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# TYRE WEAR AND SUBSTANCES OF CONCERN

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 Bundesministerium  
Land- und Forstwirtschaft,  
Regionen und Wasserwirtschaft

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Klimaschutz, Umwelt,  
Energie, Mobilität,  
Innovation und Technologie

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# CONTENT

## Tyre wear

- introduction
- composition and quantities
- scientific studies

## Substances of concern in tyre wear

### Focus on antioxidants/antiozonants

- usage and tonnage band
- concerns and toxicity
- fate and distribution
- results

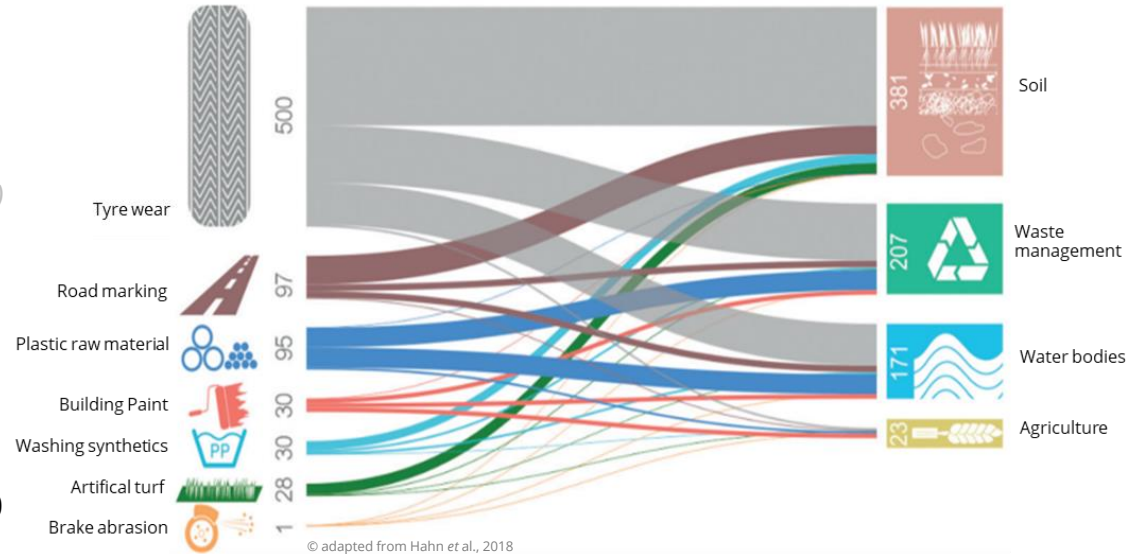
## Conclusion and outlook



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# TYRE WEAR - INTRODUCTION

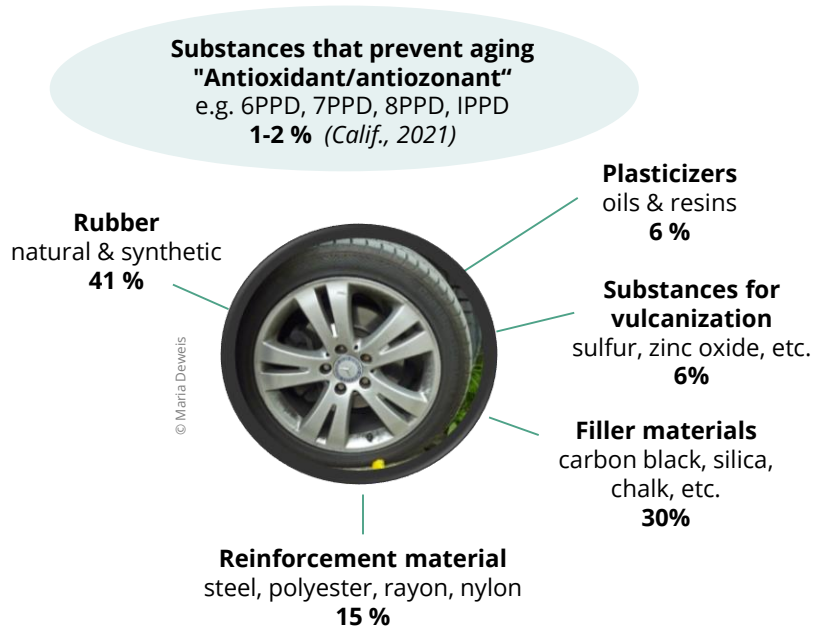
- The **number of vehicles** will almost **double** in the next 30 years: 1.3 billion in 2020 - 2.5 billion in 2050. *(Ceder 2021)*
- **Roads** and **traffic** are cited as a major source of land-based microplastic particle pollution.  
*(Boucher et al., 2020, Sundt et al., 2021, Hahn et al, 2018)*
- **persistency of tyre wear:** half-life 450 days in soil; 5.000 days in sediment.  
*(Lough et al., 2005; Councell et al., 2004)*
- vehicle weight increases tyre wear.



## ENVIRONMENTAL DATA are urgently needed:

- for quantity and impact assessment
- for the development and evaluation of efficient measures

# TYRE WEAR – COMPOSITION AND QUANTITIES



## Emission tyre abrasion into environment

CH: ~ 0,8 kg / yr / person\*  
USA: 4,7 kg / yr / person (*Calif., 2021*)  
AT: ~2,4 kg / yr / person  
21.200 tonnes / year (*Prenner et al., 2021*)  
EU: 500.000 tonnes / year (*ADAC, 2022*)

\* adapted from Thibault Masset (EPFL, eawag)



## Estimates based on models

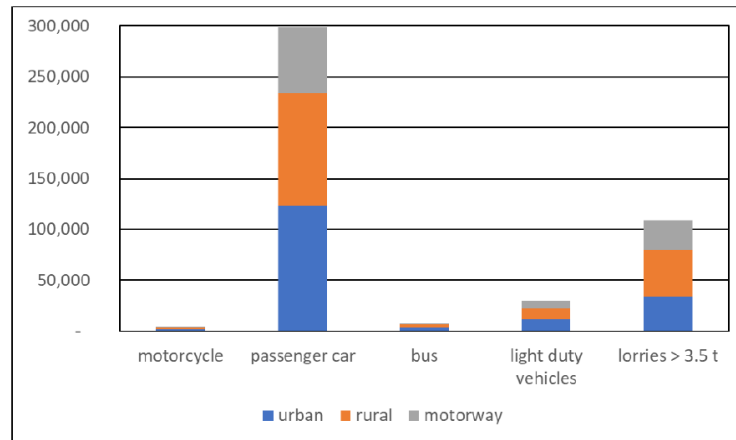
- environmental monitoring needed
- fate? degradation or accumulation?

[Woraus besteht ein Reifen? | Continental Reifen \(continental-reifen.de\)](https://www.continental-reifen.de)

# TYRE WEAR – QUANTITIES

## Microplastics emissions from automotive tyres in the EU

Extrapolation of the tyre wear emission rate with that of mileage (taking into account vehicle and road types) resulted in a total emitted mass in the EU27 of approximately **450,000 t/a (TWP)**



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## The relative contribution of the six sources to microplastics release in the environment in the EU

Source	Potential microplastic release per year in the EU (tonnes)
Tyres	~450,000
Pellets	~118,000 – 183,000
Textiles	~38,624 (36,040)
Paints	~481,900
Geotextiles	~4,800 – 15,800
Detergent Capsules	~18,009 – 20,000

On average, the abrasion of a vehicle for all 4 tires is about 120 g / 1,000 km. Differences in the amount of tyre abrasion between brands: 59 – 171g / 1,000 km (ADAC, 2022)

# TYRE – WEAR - SCIENTIFIC STUDIES

**Salmon have been dying mysteriously on the West Coast for years. Scientists think a chemical in tires may be responsible**

By **Oliver Kahn, CNN**  
Updated 12:11 PM (GMT+01:00) December 1, 2021

**The New York Times**

DOI: [10.1126/science.abd6951](https://doi.org/10.1126/science.abd6951)

**Microplastics detected in cirrhotic liver tissue**

Thomas Horvath,<sup>1\*</sup> Matthias Tamminga,<sup>2\*</sup> Beibei Liu,<sup>3</sup> Marcial Sebode,<sup>4</sup> Antonella Caranbia,<sup>5</sup> Lutz Fischer,<sup>6</sup> Klaus Püschel,<sup>6</sup> Samuel Huber,<sup>6</sup> and Elke Kerstin Fischer<sup>2\*\*</sup>

<sup>1</sup>Department of Medicine, Gastroenterology and Hepatology, University Medical Center Hamburg Eppendorf, Hamburg, Germany  
<sup>2</sup>Center for Earth System Research and Sustainability (CES), University of Hamburg, Hamburg, Germany  
<sup>3</sup>Department of Transplant Surgery, University Medical Center Hamburg Eppendorf, Hamburg, Germany  
<sup>4</sup>Institute of Legal Medicine, University Medical Centre Hamburg Eppendorf, Hamburg, Germany

**Summary**  
**Background** The contamination of ecosystem compartments by microplastics (MPs) is an ubiquitous problem. MPs have been observed in mice tissues, and recently in human blood, stool and placenta. However, two aspects remain unclear: whether MPs accumulate in peripheral organs, specifically in the liver, and if liver cirrhosis favours this process. We aimed to examine human liver tissue samples to determine whether MPs accumulate in the liver.

**Methods** This proof-of-concept case series, conducted in Germany, Europe, analyzed tissue samples of 6 patient<sup>†</sup>

<https://doi.org/10.1016/j.ebiom.2022.104147>

Contents lists available at ScienceDirect  
**Environmental Pollution**  
 journal homepage: [www.elsevier.com/locate/envpol](http://www.elsevier.com/locate/envpol)

**Statistical modelling of the material flows of micro- and nanoplastic particles caused by the use of vehicle tyres<sup>a,b</sup>**

Stefanie Premer<sup>a</sup>, Astrid Allesch<sup>a,c</sup>, Margarethe Staudner<sup>a</sup>, Martin Rexeis<sup>a</sup>, Michael Schwingshackl<sup>a</sup>, Marion Huber-Humer<sup>a</sup>, Florian Part<sup>a</sup>

<sup>a</sup> University of Natural Resources and Life Sciences, Institute of Waste Management, Muthgasse 107, 1190, Vienna, Austria  
<sup>b</sup> Kometall w7 GmbH, Schützenfeldgasse 51/17, 1070, Vienna, Austria  
<sup>c</sup> Graz University of Technology, Institute of Internal Combustion Engines and Thermodynamics, Inffeldgasse 19-10, 8010, Graz, Austria

<https://doi.org/10.1016/j.envpol.2021>

**ENVIRONMENTAL Science & Technology**

pubs.acs.org/est

**Uptake, Metabolism, and Accumulation of Tire Wear Particle-Derived Compounds in Lettuce**

Stephanie Castan,<sup>1</sup> Anya Sherman,<sup>2</sup> Ruoting Peng, Michael T. Zumstein, Wolfgang Wanek, Thorsten Hüfner, and Thilo Hofmann<sup>1\*</sup>

**Cite This:** <https://doi.org/10.1021/acs.est.2c05660> **Read Online**

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**ABSTRACT:** Tire wear particle (TWP)-derived compounds may be of high concern to consumers when released in the root zone of edible plants. We exposed lettuce plants to the TWP-derived compounds diphenylguanidine (DPG), hexamethoxy-methylmelamine (HMMA), benzothiazole (BTZ), N-phenyl-N'-[1-(2-dimethylbutyl)-p-phenylenediamine (6PPD)], and its quinone transformation product (6PPD-q) at concentrations of 1 mg L<sup>-1</sup> in hydroponic solutions over 14 days to analyze if they are taken up and metabolized by the plants. Assuming that TWP may be a long-term source of TWP-derived compounds to plants, we further investigated the effect of leaching from TWP on the concentration of leachate compounds in lettuce leaves by adding constantly leaching TWP to the hydroponic solutions. Concentrations in

<https://doi.org/10.1021/acs.est.2c05660>

**Health impact of tyre particles causing 'increasing concern', say scientists**

Far more tiny particles now come from tyres than are emitted from exhausts but new tyre designs may help

More than half of all the small particle pollution from road transport came from tyre and brake wear in 2021, a UK government report estimates. Photograph: Roman Makedonsky/Alamy

Scientists are "increasingly concerned" by the health impact of air pollution produced by the wear of vehicle tyres. The particles are especially damaging due to the toxic chemicals they are made from, say the scientists from Imperial College London.

Health impact of tyre particles causing 'increasing concern', say scientists | Air pollution | The Guardian (23. 02. 2023)

## TYRE WEAR – ADDITIVES

- Tyres: up to **200 additives** added (Baumann et al., 1998)
- **> 4.000 individual signals** detected in road runoff from a multi-lane highway, one hundred detected in the tissues of adult coho salmon (Du et al., 2017)
- Large number of 6PPD transformation products detected (Seiwert et al., 2021)
- Substances "leached" from tyre abrasion pose a threat to receiving water bodies, some examples.
  - Diphenylguanidin (DPG)
  - Hexamethoxymethylmelamine (HMMM) and 30 transformation products (Alhelou et al., 2019; Winer et al., 2022)
  - Benzothiazol (BTZ) → in µg/L in river water (Seiwert et al., 2020)
  - para-substituted phenyldiamines (PPDs) and their quinones

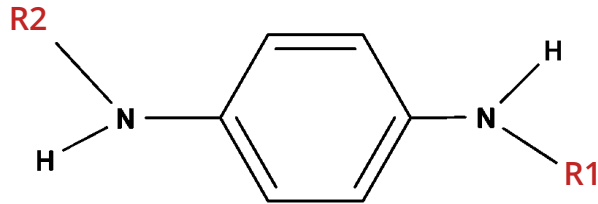
**“What goes in is not what comes out”**

(Broekhuizen et al., 2022)

# PPDs

Addition of PPDs to protect rubber from O<sub>2</sub>/O<sub>3</sub>

**PPDs = para-substituted phenylenediamine**

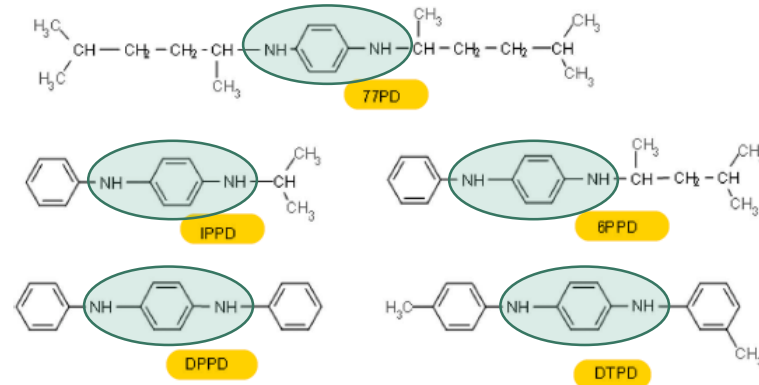


- Typ 1: R1 = alkyl-, R2= alkyl- **77PD**
- Typ 2: R1 = alkyl-, R2= aryl- **IPPD, 6PPD, 7PPD, 8PPD**
- Typ 3: R1 = aryl-, R2= aryl- **DPPD, DTPD**



© Cataldo et al., 2019

**ozone - cracks**  
*Induced by  
mechanical stress*





## PPDs

- Prevention of aging: **antioxidant, antiozonant**
- in EU registered → e.g. IPPD, 6PPD, 7PPD, 77PD (not 8PPD)
- Tonnage band: 1 – 100.000 t / year in EU  
highest tonnage in EU: **6PPD** (10.000 – 100.000 t / yr)
- **6PPD no harmonised classification**,  
but self-classification:  
Acute Tox 4, H302; Skin Sens 1, H317; **Repr 1B**, H360;  
**Aquatic Acute 1**, H400; **Aquatic Chronic 1**, H410
- **dossier** on **6PPD** submitted from Austria →  
**harmonised classification & labelling (CLH)**  
[Registry of CLH intentions until outcome - ECHA \(europa.eu\)](#)



© Cataldo et al., 2019

Salmon have been dying mysteriously on the West Coast for years. Scientists think a chemical in tires may be responsible

The New York Times

By Drew Kates, CNN  
© 1999-2020 CNN (2020) (NYT) (December 3, 2020)



How Scientists Tracked Down a Mass Killer (of Salmon)

Something was decimating the salmon that had been restored to creeks around Puget Sound.

Science

EMBARGOED UNTIL 2:00PM US ET, THURSDAY 3 DECEMBER 2020

REPORTS

Cite as: Z. Tian et al., Science 10.1126/science.aba0951 (2020).

A ubiquitous tire rubber-derived chemical induces acute mortality in coho salmon

transformation product:  
6PPD-Quinone, mortality (< 5 hrs)  
in juvenile silver salmon

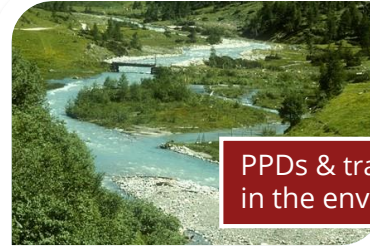
# CONCERNS

© FWW: Lunge



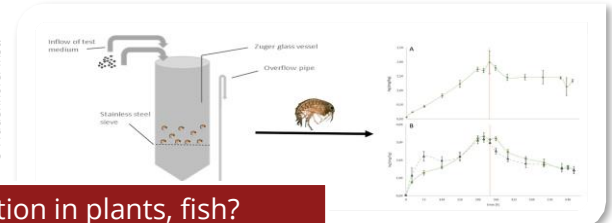
tyre wear in lungs?

© Kurt Farasin



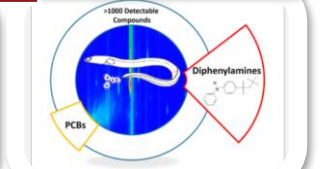
PPDs & transformation products  
in the environment

© Frauenhofer Inst.



Bioaccumulation in plants, fish?

© Hornik-Gausterer



© Sühring et al., 2016

# PPDs - PROPERTIES AND OCCURENCE





## 6PPD

Proposed harmonised classification by the dossier submitter

[Registry of CLH intentions until outcome - ECHA \(europa.eu\)](#)

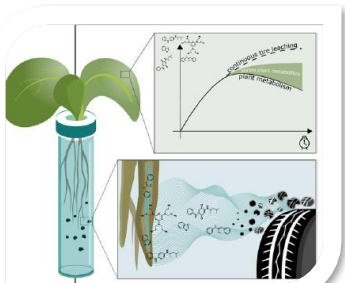
- Acute Tox. 4, H302
- Skin Sens. 1A, H317
- Repr. 1B, H360FD
- Aquatic Acute 1, H400
- Aquatic Acute 1, M-factor=10 000
- Aquatic Chronic 1, H410
- Aquatic Chronic 1, M-factor=10

## Exploration of emerging environmental pollutants 6PPD and 6PPDQ in honey and fish samples

Jiawen Ji<sup>a</sup>, Changsheng Li<sup>b</sup>, Bingjie Zhang<sup>a</sup>, Wenjuan Wu<sup>a</sup>, Jianli Wang<sup>a</sup>, Jianhui Zhu<sup>a</sup>, Desheng Liu<sup>a</sup>, Rumin Gao<sup>a</sup>, Yongqiang Ma<sup>a</sup>  , Sen Pang<sup>a</sup>  , Xuefeng Li<sup>a</sup>

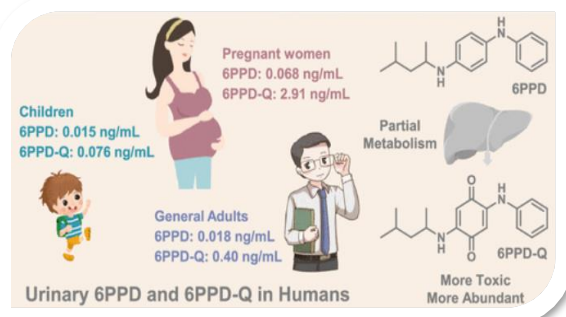
<https://doi.org/10.1016/j.foodchem.2022.133640>

## 6PPD-Quinone accumulation in roots (carrots)?



© Castan et al., 2022

## 6PPD und 6PPD-Quinone in urin

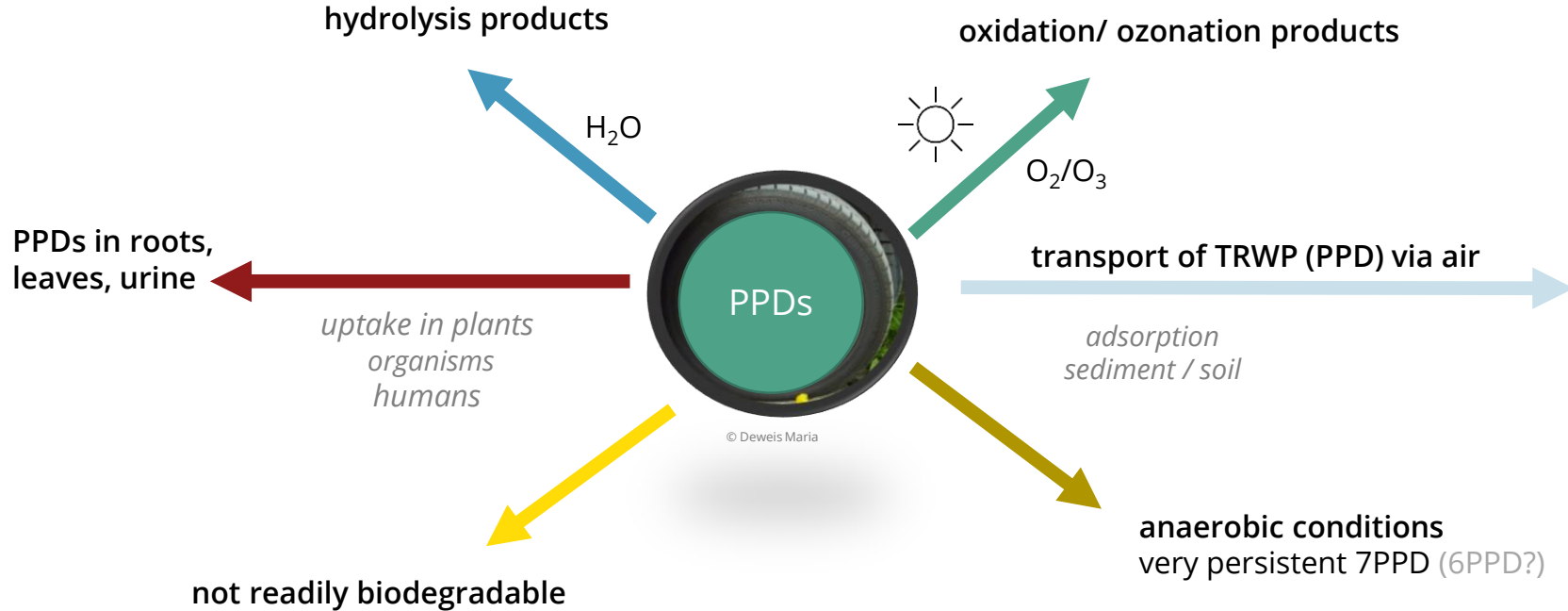


© Du et al., 2022

## Screening p-Phenylenediamine Antioxidants, Their Transformation Products, and Industrial Chemical Additives in **Crumb Rubber** and **Elastomeric Consumer Products**

DOI: [10.1021/acs.est.2c07014](https://doi.org/10.1021/acs.est.2c07014)

# PPDs – FATE, DISTRIBUTION



# 6PPD-QUINONE - TOXICITY

- **Coho salmon**

- rapid mortality (< 5 hours)
- parent compound less toxic than transformation product
- irreversible
- exact mode of action unknown

- **Brook trout**

- **Rainbow trout**

**24h-LC<sub>50</sub> 6PPD-Quinone:**  
**0,095 µg/L** (Tian et al., 2022)

LC lethal concentration

**24h-LC<sub>50</sub> 6PPD-Quinone:**  
**0,59 µg/L** (Brinkmann et al., 2022)

**72h-LC<sub>50</sub> 6PPD-Quinone:**  
**1 µg/L** (Brinkmann et al., 2022)



@Tian et al., 2020

## PPDs - RESULTS

No. of samples		IPPD		6PPD		6PPD-Quinone	
		[µg/L]	DF	[µg/L]	DF	[µg/L]	DF
	<b>Aqueous samples:</b>						
12	surface water	n.d.	0/12	n.d.	0/12	n.d.	0/12
3	road run-off	n.n. - 0,11	1/3	1,0 - 1,7	3/3	0,76 - 1,3	3/3
8	waste water (influent)	n.d.	0/8	n.d. - < 0.64	1/8	n.d. - 0.20	4/8
	<b>Solid samples:</b>						
		[µg/kg]		[µg/kg]		[µg/kg]	
10	biota (fish)	n.d.	0/10	n.d. - < 0,19	1/10	n.d.	0/10

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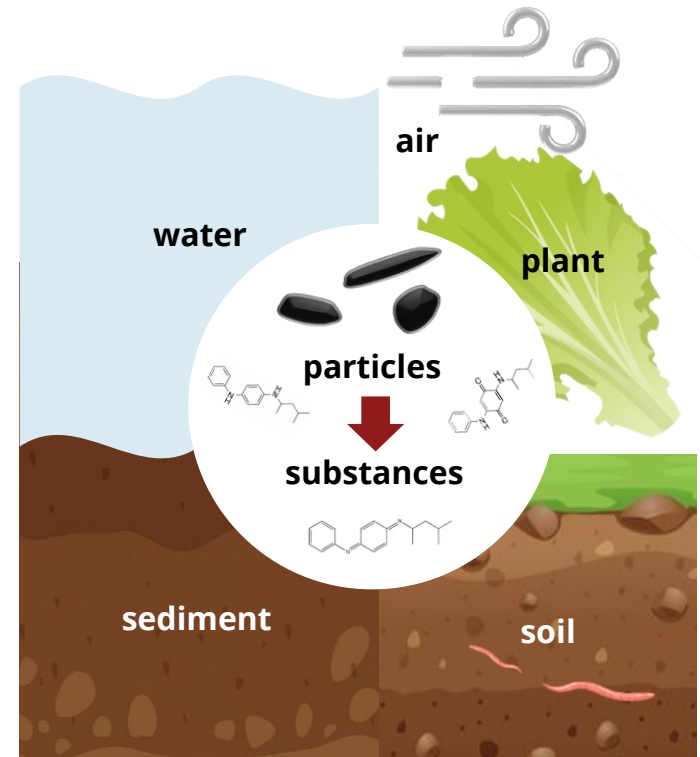
**Silver salmon**  
**LC<sub>50</sub> 6PPD-Quinone:**  
**0,095 µg/L**

**Brook trout**  
**LC<sub>50</sub> 6PPD-Quinone:**  
**0,59 µg/L**

DF Detection frequency  
n.d. not detected  
LC Lethal concentration

## CONCLUSION AND OUTLOOK

- Are there more environmental relevant substances?
- **Environmental monitoring** is **needed**, to answer the question, which substances / products are of concern and which conditions lead to peak concentrations.  
*"what is in, is not what we find in the environment"*
- **cross-media understanding** of occurrence, transport/fate and behaviour in the environment (particles ↔ substances of concern).
- investigation of **effects on organisms** and **the food chain** (vegetables)
- measures necessary to reduce exposure (substances in tyres, tyre abrasion, treatment of run-off,...)
- pilot-project on tyre wear and substances of concern conducted, development of a **comprehensive project** ongoing
- IG plastics, important platform to work together on solutions



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© brgfx / Freepik

## FURTHER INFORMATION

Ceder et al., 2021: Urban mobility and public transport: future perspectives and review

<https://doi.org/10.1080/12265934.2020.1799846>

Tian et al., 2022: A ubiquitous tire rubber-derived chemical induces acute mortality in coho salmon

DOI: [10.1126/science.abo5785](https://doi.org/10.1126/science.abo5785)

Brinkmann et al., 2022: Acute Toxicity of the Tire Rubber-Derived Chemical 6PPD-quinone to Four Fishes of Commercial, Cultural, and Ecological Importance

<https://doi.org/10.1021/acs.estlett.2c00050>

Ji et al., 2022: Exploration of emerging environmental pollutants 6PPD and 6PPDQ in honey and fish samples

<https://doi.org/10.1016/j.foodchem.2022.133640>



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