Comparing workers measured dust exposure with predicted exposures using a NF/FF model, NanoSafer II, and the ART exposure assessment tools

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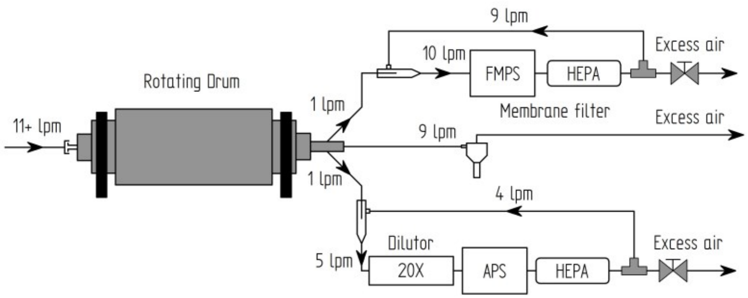
Outline

- Source characterization using dustiness index
- Short introduction to:
  - NF/FF model
  - NanoSafer II
  - The ART
- Performance test: pouring of pigment/filler powders to a mixing tank in a paint factory
- Conclusions
- List of references

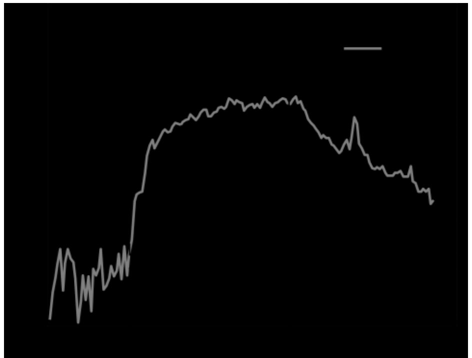
Dustiness index, *DI*

- Measured using small amount of material (*e.g.* 6 g in small-rotary drum; Schneider and Jensen, 2008)
- Modifying factors are used to scale *DI* to predict industrial emissions
- The emission from process *i* by handling of powder *j* is:

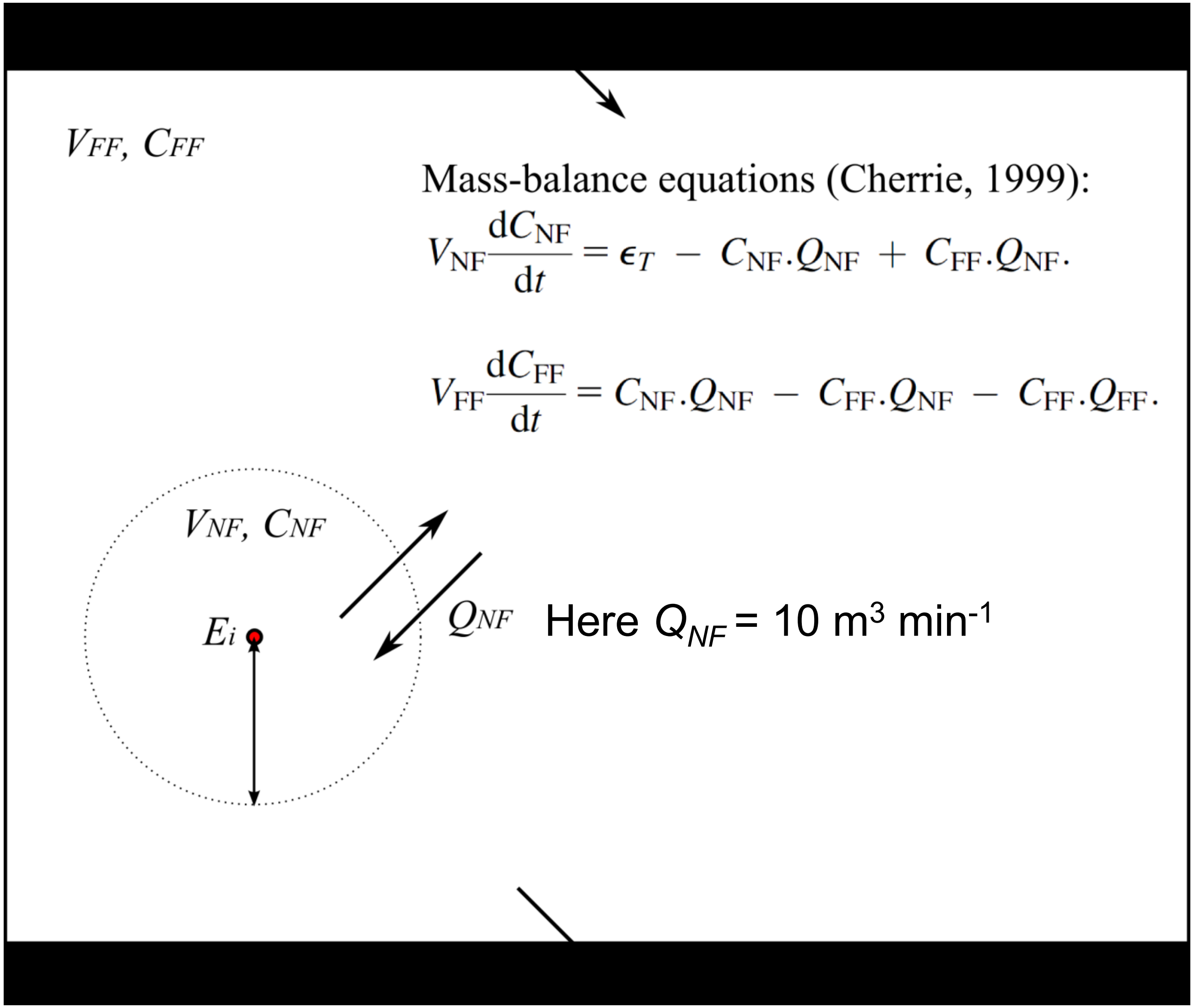
$$E_{i,j} = DI_j \cdot H_i \cdot \frac{dM_j}{dt} \cdot LC$$



$E_{i,j}$ = Emission rate [units min^{-1}]
Di_j = Dustiness index [units kg^{-1}]
H_i = Handling energy factor [-]
dM_j/dt = mass flow [kg min^{-1}]
LC = Localized controls [-]



The NF/FF model



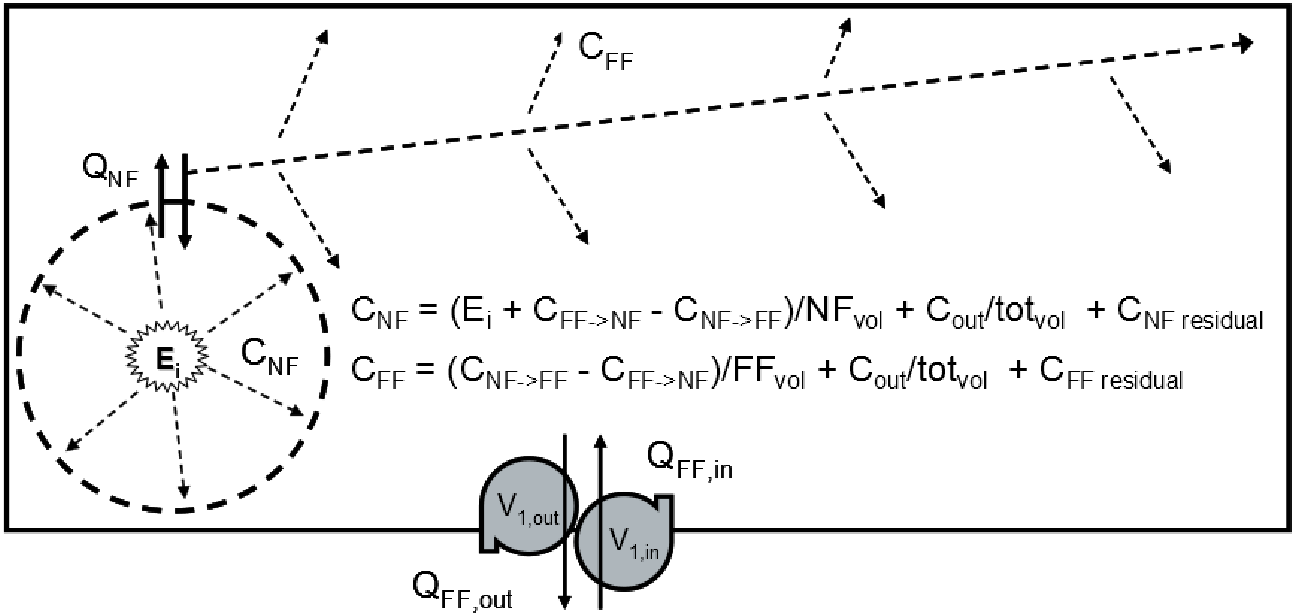
Assumptions:

- All mass entering the model volume is created at a source inside the NF volume
- Particles are fully mixed at all times in the NF and FF
- Limited air exchange between NF and FF volumes ($3\ m^3\ min^{-1} < Q_{NF} < 30\ m^3\ min^{-1}$; Cherrie, 1999)
- No other particle losses than FF ventilation.

Zhang et al., (2009) describes the NF/FF model in detail.

NanoSafer II

- Same assumptions as in the NF/FF model
- Dispersion based on Schneider et al., (2004)



Assumptions:

- All mass entering the model volume is created at a source inside the NF volume
- Particles are fully mixed at all times in the NF and FF
- No other particle losses than FF ventilation.

The ART (Fransman *et al*. 2011)

Table 6. Application of modifying factors in the example

Modifying factor	Relevant parameter	Description	Multiplier
Substance emission potential	Dustiness	Fine dust	0.3
	Moisture contents	Dry product	1.0
	Weight fraction	100% active ingredient	1.0
Activity emission potential: (activity class: transfer of powders, granules, or pelletized material. Activity subclass: falling of powders)	Use rate	Transferring 1–10 kg min^{-1}	1.0
	Carefulness of handling	Routine transfer	1.0
	Drop height	<0.5 m	1.0
	Level of process containment	Open process	1.0
Localized controls		No localized controls	1.0
Surface contamination		Demonstrable and effective housekeeping practices	0.001
Dispersion (indoors)	Room volume	300 m^3	0.8
	Ventilation rate	10 ACH	

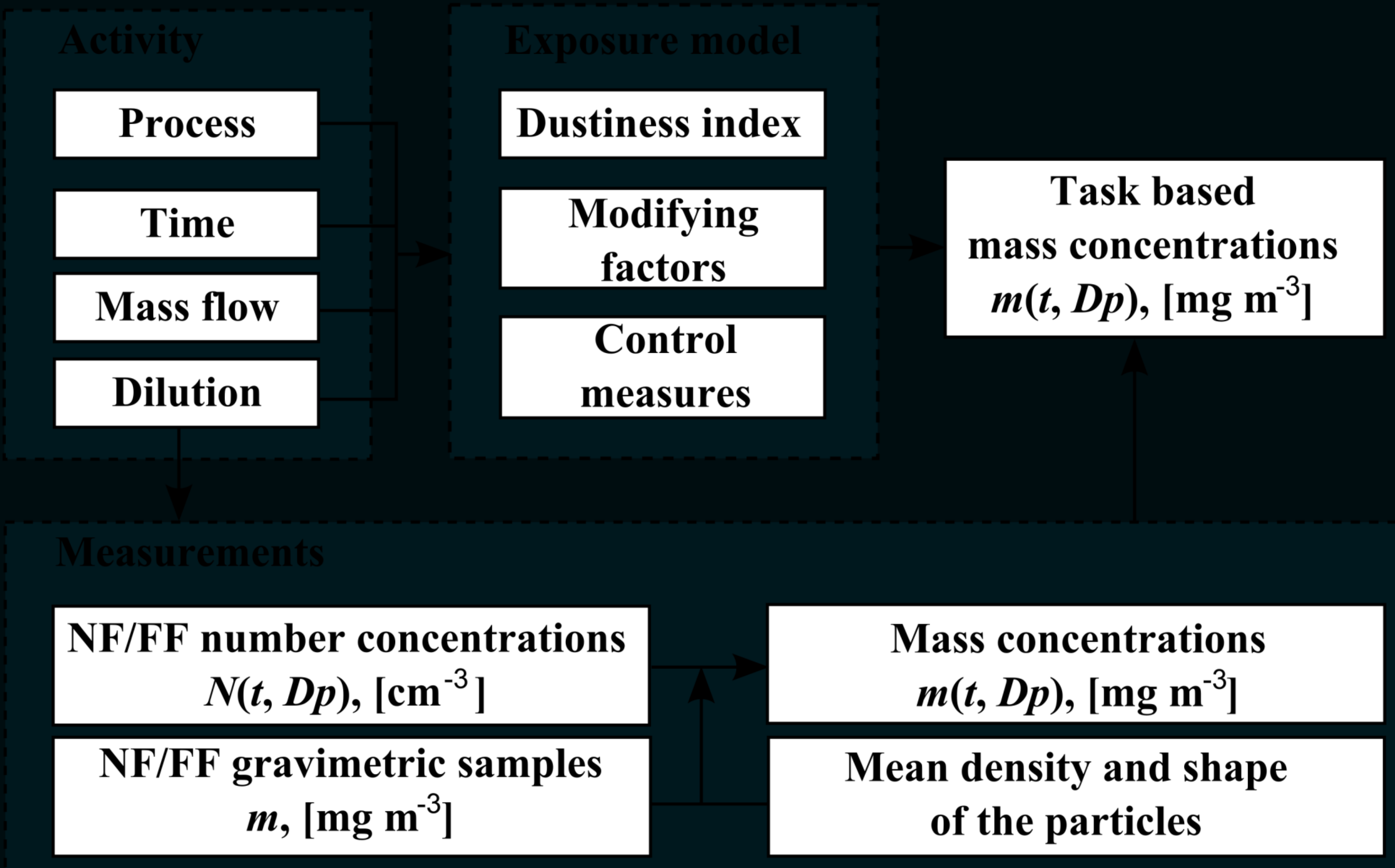
Example of calculation:

$$C_{\mathrm{nf}} = (E_{\mathrm{nf}} \cdot H_{\mathrm{nf}} \cdot \mathrm{LC}_{\mathrm{nf1}} \cdot \mathrm{LC}_{\mathrm{nf2}}) \cdot D_{\mathrm{nf}},$$

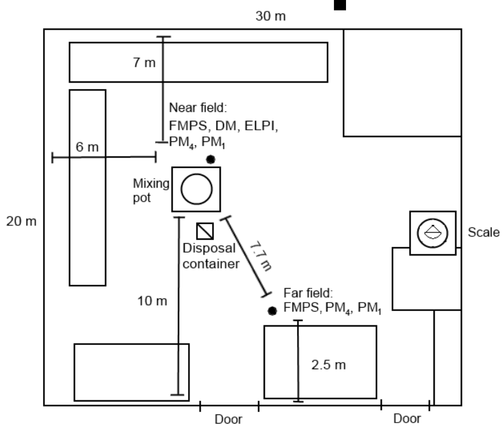
$$C_{nf} = ((0.3 \times 1.0 \times 1.0) \times (1.0 \times 1.0 \times 1.0 \times 1.0) \times 1.0 \times 1.0) \times 0.8 = 0.24,$$

$$C_t = \frac{1}{t_{\mathrm{total}}} \sum_{\mathrm{tasks}} \{ t_{\mathrm{exposure}} \cdot (C_{\mathrm{nf}} + C_{\mathrm{ff}} + \mathrm{Su}) \} + t_{\mathrm{nonexposure}} \cdot 0$$

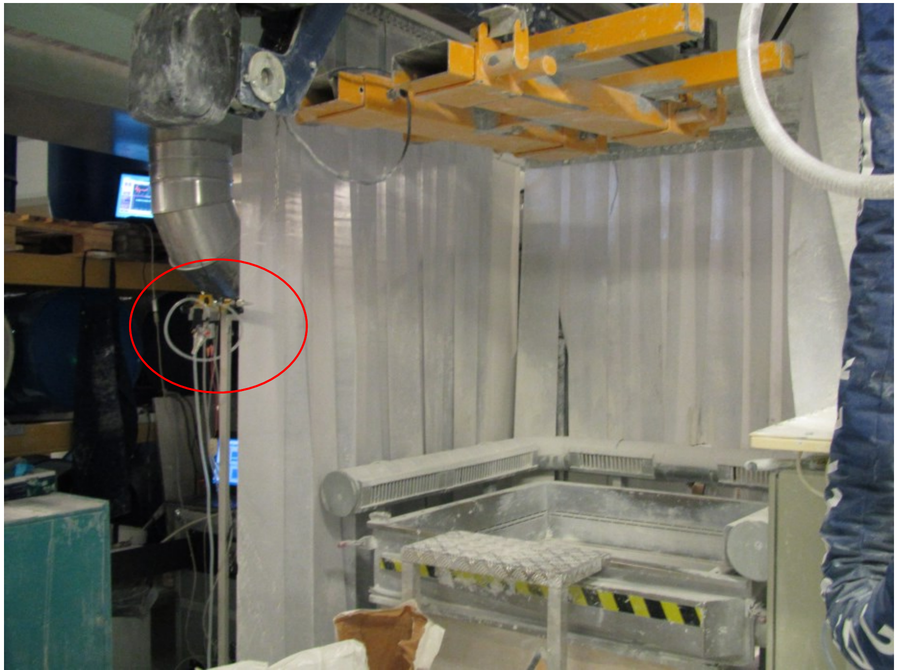
Testing performance of exposure assessment model



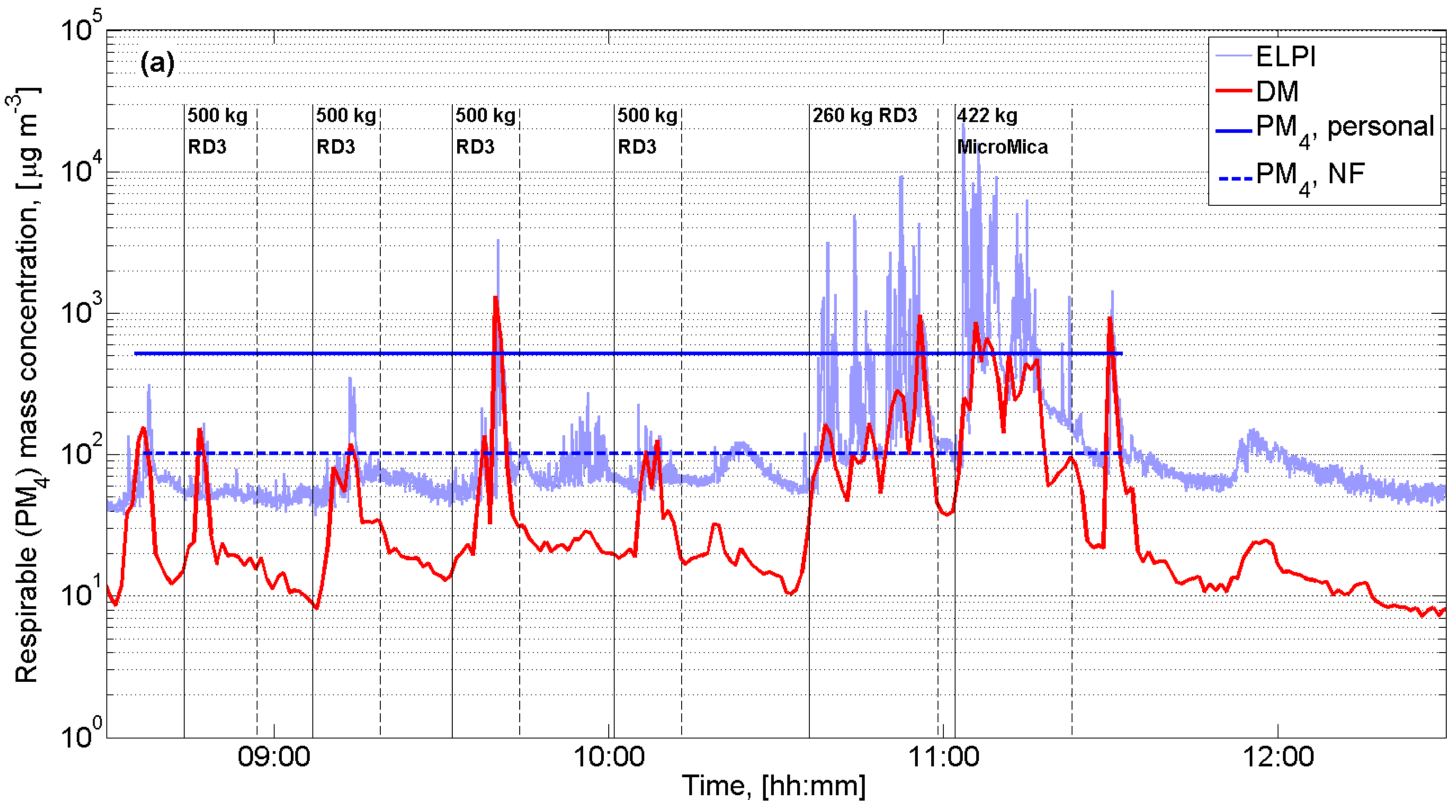
Pouring of (non-NOAA) powders in a paint factory (Koivisto *et al.*, 2015)



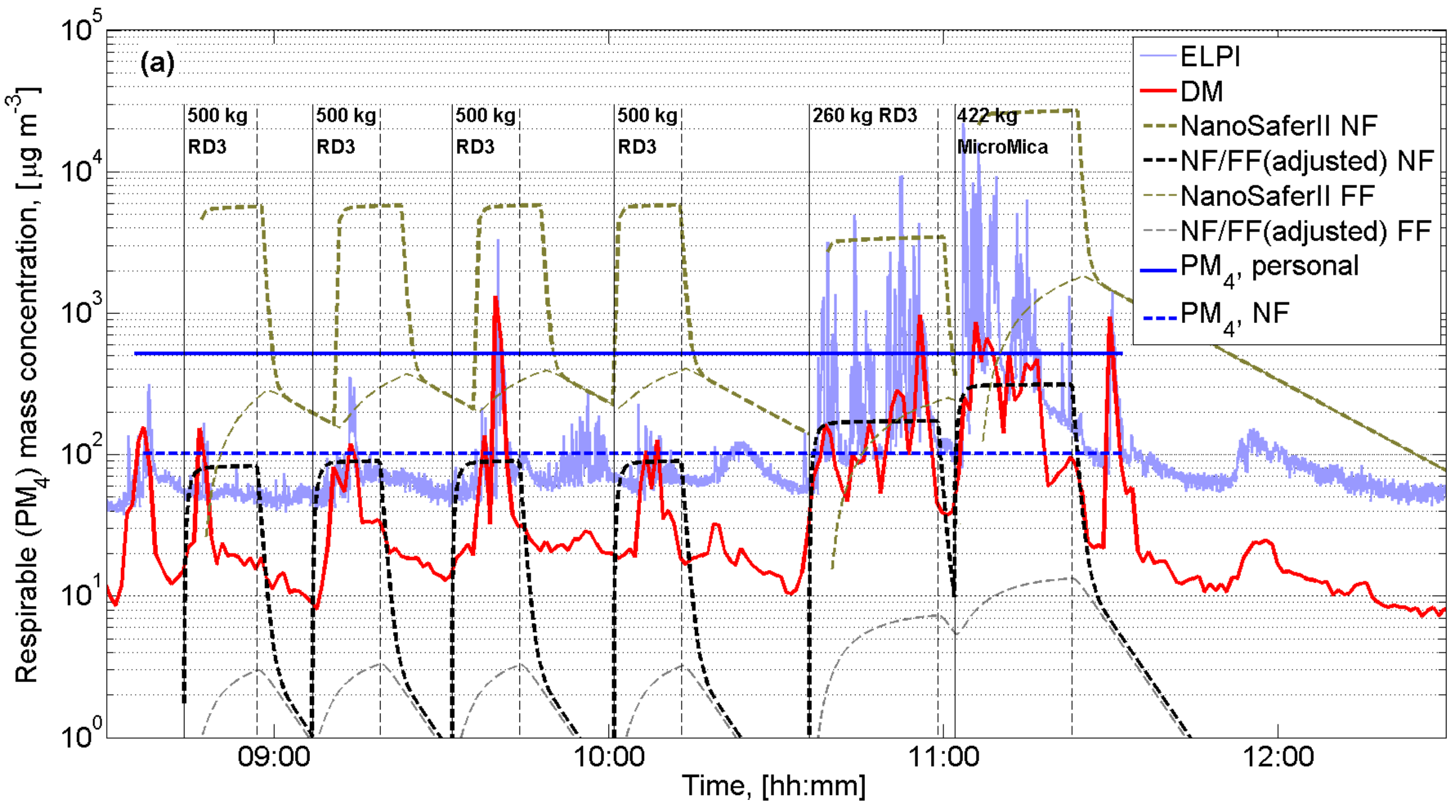
- Pouring from 25 bags and 500 kg sacs
- We measured:
  - Powders dustiness indices
  - Task based NF/FF concentrations
- Task based potential exposures were assessed (the NF/FF, NanoSafer II, and the ART)



Measured PM_4 concentrations



Measured and modeled PM_4 concentrations



Process specific concentrations

Pouring process	n[a]	$PM_{4,DM}$, (mg m^{-3})	NF/FF H_i (when $m_{NF/FF} = PM_{4,DM}$)	NanoSafer II, (mg m^{-3})	The ART[b], (mg m^{-3})
BB RD3	4	0.08	2.35	5.4	0.9 (0.47 – 1.7)
BB TR92	5	0.36	18.60	1.3	0.9 (0.47 – 1.7)
BB Microdol	2	0.77	7.40	4.0	0.9 (0.47 – 1.7)
SB RD3	1(10)	0.17	0.78	3.3	2.7 (1.4 – 5.1)
SB Micro Mica	1(17)	0.31	0.19	2.6	2.7 (1.4 – 5.1)
SB SatinTone	1(16)	0.98	1.09	1.2	2.7 (1.4 – 5.1)
SB Microdol	1(11)	0.25	0.23	1.2	2.7 (1.4 – 5.1)

[a]Brackets show the number of poured SBs during the pouring process
[b]Brackets show the 75[th] percentile inter-quartile confidence interval

Note: NanoSafer II gives the exposure potential without emission controls

Conclusions

- More studies are needed to understand:
  - Scaling of *DI* to industrial scale
    - Effect of aging and powders moisture content to dustiness
    - Energy factors/release potentials in different processes (e.g. sieving,..)
  - Localized controls (currently relies mainly on Fransman *et al*., 2008)
  - Dispersion of particles (mainly: $Q_{NF\text{-}FF}$)
- Emission term in general form:
  - e.g. µg min^{-1}, $µm^2$ min^{-1}, particles min^{-1}
- Pressing need for (size-resolved) emission sources' databases (Hussein *et al*., 2014)

References

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