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Health effects of airport emission particles

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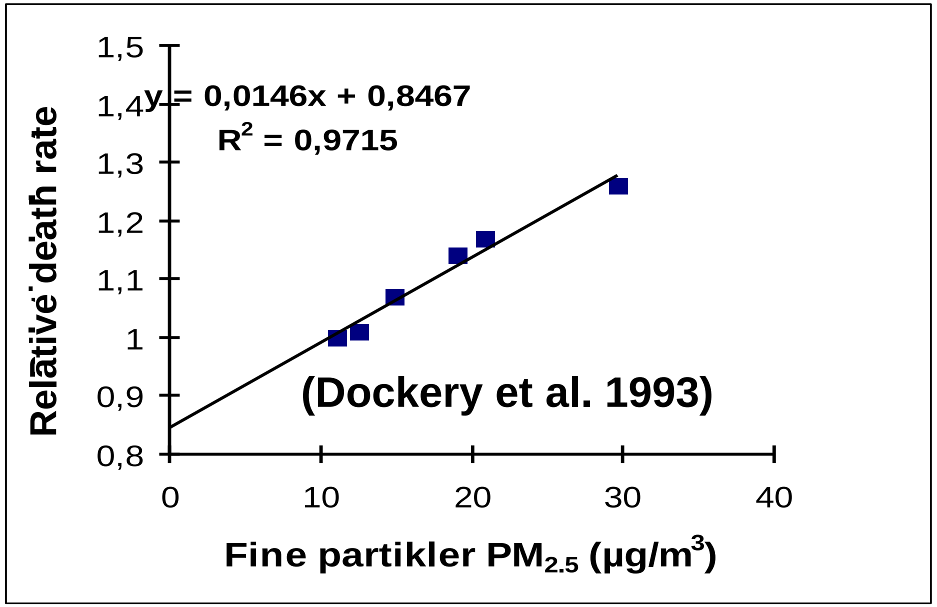
Nanosafety at the National Research Centre for the Working Environment, Copenhagen, Denmark

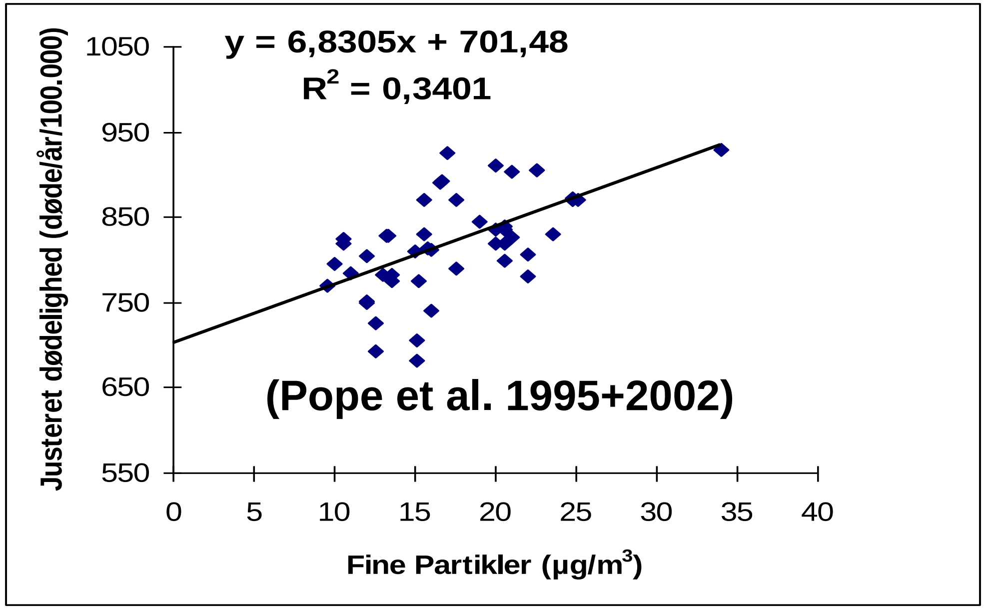
- Government research institute under the Ministry of Employment
- Nanosafety as strategic research area 2005-2019
- Advisors for the Danish Working Environment Authorities, EPA, EU, OECD, WHO
- Past and present partners in more than 30 EU projects on (nano)particle safety

Concern: Association between particulate air pollution and mortality

6 cities with 8000 people



151 urban areas with 500.000 people



Direct correlation between mortality and particle concentration ($PM_{2.5}$):

7 deaths/100 000 persons/year/ ug/m³ PM 2.5

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Evaluation of carcinogenicity by IARC (WHO's International Agency for Research on Cancer)

- Diesel engine exhaust is classified as carcinogenic to humans (class 1) by IARC
- Gasoline engine exhaust is classified as possibly carcinogenic to humans (class 2B) by IARC
- Carbon black (pure carbon particles) is classified as possibly carcinogenic to humans (class 2B)

- Almost all current aviation fuel/jet fuels are extracted from the middle distillates of crude oil (kerosene fraction), which is in between the fractions used for gasoline and diesel

Risk estimate for diesel based on epidemiological evidence

Table 1. Exposure–response estimates (lnRR for a 1-μg/m³ increase in EC) from individual studies and the primary combined estimate based on a log-linear model.

Model[a]	Intercept	β (95%CI)
All studies combined	0.088	0.00098 (0.00055, 0.00141)
Silverman et al. (2012) only	–0.18	0.0012 (0.00053, 0.00187)
Steenland et al. (1998) only	–0.032	0.00096 (0.00033, 0.00159)
Garshick et al. (2012) only	0.24	0.00061 (–0.00088, 0.00210)

[a]Log-linear risk model (lnRR = intercept + β × exposure). Exposure defined as EC in μg/m³-years.

Table 2. Excess lifetime risk per 10,000 for several exposure levels and settings, United States in 2009.

Exposure setting	Average EC exposure (μg/m³)	Excess lifetime risk through age 80 years (per 10,000)
Worker exposed, age 20–65 years	25	689
Worker exposed, age 20–65 years	10	200
Worker exposed, age 20–65 years	1	17
General public, age 5–80 years	0.8	21

Based on linear risk function, lnRR = 0.00098 × exposure, assuming a 5-year lag, using age-specific (5-year categories) all cause and lung cancer mortality rates from the United States in 2009 as referent.

Vermeulen et al, EHP, 2014

New meta-analysis of case-cohort studies using JEM for exposure assessment:
Excess life time risks associated with 45 years of EC exposure at 50, 20, and 1 μg/m³ were 3:100, 1:100, and, 4:10 000, respectively, (PMID: 32330395, April 2020)

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NRCWE study

- Work place exposure assessment at a non-commercial airfield with jet fighters
- Particle collection and characterisation of particles collected at a large commercial airport and a non-commercial airfield
- Animal study where mice were exposed to collected particles in the lungs alongside standard NIST diesel exhaust particles and carbon nanoparticles
- Published open access 2019

Bendtsen *et al. Particle and Fibre Toxicology* (2019) 16:23
https://doi.org/10.1186/s12989-019-0305-5
Particle and Fibre Toxicology

RESEARCH Open Access

Airport emission particles: exposure characterization and toxicity following intratracheal instillation in mice

Check for updates

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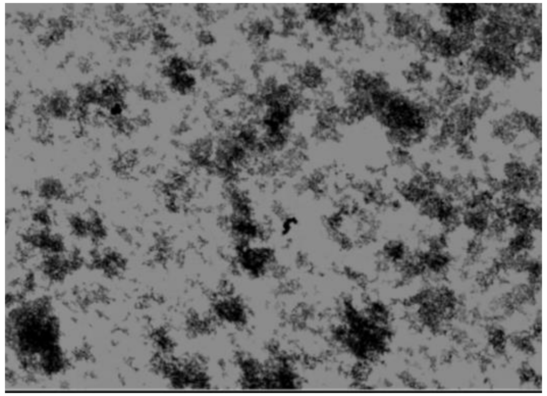
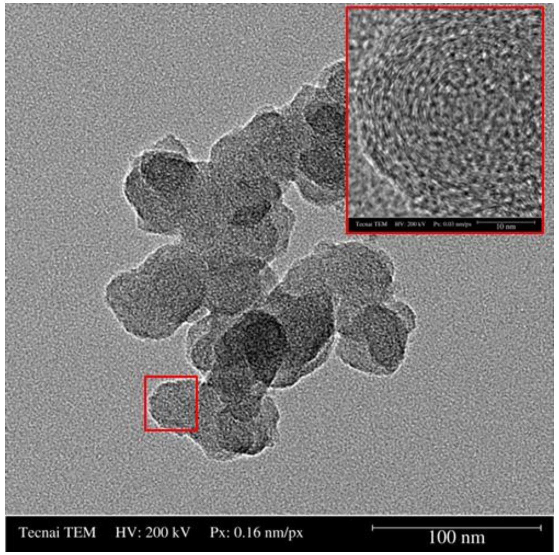
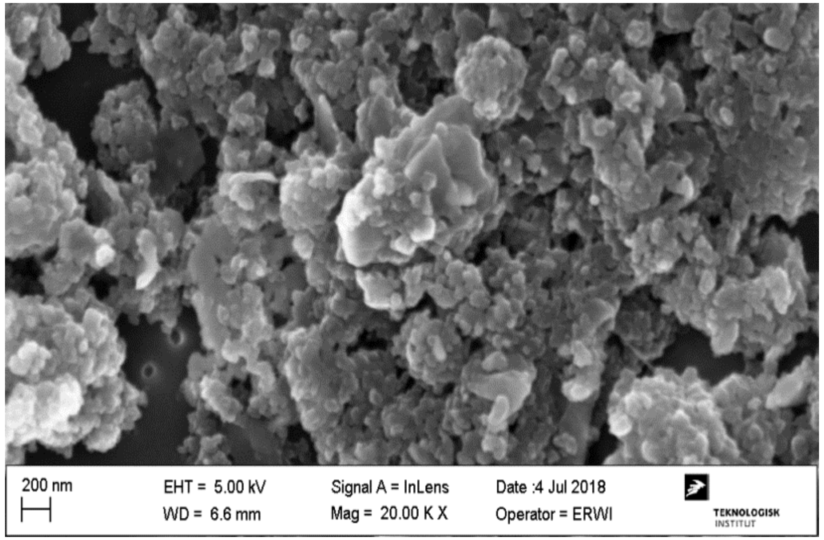
Jet engine emission particles

- Large amounts of nanosized carbon-based particles
- Primary particle size ca. 15 nm (smaller than DEP)
- Aggregates in air
- PAH (polyaromatic hydrocarbon) content similar to standard NIST DEPs
- Metal content similar to standard NIST DEP

- Airport emissions from the commercial airport were much more complex and contained salt crystals, organic particles ect in addition to the small soot particles







EM picture of jet fighter emissions during taxi (from a chasing car)

Exposure levels for the Crew Cheif at the non-commercial airfield

Table 2 Average exposures and doses of jetfighter personnel at a non-commercial airfield

Event	*t*, [min]	*n*, ×10^6 [cm^{-3}]	*m*, [μg m^{-3}]	m_{PM4}, [μg m^{-3}]	DR_N, × 10^{10} [min^{-1}]	HA, n[%]	TB, n[%]	AL, n[%]	DR_m, [μg min^{-1}]	HA, m[%]	TB, m[%]	AL, m[%]	Particles [× 10^{12}]/ Event	Mass [μg]/ Event
PL	15.1	7.7	1086	537	15	21.2	27.2	51.6	18.7	84.6	4.7	10.7	2.26	280
PA + FT	21.3	2.67	410	228	5.4	21.7	27.7	50.7	7	83.6	4.9	11.5	1.15	150
t_{PM4}	170	1.22	194	89	2.4	21.4	27.4	51.3	3.5	85.8	4.6	9.6	4.12	600

Average exposures and doses during Plane Leaving (PL), Plane Arrival and fueling the plane (PA + FT combined), and over one flight cycle (t_{PM4}). From left to right: average event time (*t*) in minutes, average particle number concentration (*n*), mass concentration (*m*) and mass fraction smaller than 4 μm (m_{PM4}), inhaled number dose per minute (DR_N), predicted fraction of particles deposited in extra-thoracic (*HA*), tracheo-bronchial (*TB*) and alveolar (*AL*) lung regions, inhaled mass dose per minute (*DRm*), predicted fraction of mass deposited in extra-thoracic (*HA*), tracheo-bronchial (*TB*) and alveolar (*AL*) lung regions, total particles per event and total mass per event

Exposure levels in a jet engine test facility: 2-4 x 10^6 particles/cm^3 (data in supplementary)

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Animal study of health effects following lung exposure to 2 types of airport emission particles

- Animal studies are used to establish causal relationships, which is difficult in epidemiological studies
- Mice were exposed to JEP (jet emission particles) and CAP (Commercial airport particles) by pulmonary instillation at 3 dose levels and followed for 1, 28 and 90 days
- Endpoints:
  - Lung histology (Biopersistence and histological changes)
  - Lung inflammation (biomarker of toxicity)
  - Acute phase response (biomarker for risk of cardiovascular disease)
  - DNA damage in lung, lung fluid cells, liver (biomarker for risk of cancer)

Two different airport emission particles cause the same health effects in mice as standard NIST diesel exhaust particles and carbon nanoparticles

- The two airport emission particles induce the same health effects in mice as two NIST standard diesel exhaust particles including:
  - inflammation (general toxicity marker),
  - acute phase response (biomarker of cardiovascular risk)
  - DNA damage (biomarker of cancer risk)
  - No histological changes were observed

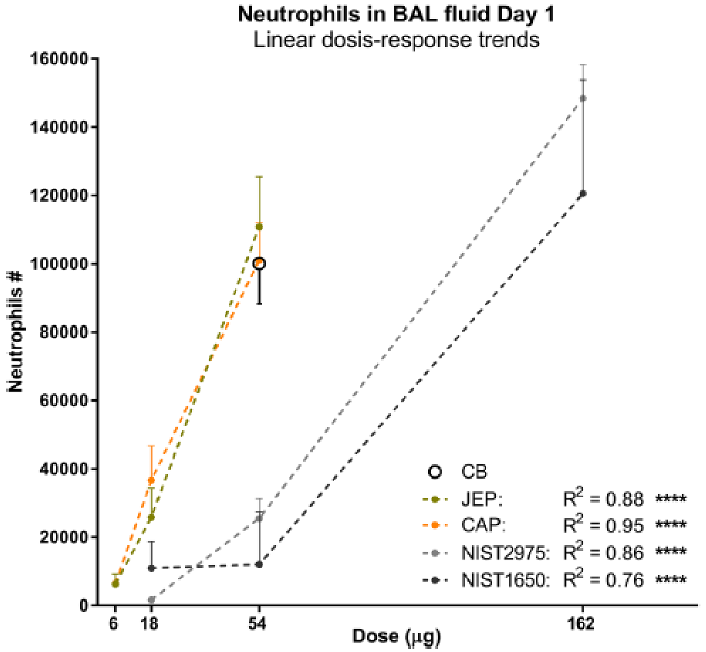

Fig. 4 Illustration of dose-response linearity between instilled doses of airport-collected particles, NIST2975, NIST1650 and neutrophil influx in BAL. Increasing dose-response effects were confirmed with test for linear trend, where the *alerting R2* (referred to as R2) is the fraction of the variance between group means that is accounted for by the linear trend (Altman/Sheskin, provided by GraphPad Prism). Data for NIST1650 was obtained from a previously published study [19]. Significant linear trends were verified for total cell numbers (not shown) and neutrophils in BAL fluid, with R2 between 0.76 and 0.95

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Summary

- Aircraft emission particles have similar physico-chemcial properties as diesel exhaust particles and carbon nanopariticles
- Aircraft emission particles have similar health effects as diesel exhaust particles and carbon nanoparticles in mice including increased inflammation, and increased biomarkers of risk of cardiovascular disease and cancer
- The study suggests that aircraft engine emission particles and airport emissions have similar health effects as diesel exhaust particles and other traffic related emissions and have similar potency

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Thank you for your attention

The study was part of Danish Centre for Nanosafety 2