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

K. A. Jensen, M Levin, SH Nielsen, AØ Jensen, B Liguori, AJ Koivisto, IK Koponen
National Research Centre for the Working Environment, Copenhagen, DENMARK
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 ($D_{inh}$, $D_{tho}$, $D_{resp}$)

- **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 ($\geq$500 cm$^3$ powder; drop until powder used, in 50%RH air)
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)
- Simultaneous online measurement with different aerosol monitors and PM.

(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 assessment of release potential (importance for processing, design and risk management)

- New additional aims
  - More specific test methods
  - Data for more quantitative exposure assessment and prioritization in material selection (nano-focus)
Dustiness data already used for technical evaluation and exposure assessment

Emission Potential
Simulated work processes

Workplace Measurement
Exposure (Risk) Modelling
Exposure scaling/estimation in several Control Banding tools

<table>
<thead>
<tr>
<th>Probability factor</th>
<th>Maximum points</th>
<th>Maximum probability score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated amount of nanomaterial</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>Dustiness/mistiness</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Number of employees with similar exposure</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Frequency of operation</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Duration of operation</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

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

### 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

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

<table>
<thead>
<tr>
<th>General description</th>
<th>Relative dustiness potential</th>
<th>Typical materials</th>
<th>TRA Selection Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not dusty</td>
<td>1</td>
<td>Plastic granules, pelleted fertilisers</td>
<td>Low</td>
</tr>
<tr>
<td>Slightly dusty</td>
<td>10 - 100 times dustier</td>
<td>Dry garden peat, sugar, salt</td>
<td>Low /Medium</td>
</tr>
<tr>
<td>Dusty</td>
<td>100 - 1,000 times dustier</td>
<td>Talc, graphite</td>
<td>Medium</td>
</tr>
</tbody>
</table>

#### Table R.14-10: Definition of dustiness bands

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>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</td>
</tr>
<tr>
<td>Medium</td>
<td>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</td>
</tr>
<tr>
<td>Low</td>
<td>Pellet-like, non friable solids. Little evidence of any dust observed during use. For example: PVC pellets, waxes</td>
</tr>
</tbody>
</table>
First order estimation of NF and FF
NOAA dust exposure potential (e.g., NanoSafer algorithm)

\[
\begin{align*}
C_{\text{FF}} &= \frac{(NF_{\text{NF}\rightarrow\text{FF}} - NF_{\text{FF}\rightarrow\text{NF}} + FF_{\text{residual}})}{V_{\text{FF}}} \\
C_{\text{NF}} &= \frac{(E_i + NF_{\text{FF}\rightarrow\text{NF}} - NF_{\text{NF}\rightarrow\text{FF}} + NF_{\text{residual}})}{V_{\text{NF}}}
\end{align*}
\]

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

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<tr>
<td>Slightly dusty</td>
<td>10–100 times</td>
<td>Product such as sugar,</td>
<td>Low/Medium</td>
</tr>
<tr>
<td>Dusty</td>
<td>100–1,000 times drier</td>
<td>Talc, graphite</td>
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<tr>
<th>Dustiness class</th>
<th>DI(resp)</th>
<th>DI(inh)</th>
</tr>
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<tbody>
<tr>
<td>High</td>
<td>&gt;250 mg/Kg</td>
<td>5000 mg/Kg</td>
</tr>
<tr>
<td>Moderate</td>
<td>250 mg/Kg</td>
<td>1000–5000 mg/Kg</td>
</tr>
<tr>
<td>Low</td>
<td>50 mg/Kg</td>
<td>200–1000 mg/Kg</td>
</tr>
<tr>
<td>Very Low</td>
<td>10 mg/Kg</td>
<td>&lt;200 mg/Kg</td>
</tr>
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Max/Min Index ratio ≥ 100
Max/Min Index ratio ≥ 25
Variation Inhalable dustiness indices of fine pigments and “nanopowders”?

2 of 66 "NM" above 25000 mg/Kg

Need for Very High?

Max/Min Index ratio $\geq 142$

8 NM and pigments in Very Low
Variation respirable dustiness indices of fine pigments and “nanopowders”?

9 of 62 NM above 5000 mg/Kg

Need for Very High?

Max/Min Index ratio ≥ 6869 (one extreme)
Max/Min Index ratio ≥ 1398 (second highest)
## Applicability of Dustiness ranges for NOAA: EN15051 Rotating Drum systems

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### Dustiness class

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<th>Max/Min Index ratio ≥ 100</th>
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<tr>
<td>High</td>
<td>250 mg/Kg</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
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<td></td>
</tr>
<tr>
<td>Low</td>
<td>10 mg/Kg</td>
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</tr>
<tr>
<td>Very Low</td>
<td></td>
<td>&lt; 200 mg/Kg</td>
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Experimentally DI (resp) Max/Min Index ratio ≥ 6869 (one extreme)

Experimentally DI (inh) Max/Min Index ratio ≥ 142 (second highest)
Variation in dustiness classies within 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 study (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 -

Size-distributions and maximum relevant size?  
- Nano-Objects Aggregates and Agglomerates -

Biological relevant size fraktions (CEN, 1992)

One 10 nm NP  
Vol 5.24 \(10^{-25}\) m³

8000 NP’s in one  
200 nm agglomerate of  
10 nm NPs  
Vol 4.19 \(10^{-21}\) m³

1 \(10^6\) NP’s in one  
1 μm agglomerate of  
10 nm NPs  
Vol 5.24 \(10^{-19}\) m³

NOAA dust

Total deposition

Respirable Fraction

Head Deposition (larynx)

Thoracic deposition

Alveolar

Particle Size [um]
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
- \(\Delta t\) = integration time
- \(\tau\) = time constant for calculation (20 sec)

(measured value)
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 “dustiness 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).