

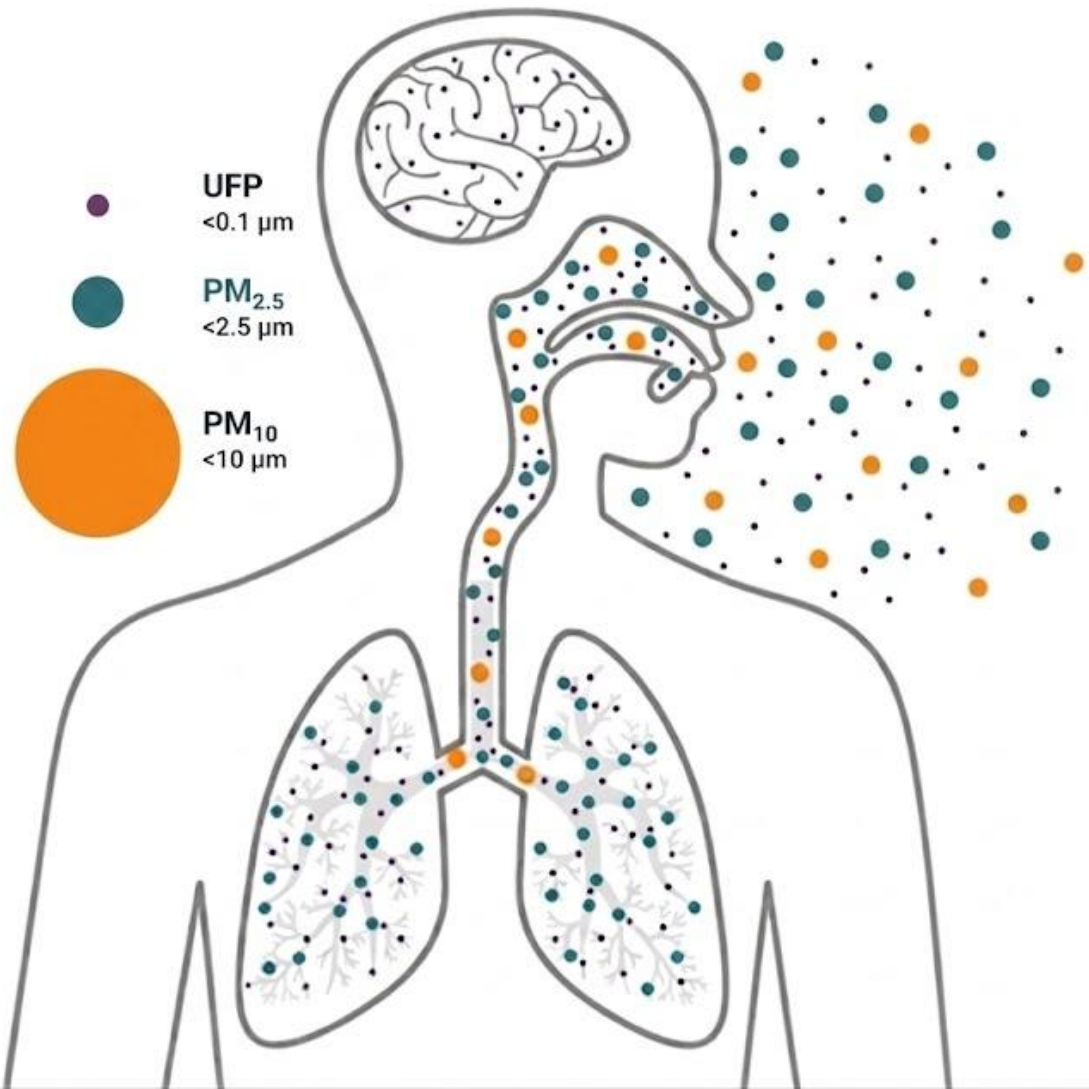
The background of the slide is a photograph of a busy city street, likely in Zurich, Switzerland. The street is filled with cars, vans, and trucks, some of which are blurred due to motion. In the background, there are several multi-story brick buildings with many windows. The sky is overcast. The overall scene depicts a typical urban environment with significant traffic and air pollution, which is the context for the research presented in the slide.

The health effects of long-term exposure to ultrafine particles

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ETH Nanoparticles Conference
Zürich – June 3rd, 2026

Are UFP harmful to health?



Can deposit deep in the lungs, pass into circulation and reach all organs

Exposure induces oxidative stress and inflammation

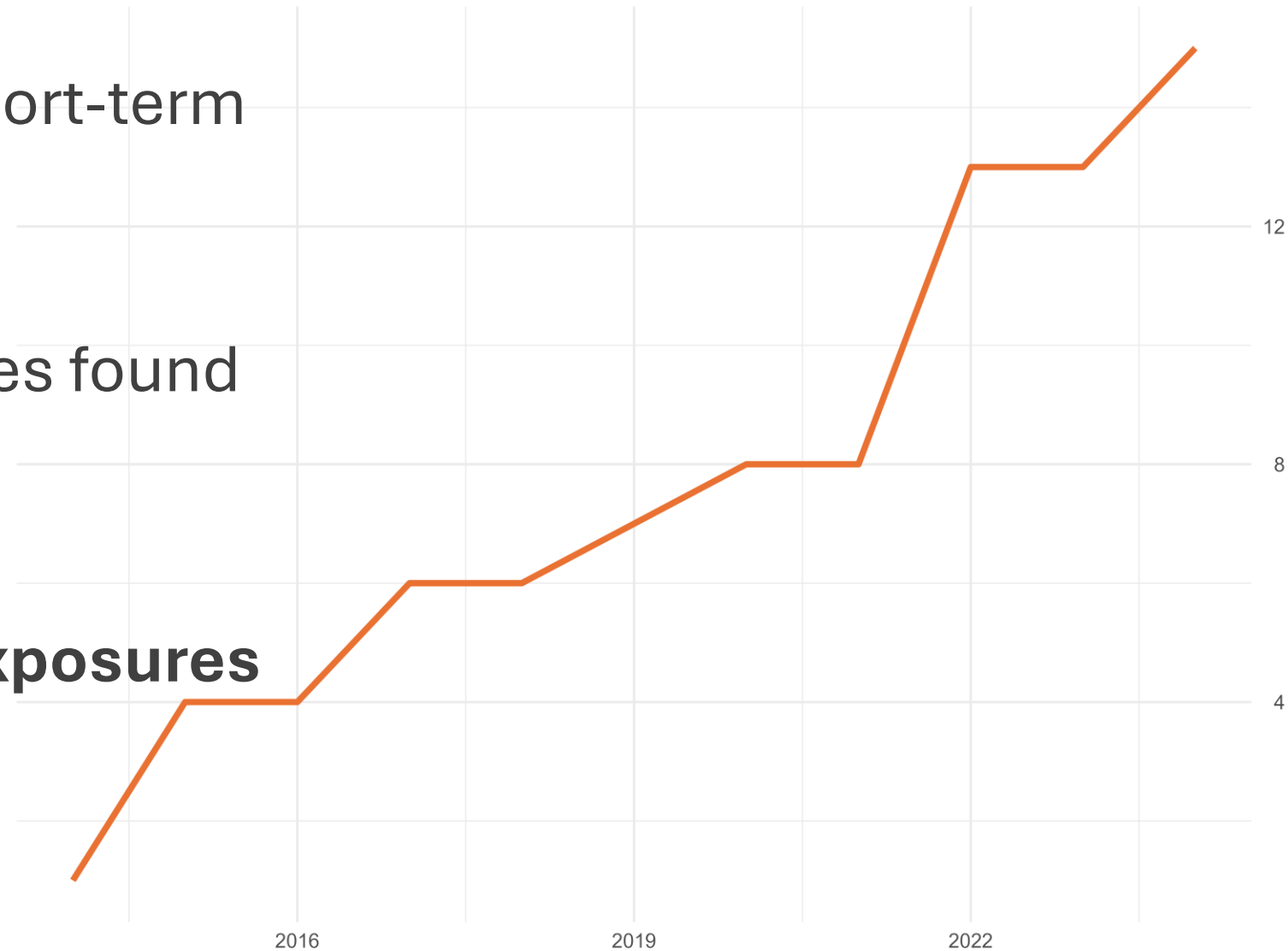
Epidemiological evidence is limited due to scarce exposure data

Epidemiological evidence

Most studies examine short-term exposures

Only ten long-term studies found
(Ohlwein et al. 2019)

**Studies on long-term exposures
increased recently**



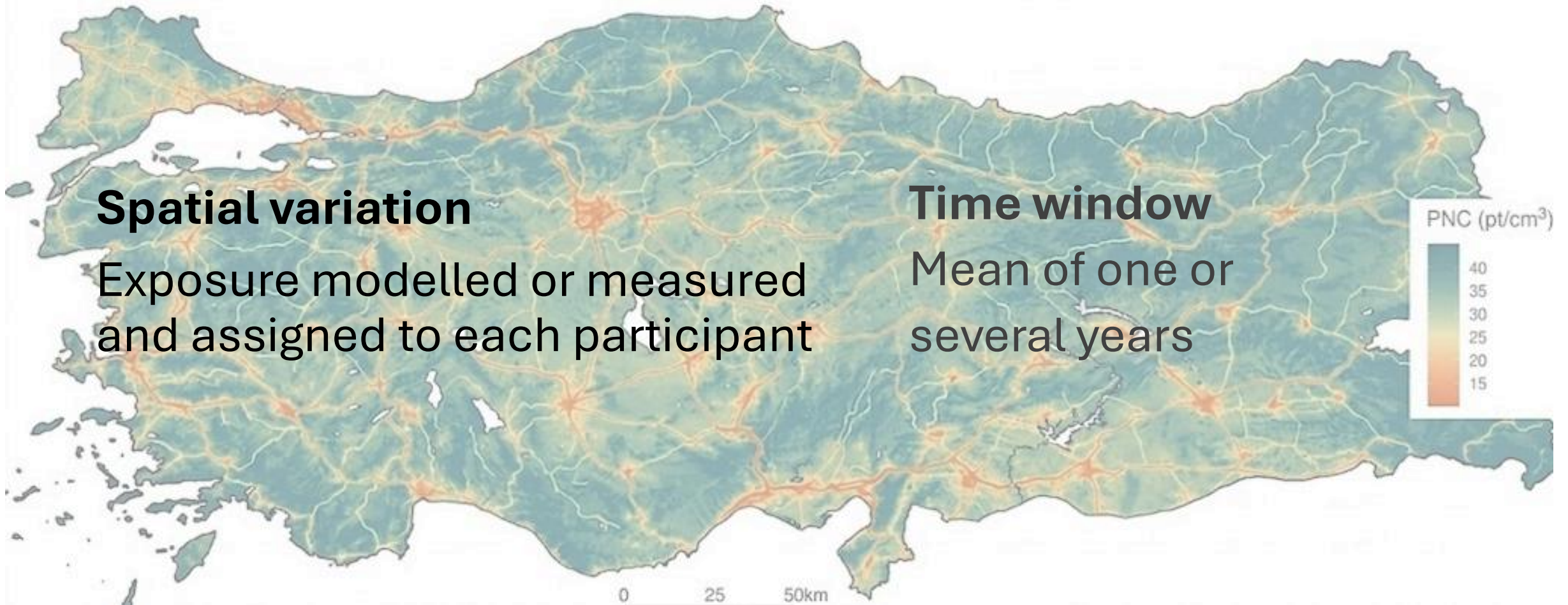
What are long-term studies?

Spatial variation

Exposure modelled or measured and assigned to each participant

Time window

Mean of one or several years



Systematic review

Databases

PubMed, LUDOK

Period

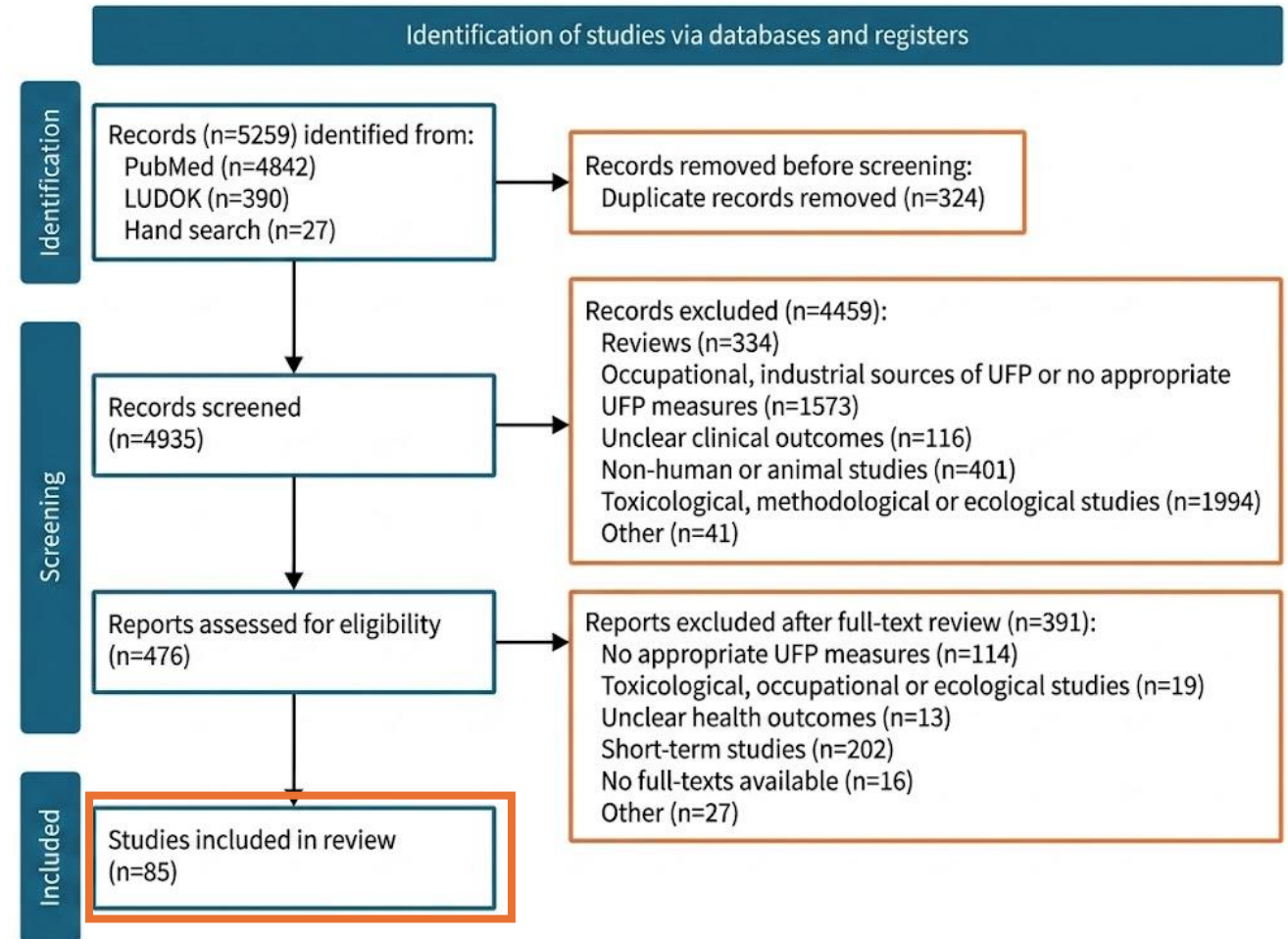
01/11/2011 – 31/12/2024

Inclusion criteria

Epidemiological study

General/patient population

No./mass concentration <100 nm (UFP) or <3000 nm (quasi-UFP)



Location	Western Europe	40
	North America	40
	Northeast Asia	3
	Western Pacific	2
Study design	Cohort	57
	Case-control	5
	Case-cohort	1
	Cross-sectional	21
Exposure assessment model	Land-use regression	37
	Chemical transport	20
	Hybrid	11
	Interpolation/Kriging	5
	Dispersion model	3
	Measurements	9
Exposure metric	UFP	73
	Quasi-UFP	12

Co-pollutant adjustment	PM _{2.5}	39
	NO ₂	37
	BC/EC	12
	Noise	20
Outcome type	Mortality	7
	Morbidity	32
	Subclinical	32
	Pregnancy/birth	10
Organ system	Cardiovascular	19
	Respiratory	15
	Inflammation	15
	Metabolic	13
	Neurological	10
	Pregnancy	9
	Cancer	10
	Psychiatric	5

Outcome group	Study	Study outcome	Single-pollutant association (estimate and 95% CI)
Natural	Bouma et al. 2023 (55)	Natural (all-cause)	HR: 1.01 (1.01; 1.02) per 2,723 pt/cm ³
	Ostro et al. 2015 (24)		HR: 1.01 (0.98; 1.05) per 969 ng/m ³
	Lloyd et al. 2024 (46)		HR: 1.07 (1.06; 1.09) per 10,000 pt/cm ³ †
	Pond et al. 2022 (26)		HR: 1.03 (1.02; 1.04) per 5,007 pt/cm ³
	Qi et al. 2024 (25)		RR: 1.10 (1.05; 1.17) per 834 pt/cm ³ ‡
	Goobie et al. 2024 (85)	Natural mortality or lung transplantation in fILD patients	HR: 1.01 (0.98; 1.03) per 1,000 pt/cm ³

Adverse associations with natural, cardiovascular (CV), respiratory, cancer and psychiatric mortality

58% of estimates adjusted for co-pollutants

Few estimates (natural, lung cancer, CV mortality) positive after NO₂ or PM_{2.5} adjustment

	Pond et al. 2022 (26)	All cancers	HR: 1.05 (1.02; 1.08) per 5,007 pt/cm ³
Psychiatric	Qi et al. 2024 (25)	Psychiatric diseases	RR: 1.06 (0.98; 1.14) per 834 pt/cm ³ ‡
Neurological	Peters et al. 2024 (36)	ALS	HR: 1.01 (0.96; 1.06) per 2,723 pt/cm ³
		Parkinson's disease	HR: 0.99 (0.97; 1.02) per 2,723 pt/cm ³
		Non-vascular dementia	HR: 0.99 (0.98; 1.00) per 2,723 pt/cm ³
		Alzheimer's disease	HR: 1.00 (0.98; 1.01) per 2,723 pt/cm ³
	Qi et al. 2024 (25)	Nervous system diseases	RR: 0.94 (0.78; 1.13) per 834 pt/cm ³ ‡

Mortality outcomes

Outcome group	Study	Study outcome	Single-pollutant association (estimate and 95% CI)
Cardiovascular	Downward et al. 2018 (77)	All CVD incidence	HR: 1.18 (1.03; 1.34) per 10,000 pt/cm ³
	Rodins et al. 2020 (106)		HR: 1.07 (0.93; 1.23) per 100 pt/cm ³
	Downward et al. 2018 (77)†	Stroke incidence	HR: 1.11 (0.88; 1.41) per 10,000 pt/cm ³
	Poulsen et al. 2023 (104)		HR: 1.04 (1.03; 1.05) per 4,248 pt/cm ³
	Rodins et al. 2020 (106)		HR: 1.06 (1.01; 1.10) per 100 pt/cm ³
	Li et al. 2017 (54)	Stroke prevalence	OR: 1.61 (0.88; 2.92)

Most consistent: myocardial infarction (MI), diabetes, stroke, brain tumour, childhood autism

60% of estimates adjusted for co-pollutants

Robust to NO₂ or PM_{2.5} adjustment: hypertension, diabetes, cancer and MI

Morbidity outcomes

Neurological		Mood stabilizer drugs	HR: 1.01 (1.00; 1.01) per 2,673 pt/cm ³
	Carter et al. 2023 (38)	Childhood autism incidence	HR: 1.02 (1.01; 1.03) per IQR
	Goodrich et al. 2024 (39)¶		cPIP: 0.76
	Yu et al. 2024 (40)		HR: 1.07 (1.02; 1.12) per 0.47 µg/m ³
Digestive system	Blanco et al. 2024 (41)	Dementia incidence	HR: 1.00 (0.93; 1.06) per 2,000 pt/cm ³
	Lomme et al. 2023 (42)	Parkinson's disease prevalence	OR: 1.29 (0.87; 1.93) per Q4 vs Q1
	Matthiasen et al. 2022 (43)	Non-alcoholic fatty liver disease	OR: 1.12 (1.02; 1.23) per 26.55 µg/m ³

Outcome group	Study	Study outcome	Single-pollutant association (estimate and 95% CI)
Cardiovascular	Endes et al. 2017 (78)	Arterial stiffness	OR: 1.14 (0.71; 1.81) per IQR
	Aguilera et al. 2016 (70)	Atherosclerosis (CIMT)	% ch: 2.06 (0.03; 4.10) per 12,639 pt/cm ³
	Hennig et al. 2020 (87)		OR: 1.15 (0.95; 1.41) per 528 pt/mL
	Peralta et al. 2022 (102)		0†
	Corlin et al. 2018 (52)	Blood pressure	SBP: % ch: 5.23 (-0.68; 11.14), DBP: 0.96 (-2.08; 4.00); per nat. log-unit incr.
	Corlin et al. 2018 (53)		% ch: 1.81% (0.94; 3.48) per 5,000 pt/mL
	Corlin et al. 2018 (52)	Pulse pressure	% ch: 4.27 (-0.79; 9.32) per natural log-unit increase
	Corlin et al. 2018 (53)		% ch: 0.70 (-0.27; 1.67) per 5,000 pt/mL
	Woeckel et al. 2024 (69)	Global LV wall thickness	% ch: -1.03 (-2.53; 0.48) per 2,242 pt/cm ³
		Cardiac AT	% ch: 1.64 (-3.40; 6.68) per 2,242 pt/cm ³
Respiratory	Yu et al. 2021 (116)	Lung function	(-)‡

Less consistent; mostly non-significant/null associations

Adverse associations: inflammation markers, atherosclerosis, childhood obesity, cognitive markers

25% of estimates adjusted for co-pollutants

	Ogurtsova et al. 2023 (100)		0§
	Glaubitz et al. 2022 (82)	Functional connectivity	0§
	Herder et al. 2020 (88)	DSPN prevalence	RR: 1.10 (1.01; 1.20) per 1,700 pt/cm ³
	Herder et al. 2020 (88)	DSPN incidence	RR: 1.11 (0.99; 1.24) per 1,700 pt/cm ³
	Herder et al. 2023 (89)		RR: 1.13 (1.00; 1.28) per 2,000 pt/cm ³
	Lubczyska et al. 2021 (95)	Brain volume in preadolescents	0§
	Lucht et al. 2022 (96)	Cortical thickness in the DMN	0§
	Nußbaum et al. 2020 (99)	Cognitive domains	(-)§
	Sunyer et al. 2015 (107)		+§
	Nußbaum et al. 2020 (99)	Cognitive function	(-)§
	Goodrich et al. 2024 (86)	Cognitive function in children§	cPIP: 0.73-0.96
	Nußbaum et al. 2020 (99)	Area-specific grey-matter thickness	0§
Others	Liao et al. 2024 (67)	Self-perceived health status	EQ-5D: % ch: -0.33 (-0.97; 0.33), EQVAS: -0.89 (-1.68; -0.10), per 1,900 pt/cm ³

Subclinical outcomes

**Pregnancy
and birth
outcomes**

Adverse associations: preterm birth, low birth weight, blood glucose levels, gestational diabetes

42% adjusted for co-pollutants

Robust to NO₂ adjustment: preterm birth, blood glucose levels, gestational diabetes

Discussion

Two-pollutant models for determining independent effects

Missing in many studies

Difficult to interpret with high UFP/co-pollutant correlations

Exposure assessment needs to reflect large spatial variation

Exposure misclassification due to central monitoring,
coarse model resolution, imprecise assignment

Promising new modelling approaches based on mobile monitoring

Few studies on individual sources, e.g. airports or traffic

Summary and conclusions

Substantial increase in evidence on long-term health effects of UFP (75 studies since 2019)

Potential adverse effects on **wide range of outcomes**

More consistent associations for mortality and morbidity than for subclinical outcomes

Cardiovascular and metabolic diseases, inflammation biomarkers and cancer more consistently associated than respiratory diseases

Inadequate evidence for independent effects

**More studies needed with special focus
on co-pollutant adjustment**

Thank you!

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Funding

KoPilot Project, German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

