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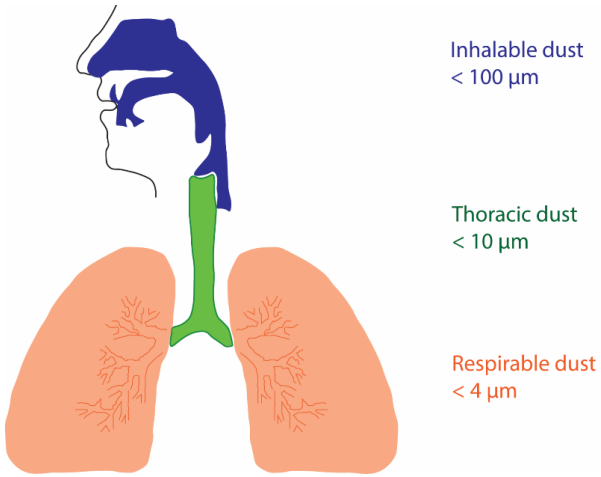
Workplace exposure to airborne particles in the plastics recycling and manufacturing industry



Presenter: Keld Alstrup Jensen kaj@nfa.dk

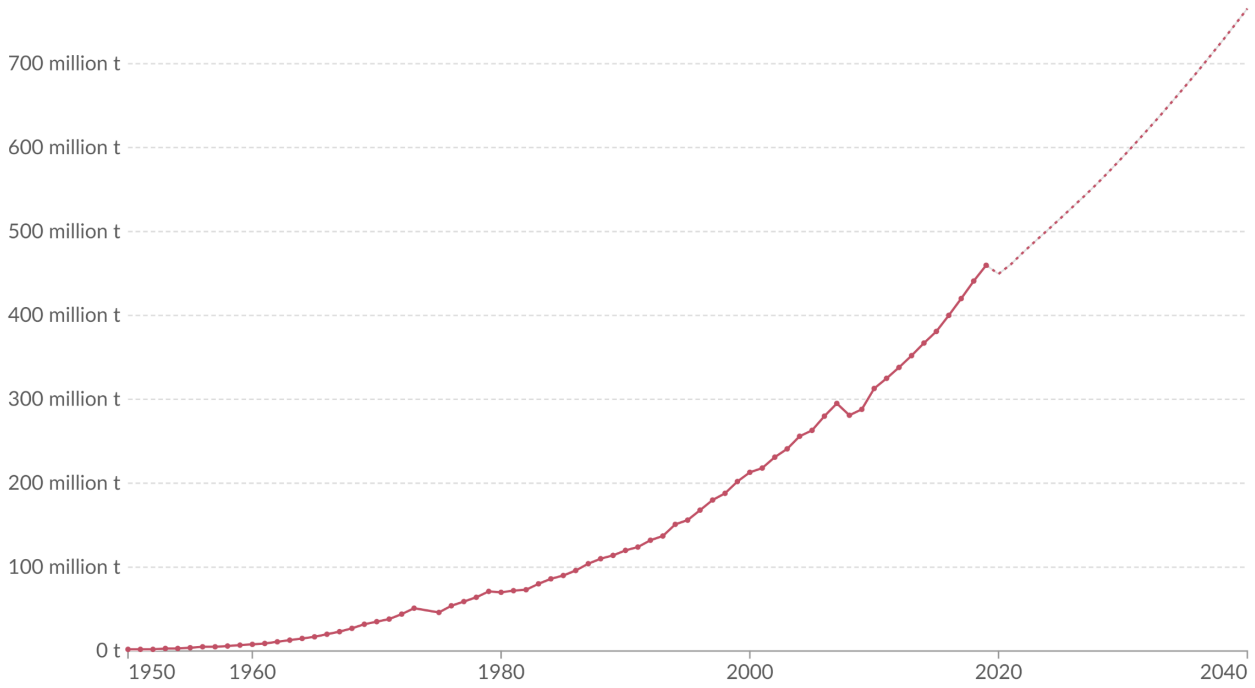
Co-authors: Patrick L. Ferree, Carla Ribalta, Alexander CØ Jensen, Anders Brostrøm, Trine Berthing, Ana Sofia Fonseca

The 2022 projected growth of plastic production and waste

Global plastic production with projections, 1950 to 2040

Our World in Data

Annual production of polymer resin and fibers. Projections are based on the "business-as-usual" scenario which assumes that current policies remain unchanged in the foreseeable future.



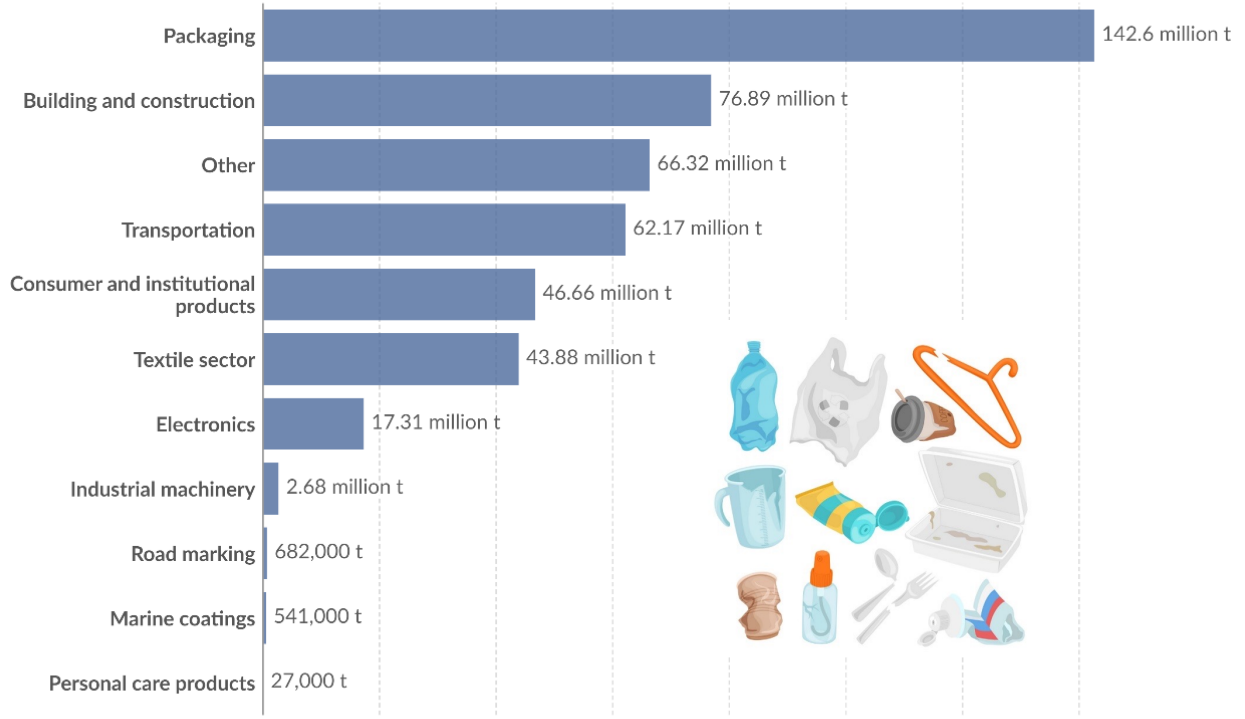
Data source: Geyer et al. (2017); OECD (2022)

OurWorldInData.org/plastic-pollution | CC BY

Annual global plastic waste generation by industrial sector, 2019

Our World in Data

Global plastic waste generation is measured in tonnes per year.



Data source: OECD (2022)

OurWorldInData.org/plastic-pollution | CC BY

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The EU Green Deal and ambition on plastic circularity

- **Goal: 55% of plastic packaging waste should be recycled by 2030 and new plastics packaging 100% recyclable.**
  - Political focus: environmental pollution with micro- and nanoplastics and associated consumer health.

- **BUT what about the working environment?**
  - Plastic production involves several handling steps of raw materials and high-temperature processes.
  - Does use of recycled plastics contribute to the occupational exposure in the production facilities?

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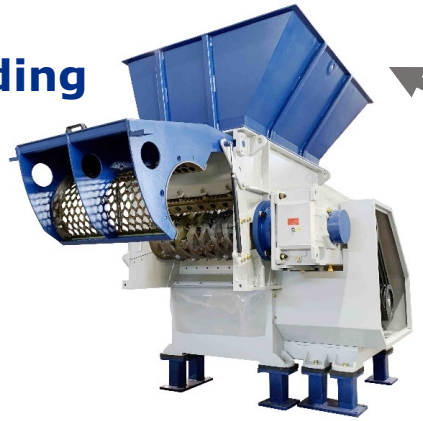
Mechanical recycling and production of PET plastics for packaging

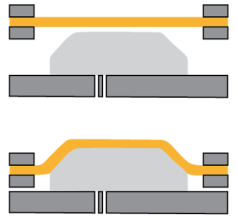
Pristine PET

Shredded PET

Shredding

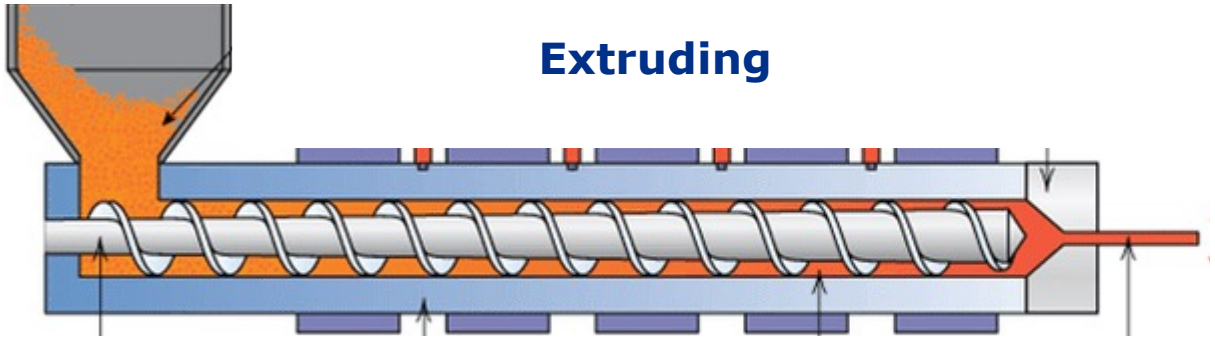


Thermoforming

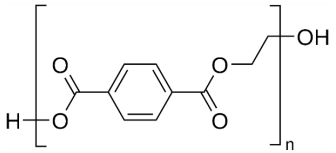


Rolling

Extruding



Feeding



PET = polyethylene terephthalate

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This study

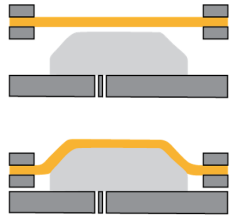
What is the occupational exposure to airborne particles (incl. nano- and microplastics) during these processes?

Pristine PET

Shredded PET

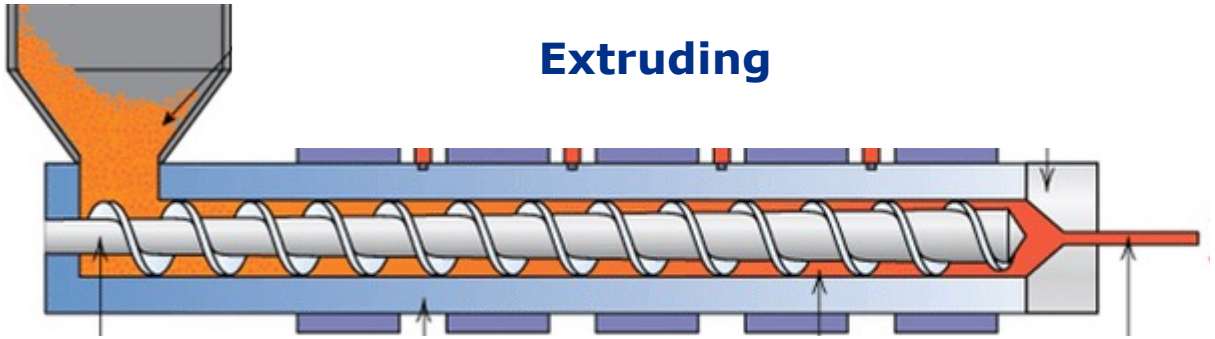
Mini Shredding

Thermoforming



Feeding

Extruding



Rolling

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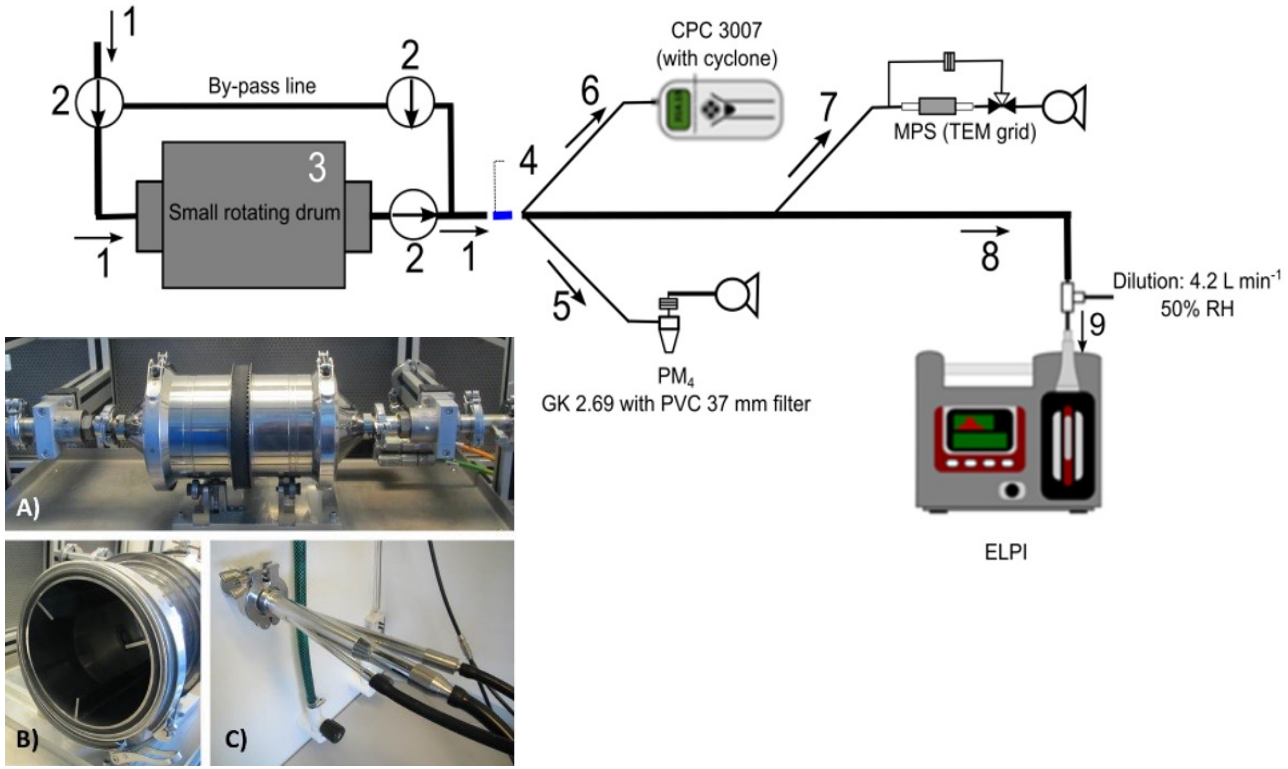
Strategy for exposure assessment

Release testing of respirable dust from raw materials using the EN17199:1999 dustiness test method (and exposure modelling).



Workplace measurement along the production line at a large packaging manufacturing company

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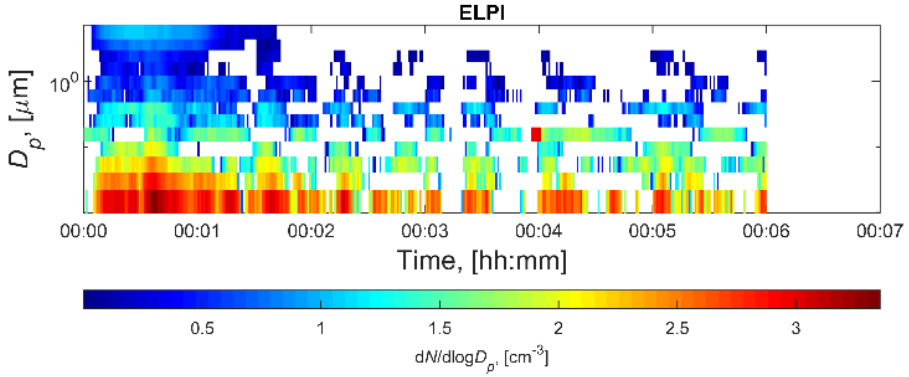
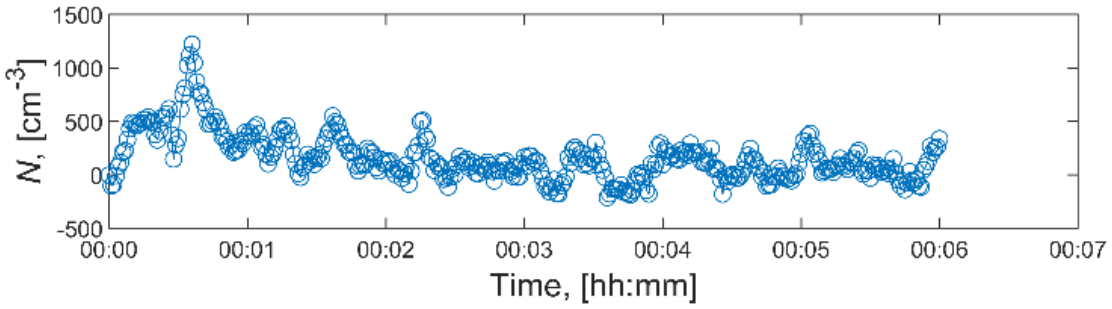
Respirable dust release potential (EN17199-4:2019)

- Typical raw materials

	DI_M [a] (mg/kg)	±σ DI_M (mg/kg)	LOQ (mg/kg)	DI_N [b] (1/kg)	±σ DI_N (1/kg)
Pre MB 22001 (APET with Carbon Black)	2.1	1.4			000
TDC S 415 (APET granulate)	0.8				200
PET granulate (pristine gran. 0,8 IV).	**6.**				300
PET shredded bottles (washed)	**4.8**				17 900
PET shredded foil	**7.3**			72 200	37 900
Holcobatch Violet (Pigment)	2.1	0.3	6.1	76 700	41 900

Very low dustiness according to EN15051 ranking, but high exposure potential in high-energy high tonnage processes!





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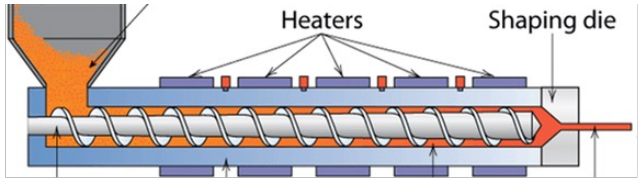
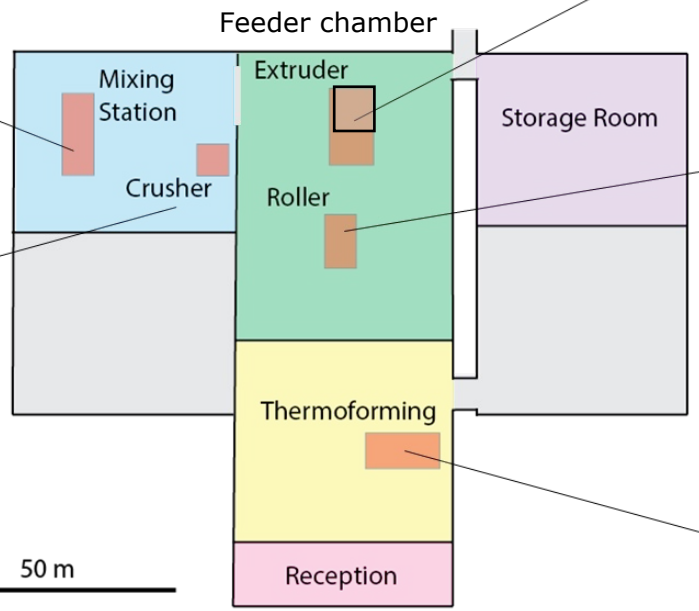
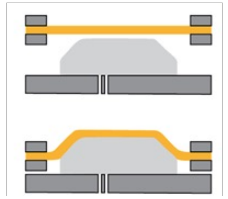
Workplace measurements

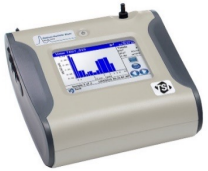






ELPI+
(Feeder chamber)
6 nm – 10 µm

Nanoscan SMPS
10 – 420 nm



OPS
300 nm – 10 µm

Gravimetric Filters
(NF; FF)
Total and Resp. Dust (GK2.69)

TEM grids
Analysis of particle morphology

FMPS
(Reception)
5.6 – 560 nm

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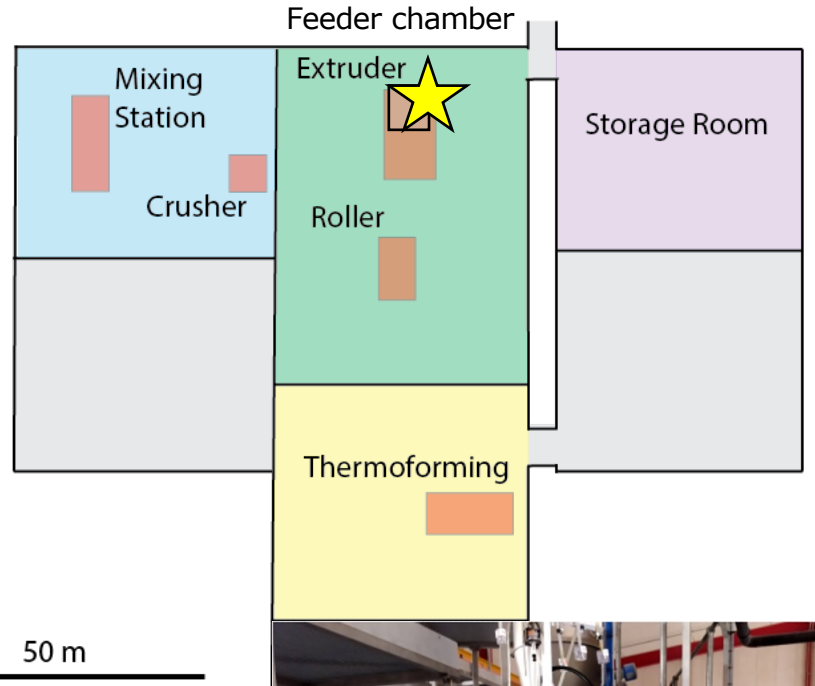
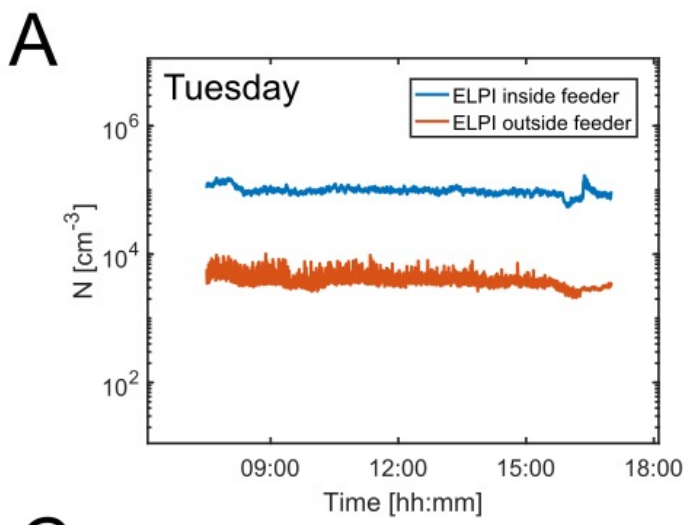
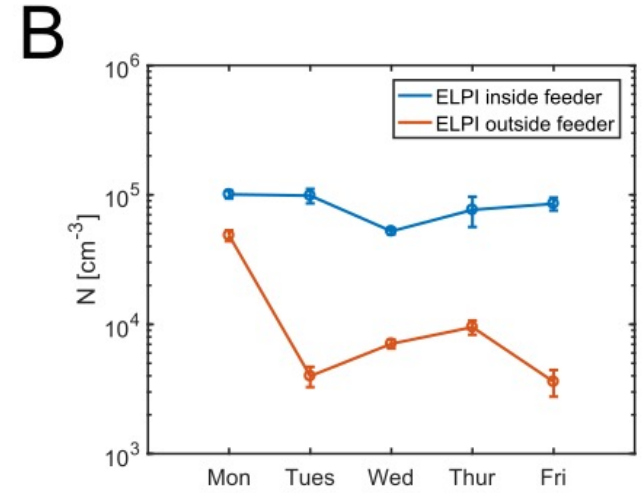
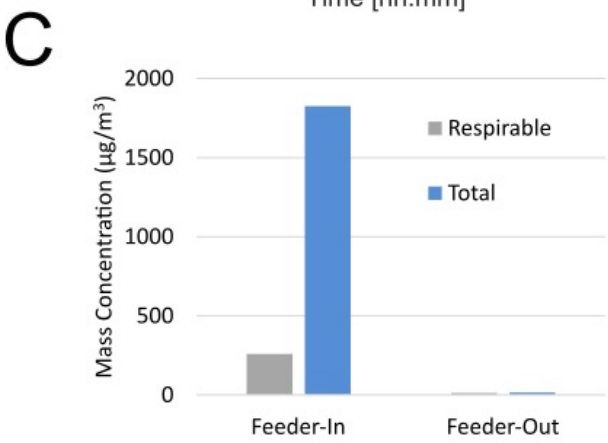
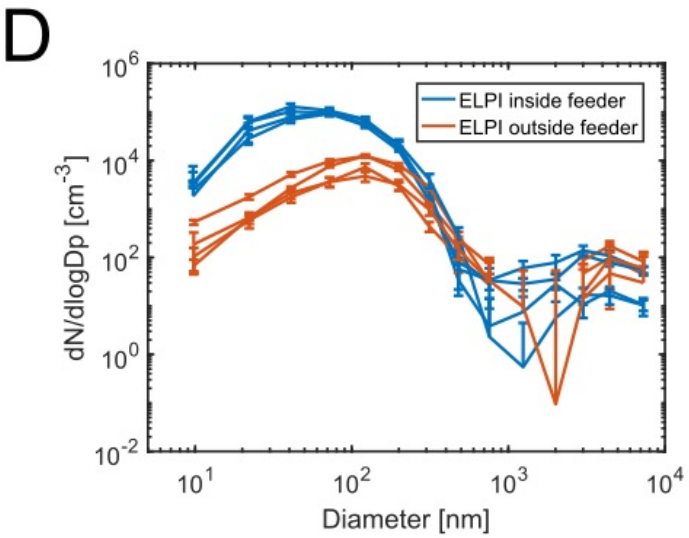
Inside and outside of the feeder chamber











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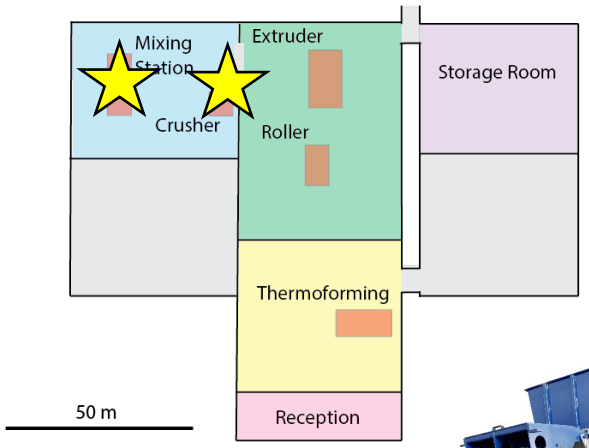
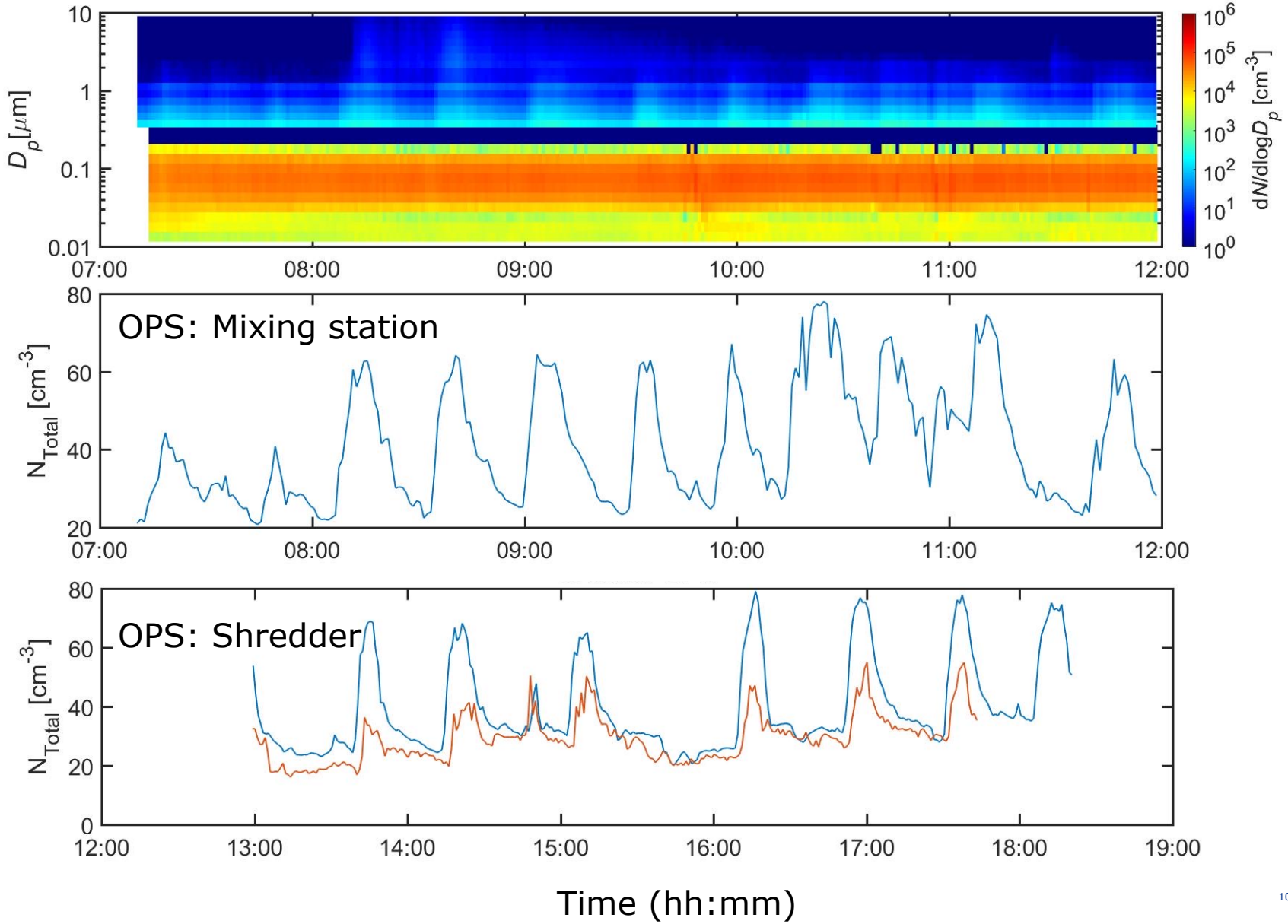
The mixing and mini-shredder stations





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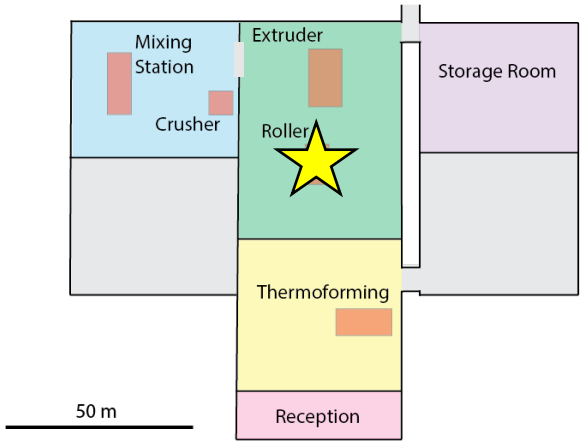
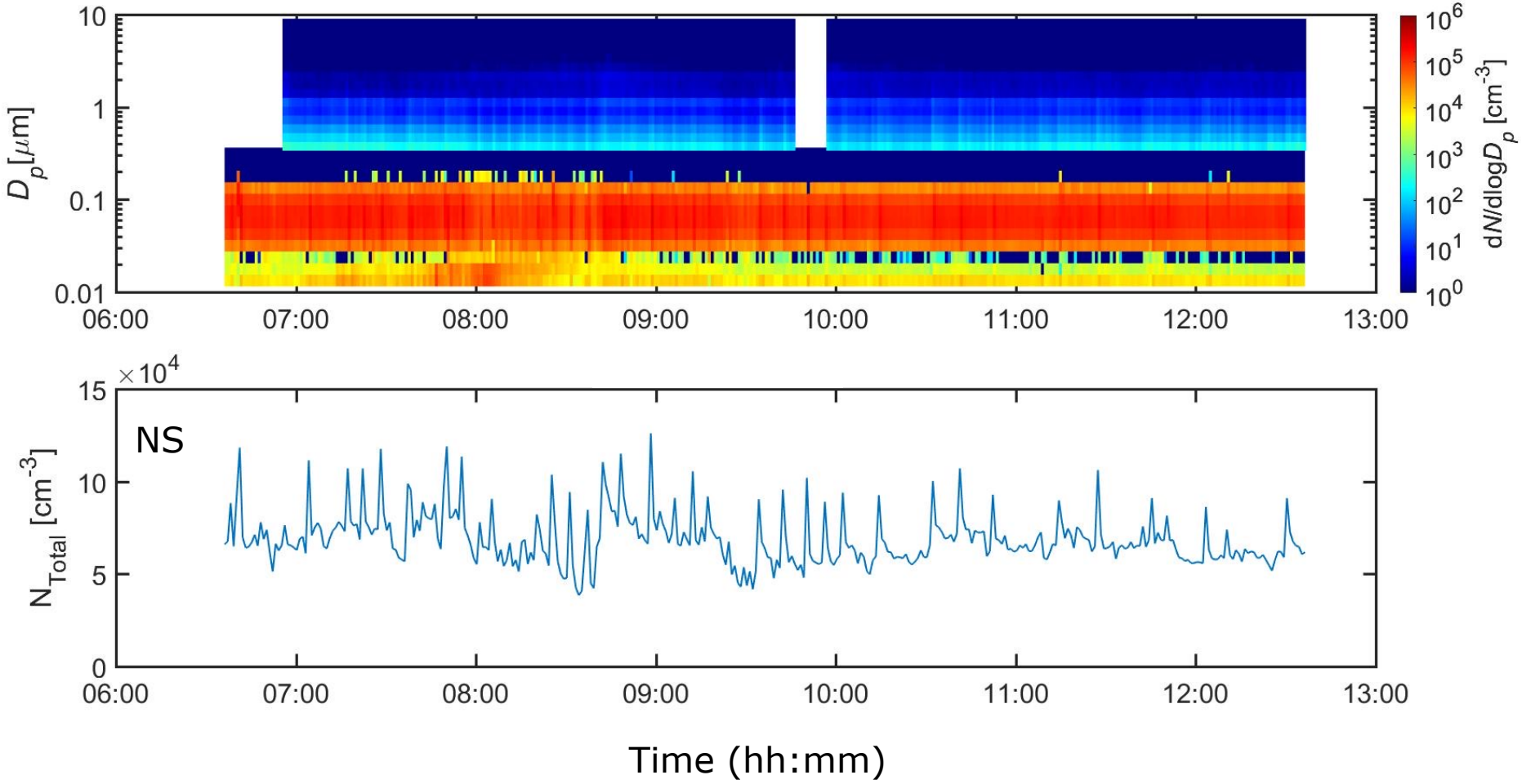
Rolling





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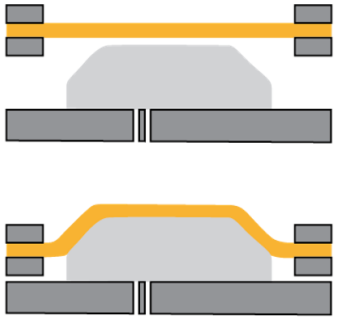
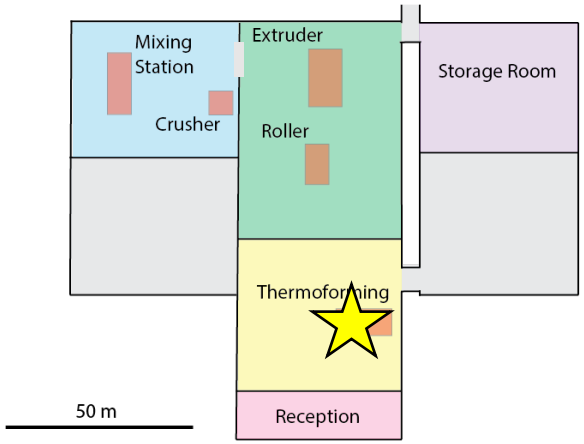
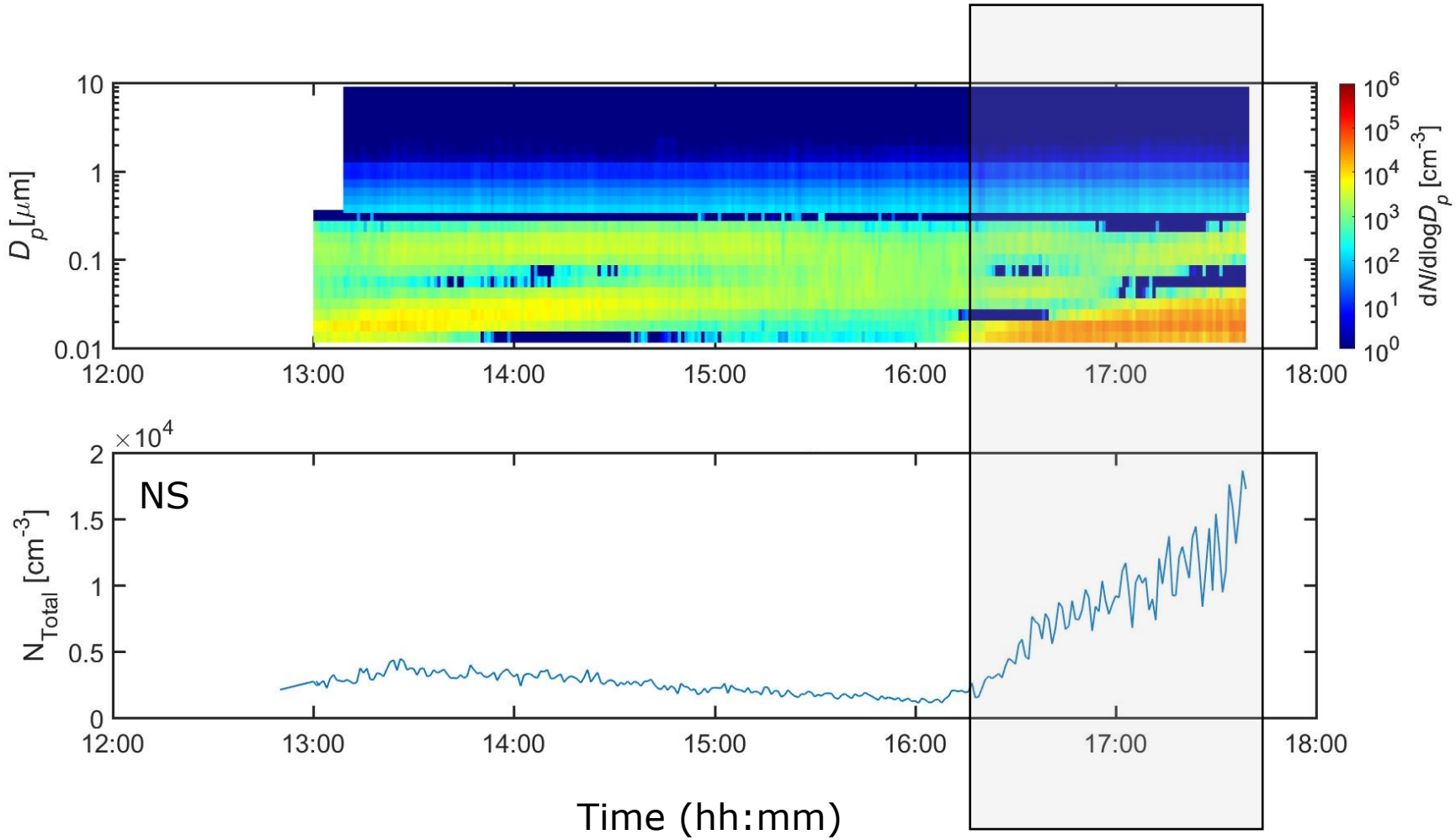
Thermoforming





Production stop
”burn of”



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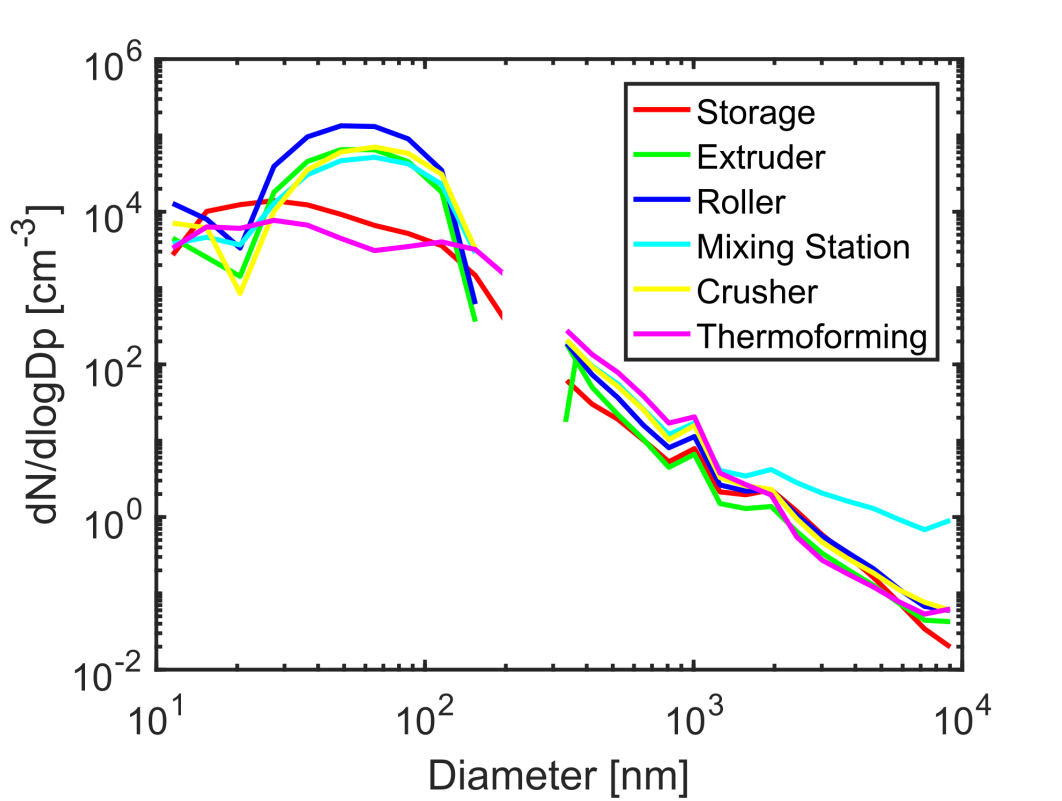
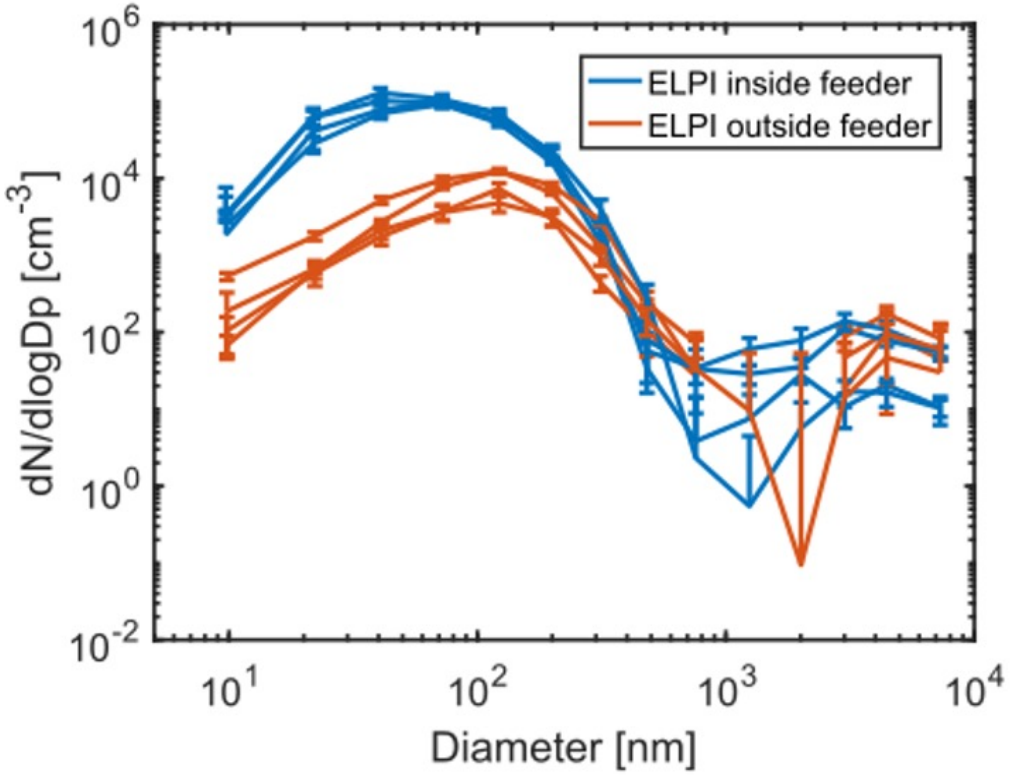
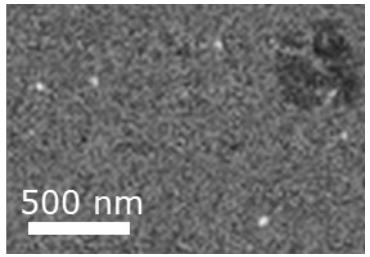
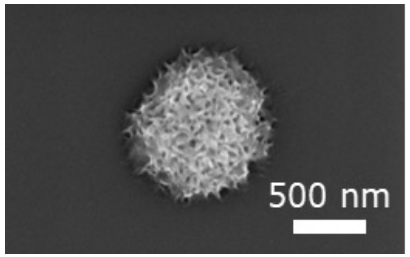
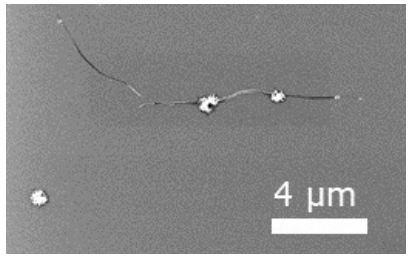
Particle number size distributions and particle types

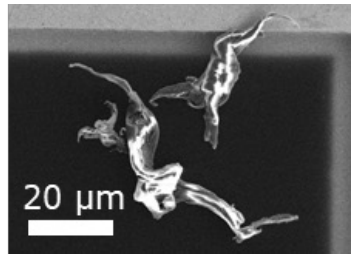












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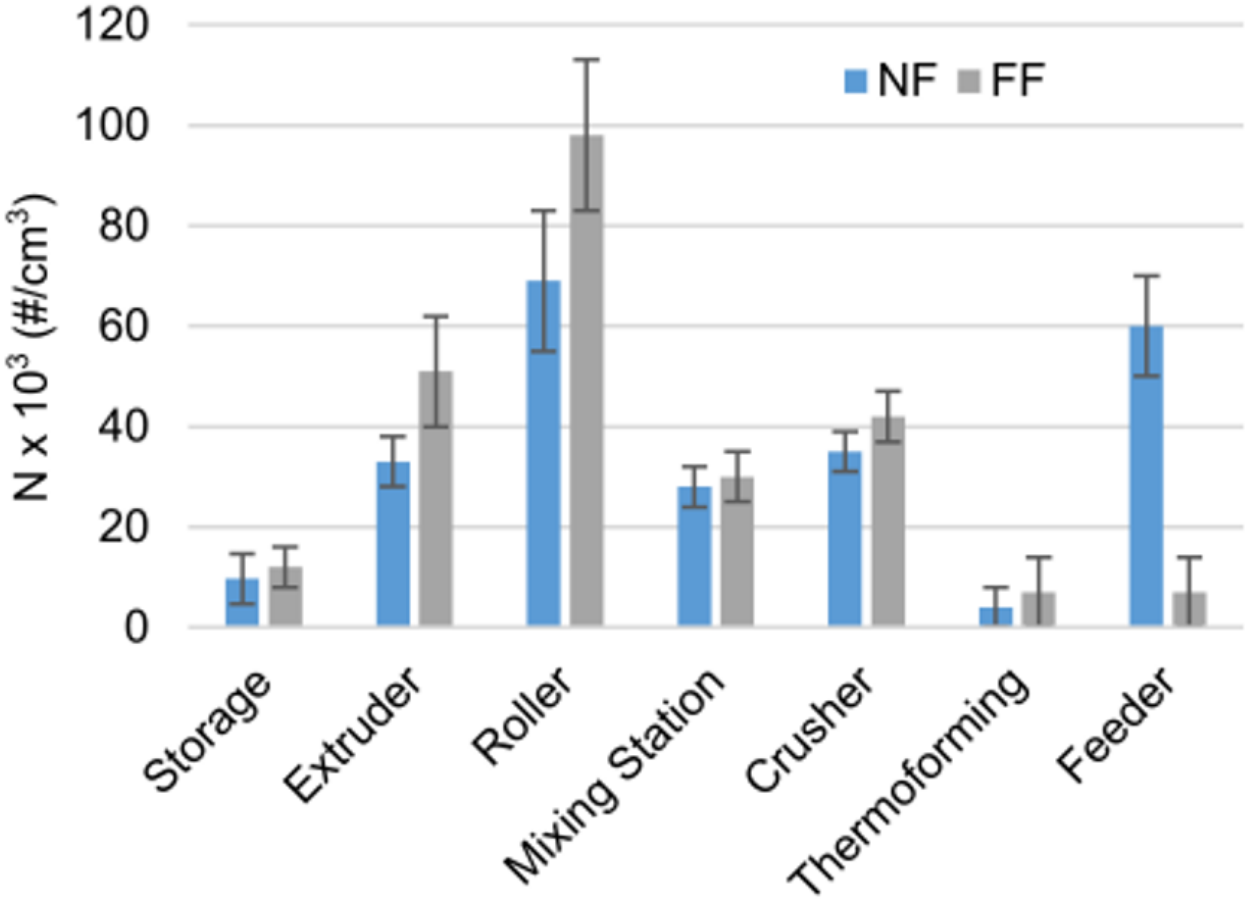
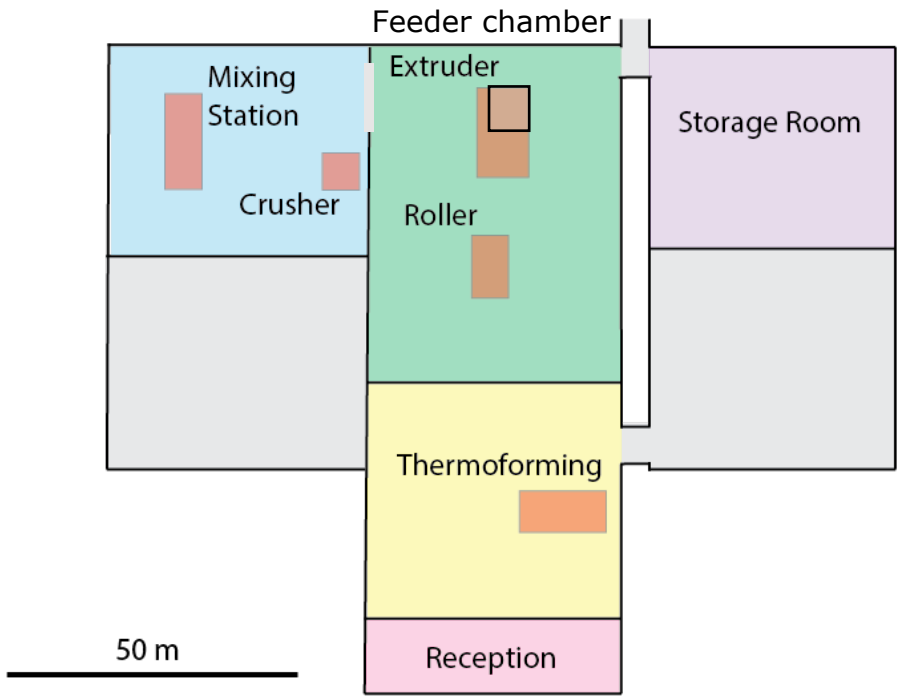
Average total particle number concentrations





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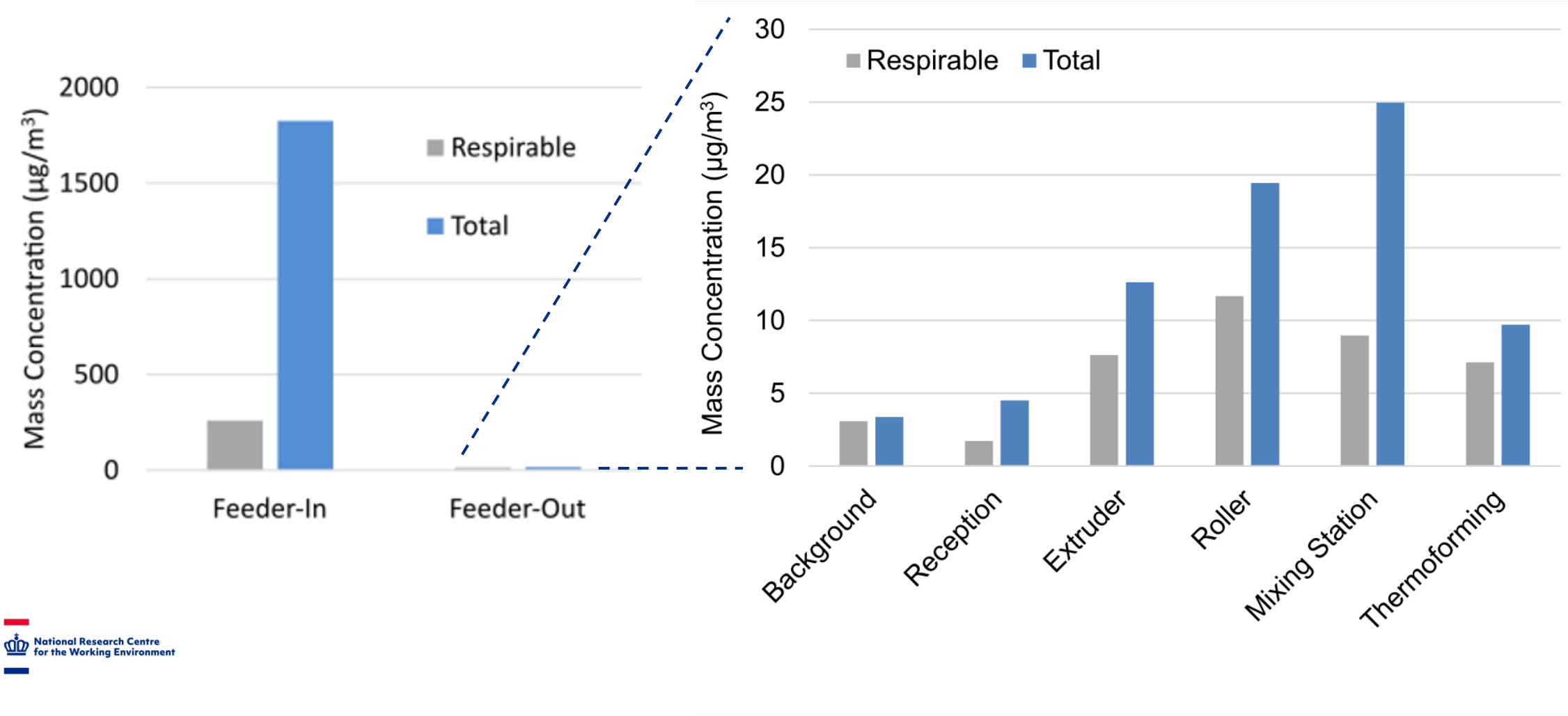
Average dust mass concentrations (gravimetric)



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Three take home messages!

1. **The respirable dustiness of plastic raw materials (master batches and pigment samples) are very low and similar, but levels are still significant when working with large tonnages.**
2. **The concentrations of airborne particles and dust in the factory are by mass generally low, except in the feeding chamber, but in numbers high at some processes (average ≤ 1E5 cm^{-3}) and dominated by ultrafine particles.**
   - *Coarse particles are important in handling processes of raw materials*
   - *Ultrafine particles are important in all processes and overall in the factory*
3. **Workers are indeed exposed to airborne nano- and microplastic particles as observed by morphology in SEM; ultrafine particles remains to be positively identified.**

Thank you for listening!

We gratefully acknowledge funding by:

FFIKA: Focused research effort on chemicals in the working environment (Danish Financial Act; Danish Government)

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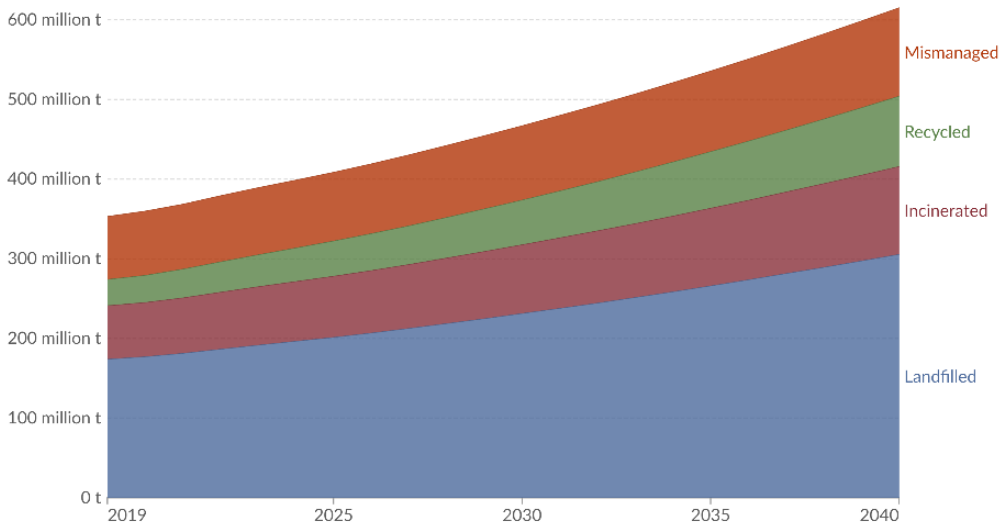
Plastic waste and disposal routes

Projections of plastic waste by disposal method, World

Our World in Data

Mismanaged plastic waste is plastic that is either littered or inadequately disposed[1]. A country's total does not include waste that is exported overseas, where it may be mismanaged. Based on the "business-as-usual" scenario which assumes that current policies remain unchanged in the foreseeable future.



Data source: OECD (2023) OurWorldInData.org/plastic-pollution | CC BY
Note: Regional aggregates were calculated by Our World in Data and are based on those specified by the OECD[2].

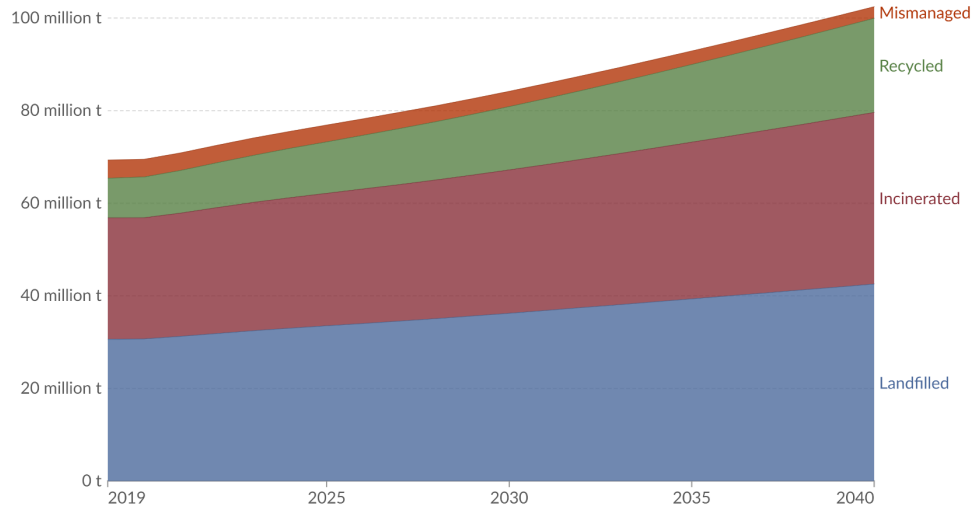
1. Inadequately disposed plastic waste: Inadequately disposed plastic waste is not formally managed and includes disposal in dumps or open, uncontrolled landfills, where it is not fully contained. This makes it at a much higher risk of leaking into the natural environment, rivers, or the ocean.

2. OECD regions: The definitions of regions, as stipulated by the OECD, are: - Other OECD America: Chile, Colombia, Costa Rica, Mexico - OECD EU countries : Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden - OECD Non-EU countries: Iceland, Israel, Norway, Switzerland, Turkey, United Kingdom - OECD Oceania: Australia, New Zealand - OECD Asia: Japan, Korea - Latin America: Non-OECD Latin American and Caribbean countries - Other EU: Bulgaria, Croatia, Cyprus, Malta, Romania - Other Eurasia: Non-OECD European and Caspian countries, including Russian Federation - Middle East & North Africa: Algeria, Bahrain, Egypt, Iraq, Islamic Rep. of Iran, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Tunisia, United Arab Emirates, Syrian Arab Rep., Western Sahara, Yemen - Other Africa: Sub-Saharan Africa - China: People's Republic of China, Hong Kong (China) - Other non-OECD Asia: Other non-OECD Asian and Pacific countries

Projections of plastic waste by disposal method, Europe

Our World in Data

Mismanaged plastic waste is plastic that is either littered or inadequately disposed[1]. A country's total does not include waste that is exported overseas, where it may be mismanaged. Based on the "business-as-usual" scenario which assumes that current policies remain unchanged in the foreseeable future.



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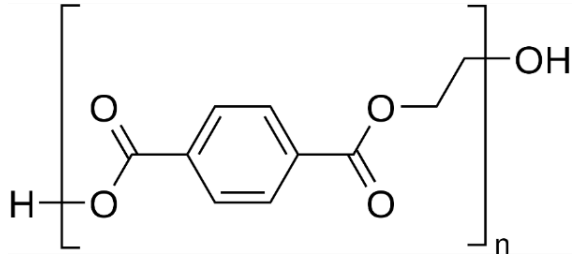
More on the raw materials

PET = polyethylene terephthalate

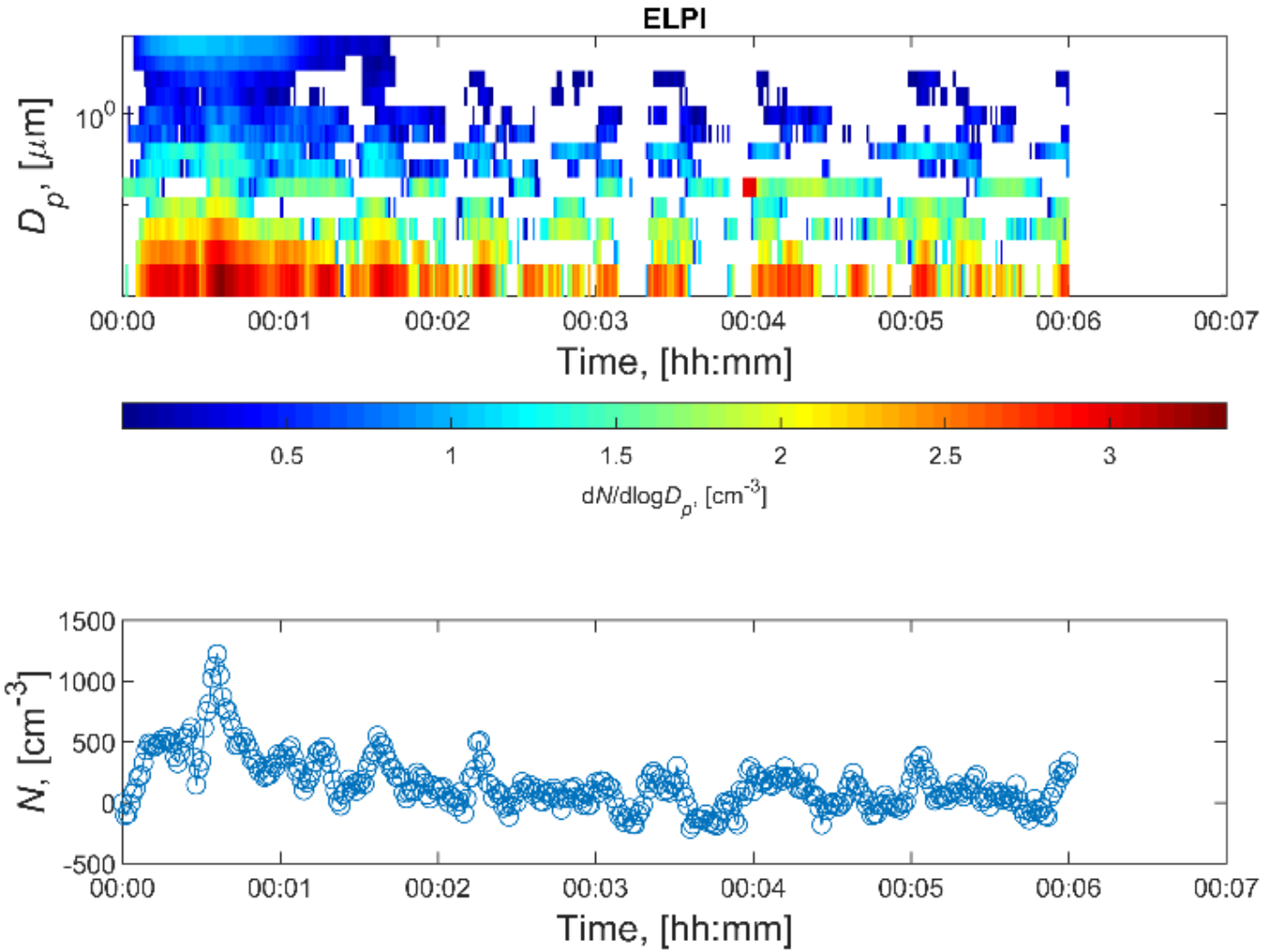


- A-PET
  - Food packaging
  - Available up to 85% recycled
- C-PET
  - Ready-meals
- R-PET
  - Minimum of 50% recycled materials, but certified for food packaging
- PET/PE
  - Used to package meat products

Particle release potential from dustiness testing

- Typical raw materials

Pre MB 22001 (APET with Carbon Black)
TDC S 415 (APET granulate)
PET granulate (pristine gran. 0,8 IV).
PET shredded bottles (washed)
PET shredded foil
Holcobatch Violet (Pigment)



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Modelled exposure potential – Worst case scenario

NanoSafer Control Banding Report for Airborne Occupational Exposure Assessment

High exposure potential in high-energy high tonnage processes!

Assessment of

Material assessed: PET Granulate (pristine granulate 0,8 IV). **Producer:** NN	**Work situation assessed:** Feeding PET with no encloser in feeder chamber **Process type:** Powder Handling

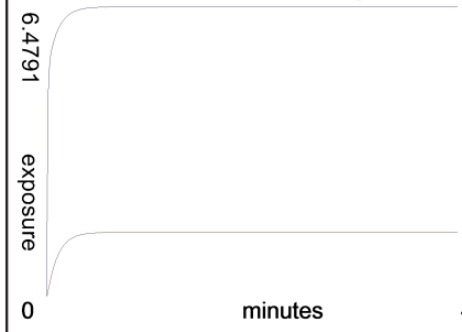
Exposure situation data entered

Process type: Powder handling
Energy level: H10: (e.g., drop heights > 1 m, dry mixing, cleaning with brush or compressed air, accidents)
Amount used in cycle: 10000 kg
Cyclus duration: 480 min
Number of cycles per day: 1 times
Pause between cycles: 0 min
Mass handled per task in cycle: 10000 kg
Time required per task in cycle: 480 min
Length room: 10 meters
Width room: 10 meters
Height room: 5 meters
Room air exchange rate: 10 times per hour
Activity level room: Moderate

Result of assessment

Estimated hazard level 0.2
The hazard level is estimated based on
High aspect ratio material: No
OEL of analogue bulk material: 2 mg/m3
Solubility: Insoluble (< 1 g/L)
Presence of surface coating: No
Known hazards of analogue bulk material

Estimated time-resolved exposure index



Near-field Acute	Near-field Daily	Far-field Acute	Far-field Daily
3.243	6.431	0.7151	1.390
EB5: Very high exposure	EB5: Very high exposure	EB4: High exposure potential	EB5: Very high exposure

$2x2mg/m^3x3.243 = 13.30\ mg/m^3$

$2mg/m^3x6.431 = 12,86\ mg/m^3$

National Research Centre for the Working Environment

Modelled exposure potential - Careful pouring of granulates

NanoSafer Control Banding Report for Airborne Occupational Exposure Assessment

Moderate exposure potential in low-energy high tonnage processes!

Assessment of

Material assessed: PET Granulate (pristine granulate 0,8 IV). **Producer:** NN	**Work situation assessed:** Pouring PET 10X plastic granulate from BigBags H2 **Process type:** Powder Handling

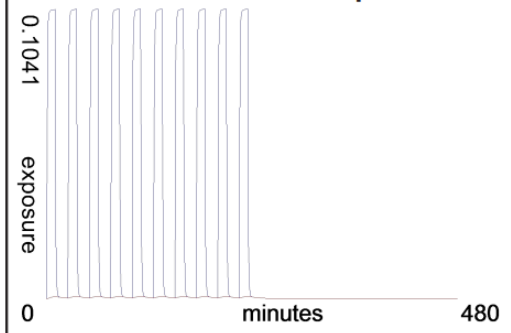
Exposure situation data entered

Process type: Powder handling
Energy level: H2: (e.g., pouring of powders with 1-2 cm drop in free air; careful wet mixing)
Amount used in cycle: 1000 kg
Cyclus duration: 10 min
Number of cycles per day: 10 times
Pause between cycles: 15 min
Mass handled per task in cycle: 1000 kg
Time required per task in cycle: 10 min
Length room: 40 meters
Width room: 40 meters
Height room: 10 meters
Room air exchange rate: 10 times per hour
Activity level room: Moderate

Result of assessment

Estimated hazard level 0.2
The hazard level is estimated based on
High aspect ratio material: No
OEL of analogue bulk material: 2 mg/m3
Solubility: Insoluble (< 1 g/L)
Presence of surface coating: No
Known hazards of analogue bulk material

Estimated time-resolved exposure index



Near-field Acute	Near-field Daily	Far-field Acute	Far-field Daily
0.0347	0.0218	0.0004	0.0003
EB1: Very low exposure potential	EB1: Very low exposure potential	EB1: Very low exposure potential	EB1: Very low exposure potential

$2x2mg/m^3x0.0347 = 138.8\ \mu g/m^3$

$2mg/m^3x0,0218 = 43,6\ \mu g/m^3$

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