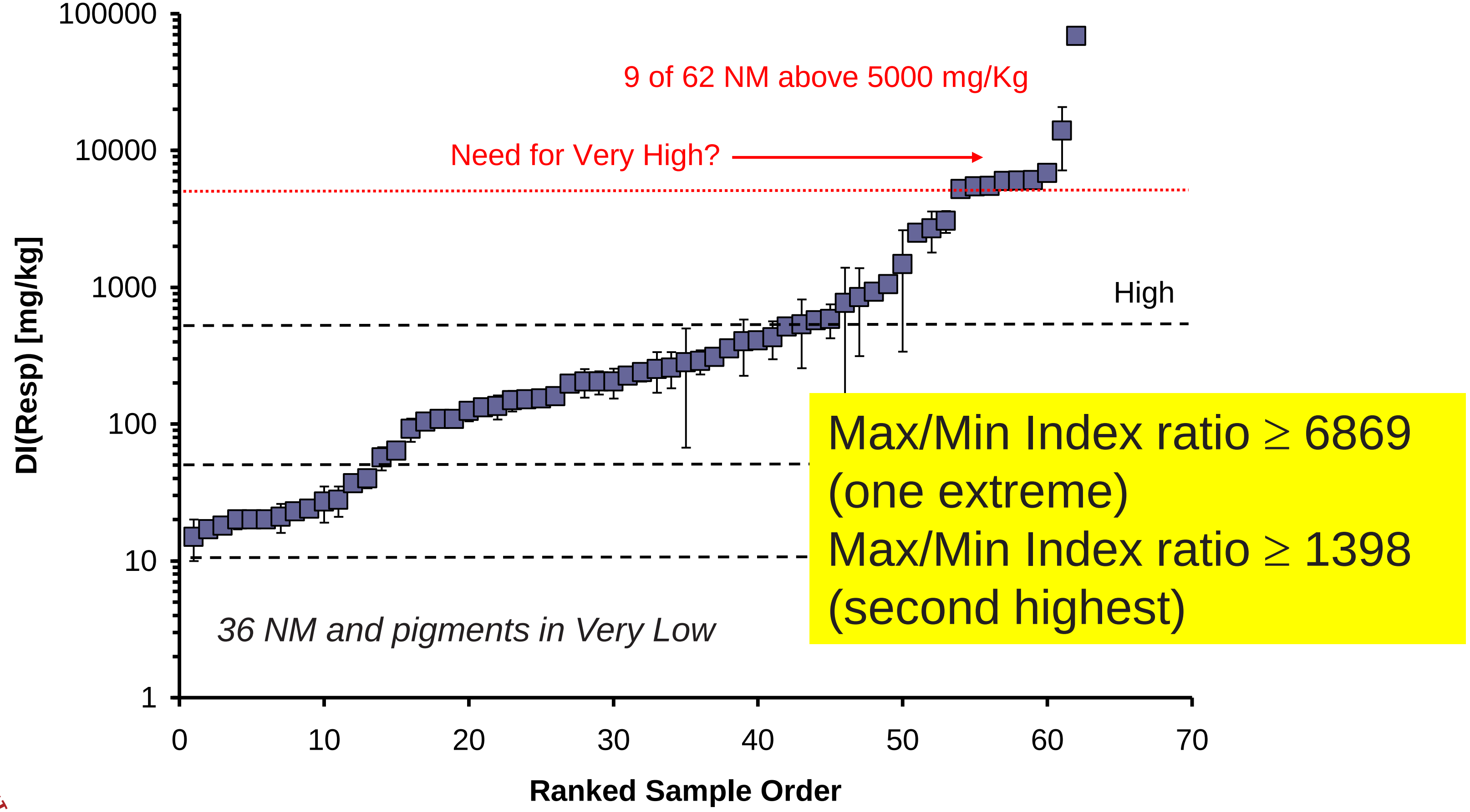
Variation respirable dustiness indices of fine pigments and “nanopowders”?



Applicability of Dustiness ranges for NOAA: EN15051 Rotating Drum systems

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General description	Relative dustiness potential	Typical materials	TRA Selection Value
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Dusty	100 - 1,000 times dustier	Talc, graphite	**Medium**

Max/Min Index ratio ≥ 100

EN15051

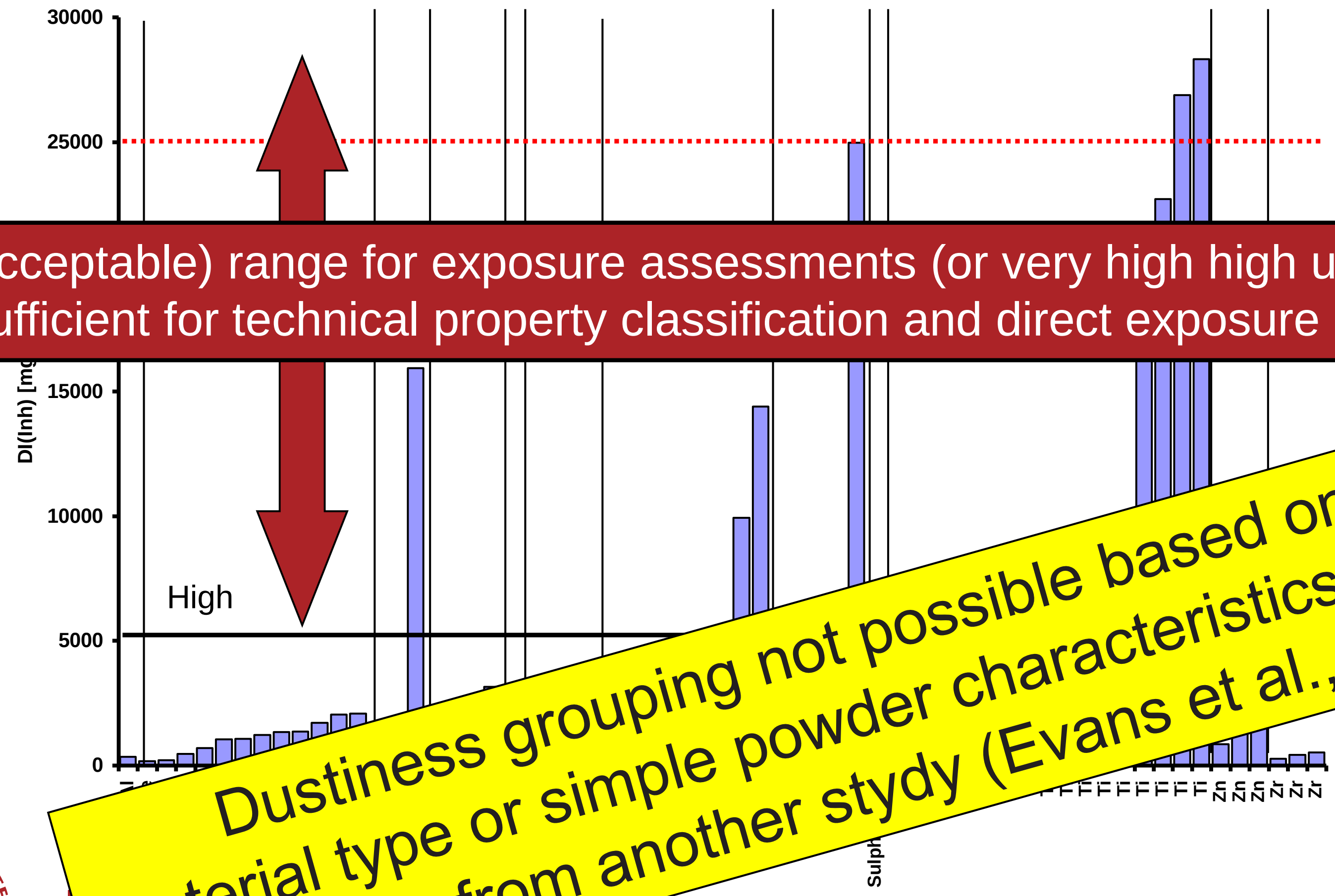
Dustiness class	DI(resp [illegible]	[illegible]
High	[illegible]	[illegible]
Moderate	[illegible]	[illegible]
Low	[illegible]	200 – 1000 mg/Kg
Very Low	[illegible]	< 200 mg/Kg

Max/Min Index ratio ≥ 25

Experimentally DI(resp)
Max/Min Index ratio ≥ 6869
(one extreme)
Max/Min Index ratio ≥ 1398
(second highest)

Experimentally DI (inh)
Max/Min Index ratio ≥
142

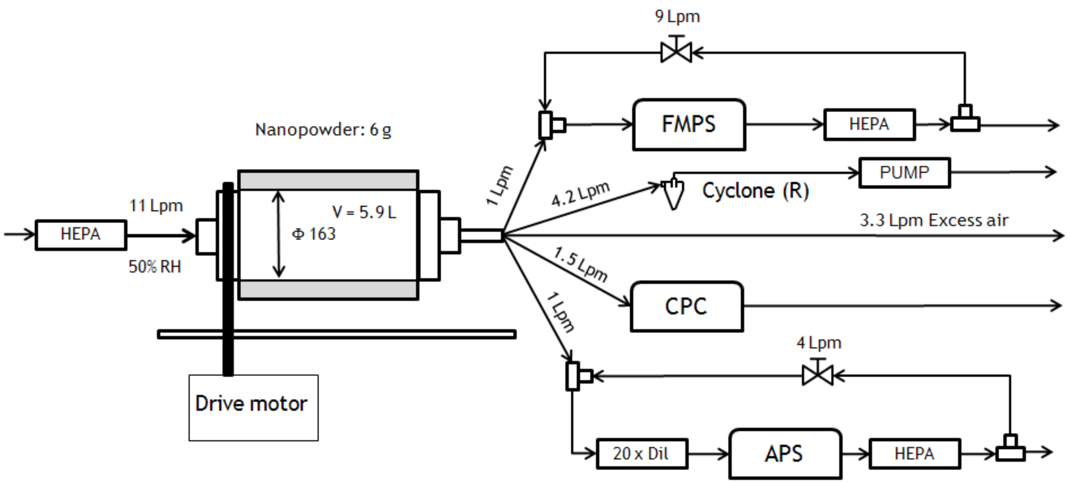
Variation in dustiness classies withing material groups?



Huge (unacceptable) range for exposure assessments (or very high high uncertainty)
Possibly sufficient for technical property classification and direct exposure management

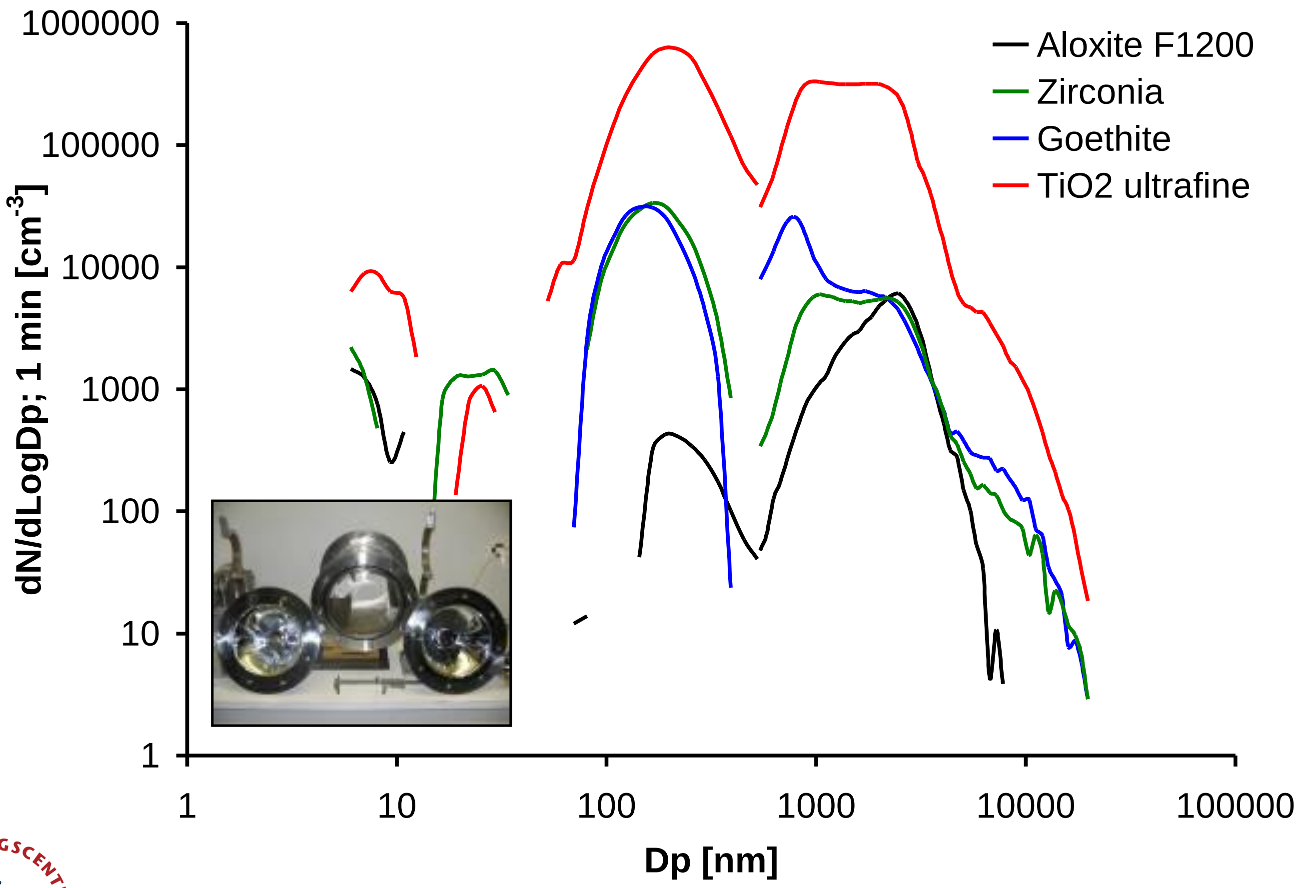
Dustiness grouping not possible based on material type or simple powder characteristics alone! (also clear from another stydy (Evans et al., 2014)

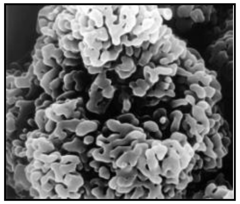
Benefits of the online monitoring data in the nanospecific dustiness testing?

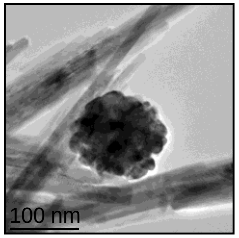


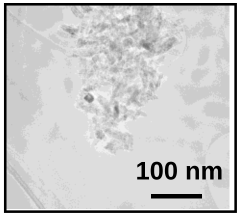
Dust particle size-distributions
Dustiness kinetics (Particle Generation Rate)

Added value of Size-distribution Measurements?
- Nano-Objects Aggregates and Agglomerates -









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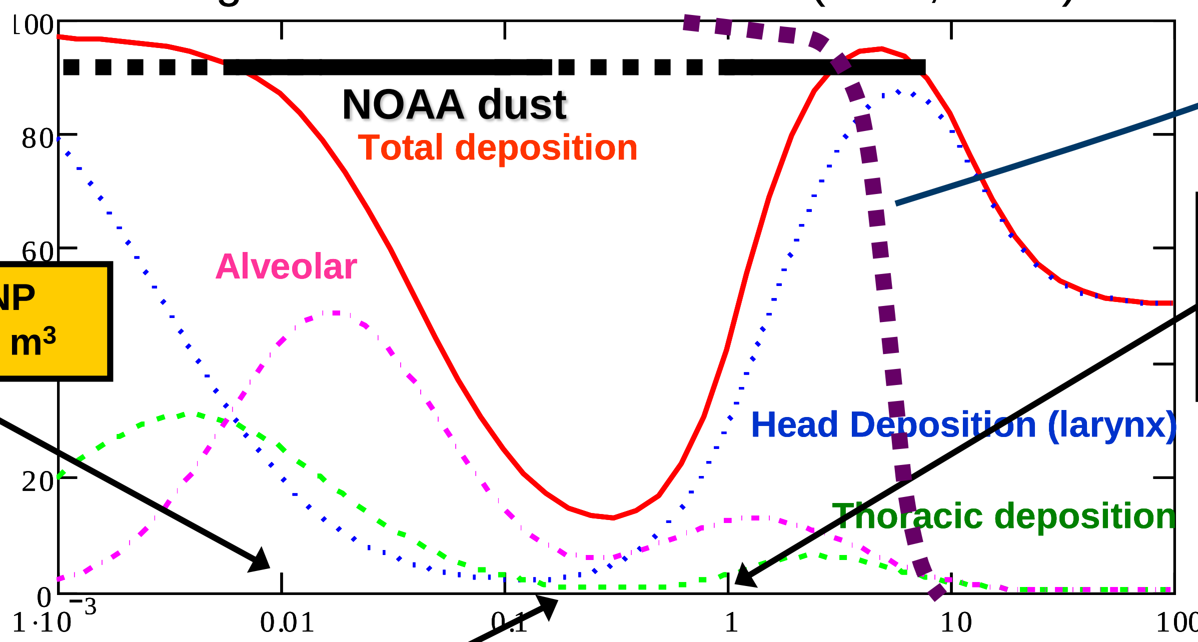
Data from Schneider and Jensen. Ann. Occ. Hyg. 52 (2008)

Size-distributions and maximum relevant size?

- Nano-Objects Aggregates and Agglomerates -

Respirable Fraction

Biological relevant size fraktions (CEN, 1992)



Particle Size [um]

One 10 nm NP
Vol 5.24 10^{-25} m^3

1 10^6 NP's in one 1 µm agglomerate of 10 nm NPs
Vol 5.24 10^{-19} m^3

8000 NP's in one 200 nm agglomerate of 10 nm NPs
Vol 4.19 10^{-21} m^3

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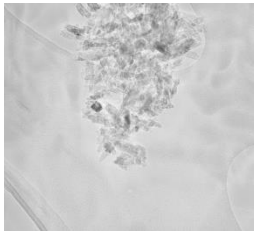
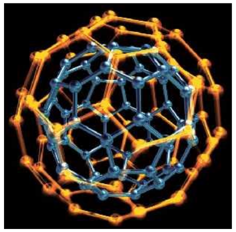
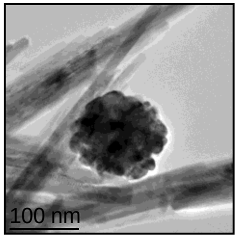
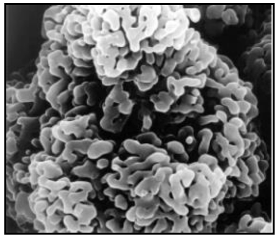
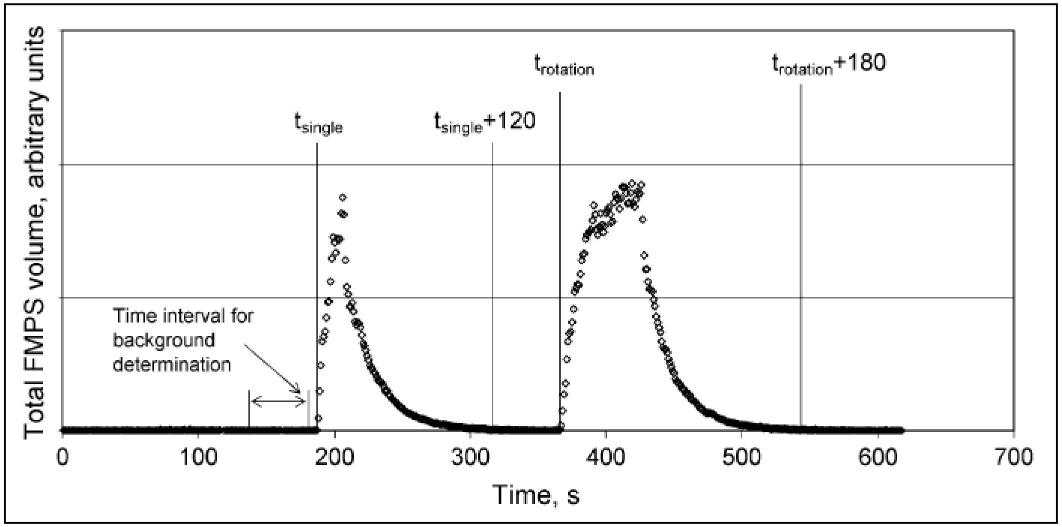




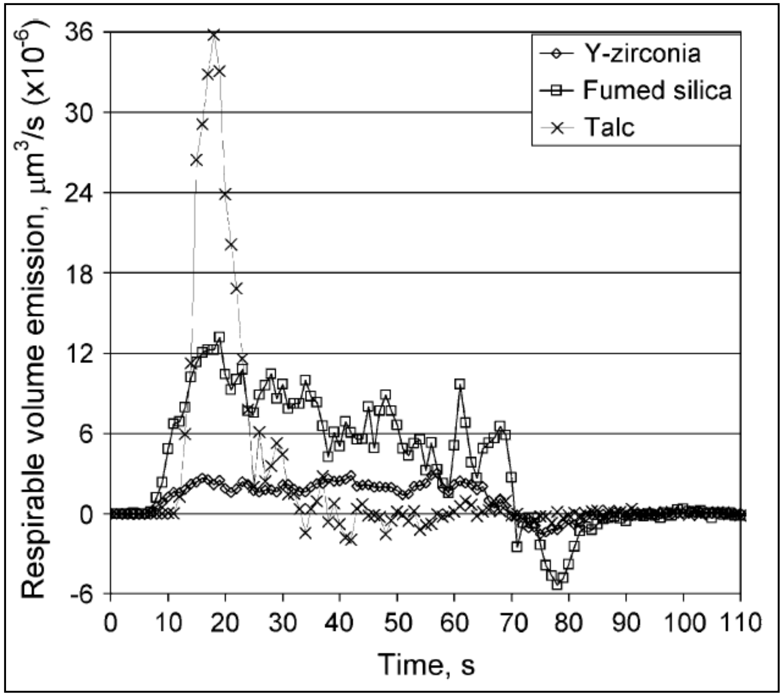




Added value of online particle concentration measurements (Particle Generation Rate)



Schneider and Jensen AOH (2008)



$PGR_i = k\Delta t^{-1}(C_i - C_{i-1}\exp(-\Delta t \tau^{-1}))$

K = volume of drum

C_i = volume concentration

Δt = integration time

τ = time constant for calculation (20 sec) (measured value)

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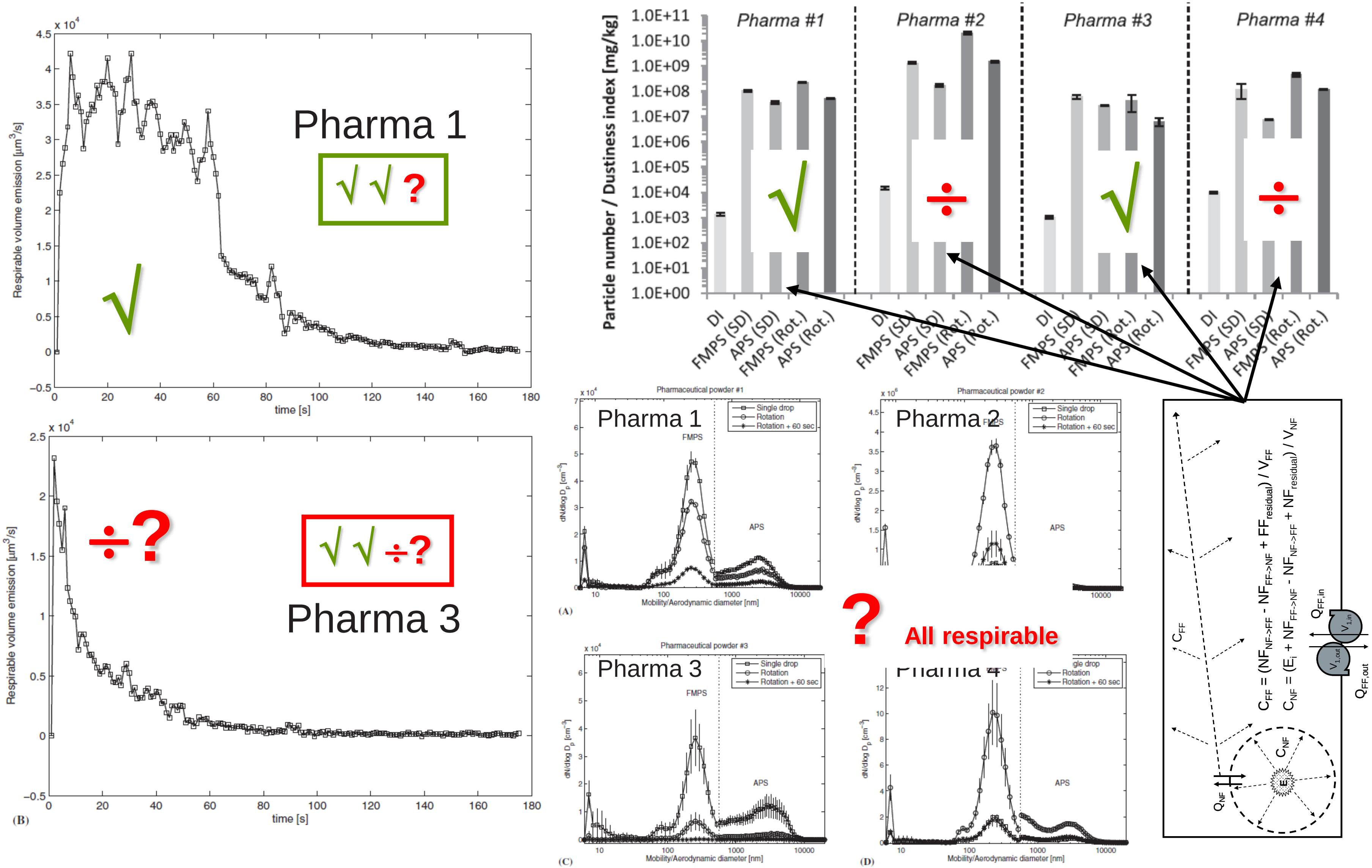
Example of use of dustiness data for material decision making

Levin et al. JOEH (2014)



Conclusions

- Existing dustiness categories as for example derived for ECETOC TRA, EMKG-EXPO Tool, and the classes in EN15051, appears to be too crude to cover nanopowder dustiness indices. Absolute measured values are preferred.
- Size-distribution measurements give highly valuable information for specific assessments of the potential inhalation dose and potential aerosol dynamics (there is a huge difference in filtration and aerosol dynamic behavior with particle size)
- Data on dustiness “dustines kinetics” (particle generation rate) give further insight into powder behavior and dust release mechanisms during mechanical agitation.
- Dustiness indices, number size-distributions, and dustiness kinetics (particle generation rates) appears to be very suitable parameters for prioritization in safer material selection and assessing potential exposure during powder handling (demonstrated in Levin et al., JOEH. 2014).

?