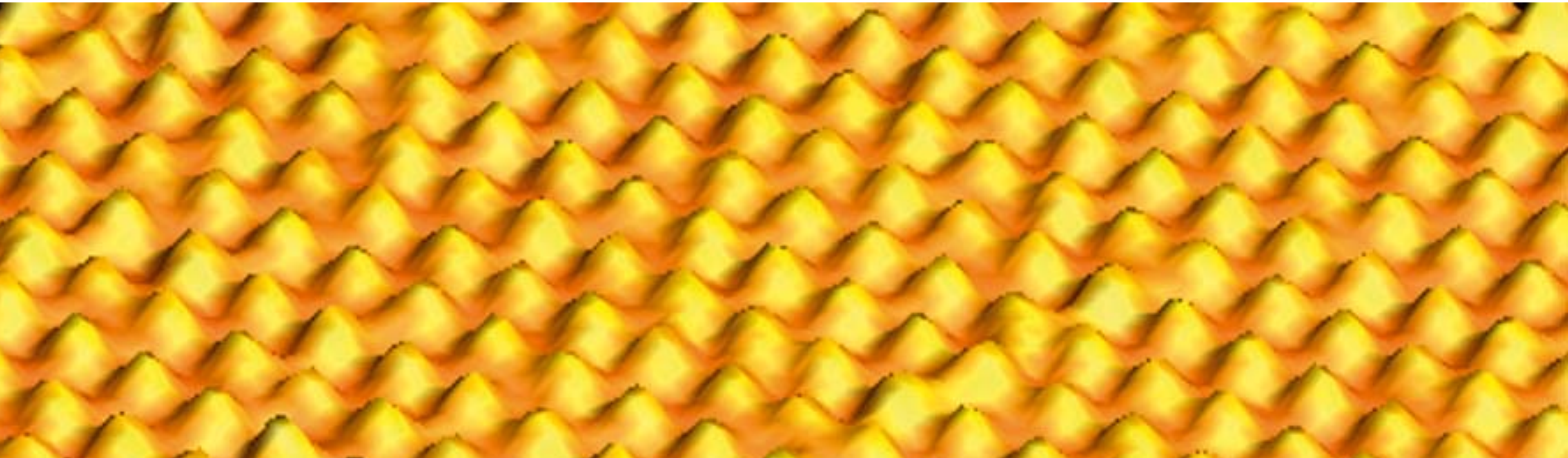
Empa. Materials Science and Technology.



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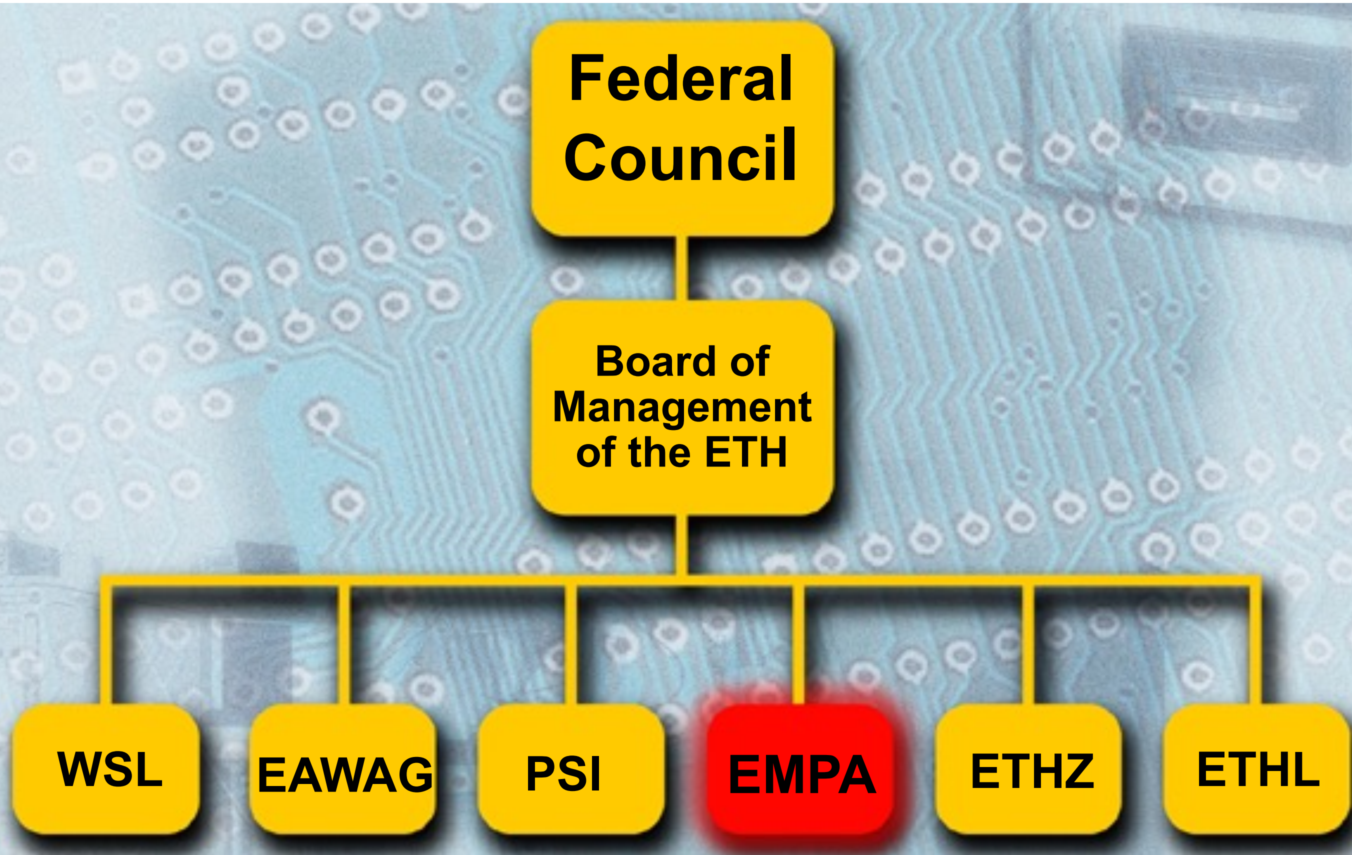

WSL - Swiss Federal Institute for Forest, Snow and Landscape Research
EAWAG - Swiss Federal Institute of Aquatic Science and Technology
PSI - Paul Scherrer Institute

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Materials Science and Technology

Empa's mission is:

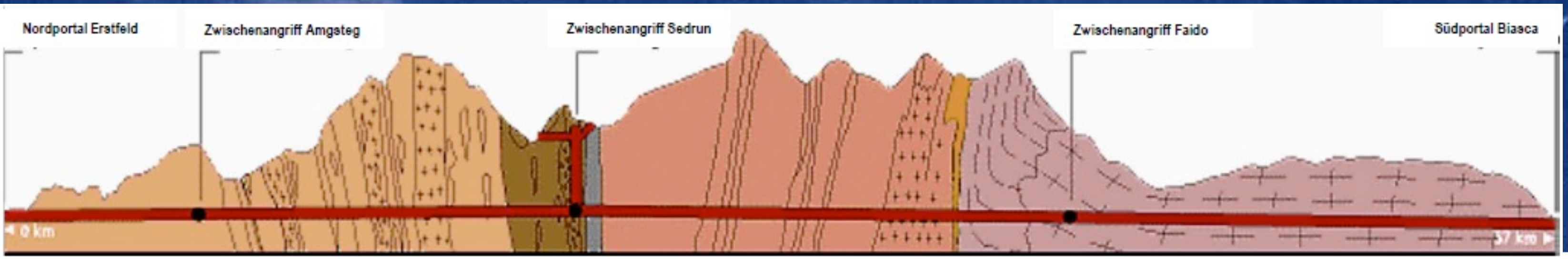
- building better bridges
- bridging research and applications
- bridging society, research and industry

NEAT – the longest railway tunnel in the world

Visionary decisions of the Swiss people 30 years ago!

- 2 Federal votes on environmental politics
  - Construction of a railway link through the Swiss Alps, 21.9.92
  - Initative to protect the Alps, 20.2.94

- 2 Tunnels of 57 km, overall 153 km shafts & tunnels
- At costs of more than 20 billion CHF
- Constructed from 1993-2017
- Hundreds of construction workers and diesel engines involved



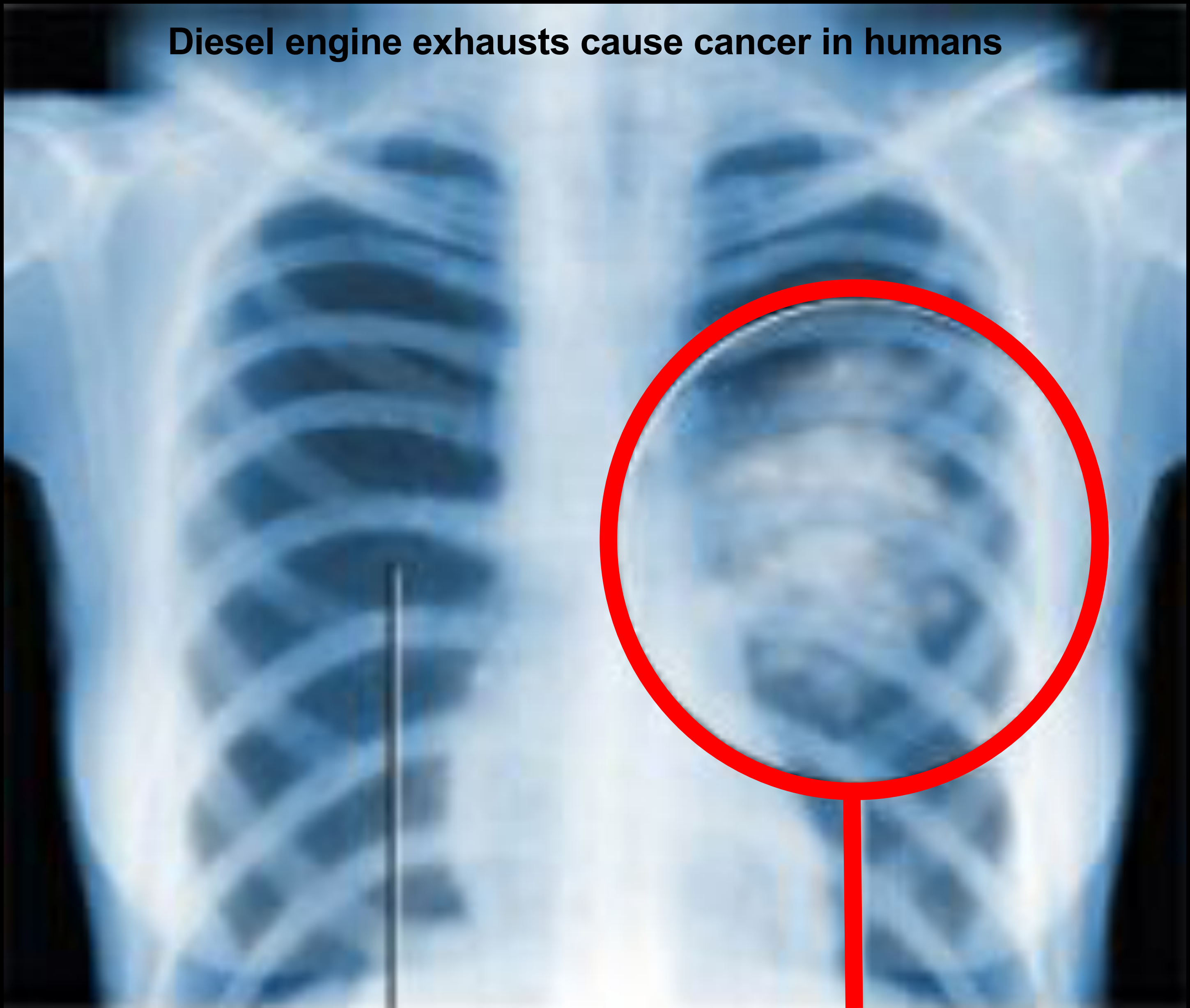
NEAT – the longest railway tunnel in the world

NEAT – the longest railway tunnel in the world

- Enough fresh air at the construction site?
- Concentration of pollutants within occupational health limits?
  (MWC of diesel exhausts: 0.1 g/m3 (> 1000x dilution needed)
- Start of the VERT project (since 1995 with Empa)
  VERT: Verminderung der Emissionen von Realmaschinen im Tunnelbau
  (reduction of emissions of real-world enignes in tunnels)

	Gases				Aerosols	
[mg/Nm^3]	CO	NO	NO_2	SO_2	PM / DME	H_2SO_4
Emisisons of construction heavy duty engines	1000	2700	300	100	250	25
Exposition limits						
Switzerland MAK (max. working place conc.)	35	30	6	5	0.2 (EC +OC)	1
Germany TRGS (limits for working places)	35	30	6	5	0.1 (EC)	1
Required dilution	>26	>90	>50	>20	>1000	>25

World Health Organization, IARC
Diesel engine exhaust: a group 1 carcinogen



World Health Organization, IARC
Diesel engine exhaust: a group 1 carcinogen

Diesel engine exhausts cause cancer in humans

International Agency for Research on Cancer

World Health Organization

PRESS RELEASE
N° 213

12 June 2012

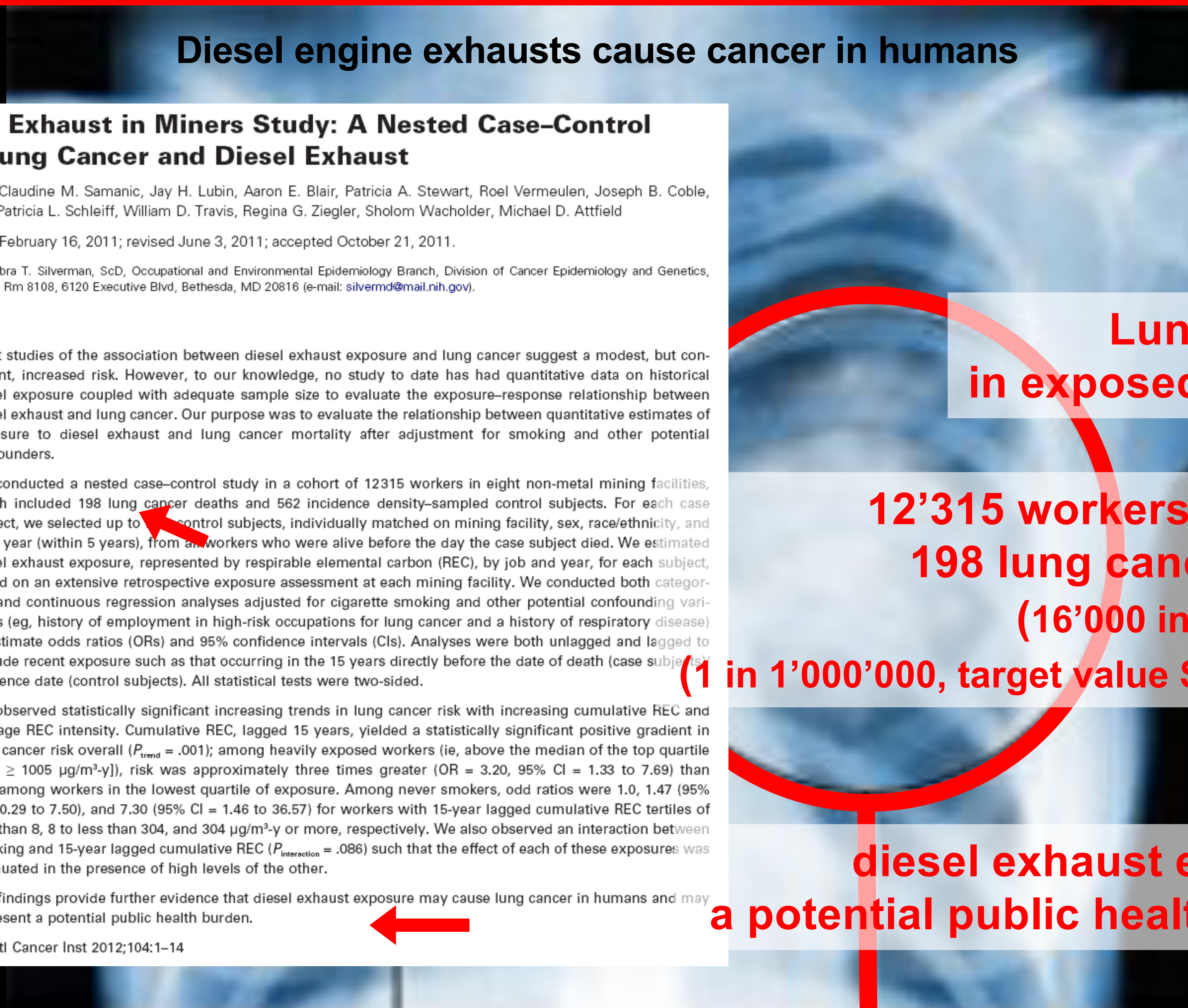
IARC: DIESEL ENGINE EXHAUST CARCINOGENIC

Lyon, France, June 12, 2012 -- After a week-long meeting of international experts, the International Agency for Research on Cancer (IARC), which is part of the World Health Organization (WHO), today classified diesel engine exhaust as **carcinogenic to humans (Group 1)**, based on sufficient evidence that exposure is associated with an increased risk for lung cancer.

Background
In 1988, IARC classified diesel exhaust as *probably carcinogenic to humans (Group 2A)*. An Advisory Group which reviews and recommends future priorities for the IARC Monographs Program had recommended diesel exhaust as a high priority for re-evaluation since 1998.

There has been mounting concern about the cancer-causing potential of diesel exhaust, particularly based on findings in epidemiological studies of workers exposed in various settings. This was re-emphasized by the publication in March 2012 of the results of a large US National Cancer Institute/National Institute for Occupational Safety and Health study of occupational exposure to such emissions in underground miners, which showed an increased risk of death from lung cancer in exposed workers (1).

World Health Organization, IARC
Diesel engine exhaust: a group 1 carcinogen



Diesel engine exhausts cause cancer in humans

The Diesel Exhaust in Miners Study: A Nested Case–Control Study of Lung Cancer and Diesel Exhaust

Debra T. Silverman, Claudine M. Samanic, Jay H. Lubin, Aaron E. Blair, Patricia A. Stewart, Roel Vermeulen, Joseph B. Coble, Nathaniel Rothman, Patricia L. Schleiff, William D. Travis, Regina G. Ziegler, Sholom Wacholder, Michael D. Attfield

Manuscript received February 16, 2011; revised June 3, 2011; accepted October 21, 2011.

Correspondence to: Debra T. Silverman, ScD, Occupational and Environmental Epidemiology Branch, Division of Cancer Epidemiology and Genetics, National Cancer Institute, Rm 8108, 6120 Executive Blvd, Bethesda, MD 20816 (e-mail: silvermd@mail.nih.gov).

Background Most studies of the association between diesel exhaust exposure and lung cancer suggest a modest, but consistent, increased risk. However, to our knowledge, no study to date has had quantitative data on historical diesel exposure coupled with adequate sample size to evaluate the exposure–response relationship between diesel exhaust and lung cancer. Our purpose was to evaluate the relationship between quantitative estimates of exposure to diesel exhaust and lung cancer mortality after adjustment for smoking and other potential confounders.

Methods We conducted a nested case–control study in a cohort of 12315 workers in eight non-metal mining facilities, which included 198 lung cancer deaths and 562 incidence density–sampled control subjects. For each case subject, we selected up to four control subjects, individually matched on mining facility, sex, race/ethnicity, and birth year (within 5 years), from all workers who were alive before the day the case subject died. We estimated diesel exhaust exposure, represented by respirable elemental carbon (REC), by job and year, for each subject, based on an extensive retrospective exposure assessment at each mining facility. We conducted both categorical and continuous regression analyses adjusted for cigarette smoking and other potential confounding variables (eg, history of employment in high-risk occupations for lung cancer and a history of respiratory disease) to estimate odds ratios (ORs) and 95% confidence intervals (CIs). Analyses were both unlagged and lagged to exclude recent exposure such as that occurring in the 15 years directly before the date of death (case subjects)/reference date (control subjects). All statistical tests were two-sided.

Results We observed statistically significant increasing trends in lung cancer risk with increasing cumulative REC and average REC intensity. Cumulative REC, lagged 15 years, yielded a statistically significant positive gradient in lung cancer risk overall (P_{trend} = .001); among heavily exposed workers (ie, above the median of the top quartile [REC ≥ 1005 μg/m³-y]), risk was approximately three times greater (OR = 3.20, 95% CI = 1.33 to 7.69) than that among workers in the lowest quartile of exposure. Among never smokers, odd ratios were 1.0, 1.47 (95% CI = 0.29 to 7.50), and 7.30 (95% CI = 1.46 to 36.57) for workers with 15-year lagged cumulative REC tertiles of less than 8, 8 to less than 304, and 304 μg/m³-y or more, respectively. We also observed an interaction between smoking and 15-year lagged cumulative REC ($P_{interaction}$ = .086) such that the effect of each of these exposures was attenuated in the presence of high levels of the other.

Conclusion Our findings provide further evidence that diesel exhaust exposure may cause lung cancer in humans and may represent a potential public health burden.

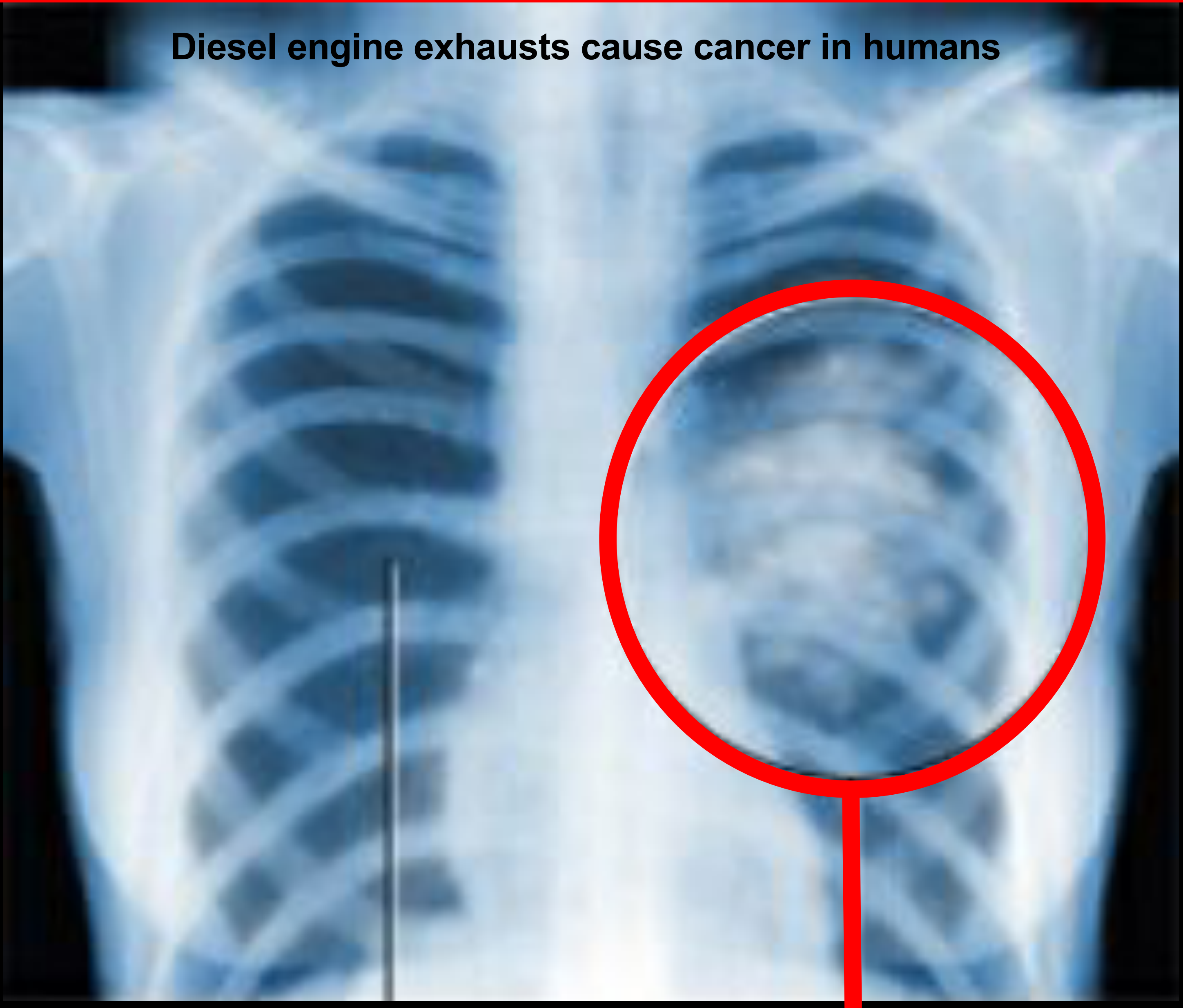
J Natl Cancer Inst 2012;104:1–14

Lung cancer in exposed workers

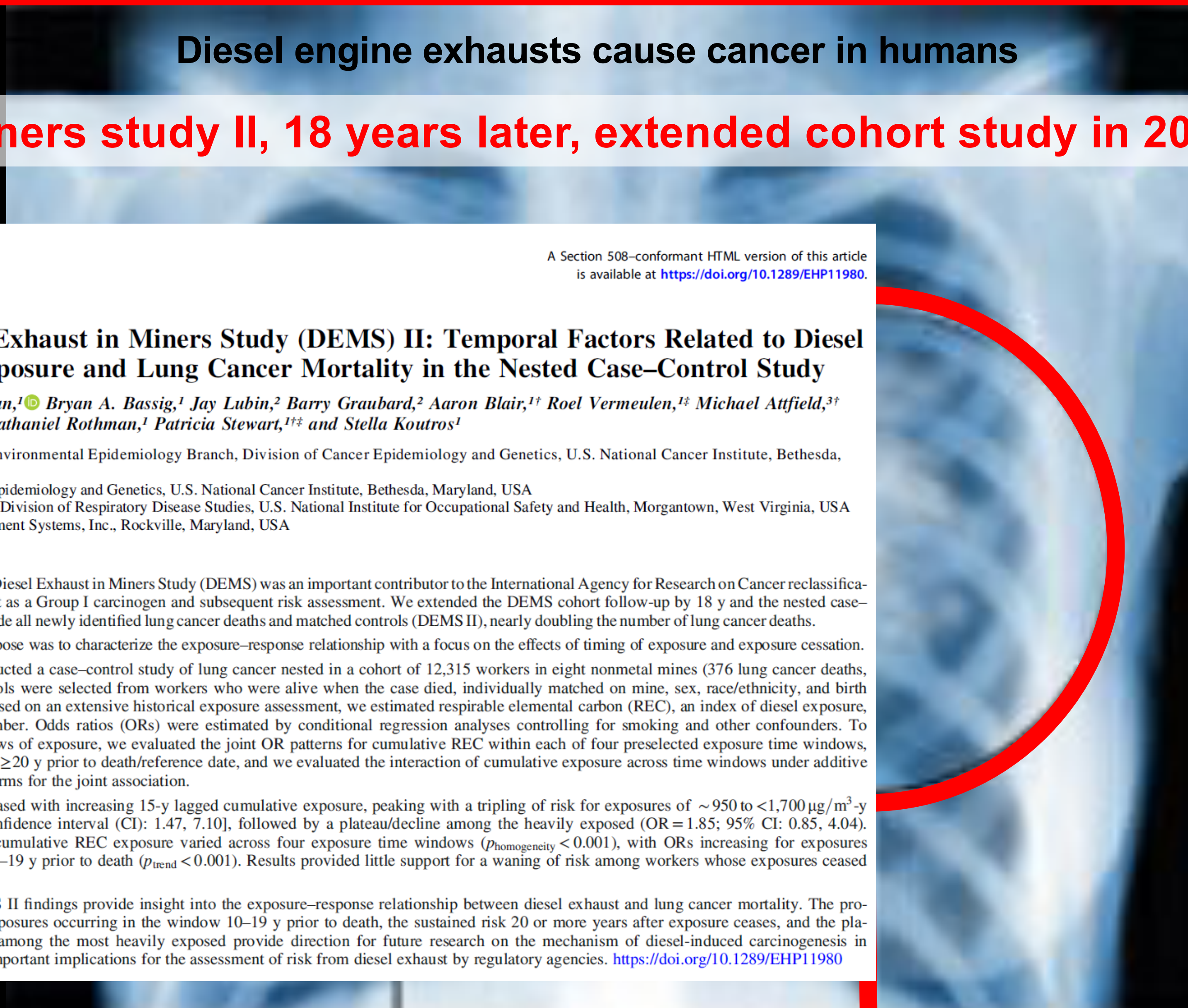
12'315 workers, 8 mines
198 lung cancer death
(16'000 in 1'000'000)
(1 in 1'000'000, target value Swiss LRV)

diesel exhaust exposure: a potential public health burden

World Health Organization, IARC
Diesel engine exhaust: a group 1 carcinogen



World Health Organization, IARC
Diesel engine exhaust: a group 1 carcinogen



Diesel engine exhausts cause cancer in humans

Miners study II, 18 years later, extended cohort study in 2023

Research

A Section 508–conformant HTML version of this article is available at https://doi.org/10.1289/EHP11980.

The Diesel Exhaust in Miners Study (DEMS) II: Temporal Factors Related to Diesel Exhaust Exposure and Lung Cancer Mortality in the Nested Case–Control Study

Debra T. Silverman,[1] Bryan A. Bassig,[1] Jay Lubin,[2] Barry Graubard,[2] Aaron Blair,[1†] Roel Vermeulen,[1‡] Michael Attfield,[3†] Nathan Appel,[4] Nathaniel Rothman,[1] Patricia Stewart,[1†‡] and Stella Koutros[1]

[1]Occupational and Environmental Epidemiology Branch, Division of Cancer Epidemiology and Genetics, U.S. National Cancer Institute, Bethesda, Maryland, USA
[2]Division of Cancer Epidemiology and Genetics, U.S. National Cancer Institute, Bethesda, Maryland, USA
[3]Surveillance Branch, Division of Respiratory Disease Studies, U.S. National Institute for Occupational Safety and Health, Morgantown, West Virginia, USA
[4]Information Management Systems, Inc., Rockville, Maryland, USA

Background: The Diesel Exhaust in Miners Study (DEMS) was an important contributor to the International Agency for Research on Cancer reclassification of diesel exhaust as a Group I carcinogen and subsequent risk assessment. We extended the DEMS cohort follow-up by 18 y and the nested case–control study to include all newly identified lung cancer deaths and matched controls (DEMS II), nearly doubling the number of lung cancer deaths.

Objective: Our purpose was to characterize the exposure–response relationship with a focus on the effects of timing of exposure and exposure cessation.

Methods: We conducted a case–control study of lung cancer nested in a cohort of 12,315 workers in eight nonmetal mines (376 lung cancer deaths, 718 controls). Controls were selected from workers who were alive when the case died, individually matched on mine, sex, race/ethnicity, and birth year (within 5 y). Based on an extensive historical exposure assessment, we estimated respirable elemental carbon (REC), an index of diesel exposure, for each cohort member. Odds ratios (ORs) were estimated by conditional regression analyses controlling for smoking and other confounders. To evaluate time windows of exposure, we evaluated the joint OR patterns for cumulative REC within each of four preselected exposure time windows, <5, 5–9, 10–19, and ≥ 20 y prior to death/reference date, and we evaluated the interaction of cumulative exposure across time windows under additive and multiplicative forms for the joint association.

Results: ORs increased with increasing 15-y lagged cumulative exposure, peaking with a tripling of risk for exposures of ~ 950 to $<1{,}700\ \mu g/m^3$-y [OR = 3.23; 95% confidence interval (CI): 1.47, 7.10], followed by a plateau/decline among the heavily exposed (OR = 1.85; 95% CI: 0.85, 4.04). Patterns of risk by cumulative REC exposure varied across four exposure time windows ($p_{homogeneity} < 0.001$), with ORs increasing for exposures accrued primarily 10–19 y prior to death ($p_{trend} < 0.001$). Results provided little support for a waning of risk among workers whose exposures ceased for ≥ 20 y.

Conclusion: DEMS II findings provide insight into the exposure–response relationship between diesel exhaust and lung cancer mortality. The pronounced effect of exposures occurring in the window 10–19 y prior to death, the sustained risk 20 or more years after exposure ceases, and the plateau/decline in risk among the most heavily exposed provide direction for future research on the mechanism of diesel-induced carcinogenesis in addition to having important implications for the assessment of risk from diesel exhaust by regulatory agencies. https://doi.org/10.1289/EHP11980

World Health Organization, IARC
Diesel engine exhaust: a group 1 carcinogen

Diesel engine exhausts cause cancer in humans

Miners study II, 18 years later, extended cohort study in 2023

Research

A Section 508–conformant HTML version of this article
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The Diesel Exhaust in Miners Study (DEMS) II: Temporal Factors Related to Diesel Exhaust Exposure and L

Debra T. Silverman,[1] Bryan A. Bass
Nathan Appel,[4] Nathaniel Rothman,[1]

[1]Occupational and Environmental Epidemiol
Maryland, USA
[2]Division of Cancer Epidemiology and Genetic
[3]Surveillance Branch, Division of Respiratory I
[4]Information Management Systems, Inc., Rock

Background: The Diesel Exhaust in Miners
tion of diesel exhaust as a Group I carcinoge
control study to include all newly identified lu

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Methods: We conducted a case–control stu
718 controls). Controls were selected from
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for ≥20 y.

Conclusion: DEMS II findings provide ins
nounced effect of exposures occurring in the
teau/decline in risk among the most heavil
addition to having important implications fo

Research

A Section 508–conformant HTML version of this article
is available at https://doi.org/10.1289/EHP12840.

Diesel Exhaust Exposure and Cause-Specific Mortality in the Diesel Exhaust in Miners Study II (DEMS II) Cohort

Stella Koutros,[1] Barry Graubard,[2] Bryan A. Bassig,[3] Roel Vermeulen,[4] Nathan Appel,[5] Marianne Hyer,[5] Patricia A. Stewart,[6] and Debra T. Silverman[1]

[1]Occupational and Environmental Epidemiology Branch, Division of Cancer Epidemiology and Genetics, National Cancer Institute (NCI), National Institutes of Health (NIH), Department of Health and Human Services (DHHS), Bethesda, Maryland, USA
[2]Biostatistics Branch, Division of Cancer Epidemiology and Genetics, NCI, NIH, DHHS, Bethesda, Maryland, USA
[3]Formerly Occupational and Environmental Epidemiology Branch, Division of Cancer Epidemiology and Genetics, NCI, NIH, DHHS, Bethesda, Maryland, USA
[4]Institute for Risk Assessment Sciences, Division of Environmental Epidemiology, Utrecht University, Utrecht, the Netherlands
[5]Information Management Services, Inc. Rockville, Maryland, USA
[6]Stewart Exposure Assessments, LLC, Arlington, Virginia, USA

Background: With the exception of lung cancer, the health effects associated with diesel exhaust for other cancers and nonmalignant health outcomes are not well understood.

Objectives: We extended the mortality follow-up of the Diesel Exhaust in Miners Study, a cohort study of 12,315 workers, by 18 y (ending 31 December 2015), more than doubling the number of observed deaths to $n = 4,887$, to evaluate associations between mortality and diesel exhaust exposure.

Methods: Quantitative estimates of historical exposure to respirable elemental carbon (REC), a surrogate for diesel exhaust, were created for all jobs, by year and facility, using measurements collected from each mine, as well as historical measurements. Standardized mortality ratios (SMRs) and hazard ratios (HRs) were estimated for the entire cohort and by worker location (surface, underground).

Results: We observed an excess of death for cancers of the lung, trachea, and bronchus ($n = 409$; SMR = 1.24; 95% CI: 1.13, 1.37). Among workers who ever worked underground, where the majority of diesel exposure occurred, excess deaths were evident for lung, trachea, and bronchus cancers ($n = 266$; SMR = 1.26; 95% CI: 1.11, 1.42). Several nonmalignant diseases were associated with excess mortality among workers ever-employed underground, including ischemic heart disease (SMR = 1.08; 95% CI: 1.00, 1.16), cerebrovascular disease (SMR = 1.22; 95% CI: 1.04, 1.43), and nonmalignant diseases

World Health Organization, IARC
Diesel engine exhaust: a group 1 carcinogen

U.S.A. miner's study II, 18 years later, exteded cohort study 2023

Table 1. Observed numbers of deaths and standardized mortality ratios (SMRs) f
and by worker location.

	Total cohort Person-years[a] = 422,343	
Cause of death	Observed	SMR (95% CI)
All causes of death	4,887	1.02 (1.00, 1.05)
All malignant neoplasms	1,251	1.12 (1.06, 1.18)*
Esophagus	53	1.40 (1.05, 1.83)*
Stomach	40	1.25 (0.89, 1.70)
Intestine	91	1.00 (0.81, 1.23)
Rectum	16	0.75 (0.43, 1.22)
Biliary, liver, and gall bladder	43	0.99 (0.72, 1.34)
Pancreas	67	1.04 (0.81, 1.32)
Lung, trachea, and bronchus	409	1.24 (1.13, 1.37)*
Larynx	15	1.35 (0.76, 2.23)
Prostate	92	0.90 (0.73, 1.11)
Urinary	74	1.14 (0.90, 1.44)
Kidney	34	1.02 (0.71, 1.43)
Bladder and other urinary	40	1.27 (0.91, 1.73)
Melanoma	29	1.29 (0.87, 1.86)
Mesothelioma[b]	13	2.71 (1.44, 4.64)*
Brain and other nervous	45	1.41 (1.03, 1.88)*
Lymphatic and hematopoietic	121	1.07 (0.88, 1.27)
Non-Hodgkin lymphoma with CLL[c]	61	1.22 (0.94, 1.57)
Multiple myeloma	17	0.81 (0.47, 1.29)
Leukemia[d]	51	1.09 (0.81, 1.43)
Diabetes mellitus	123	0.98 (0.81, 1.17)
Diseases of the heart	1,362	1.03 (0.98, 1.09)
Ischemic heart disease	1,103	1.06 (1.00, 1.12)
Other diseases of circulatory system	331	0.97 (0.87, 1.08)
Cerebrovascular disease	217	1.04 (0.91, 1.19)
Diseases of respiratory system	470	
Chronic obstructive pulmonary disease	284	
Other pneumoconioses	25	

Lung cancer in exposed workers

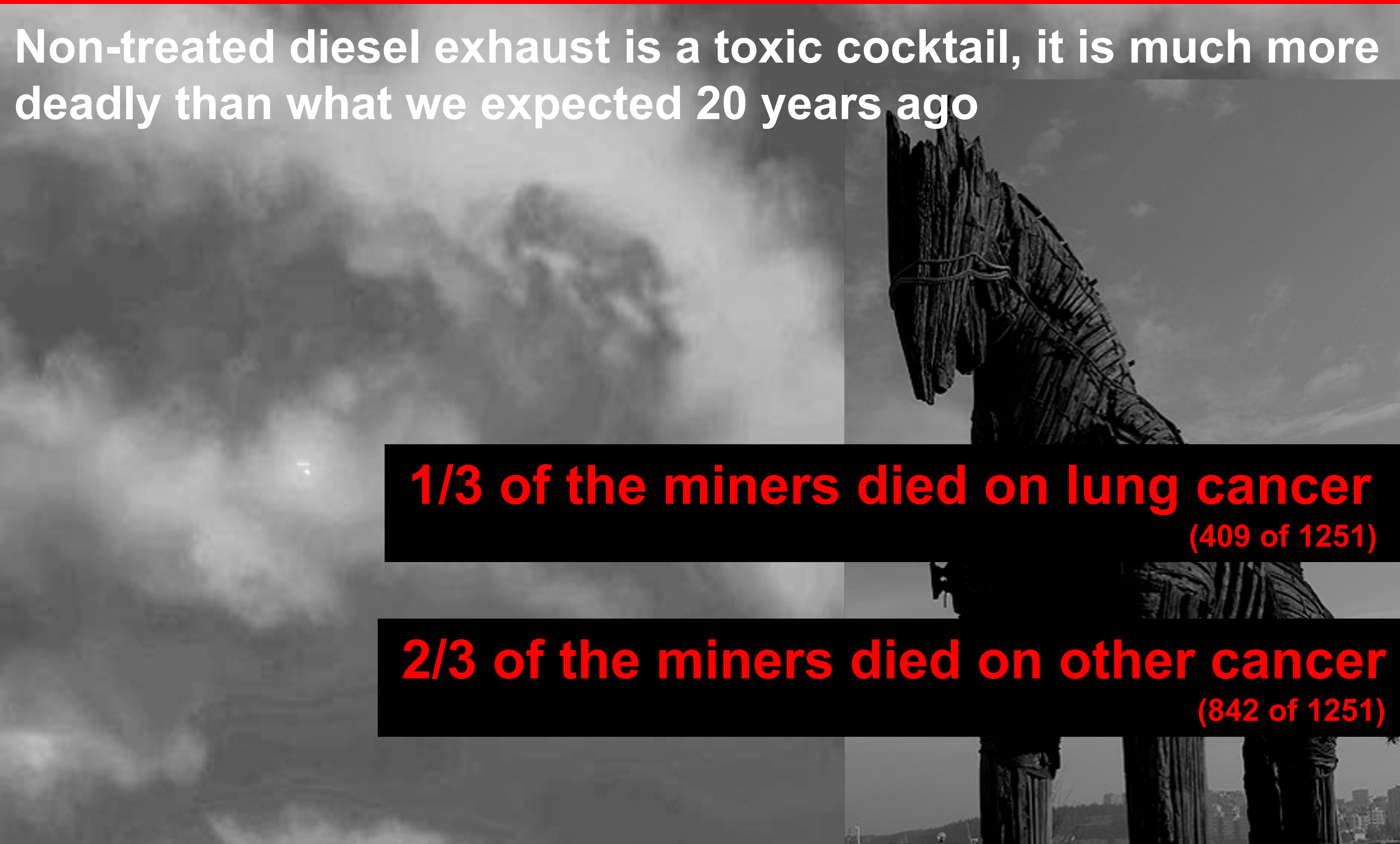
12'315 workers, 8 mines
from 198 up to 409 lung cancer death
(from 16'000 up to 33'000 in 1'000'000)
(1 in 1'000'000, target value Swiss LRV)

4'887 workers died
1251 cancer death
besides 409 lung cancer death
92 prostate
91 intestine
74 urinary (kidney, bladder)
67 pancreas
61 non-Hodgkin lymphomes
51 leukemia

(102'000 cancer death in 1'000'000)

Diesel soot particles – Trojan horses for genotoxic compounds

Non-treated diesel exhaust is a toxic cocktail, it is much more deadly than what we expected 20 years ago



1/3 of the miners died on lung cancer
(409 of 1251)

2/3 of the miners died on other cancer
(842 of 1251)

Evidence for the Trojan horse effect?

Are there any omissions?

Are there any omissions?

Are there any omissions?

What was hidden under the term «other technologies» ?

Particle Emissions from Diesel Passenger Cars Equipped with a Particle Trap in Comparison to Other Technologies

MARTIN MOHR,*
ANNA-MARIA FORSS, AND URS LEHMANN
Laboratory for Internal Combustion Engines, Empa (Swiss Federal Laboratories for Materials Testing and Research), CH-8600 Dübendorf, Switzerland

Environ. Sci. Technol. **2006**, *40*, 2375–2383

Are there any omissions?

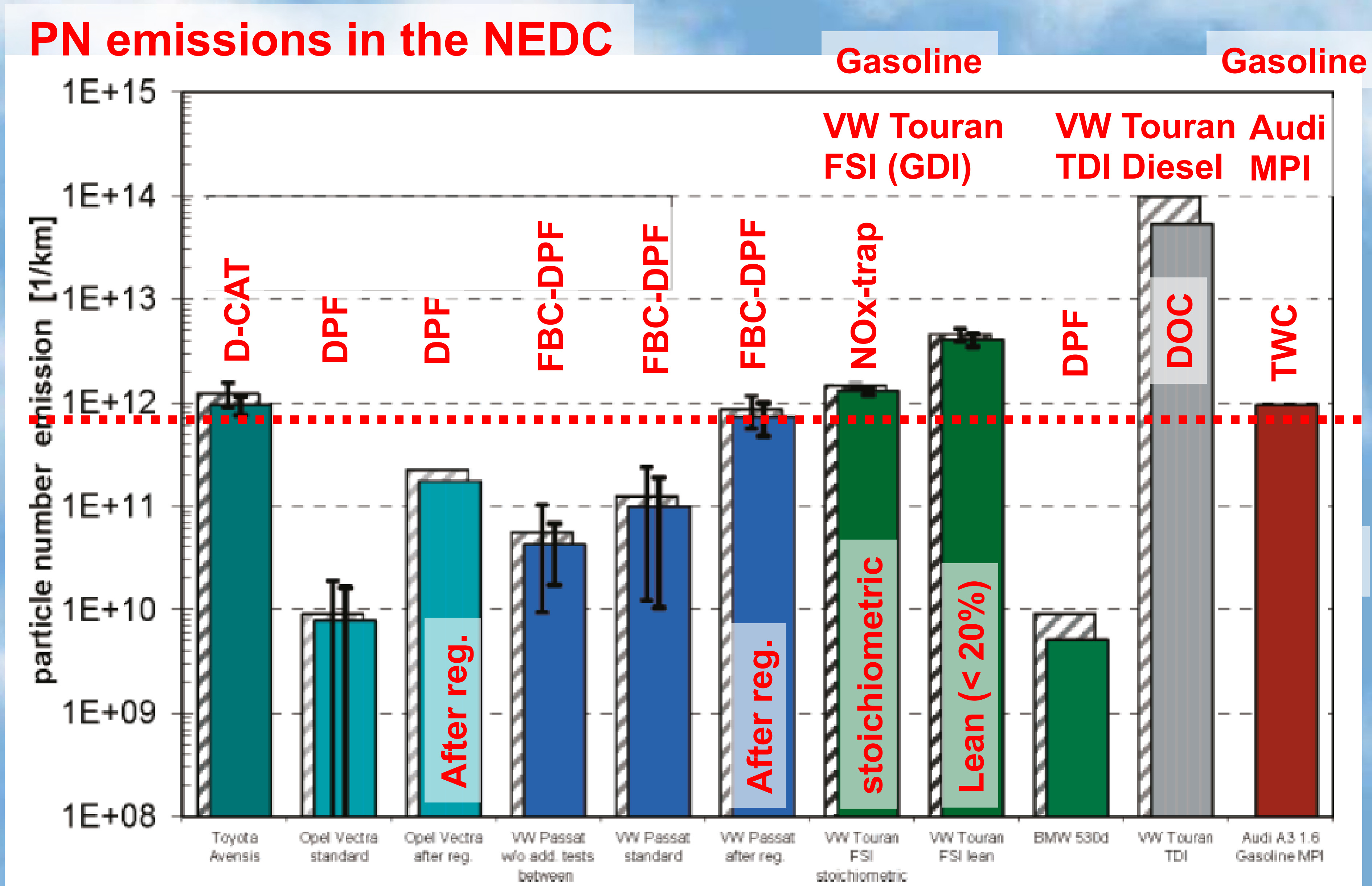
What was hidden under the term «other technologies» ?

TABLE 1. Specification of Vehicles Investigated in This Study

				Gasoline			Gasoline
manufacturer	**Toyota**	**Opel**	**VW**	**VW**	**BMW**	**VW**	**Audi**
model	Avensis 2.0 D-cat	Vectra 1.9CDTI 16V	Passat 2.0 TDI	Touran 1.6 FSI	530d	Touran 1.9 TDI	A3
fuel	diesel	diesel	diesel	gasoline	diesel	diesel	gasoline
injection	direct	direct	direct	direct	direct	direct	MPI
displacement	1995 cm^3	1910 cm^3	1968 cm^3	1598 cm^3	2993 cm^3	1896 cm^3	1595 cm^3
no of cylinders	4	4	4	4	6	4	4
power	85	110	100	85	160	77	75
aftertreatment system	combined NO_x adsorber and DPF (D-cat), oxidation catalyst	oxidation catalyst, catalyzed DPF (CSF)	oxidation catalyst, fuel borne catalyst DPF (FBC-DPF)	NO_x adsorber	oxidation catalyst, catalyzed, DPF (CSF)	oxidation catalyst	three-way catalyst (TWC)
material	Corderite	Si-SiC	Si-SiC				
certification	Euro 4	Euro 4	Euro 4	Euro 4	Euro 4	Euro 3	Euro 4
odometer	3100 km	3100 km	3100 km	8100 km	3200 km	14900 km	40000 km
no of NEDC-tests	7	6	15	7	1	1	1

Environ. Sci. Technol. **2006**, *40*, 2375−2383

Are there any omissions?



Are there any omissions?

We burned 30 years on diesel converter technology!

About 1/3 of the global vehicle fleet burns diesel

But about 2/3 of the global vehicle fleet burn gasoline

A good colleague and dear friend to remember!

4. VERT FORUM

Advanced Diesel Particle Filter- and $deNO_x$-Technologies

Impact of Biofuels

2013

Empa, Dübendorf, Überlandstrasse 129
Friday, March 22, 2013, 09.00–16.30

A good colleague and dear friend to remember!

PROGRAM

09.00 Welcome
H. Vonmont, Empa

09.05 Welcome
L. Larsen, VERT

RESEARCH AND TECHNOLOGY

09.15 Biofuels under Energy and Sustainability Aspects
R. Zah, Empa

09.30 Secondary Emissions with Biofuels and FBCs
N. Heeb, Empa

09.45 Particle Filter Retrofit (GPF) for Petrol Engines:
Why and how?
A. Mayer, TTM

10.00 Research on Metal Oxide Particles:
The GasOMeP-Project
A. Ulrich, Empa

10.15 TeVeNOx: Testing of Vehicles with
NOx Reduction Systems
J. Czerwinski, UASB

A good colleague and dear friend to remember!

Dr. Andrea Ulrich

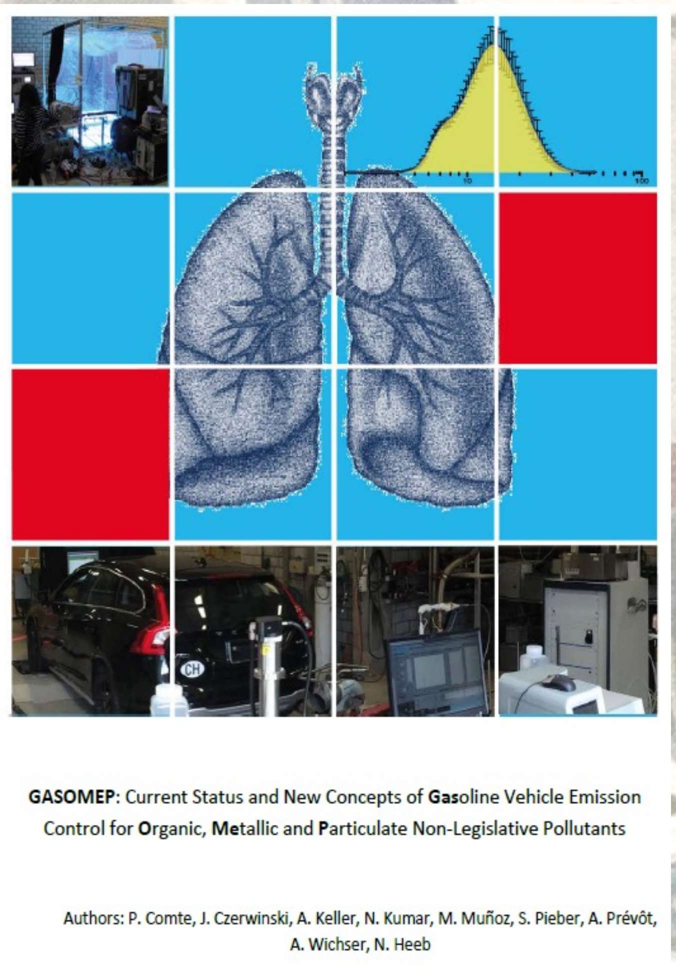
2. Nov. 1961 – 12. März 2013

Nanoparticle emissions of GDI vehicles

Europe is flooded with soot nanoparticles of GDI vehicles

GDI vehicles on the rise

- 53 mio GDI vehicles in Europe (2010-2020)
- 30% of the EU fleet will be GDI in 2020



GASOMEP: Current Status and New Concepts of **Gas**oline Vehicle Emission Control for **O**rganic, **Me**tallic and **P**articulate Non-Legislative Pollutants

Authors: P. Comte, J. Czerwinski, A. Keller, N. Kumar, M. Muñoz, S. Pieber, A. Prévôt, A. Wichser, N. Heeb

The sooting problem of GDI vehicles

GDI fleet properties: Mean GDI fleet (n=7)

GDI-1:	Mitsubishi Carisma (1.8 L)	Euro-3
GDI-2:	VW Golf (1.4 L)	Euro-4
GDI-3:	Opel Insignia (1.6)	Euro-5
GDI-4:	Volvo V60 T4F (1.6 L)	Euro-5
GDI-5:	Opel Zafira (1.6 L)	Euro-5
GDI-6:	Citroën C4 Cactus (1.2 L)	Euro-6
GDI-7:	VW Golf VII (1.4 L)	Euro-6

Diesel benchmark (with DOC+DPF, EGR)

DI:	Peugeot 4008 (1.6 L)	Euro-5

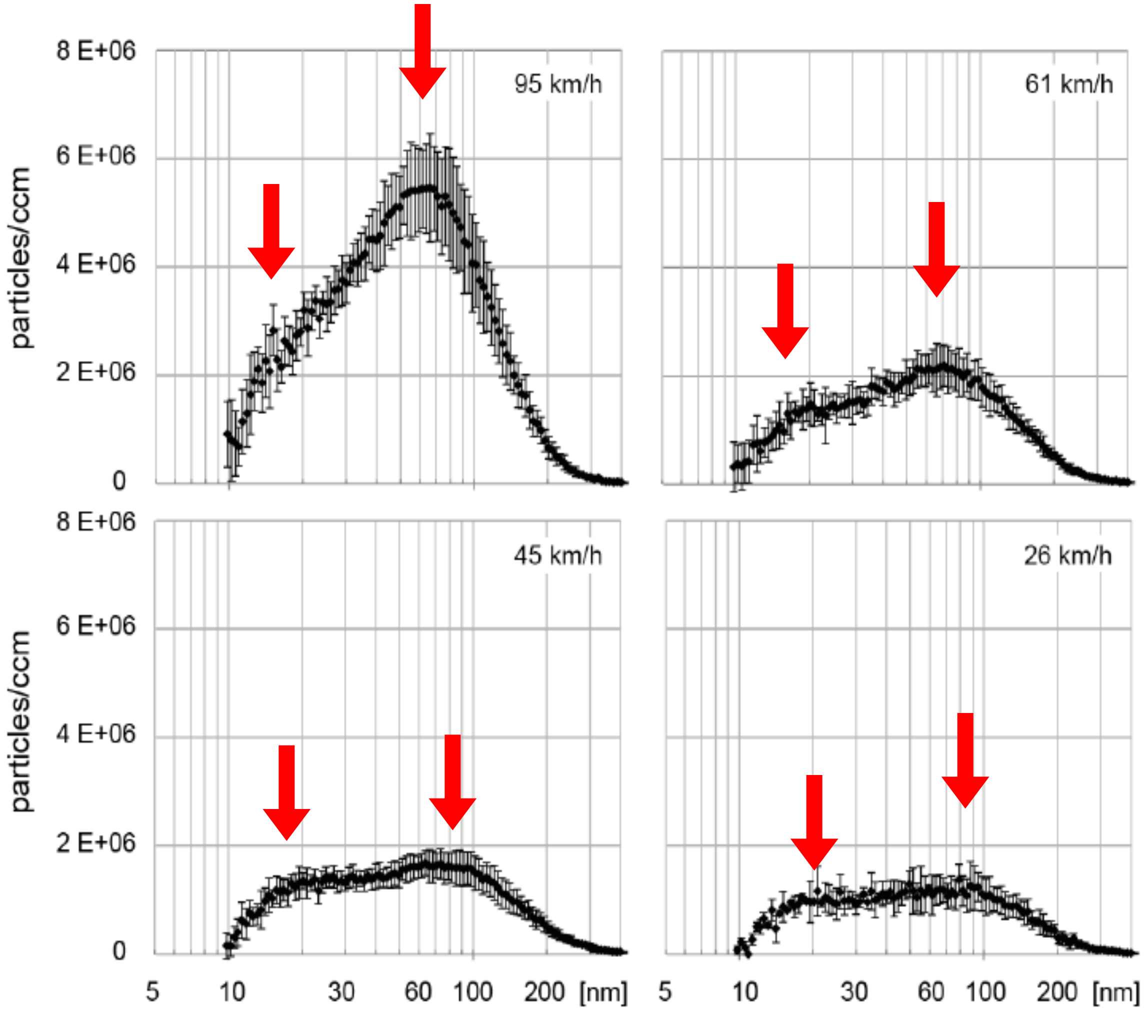





Nanoparticle emissions of GDI vehicles

- GDI particles are nano!
- Bimodal distribution
- Maxima at 20 & 80nm

GDI particles indeed are nanoparticles of 10-200 nm



Millions of new «sooting stars» are born every year now!

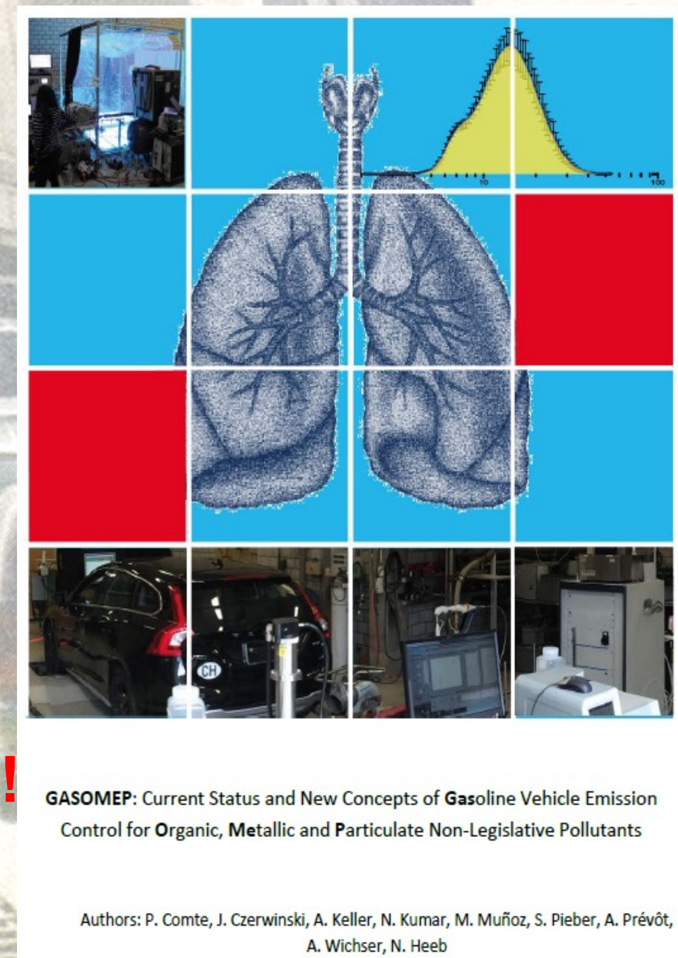
Nanoparticle emissions of GDI vehicles

Europe is flooded with soot nanoparticles of GDI vehicles

GDI vehicles on the rise

- 53 mio GDI vehicles in Europe (2010-2020)
- 30% of the EU fleet will be GDI in 2020

GDI vehicles, on average, release:
700 x more nanoparticles
and 17 x more genotoxic PAHs
than a Euro-5 diesel vehicle with DPF!



Before you buy a GDI vehicle, please read the GASOMEP report (https://www.empa.ch/web/s604/soot-particles-from-gdi)

30 years VERT on diesel technology

Something to celebrate, but much more work ahead of us!

- Filters for gasoline vehicles
- NPTI for gasoline vehicles
- Reduction of genotoxicity