



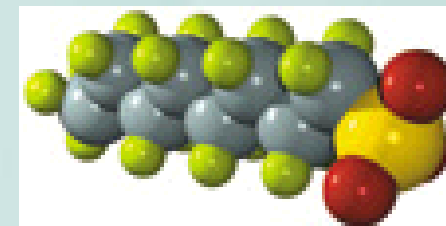
# PFAS contaminated sites – a personal journey and some lessons learned

**Dr. Roland Weber**

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<https://www.researchgate.net/profile/Roland-Weber-2>

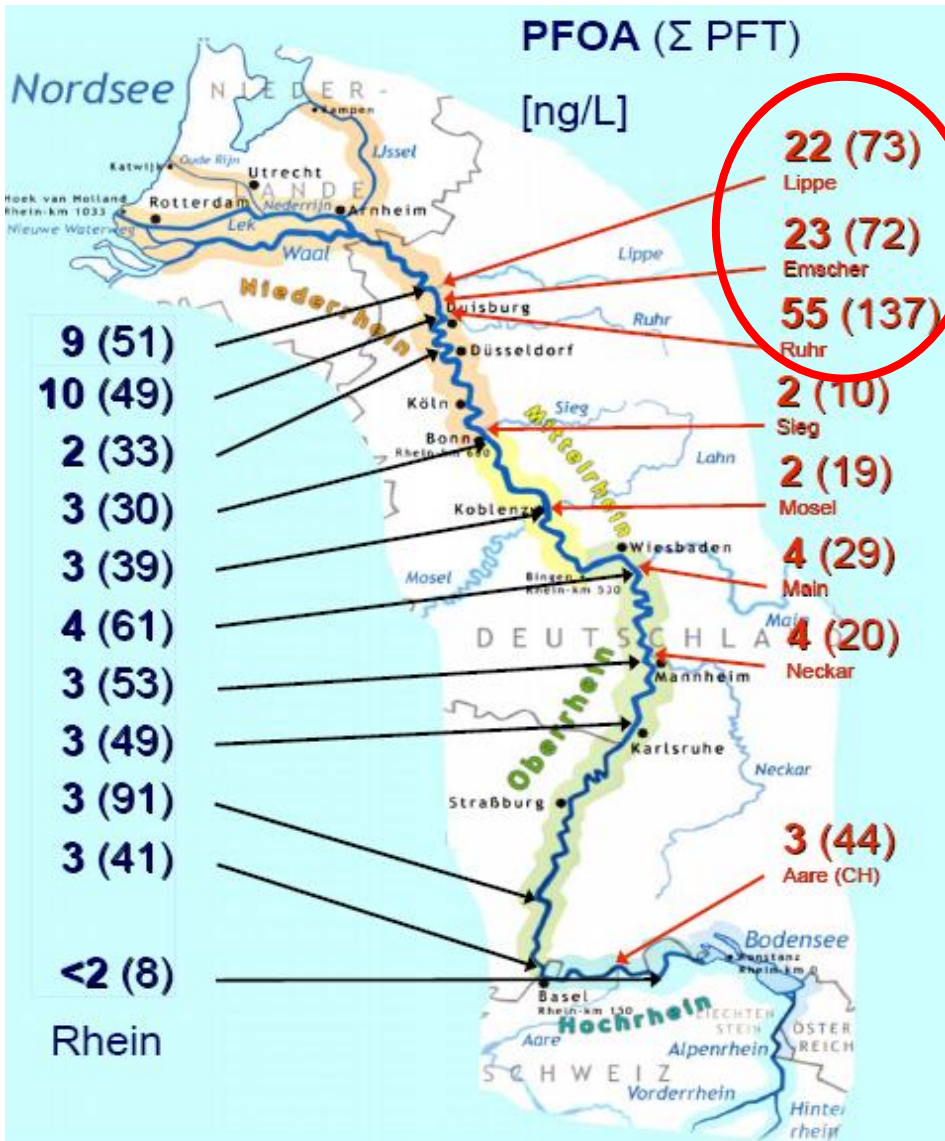
<https://scholar.google.com/citations?user=-Cexto4AAAAJ&hl=en>



# Content of Presentation

- Some lessons learnt from a PFAS pollution of drinking water from spread of industrial sludge from Belgium on German agricultural sites in North Rhine-Westphalia.
- Some experience on remediation cost.
- PFAS contamination from a PFAS production site and landfills as reservoirs for PFAS.
- Global perspective: PFAS drinking water contamination of hundreds of million citizens - PFAS pollution crossed Planetary Boundaries.
- Liabilities for PFAS contamination – some current activities in the United States.
- Solutions 1: Addressing PFAS within international Conventions and other intern. frames
- Solutions 2: Science Statements and European approach to regulate PFAS as a group and only for essential use.

# Rhine River screening (2006) revealing PFOA/PFAS pollution in Ruhr River and other rivers in North Rhine Westphalia



- Screening of PFAS in the Rhine River and tributaries (2006).
- High per-/polyfluorinated alkylated substance (PFAS) contamination in Rhine tributary rivers Ruhr, Emscher and Lippe above 70 ng/l of PFAS including >20 ng PFOA.

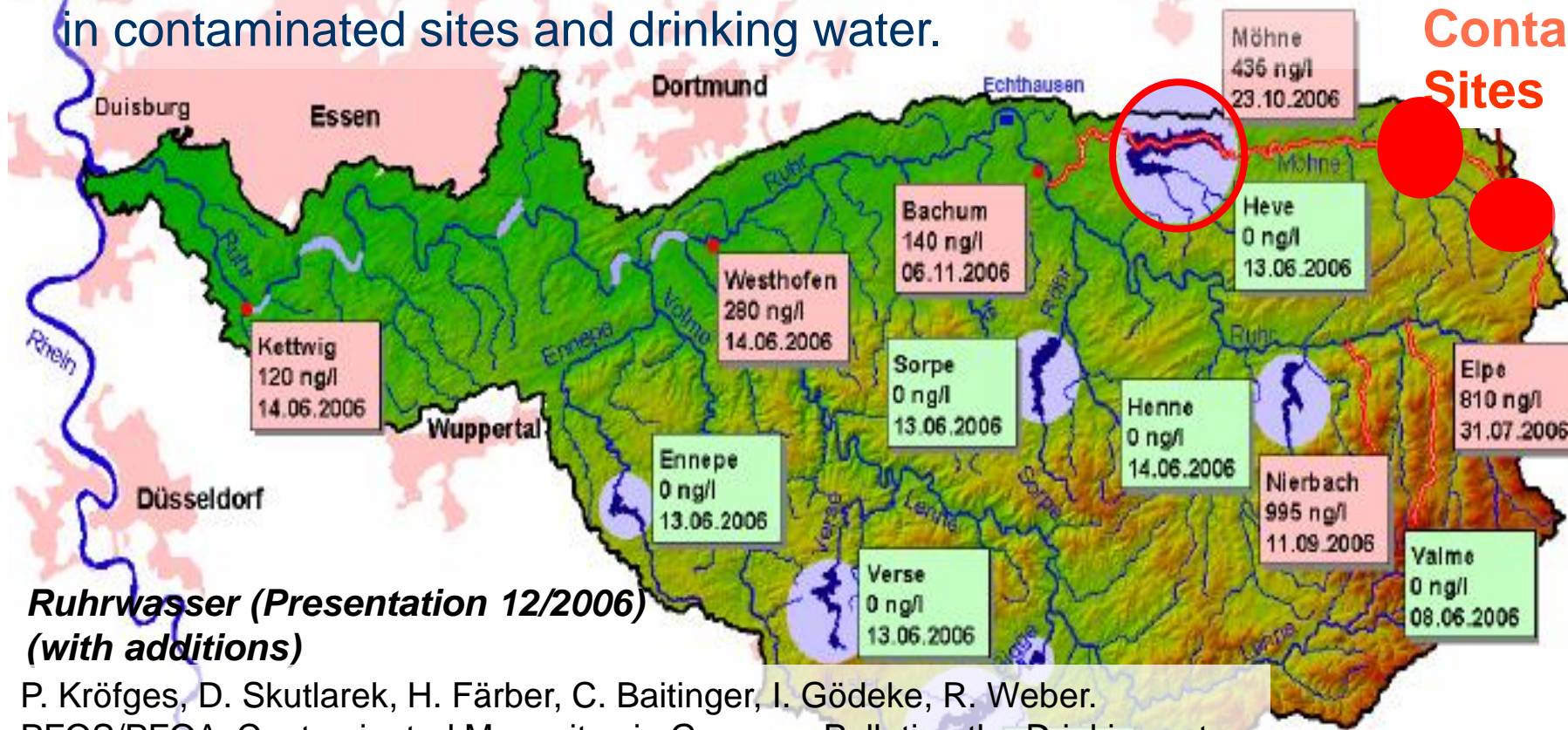
Skutlarek, Färber, Exner,  
University Bonn, March 2006)



# PFOA/PFAS pollution in Ruhr river & tributaries (2006)

## impacting drinking water of millions of people

- High contamination in the Ruhr river and the tributary Möhne river impacting drinking water of million.
- The Möhnetal reservoir contained approx. 110 kg of PFAS including 88 kg PFOA.
- Main Source: The mismanagement of industrial sludge imported from Belgium to Germany by a small German waste management company. Given to farmers and distributed on agricultural land resulting in contaminated sites and drinking water.



The major contaminated field (10 hectares) contained about 390 kg  $\Sigma$ PFOA+PFOS.



*Ruhrwasser (Presentation 12/2006)  
(with additions)*

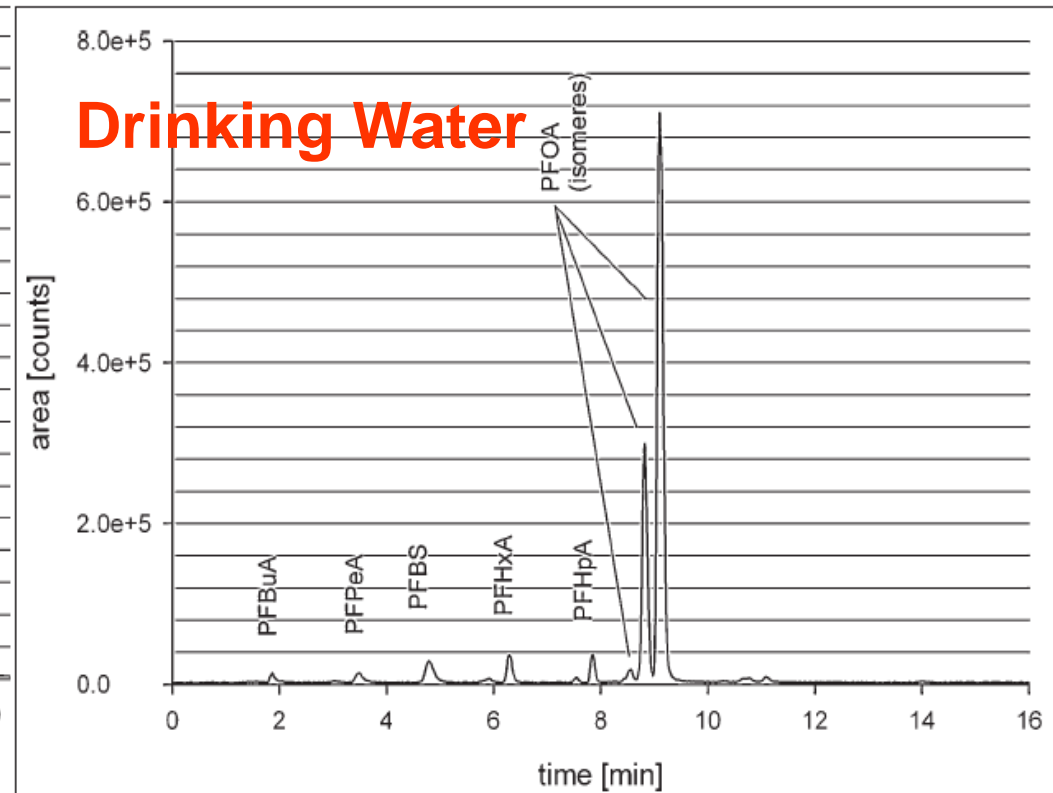
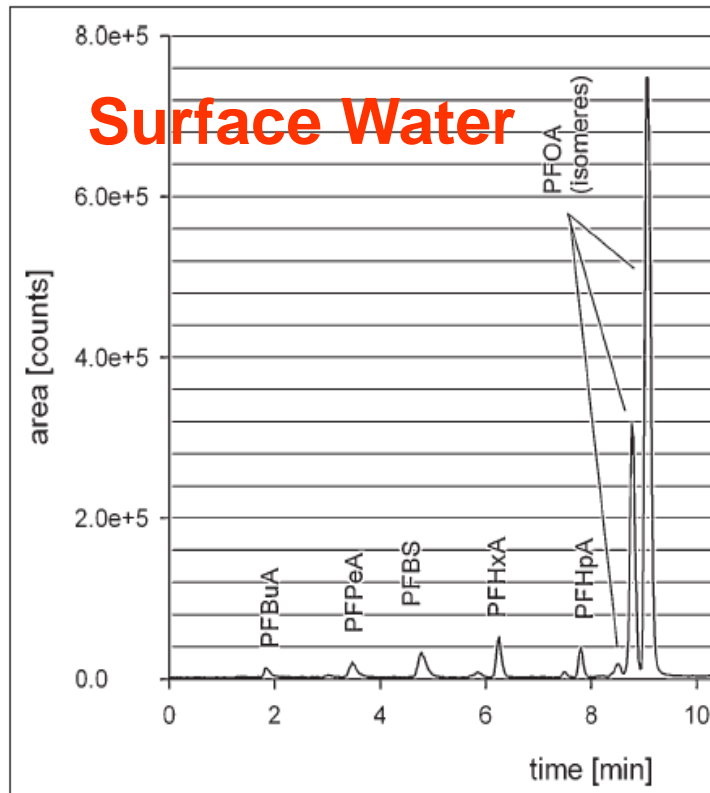
P. Kröfges, D. Skutlarek, H. Färber, C. Baitinger, I. Gödeke, R. Weber.  
PFOS/PFOA Contaminated Megasites in Germany Polluting the Drinkingwater  
Supply of Millions of People. Organohalogen Compd. 69, 877-880 (2007).

<https://dioxin20xx.org/wp-content/uploads/pdfs/2007/07-634.pdf>

# PFOA/PFAS pollution in Ruhr & tributaries (2006)

## impacting drinking water of millions of people

- Discovery: Large challenges to manage PFAS contamination in drinking water. **Most German water works did not eliminate PFAS in 2006.**
- The drinking water treatment in several water works needed a better filtration (e.g. large activated carbon or raisin filters) to reduce exposure ( $\Sigma$ **cost** approx. **100 million EURO**).
- **Lesson learned:** Upgrade of water works were needed for PFAS elimination. Large costs to filter drinking water for PFAS and the upgrade of water works can take years.



- Similar contamination
- DW up to 700 ng/l PFOA
- Several large cities (Dortmund, Essen) above 100 ng/l and temporarily above 300 ng/l

# Preliminary Recommendation of German Drinking Water Commission (2006)

Type of Limits	PFOS+PFOA	Reasoning
Target value (minimum quality)	$\leq 100$ ng/l	Health precaution (Life span)
Health guiding value	$\leq 300$ ng/l	Acceptable value (Life span)
Precautionary action value infants	500 ng/l	Precautionary protection infants
Action value adults	5000 ng/l	Recom: Not use for nutrition purpose

*Stellungnahme Trinkwasserkommission BMG (beim UBA) 21.06.06; revised 13.07.06*

**US EPA (2016):** DW health advisory PFOS+PFOA 70 ng/l. updated 2022: 0.004 ng/L PFOA;  
**Denmark drinking water limit (2021)** 2 ng/L  $\Sigma$ PFOS, PFOA, PFHxS, PFNA based on EU Food  
 Safety Authority (EFSA) Tolerable Weekly Intake (TWI) of 4.4 ng/kg  $\Sigma$ 4 PFAS per week.

**Lesson learned:** TDI/TWI and drinking water limits needed to be lowered over time  
 as more sensitive endpoints for toxic effects are discovered and documented.



# Suggested drinking water limit if considering EFSA TWI and WHO approach for guideline value

- The WHO has a methodology to derive drinking water guideline values (DWGV) based on tolerable daily intake, water consumption and weight.
- Taking the tolerable weekly intake of the EFSA (4.4 ng/kg  $\Sigma$ 4 PFAS) and the WHO DW approach, **a DWGV for the sum of PFOS, PFOA, PFHxS and PFNA of 3.8 ng/L for adults and 1.2 ng/L for children can be derived (with 20% allocation factor for water)**

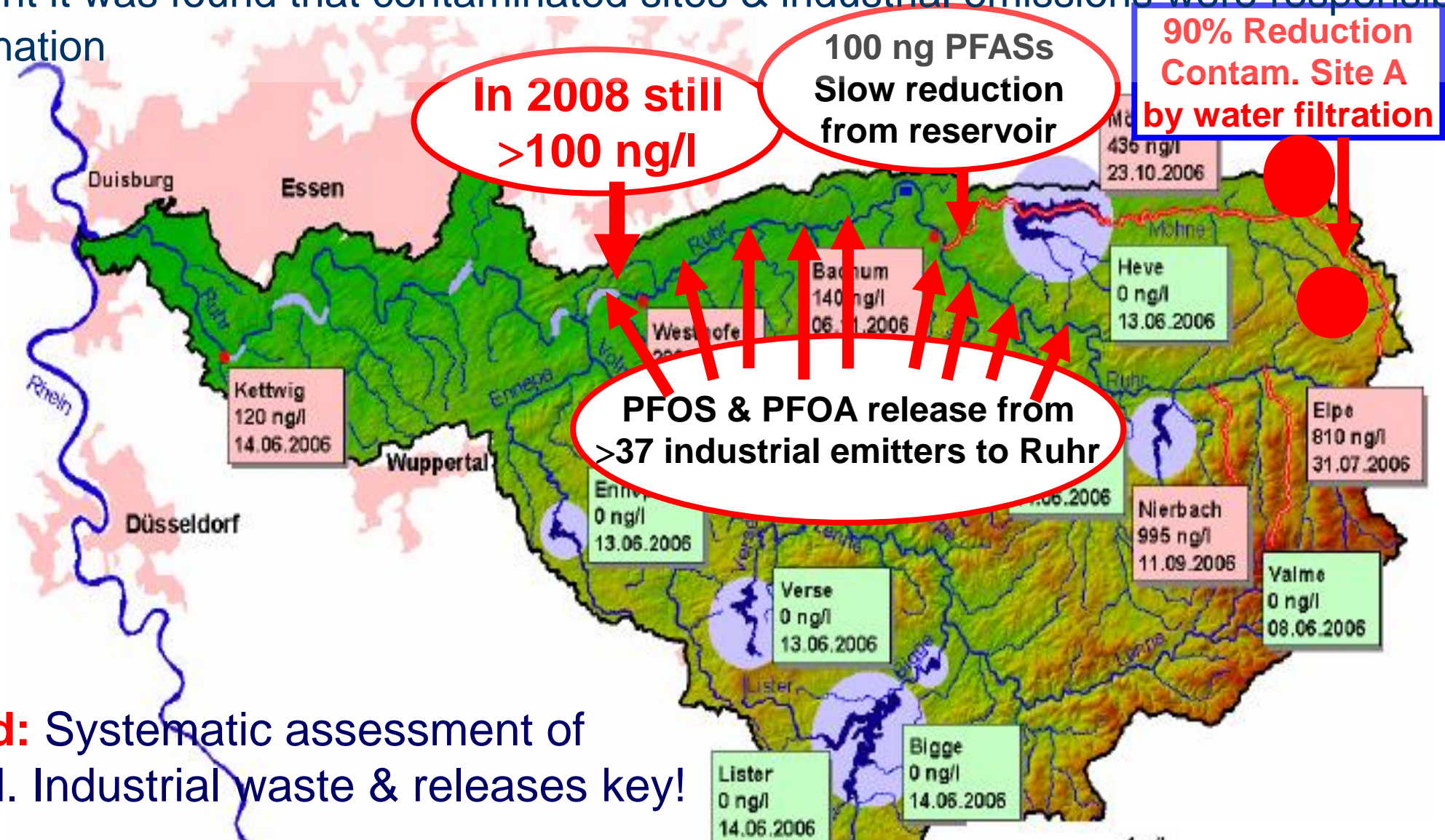
	Adult	Child
Consumption of water per day (C)	2 litres	1 litre
Body weight (bw)	60 kg	10 kg
TWI for the sum of PFOA, PFNA, PFHxS, and PFOS	4.4 ng kg <sup>-1</sup> bw week <sup>-1</sup>	
TDI for the sum of PFOA, PFNA, PFHxS, and PFOS	0.63 ng kg <sup>-1</sup> bw day <sup>-1</sup>	
Calculated guideline value (GV) for the 4 EFSA (2020) PFAS in drinking-water	19 ng l <sup>-1</sup>	6.3 ng l <sup>-1</sup>
<b>Guideline value considering a source allocation factor (P) of 20% for drinking-water</b>	<b>3.8 ng l<sup>-1</sup></b>	<b>1.2 ng l<sup>-1</sup></b>

**Denmark DW limit 2 ng/L  
( $\Sigma$ PFOS, PFOA, PFHxS and PFNA)**

# PFAS pollution in Ruhr river & tributaries (2008)

## impacting drinking water of millions of people

- After assessment it was found that contaminated sites & industrial emissions were responsible for the contamination

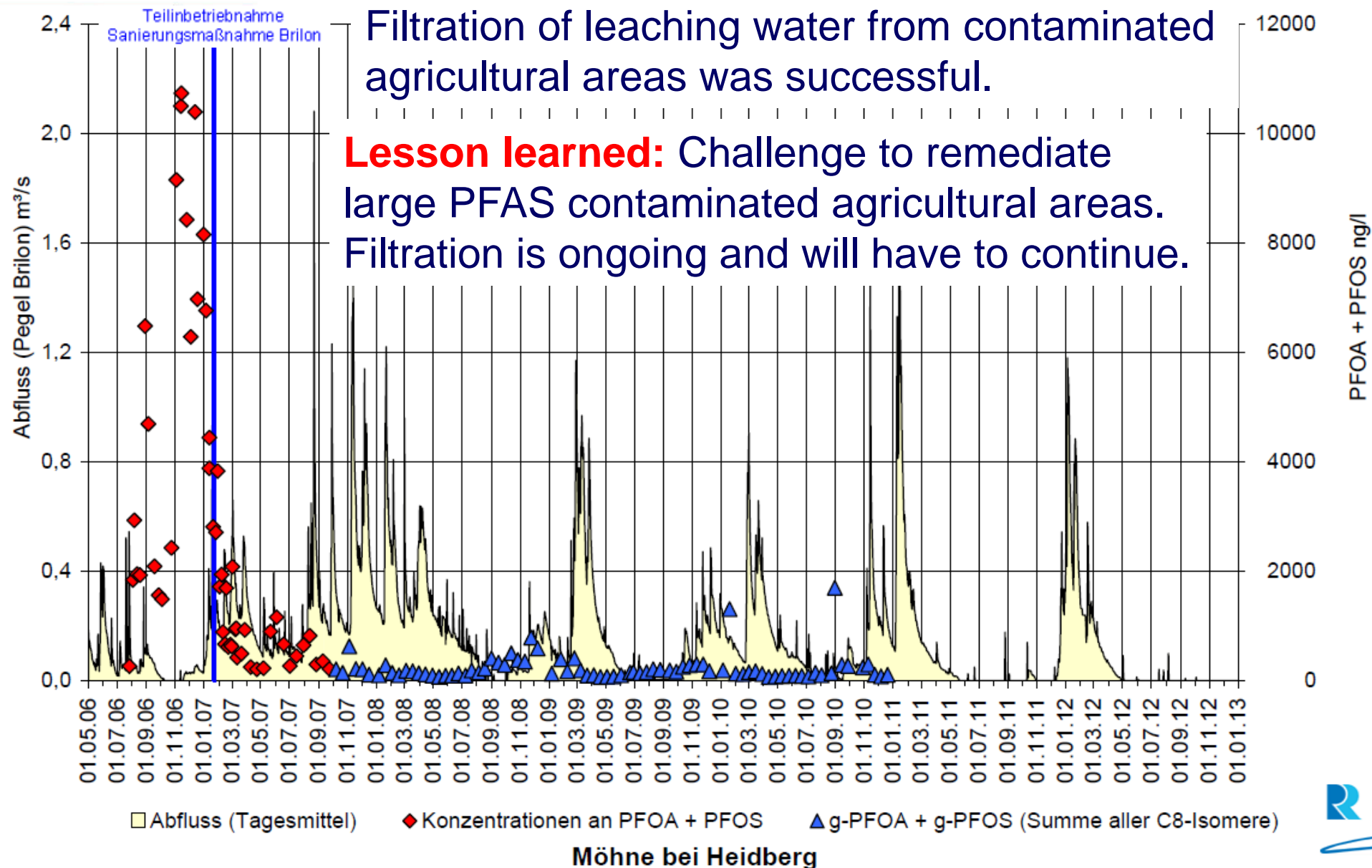


**Lesson learned:** Systematic assessment of sources needed. Industrial waste & releases key!

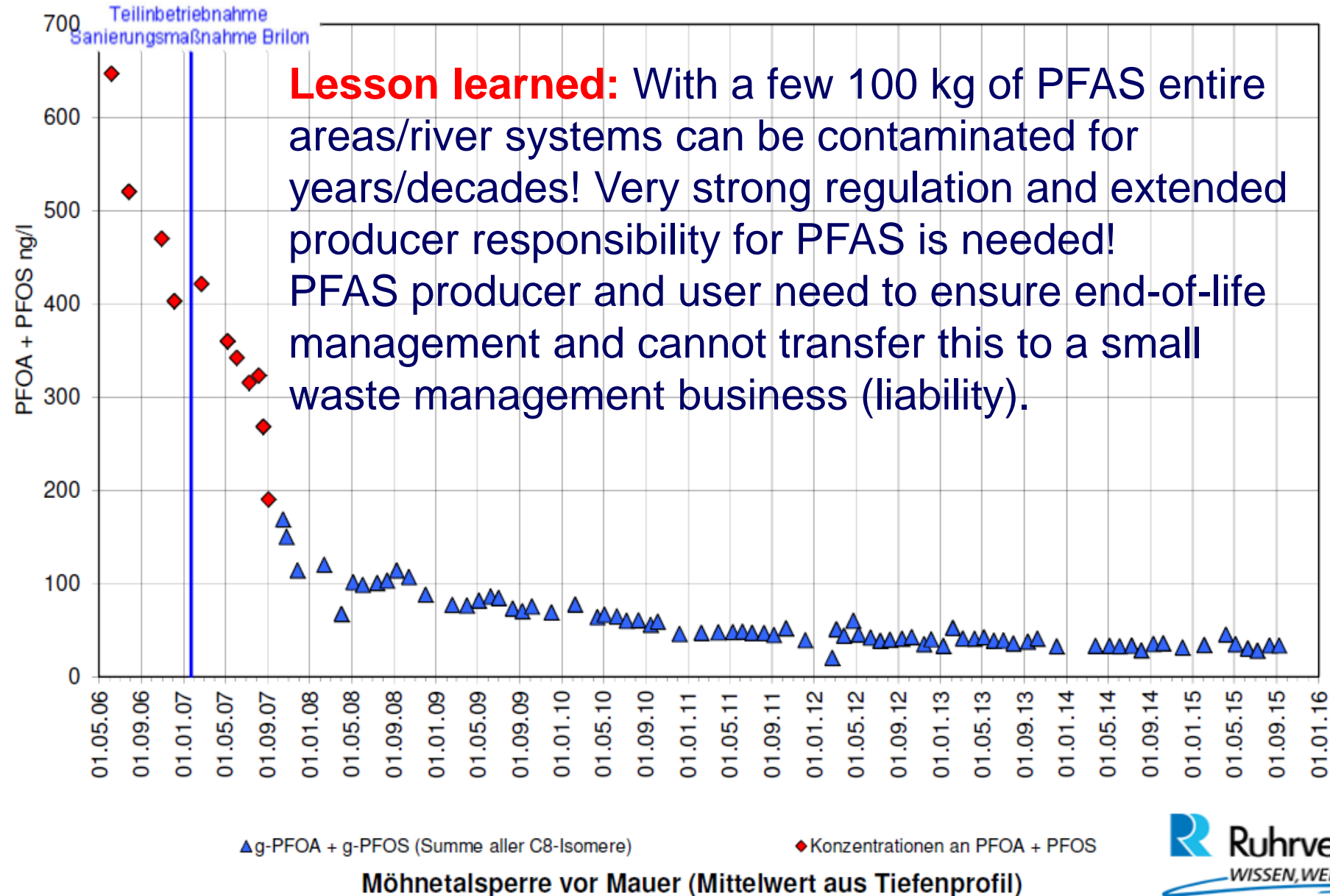


# PFAS pollution in Ruhr & tributaries (2008)

## impacting drinking water of millions of people



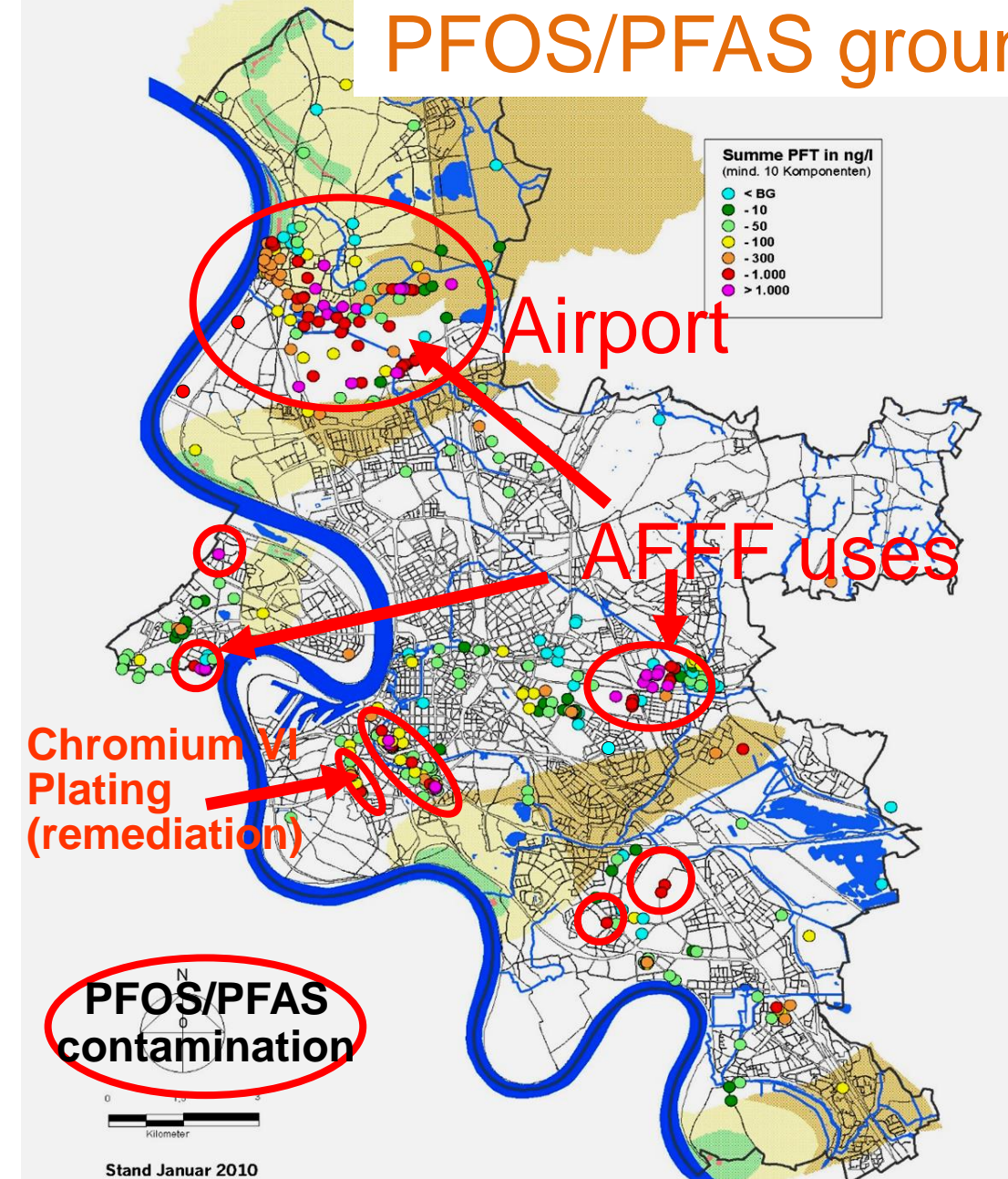
# PFAS pollution in Ruhr river & tributaries impacting the drinking water of millions of people



The PFOA+PFOS levels in the Möhne reservoir decreased over the years but after 10 years level was still far above the drinking water limit of Denmark (2 ng/L for  $\sum 4$  PFAS).

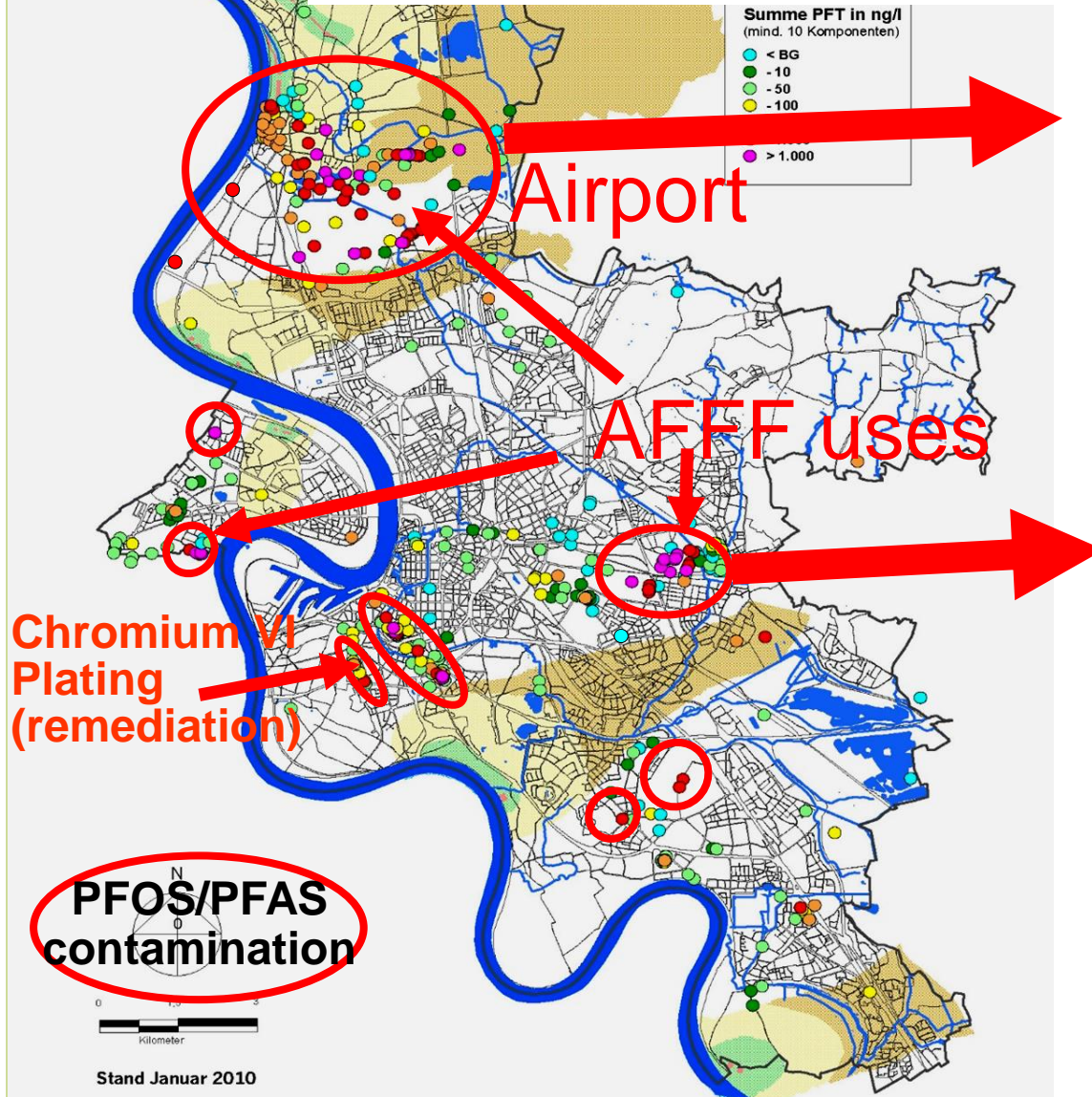
# PFOS/PFAS groundwater screening in Düsseldorf city

- Ruhr/Möhne pollution triggered assesement of PFAS pollution in the federal state of NRW.
- Düsseldorf made a program of PFAS ground water and contaminated site screening.
- PFOS/PFAS contamination was detected @:
  - Sites of major fires and use of aqueous film forming foam (AFFF)
  - Fire fighting practice areas
  - Airport (AFFF)
  - Chromium plating factories





# Further PFOS/PFAS contaminated site assessment in area: Groundwater screening in Düsseldorf city



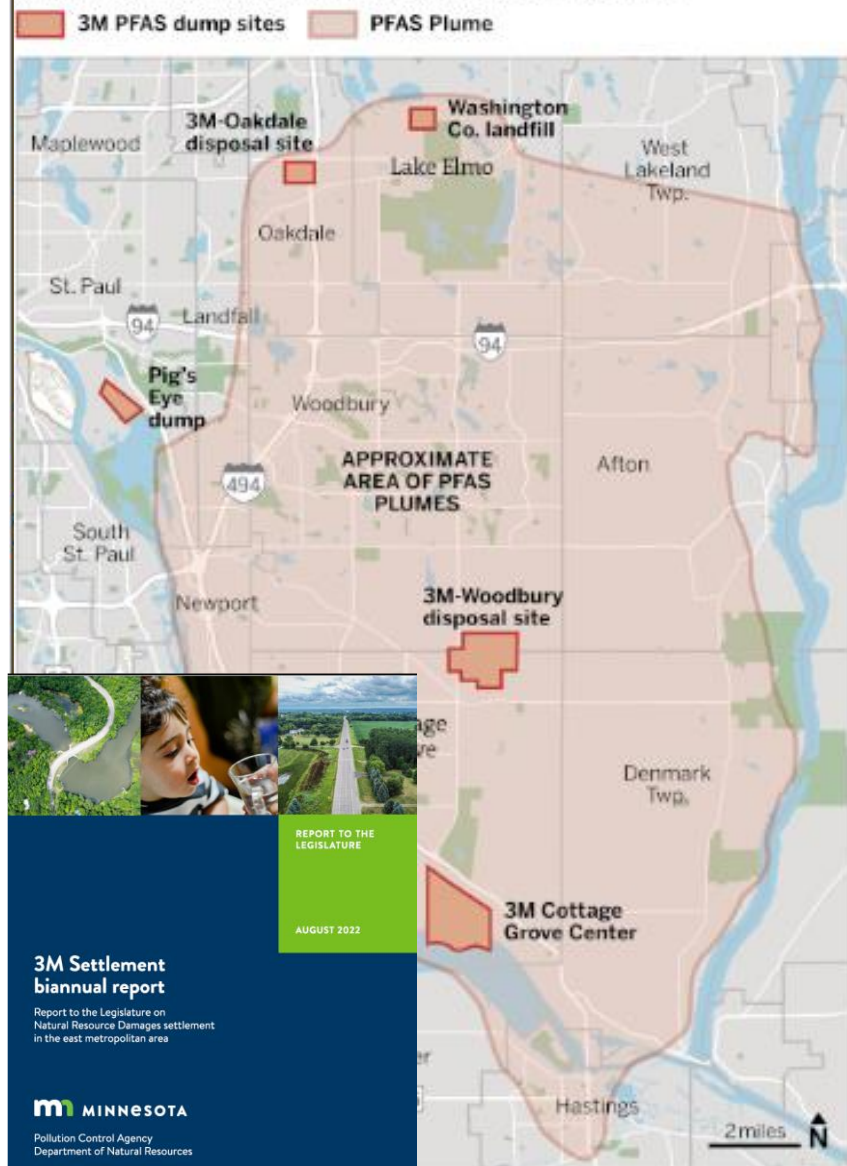
- Cost of three wells controlling the point sources were **2 million €**.
- **Total remediation cost for the airport:** might reach **100 million €** (Funke Medien 2013).  
<https://www.nrz.de/staedte/duesseldorf/pft-bringt-flughafen-duesseldorf-in-turbulenzen-id8466138.html>
- **Remediation cost of AFFF (42 m<sup>3</sup>) use for a fire were:**
  - **1 million €** assessment.
  - **>10 million €** remediation.
- Cost estimate for remediation of a large PFAS contaminated farmland (>1000 ha) in South Germany from paper mill sludge is estimated to **1-3 billion €**. (FAZ 2016) <http://www.faz.net/aktuell/wissen/baden-wuerttemberg-chemische-abfaelle-auf-dem-acker-14419295.html>

**Lesson learned:** Remediation of PFAS from groundwater/soil is challenging and expensive. No natural degradation of perfluorinated PFAS in soil or groundwater („forever chemicals“).

# PFAS contamination by 3M in Twin Cities (Minnesota)

## PFAS plume area in East Metro

Recent state tests found a large plume of contaminated groundwater beneath several East Metro suburbs, where 3M disposed of waste contaminated with PFAS decades ago. Within the outlined area, contamination levels vary greatly; spots where PFAS concentration levels exceed state health standards are much smaller.



11TH FORUM OF THE INTERNATIONAL HCH AND PESTICIDE ASSOCIATION

<https://doi.org/10.1007/s11356-012-1275-4>

## PFOS and PFC releases and associated pollution from a PFC production plant in Minnesota (USA)

Oliaei et al (2013) Environ Sci Pollut Res Int. 20, 1977-1992

Fardin Oliaei • Don Kriens • Roland Weber • Alan Watson

### Lesson learned:

- PFAS production sites can have large PFAS contamination footprint (10s to 100ds km<sup>2</sup>) polluting drinking water of thousands of people.
- Landfills from production sites can be large reservoirs for PFAS with long term release potential and might need excavation (modelling of long term fate of PFAS reservoirs of landfills is needed).
- Liability of PFAS producers and users for the cost for environmental & drinking water pollution and for human contamination needed.
- ***“Minnesota state settled its lawsuit against the 3M Company in return for a settlement of \$850 million. Minnesota’s attorney general sued 3M in 2010 alleging that the company’s production of chemicals known as PFAS had damaged drinking water and natural resources in the Twin Cities Metropolitan Area. After legal and other expenses are paid, about \$720 million will be invested in drinking water and natural resource projects in the Twin Cities east metropolitan region.”***

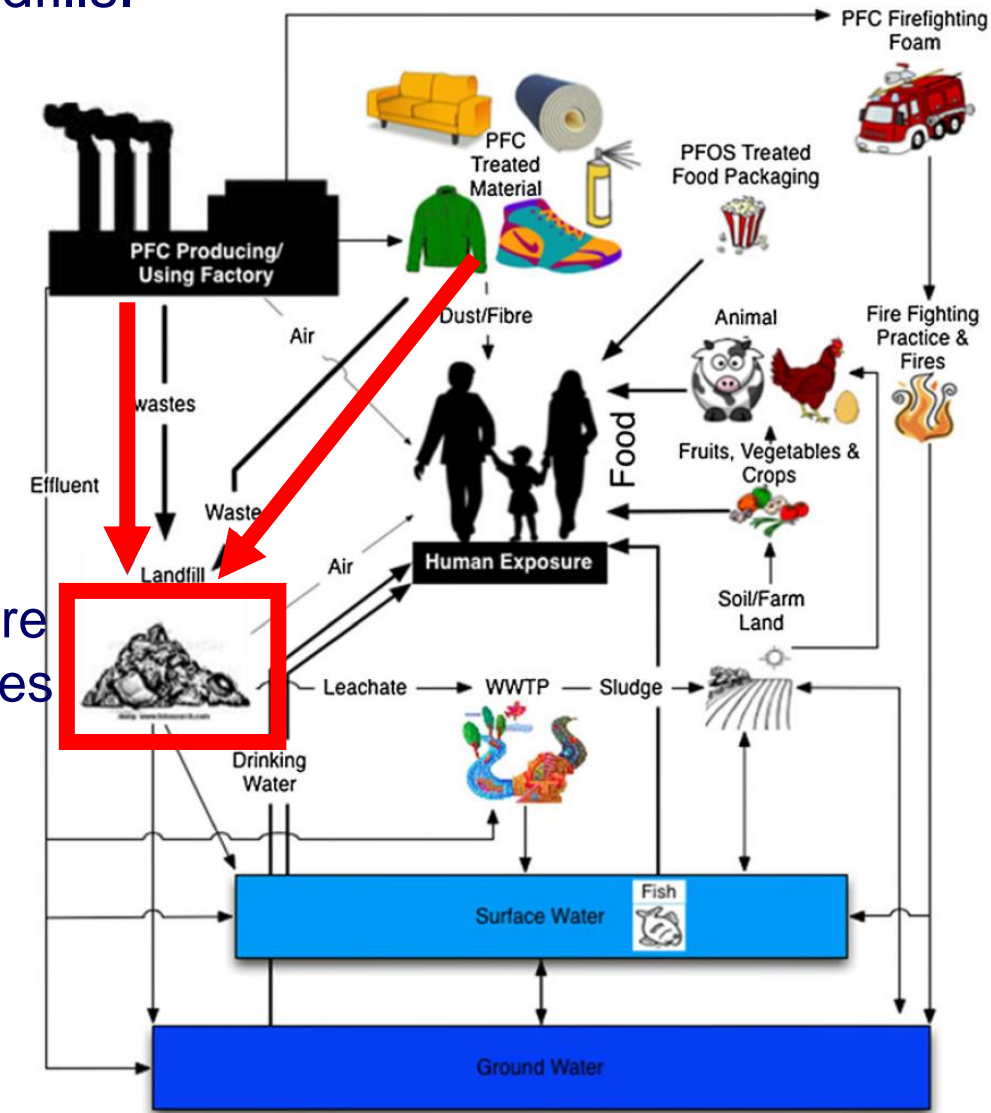
<https://3msettlement.state.mn.us/>



# PFAS reservoirs in landfills from producers, users and products

- Disposed waste from PFAS production, PFAS use in production (e.g. Wolverine case) and products containing PFAS result in PFAS reservoirs in landfills.
- Major PFOS/PFOA/PFAS reservoirs in landfills are side-chain fluoropolymers (e.g. carpets, textiles, paper). They very slowly degrade in landfills with associated long term release potential of PFOS/PFOA/other PFAS.
- Experimental based half-life estimates of the degradation of acrylate-linked fluorotelomer-based side-chain polymers in soils were 65–112 years (Washington et al. 2015)!

**Lesson learned:** Landfills where PFAS waste has been disposed are long term reservoirs releasing PFAS for decades and likely centuries



**Persistent organic pollutants  
and landfills – a review of past  
experiences and future challenges**

<https://doi.org/10.1177/0734242X10390730>

Roland Weber<sup>1,2</sup>, Alan Watson<sup>3</sup>, Martin Forter<sup>4</sup> and Fardin Oliaei<sup>5</sup>

Weber et al. (2010). Waste Manag. Res. 29, 107-121

Washington et al. (2015) Environ. Sci. Technol. 49, 915–923.

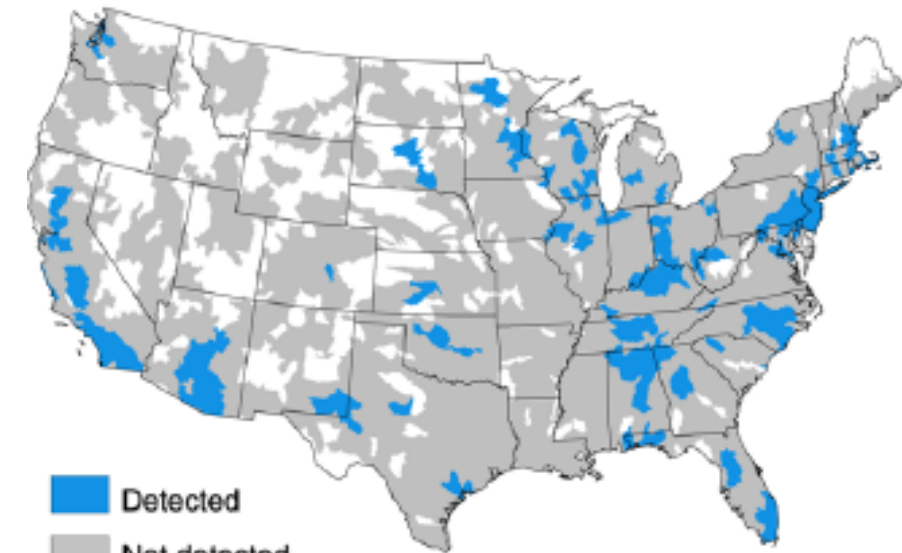
Oliaei et al. (2013). Environ Sci Pollut Res **20**, 1977–1992



# Inventory of PFAS contaminated ground/drinking water in the US

- Based on more than 36,000 water samples collected by the U.S. EPA (2013–2015), **the drinking water supplies for 6 million U.S. residents exceed** US EPA's lifetime health advisory (70 ng/L) for PFOS and PFOA.
- Considering EFSA & CDC assessment, this was still 10-100 times too high** (CDC 2017; EFSA 2020; Grandjean & Budtz-Jørgensen 2013).
- US EPA updated interim Health Advisory 2022: PFOA 0.004 ng/L

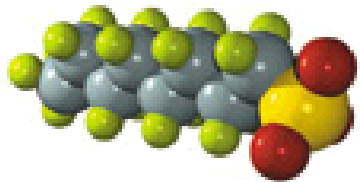
Hydrological units with detectable PFASs



The Washington Post

Energy and Environment

## Researchers find unsafe levels of industrial chemicals in drinking water of 6 million Americans



**ENVIRONMENTAL**  
Science & Technology **LETTERS**

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Letter

[pubs.acs.org/journal/estlett](https://pubs.acs.org/journal/estlett)

### Detection of Poly- and Perfluoroalkyl Substances (PFASs) in U.S. Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants

Xindi C. Hu,<sup>\*,†,‡</sup> David Q. Andrews,<sup>§</sup> Andrew B. Lindstrom,<sup>||</sup> Thomas A. Bruton,<sup>⊥</sup> Laurel A. Schaider,<sup>#</sup> Philippe Grandjean,<sup>†</sup> Rainer Lohmann,<sup>@</sup> Courtney C. Carignan,<sup>†</sup> Arlene Blum,<sup>⊥,▽</sup> Simona A. Balan,<sup>●</sup> Christopher C. Higgins,<sup>○</sup> and Elsie M. Sunderland<sup>‡,\*</sup>

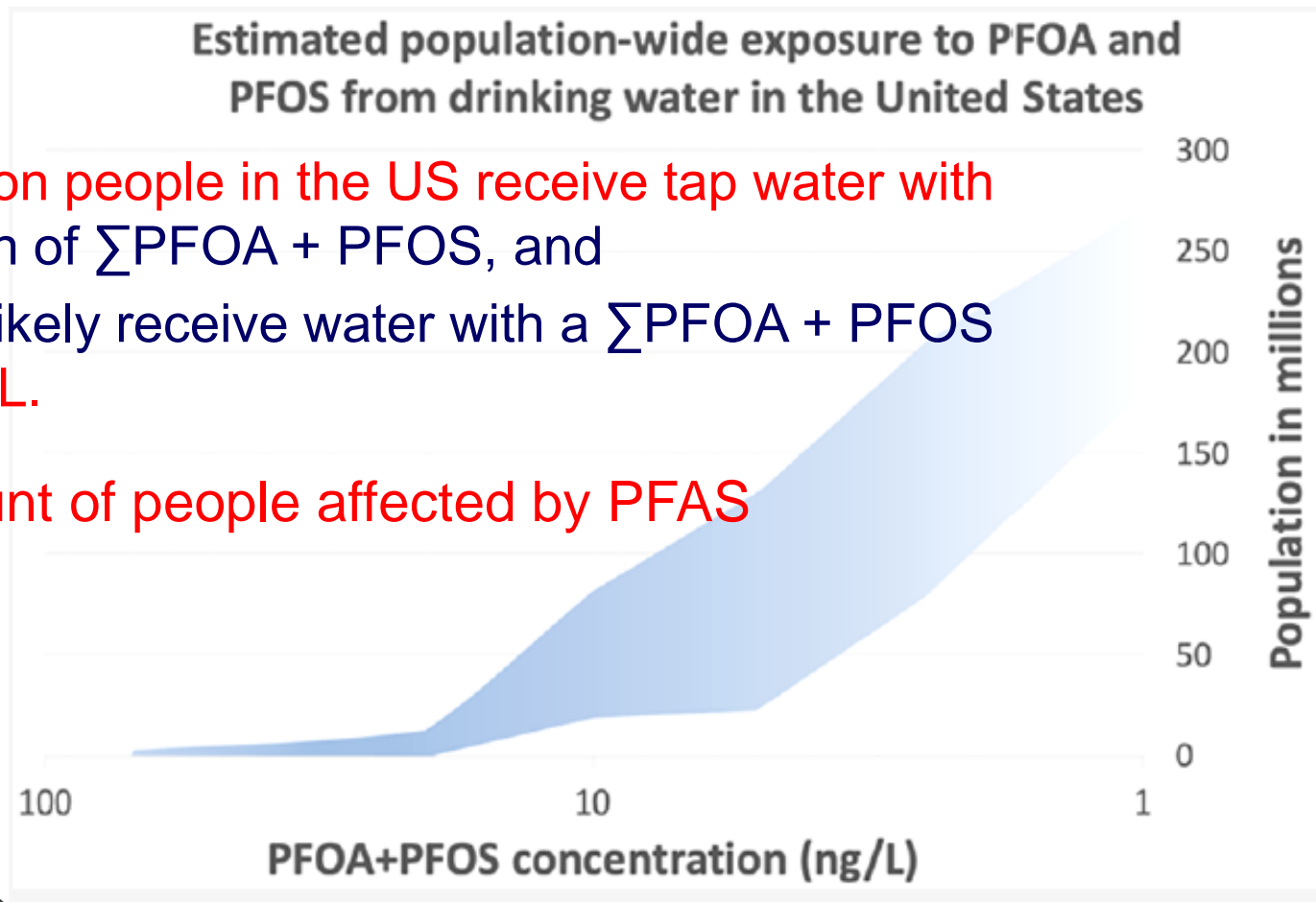
Hu et al. Environ. Sci. Technol. Lett., DOI:10.1021/acs.estlett.6b00260; August 9, 2016

# Assessment of PFAS contaminated drinking water US

- Study estimate that 18–80 million people in the US receive tap water with 10 ng/L or greater concentration of  $\Sigma$ PFOA + PFOS, and
- Over 200 million people in US likely receive water with a  $\Sigma$ PFOA + PFOS concentration at or above 1 ng/L.
- **Lesson learned:** Large amount of people affected by PFAS contaminated drinking water.



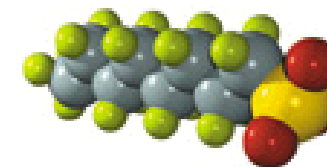
[pubs.acs.org/journal/estlcu](https://pubs.acs.org/journal/estlcu)



## Population-Wide Exposure to Per- and Polyfluoroalkyl Substances from Drinking Water in the United States

David Q. Andrews\* and Olga V. Naidenko

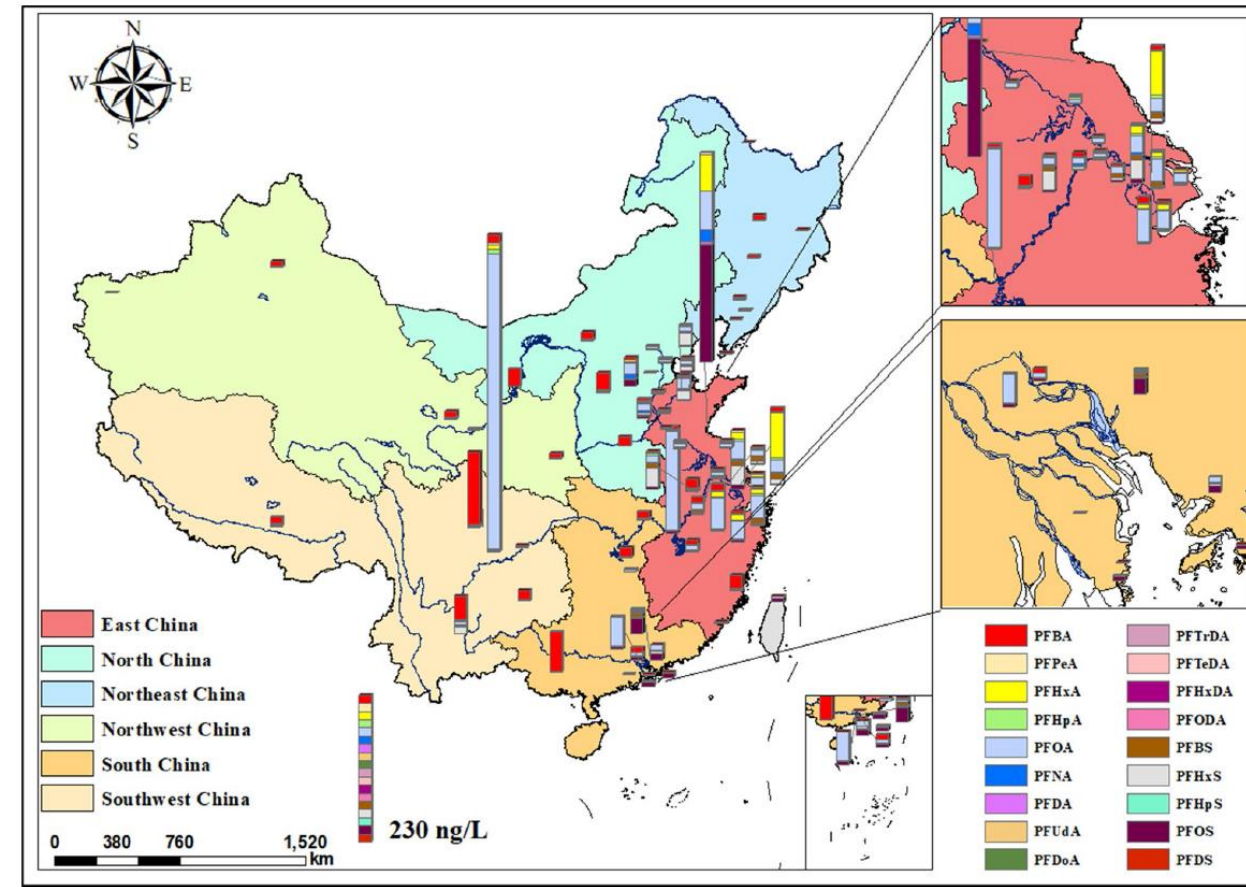
Andrews & Naidenko (2020) Environ. Sci. Technol. Lett <https://doi.org/10.1021/acs.estlett.0c00713>



# Review of PFAS Contamination in Drinking Water in China

- With colleagues from Tsinghua University we **reviewed in 2021 PFAS** data from 526 drinking water samples across 66 cities in China with a total of approx. 452 million inhabitants.
- The PFAS concentrations of >20% of the studied cities, were above the maximum contaminant level issued by the state Vermont in 2019 (20 ng/L  $\Sigma 5$  PFAS) **likely affecting 98.5 million people**, <https://dec.vermont.gov/water/drinking-water/water-quality-monitoring/pfas>
- Likely several 100 million people in China are above the Danish DW limit of 2 ng/L based on EFSA TWI for  $\Sigma 4$  PFAS.
- The East and Southwest regions of China with organofluorine and fluoropolymer production and PFAS using industries have a higher risk to the Chinese population.

**Lesson learned:** Large amount of people affected by PFAS contaminated drinking water.

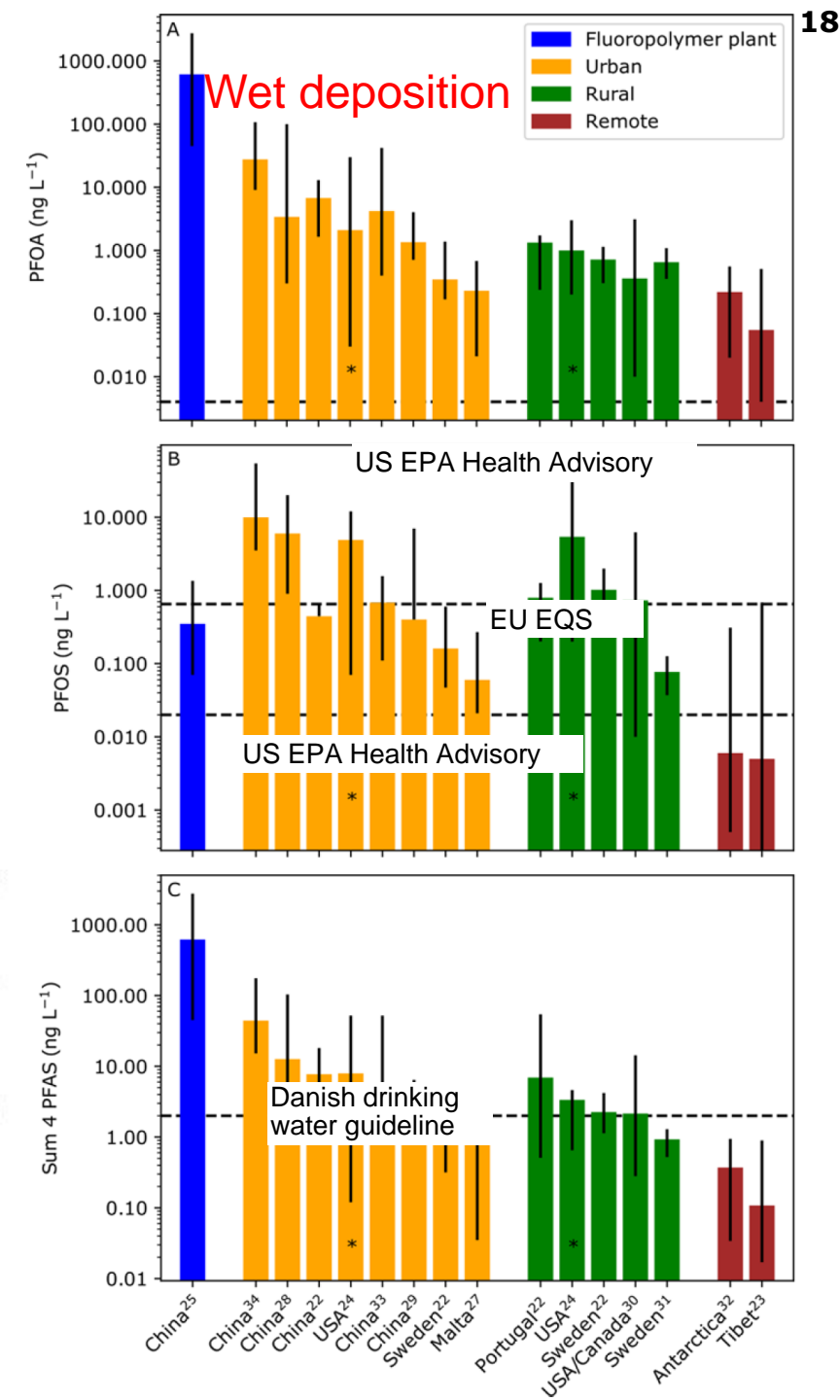
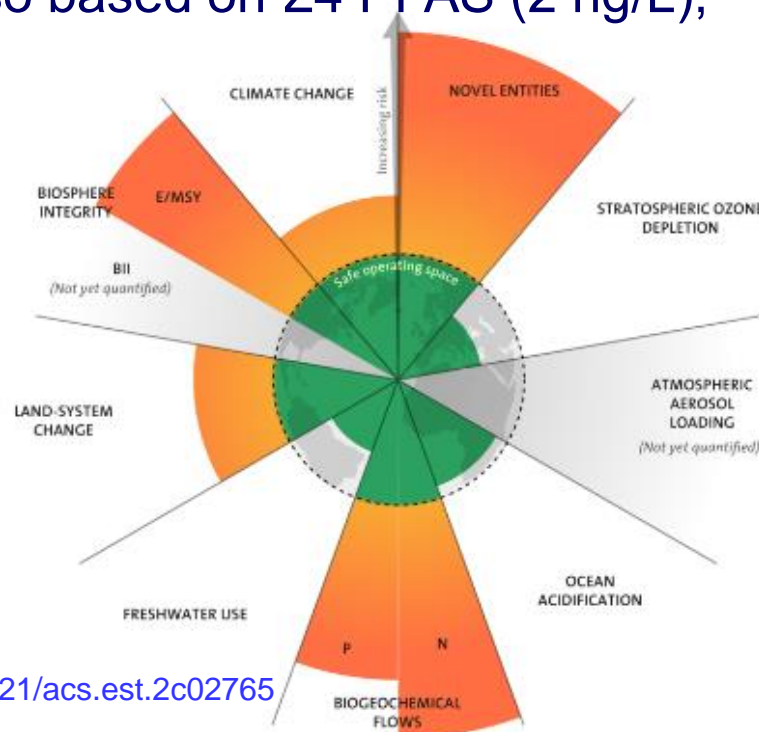




# PFAS pollution crossed Planetary Boundaries (the safe operating space of humanity)

For four PFASs (PFOS, PFOA, PFHxS, PFNA), it is concluded that the global spread of these four PFASs has led to exceedance of the **planetary boundary for PFAS pollution because:**

- 1) levels of PFOA and PFOS in rainwater often greatly exceed US Environmental Protection Agency (EPA) Lifetime Drinking Water Health Advisory levels (0.004 ng/L PFOA) and the sum of the aforementioned four PFAAs ( $\Sigma 4$  PFAS) in rainwater is often above Danish drinking water limit values also based on  $\Sigma 4$  PFAS (2 ng/L);
- 2) levels of PFOS in rainwater are often above Environmental Quality Standard for Inland European Union Surface Water (0.65 ng/L PFOS);
- 3) atmospheric deposition also leads to global soils being ubiquitously contaminated and to be often above proposed Dutch guideline values.



# PFAS pollution litigations in the USA and compensation by industry - Extended producer responsibility implemented

- There are more than 6000 lawsuits in the last 10 years because of PFAS contamination with a claim value of up to 30 billion USD.
- People are suing because they drank contaminated drinking water for years, states/cities are suing because their groundwater is contaminated, and drinking water companies are suing because they have to pay millions of dollars for expensive cleanup.

<https://news.bloomberglaw.com/pfas-project/companies-face-billions-in-damages-as-pfas-lawsuits-flood-courts>

- One of the lawsuits filed by Robert Billot aims to sue major (former/current) PFAS producers on behalf of millions of Americans which have PFAS in their blood.

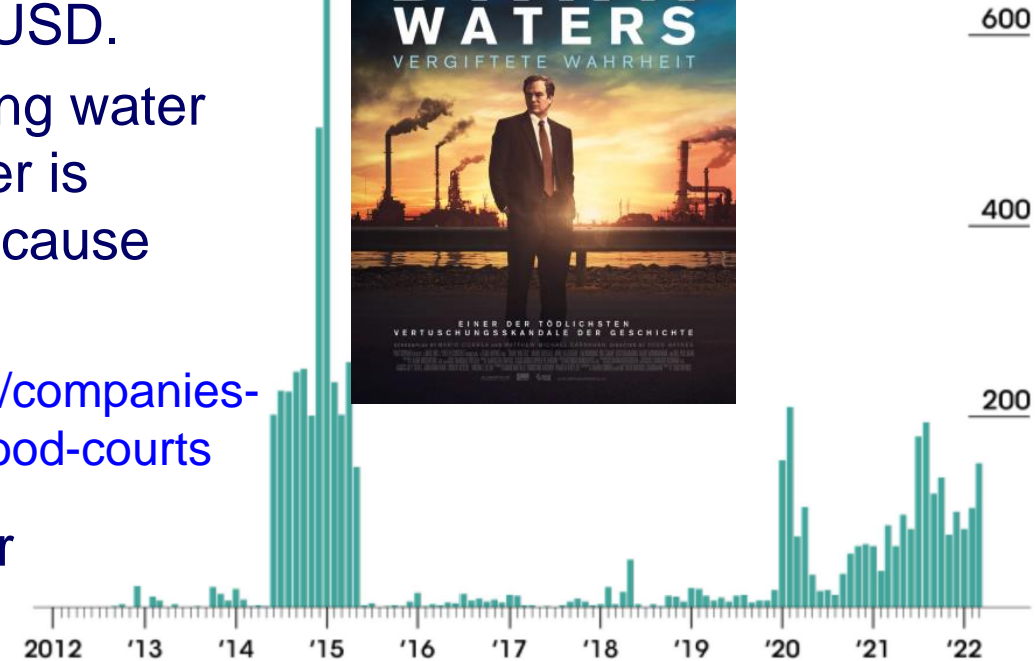


Photo Illustration: Jonathan Hurtarte; Photos: Getty Images

**Companies Face Billions in Damages as PFAS Lawsuits Flood Courts**

# PFAS pollution litigations in the USA and compensation by industry

## State of Michigan PFAS Lawsuit

- The lawsuit of the State of Michigan asserts 17 defendants knowingly designed, marketed, developed, distributed, sold, manufactured, released, supplied, transported, arranged for disposal or treatment, handled, and/or used PFAS and/or PFAS-containing products in Michigan in such a way as to cause harm to the state's natural resources and residents.
- This is the first legal action taken by the state against PFAS manufacturers and continues Michigan's leadership in tackling the serious and widespread problem of PFAS contamination.



AGC



Archroma



Arkema



Asahi Kasei



Chemours



Complainees



Corteva



Daikin





<https://www.michigan.gov/ag/initiatives/pfas-contamination>

[https://www.michigan.gov/ag/-](https://www.michigan.gov/ag/-/media/Project/Websites/AG/releases/2020/january/Complaint_20200114_final.pdf?rev=b1a06258d49a4835b174272565267734&hash=25747CA5C5A6F91EC47B51115E51E2FA)

[/media/Project/Websites/AG/releases/2020/january/Complaint\\_20200114\\_final.pdf?rev=b1a06258d49a4835b174272565267734&hash=25747CA5C5A6F91EC47B51115E51E2FA](https://www.michigan.gov/ag/-/media/Project/Websites/AG/releases/2020/january/Complaint_20200114_final.pdf?rev=b1a06258d49a4835b174272565267734&hash=25747CA5C5A6F91EC47B51115E51E2FA)



# Global threat needs global action: Listing of certain PFAS in the Stockholm Convention for global control and elimination



STOCKHOLM  
CONVENTION

- In May 2009, PFOS, PFOSF, and related precursor substances were added to the Stockholm Convention listings and became the first fluorinated persistent organic pollutants. In 2019 also PFOA and in 2022 also PFHxS and related compounds were listed in the Stockholm Convention as POPs.
- Consequently, **PFOS, PFOA, PFHxS** and related compounds need to be addressed and phased out now globally in accordance with the provisions of the Convention.
- The **Stockholm Convention** Conference of Parties (186 countries) has **made recommendations** for risk reduction of PFOS in 2011 highlighting the need for assessment of production, use, and end-of-life stages according to the life cycle principles and the need to undertake “*urgent investigations into landfills where waste from PFOS/PFOA producers or from industrial users (paper, carpet, textile, chromium plating and other industries having used PFOS) are disposed and how sludge from productions and use were managed.*”
- Recently a Stockholm Convention “Draft guidance on BAT/BEP for the management of sites contaminated with persistent organic pollutants” has been published. This document is currently revised. <http://chm.pops.int/Implementation/BATandBEP/POPsContaminatedSitesGuidance/tabid/8779/Default.aspx>
- **PFASs** are an issue of concern under the Strategic Approach to Int. Chemical Management (SAICM).
- And FAO is working on global soil contamination including PFASs (presentation in our session).

# The Madrid Statement on PFASs

Perspectives | Brief Communication

2015: Environmental Health Perspectives

## The Madrid Statement on Poly- and Perfluoroalkyl Substances (PFASs)

<http://dx.doi.org/10.1289/ehp.1509934>

Arlene Blum,<sup>1,2</sup> Simona A. Balan,<sup>2</sup> Martin Scheringer,<sup>3,4</sup> Xenia Trier,<sup>5</sup> Gretta Goldenman,<sup>6</sup> Ian T. Cousins,<sup>7</sup> Miriam Diamond,<sup>8</sup> Tony Fletcher,<sup>9</sup> Christopher Higgins,<sup>10</sup> Avery E. Lindeman,<sup>2</sup> Graham Peaslee,<sup>11</sup> Pim de Voogt,<sup>12</sup> Zhanyun Wang,<sup>4</sup> and Roland Weber<sup>13</sup>



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journal homepage: [www.elsevier.com/locate/chemosphere](http://www.elsevier.com/locate/chemosphere)



Builds on Helsingør Statement

Helsingør Statement on poly- and perfluorinated alkyl substances (PFASs)

Martin Scheringer<sup>a,\*</sup>, Xenia Trier<sup>b</sup>, Ian T. Cousins<sup>c</sup>, Pim de Voogt<sup>d</sup>, Tony Fletcher<sup>e</sup>, Zhanyun Wang<sup>a</sup>, Thomas F. Webster<sup>f</sup>



## The Madrid Statement on PFASs (2015):

- Documents the scientific consensus regarding the persistence and potential for harm of PFASs
- Lays out a roadmap to gather needed information and prevent further harm. Recommendation to policy makers, industry, science...
- Dialogue with industry (Fluorocouncil)

<http://ehp.niehs.nih.gov/1509934/>

<http://ehp.niehs.nih.gov/1509910/>

<http://ehp.niehs.nih.gov/1510207/>

**Madrid Statement signed by >200 scientist and coordinated by Green Science Policy Institute**

<http://greensciencepolicy.org/Madrid-Statement>

# Madrid Statement: Road map to gather info and prevent harm

## Governments/policy makers:

- Enact legislation to require only essential uses of PFASs enforce labelling to indicate uses.

Perspectives | Brief Communication

<http://ehp.niehs.nih.gov/1509934/>

**The Madrid Statement on Poly- and Perfluoroalkyl Substances (PFASs)**

<http://dx.doi.org/10.1289/ehp.1509934>

- The EU Commission in its chemicals strategy (2020) for sustainability towards a toxic-free environment suggests to address PFAS as a group. With the following action: **phasing out the use of PFAS in the EU, unless their use is essential**.

[https://ec.europa.eu/environment/strategy/chemicals-strategy\\_en#ecl-inpage-238](https://ec.europa.eu/environment/strategy/chemicals-strategy_en#ecl-inpage-238)

PFAS: [https://ec.europa.eu/environment/chemicals/pfas/index\\_en.htm](https://ec.europa.eu/environment/chemicals/pfas/index_en.htm)

Brussels, 14.10.2020  
COM(2020) 667 final



**COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN  
PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL  
COMMITTEE AND THE COMMITTEE OF THE REGIONS**

**Chemicals Strategy for Sustainability  
Towards a Toxic-Free Environment**

- February 2023: ECHA publishes details of a **proposed restriction of around 10 000 PFASs!** Available on ECHA's website <https://echa.europa.eu/-/echa-publishes-pfas-restriction-proposal> ECHA's scientific committees will now start evaluating the proposal in terms of the risks to people and the environment, and the impacts on society.





# THANK YOU FOR YOUR ATTENTION

Perspectives | Brief Communication

<http://ehp.niehs.nih.gov/1509934/>

## The Madrid Statement on Poly- and Perfluoroalkyl Substances (PFASs)

P. Kröfges, D. Skutlarek, H. Färber, C. Baitinger, I. Gödeke, R. Weber. (2007)  
PFOS/PFOA Contaminated Megasites in Germany Polluting the Drinkingwater  
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11TH FORUM OF THE INTERNATIONAL HCH AND PESTICIDE ASSOCIATION

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Fardin Oliaei • Don Kriens • Roland Weber • Alan Watson

## Persistent organic pollutants and landfills – a review of past experiences and future challenges

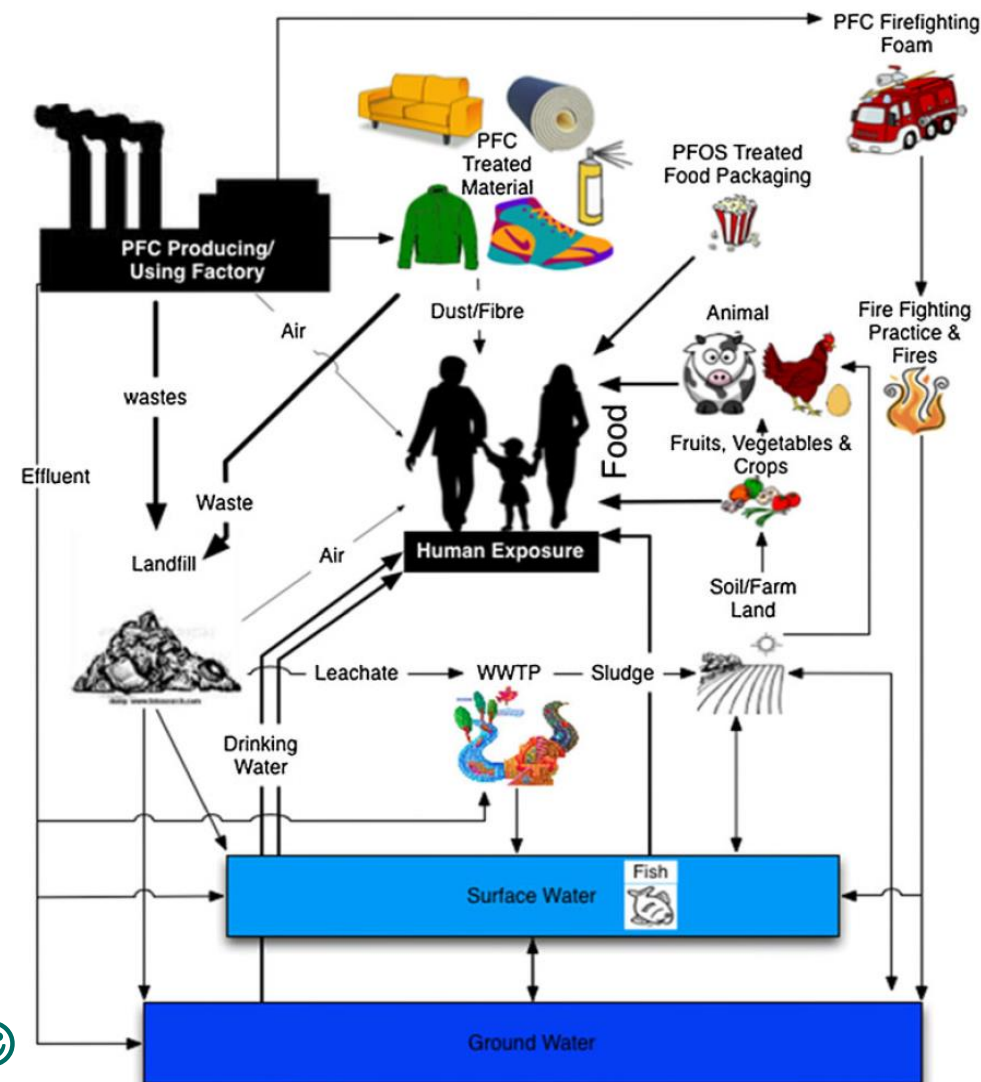
<https://doi.org/10.1177/0734242X10390730>

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Weber et al. (2011). Waste Manag. Res. 29, 107-121

Thanks to all  
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Oliaei et al (2013) Environ Sci Pollut Res Int. 20, 1977-1992