National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Toxicology and health effects of non-tailpipe emissions

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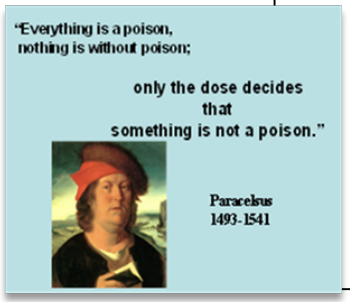
Outline
- Toxicological research methods
- Health studies non-tailpipe
- Exposure
- Research gaps
- Conclusions

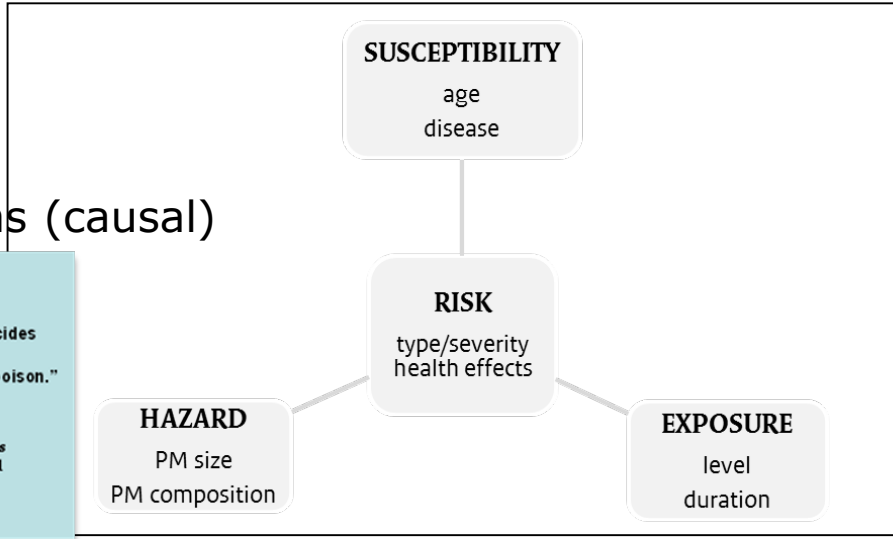
Toxicological research

Toxicology

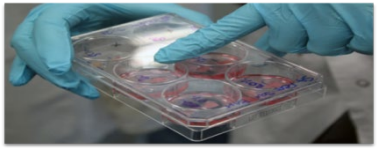
Toxicity of components and the mechanisms (causal)

Risk = hazard x exposure

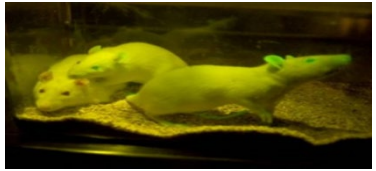




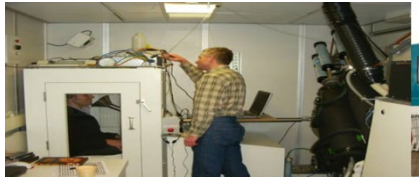
in vitro (cells)



in vivo animals



human volunteers



What are the most toxic parts of PM?

Health effects related to (groups of) chemical and physical properties

World Health Organization – REVIHAAP project

Cassee FR, Héroux ME, Gerlofs-Nijland ME, Kelly FJ., Inhal Tox 2013

WHO concluded:
Almost everything (?) can be harmful

Black carbon

Secondary inorganic aerosols

Redox active components

Particle number

PM2.5

Coarse PM

Surface area

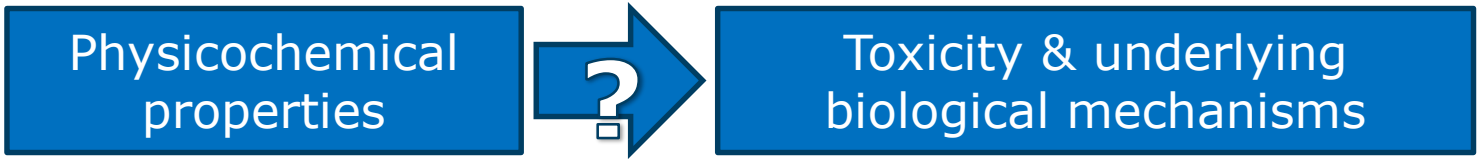
Primary organic aerosols

Transition metals

Ultrafines

Secondary organic aerosols

Understanding toxicity



- Suggested role of non-tailpipe particles in toxicity was based on composition
- Brake wear related elements such as Cu is linked to adverse health effects (Gerlofs-Nijand et al., 2007; Riediker et al., 2007)
- Role of non-tailpipe particles is also shown by in vitro studies (Gasser et al., 2009; Straffelini et al., 2015; Kazimirova et al., 2016)
- PM from brake and tyre wear significant contributors to oxidative potential, sometimes higher than other sources (Yanosky et al., 2012; Shirmohammadi et al., 2016)

Health studies non-tailpipe emissions - TRWP

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Review

Tyre and road wear particles (TRWP) - A review of generation, properties, emissions, human health risk, ecotoxicity, and fate in the environment

Beate Baensch-Baltruschat [a,*], Birgit Kocher [b], Friederike Stock [a], Georg Reifferscheid [a]

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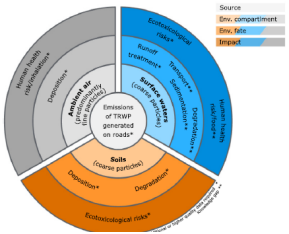
HIGHLIGHTS

- Current knowledge on TRWP is reviewed, environmentally relevant data is compiled.
- Data on annual tyre wear emissions estimated for various countries is reported.
- Entry paths into the environment and environmental fate are discussed.
- Degradation and ecotoxicological studies seldom apply real-world conditions.
- Environmental monitoring of TRWP is still hampered by challenges for analytics.

GRAPHICAL ABSTRACT



- effect on aquatic organisms
  (ecotoxicology no environmental conditions)
- risk for human health via inhalation low
  (no information risk food chain)
- data on degradation is scarce
  (non-realistic materials and conditions)

Exposure, in vitro and in vivo studies - TRWP

- Exposure – road simulator material more reliable data than from effect tests using materials such as particles shaved from tyres or fractured scrap tyres
- In vitro - DNA damage, inflammatory effects (Gualtieri et al., 2005; Karlsson et al., 2008)
- In vitro - Inflammatory responses (Lindbom et al., 2006/2007; Karlsson et al., 2011)
- In vivo (intratracheal) - Pulmonary toxicity (metal related) (Mantecca et al., 2009/2010)
- In vivo (inhalation) - no TRWP-related effects were observed (Kreider et al., 2012; Gerlofs-Nijland, 2019)
- No-Observable-Adverse-Effect-Concentration (NOAEC) 112 µg/m^3 for respirable TRWP. Human equivalent ($NOAEC_{HEC}$) 55 µg/m^3 (Kreider et al., 2012, 2019).

Health studies non-tailpipe emissions – brake wear

Arch Toxicol. 2018 Jul;92(7):2339-2351. doi: 10.1007/s00204-018-2218-8. Epub 2018 May 10.

Biological response of an in vitro human 3D lung cell model exposed to brake wear debris varies based on brake pad formulation

Hana Barosova [1 2], Savvina Chortarea [1 3], Pavlina Peikertova [2], Martin J D Clift [1 4], Alke Petri-Fink [1 5], Jana Kukutschova [2], Barbara Rothen-Rutishauser [6]

Comparative Study Inhal Toxicol. 2019 Feb;31(3):89-98. doi: 10.1080/08958378.2019.1606365. Epub 2019 May 8.

Inhalation toxicity profiles of particulate matter: a comparison between brake wear with other sources of emission

M E Gerlofs-Nijland [1], B G H Bokkers [1], H Sachse [2], J J E Reijnders [3], M Gustafsson [4], A J F Boere [1], P F H Fokkens [1], D L A C Leseman [1], K Augsburg [5], F R Cassee [1]

Ecotoxicol Environ Saf. 2016 Sep;131:37-44. doi: 10.1016/j.ecoenv.2016.05.003. Epub 2016 May 13.

Toxicity and mutagenicity of low-metallic automotive brake pad materials

Katerina Malachova [1], Jana Kukutschova [2], Zuzana Rybkova [3], Hana Sezimova [3], Daniela Placha [4], Kristina Cabanova [4], Peter Filip [5]

Part Fibre Toxicol. 2009 Nov 20;6:30. doi: 10.1186/1743-8977-6-30.

Toxic effects of brake wear particles on epithelial lung cells in vitro

Michael Gasser [1], Michael Riediker, Loretta Mueller, Alain Perrenoud, Fabian Blank, Peter Gehr, Barbara Rothen-Rutishauser

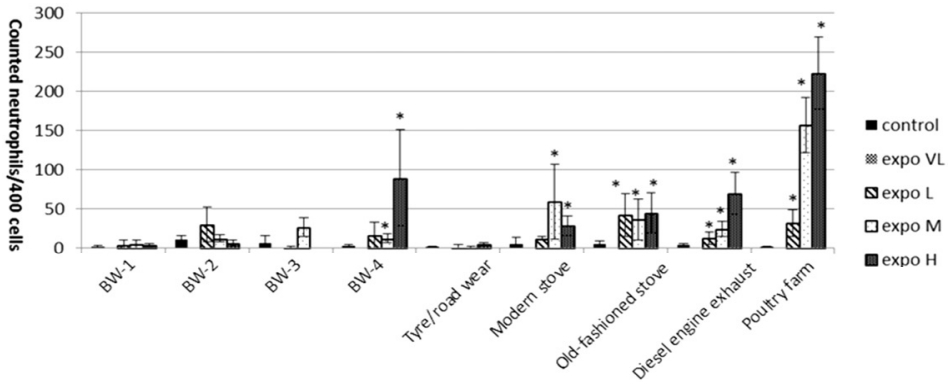
Different source-specific PM2.5 Gerlofs-Nijland et al., 2019

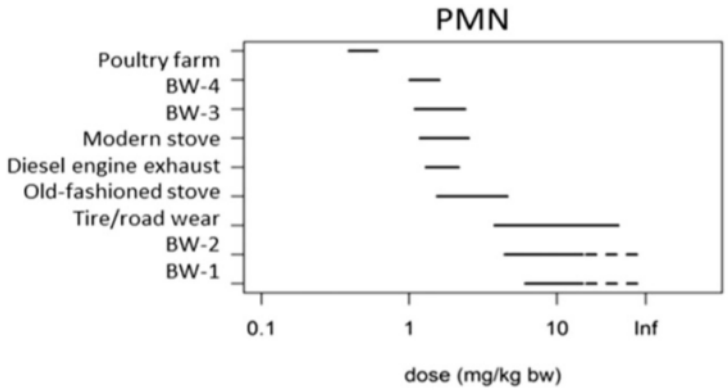
- PM2.5 sampling different sources
- Exposure nose-only inhalation
- Individual doses

Table 1. Sources used to collect PM2.5 and PM2.5 suspension sample code.

PM source	PM2.5 suspension sample code
ECE low-metallic brake pads including copper	BW-1 or brake wear 1
Semi-metallic brake pads without copper	BW-2 or brake wear 2
Non-asbestos organic (NAO) brake pads	BW-3 or brake wear 3
ECE-NAO hybrid brake pads	BW-4 or brake wear 4
Studded winter tires and asphalt concrete pavement	Tire/road wear
Modern wood stove with efficient combustion conditions	Modern stove
Old-fashioned wood stove with efficient combustion conditions	Old-fashioned stove
Diesel engine exhaust from EURO-III engine	Diesel engine exhaust
Poultry farm	Poultry farm

Health effect – hazard identification





- Inflammatory response source-related differences
- Dose-response (farm, diesel combustion)
- BMD approach to assess the differences in potency for each parameter

Gerlofs-Nijland et al., 2019

Risk – exposure * hazard

- Exposure to similar mass concentration of PM from different sources can result in diverse health (severity) of effects
- Important to combine the hazard for different health endpoints with exposure data for a given population to estimate the source-specific risk
- Higher wear rate for pads without copper and higher exposure risk
- Low inhalation dose (0.4 mg/kg) equivalent to exposure 25 $\mu g/m^3$ per day, which is the EU limit value for PM2.5
- Still in order to improve the ranking, it might be worthwhile to determine more accurate the dose–response at lower dose

Research gaps

- Exposure material may not be representative for real life exposure or all regions of the world
- Sensitive or highly exposed population groups are not considered
- Focus on cardiopulmonary effects, other effects cannot be excluded
- Still only a few effect studies and reliable effect data are necessary to assess the risk of non-tailpipe emission for human health

Conclusions

- More effect studies needed, realistic exposures including sensitive groups
- Risk potential for TRWP seems low
- Toxicity of brake wear emissions depends on the composition and especially NAO containing brake pads reveal increased hazard
- Brake wear particles can be at least as hazardous as other PM sources
  - Support for source specific policy to improve public health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Acknowledgement

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Welzijn en Sport

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