

ENV-167 Introduction to Environmental Engineering - Water

Nov. 5th – Visit of Vidy wastewater treatment plant (14:15-16:30)

5 groups of 15 people

- **Departure of the first group at 2:15 pm**
- **Departure of the last group at 3:30 pm**
- **Return of the last group at 4:30 pm**
- **Students must wear closed-toe shoes**



The Journey and Impact of Environmental Contaminants

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**Central Environmental Laboratory
EPFL**



Aims of this course

Gain a better understanding of:

- The diversity of chemical contaminants/pollutants
- The sources of environmental contaminants/pollutants
- The fate and behaviour of contaminants/pollutants in the different environmental compartments
- The effects of pollutants on the ecosystem and human health

Definition (1)

A **pollutant** is a substance detectable in the environment, at least partially due to human activity, and that may **induce adverse effects on the living organisms**.

Moriarty, Ecotoxicology: The Study of Pollutants in Ecosystems. London: Academic Press. 1983

The Safe Drinking Water Act (SDWA) defines **contaminant** as any physical, chemical, biological or radiological substance or matter in water. **The presence of contaminants does not necessarily indicate that the water poses a health risk.**

US-EPA

Definition (1)

If totally foreigner to the nature: **xenobiotics**

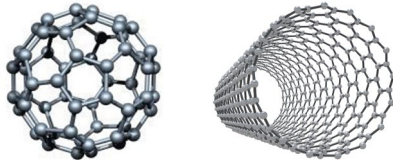
e.g. arsenic, petroleum or chloroform are not xenobiotics since they can be present naturally in rocks and/or sediments.

We can distinguish:

- **Macropollutant** (present in high concentrations or large volumes)
- **Micropollutant** (found in trace amounts ($\mu\text{g/L}$ to ng/L range))
- **Nanopollution ?** (e.g. nanotubes, fullerene, graphene, metallic nanoparticles, nanoplastics)

Examples of macropollutants:

- **Suspended solids** (e.g., sediment, silt)
- **Organic matter** (e.g., sewage)
- **Nutrients** (e.g., nitrates and phosphates from fertilizers)
- **Biodegradable materials**
- **Thermal pollution** (excess heat in water bodies)
- **Plastics and solid wastes**



Definition (2)

We call **micropolluant** a substance detectable in the environment in low concentrations ($\mu\text{g/l}$ ou ng/l), partially due to human activity, and that can induce adverse effects on the living organisms at these low concentrations.

Effects at 10 ng/L

Olympic sized swimming pool
2,500,000 L

= 25,000,000 ng

= 25000 μg

= 25 mg

= 0.025 g



109 grains
of sugar



= 4.2 g
= 18,312 grains

Definition (3)

We call **micropollutant** a substance detectable in the environment in low concentrations ($\mu\text{g/l}$ ou ng/l), partially due to human activity, and that can induce adverse effects on the living organisms at these low concentrations.

Inorganic micropollutants: heavy metals, metalloids,...

Organic micropollutants: mostly substances produced by the industry

Definition (3)

Organic compounds: Organic compounds are chemical compounds that contain carbon atoms bonded primarily to hydrogen, and often also to oxygen, nitrogen, sulfur, or halogens. They are typically associated with living organisms or products derived from them (e.g., carbohydrates, proteins, lipids, and hydrocarbons). Examples include methane (CH_4), ethanol ($\text{C}_2\text{H}_5\text{OH}$), and glucose ($\text{C}_6\text{H}_{12}\text{O}_6$).

Inorganic compounds: Inorganic compounds are chemical compounds that generally do not contain carbon–hydrogen (C–H) bonds. They are usually derived from non-living sources such as minerals and metals. Examples include sodium chloride (NaCl), water (H_2O), and carbon dioxide (CO_2).

Note: A few carbon-containing compounds like carbonates (CO_3^{2-}), carbon dioxide (CO_2), and cyanides (CN^-) are classified as inorganic despite containing carbon, because they do not follow the typical bonding patterns of organic compounds.

Definition (4)

Emerging substances can be defined as substances that have been detected in the environment, but which are currently not included in routine monitoring programmes at EU level and whose **fate, behaviour and (eco)toxicological effects are not well understood**.

Emerging pollutants can be defined as pollutants that are currently not included in routine monitoring programmes at the European level and which **may be candidates for future regulation**, depending on research on their (eco)toxicity, potential health effects and public perception and on monitoring data regarding their occurrence in the various environmental compartments.

[https://www.norman-network.net/?q=node/19#:~:text=Examples%20from%20the%20LIST%20OF,endocrine%20disrupting%20compounds%20\(EDCs\).](https://www.norman-network.net/?q=node/19#:~:text=Examples%20from%20the%20LIST%20OF,endocrine%20disrupting%20compounds%20(EDCs).)

Principal sources of pollution

Agriculture

Very different chemicals:

- fertilisers, phosphorus
 - biocides
 - antibiotics/pharmaceuticals
- emission into the air: drift
 - emission into the soil
 - transfer to water, sediment, groundwater



Principal sources of pollution

Industries (mines, pharma/chemical industries)

Very different chemicals:

- Metals
 - PAHs
 - N-nitrosamines
-
- emission into the air: smoke
 - emission into the water: discharges
 - emission into the soil: discharges
 - transfer between compartments



Principal sources of pollution

Cities / Leisure activities / Households

Very different chemicals:

- Pharmaceutical substances
 - Biocides
 - Plastics
 - POPs
-
- emission into the air
 - emission into the water
 - emission into the soil
 - transfer between compartments



Principal sources of pollution

Military activities

(conflict zones, military training sites, ammunition factories)

Very different chemicals

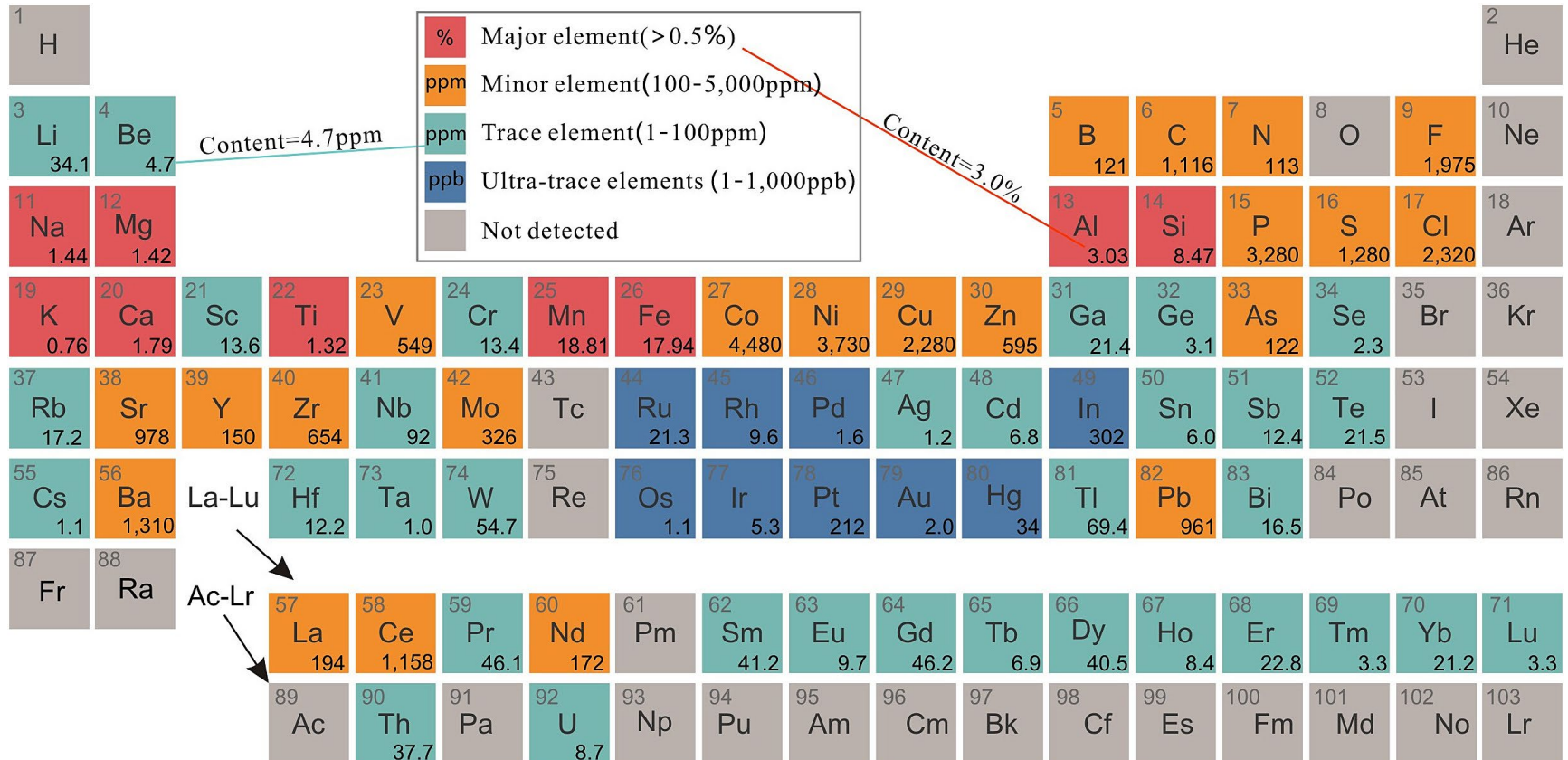
- Heavy metals
- Radioactives materials
- Explosives
- PAHs

Armed conflicts too often lead to environmental degradation or destruction, with long-lasting effects that contribute to the increased vulnerability of the affected populations.



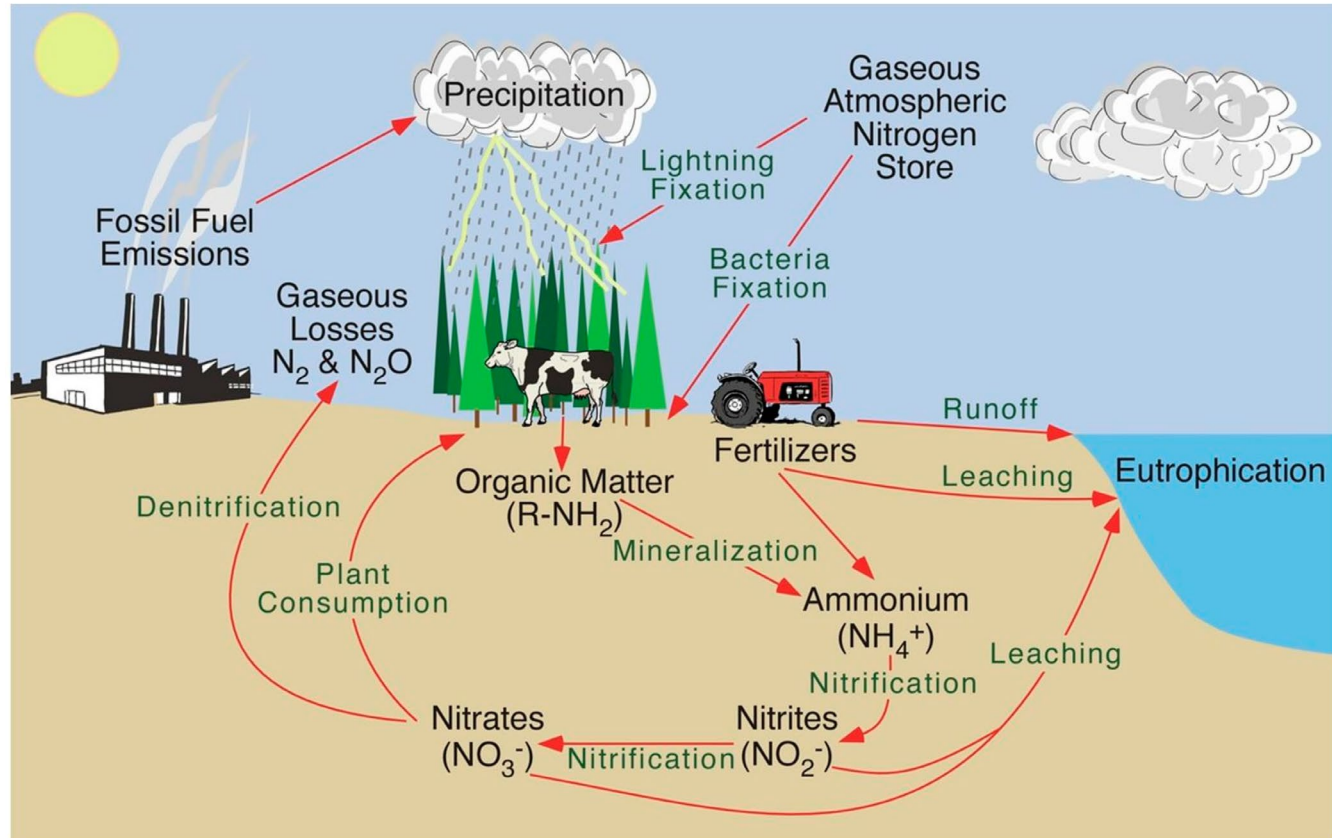
Inorganic pollutants

Inorganic pollutants



Inorganic pollutants

$\text{NO}_2^-/\text{NO}_3^-$



Moloantoa et al. 2022 <https://doi.org/10.3390/w14050799>

Inorganic pollutants

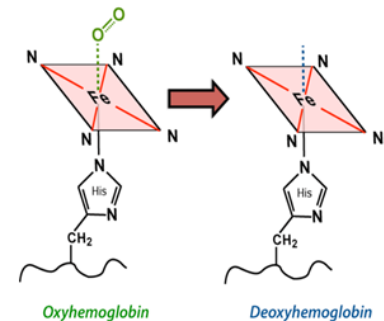
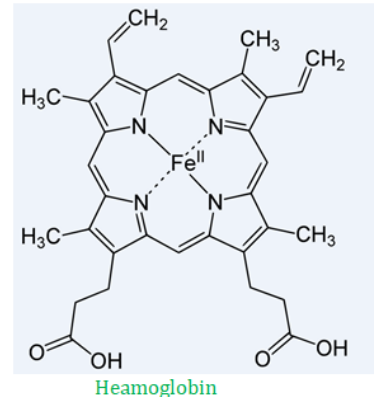
$\text{NO}_2^-/\text{NO}_3^-$

High concentrations of nitrite in freshwater ecosystems can be toxic to aquatic organisms. These living organisms can capture nitrites from water through their cells, subsequently undergoing the oxidation of their respiratory pigments (hemoglobin, hemocyanin). Since NO_2^- and Cl^- ions compete for the same active transport site, high chloride concentrations in the aquatic environment have the potential to reduce nitrite toxicity.

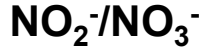
Molluscs, crustaceans

Vertebrates

Hemocyanin	Hemoglobin
Performs better in cold environments with low oxygen pressure	Performs better in oxygen rich environments
Contains copper linking other parts of the molecule	Contains iron surrounded by atoms of carbon, nitrogen, and hydrogen
Binds with oxygen non co-operatively most of the time (when non co-operatively, is one quarter as efficient as hemoglobin)	Binds with oxygen co-operatively all of the time
Free floating in blood	Connected to red blood cells

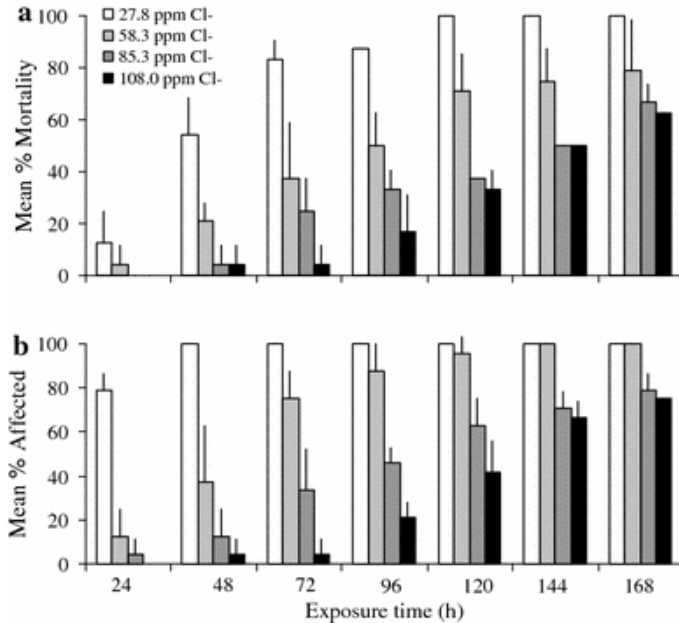


Inorganic pollutants

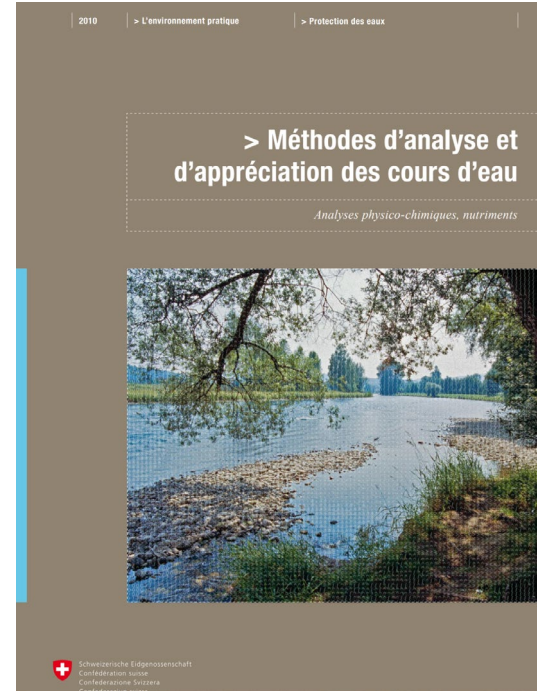


Eulimnogammarus toletanus

Antagonist effect of chloride on nitrite toxicity



Mean percentages (+SD) of mortality (a) and affected individuals (b) for *Eulimnogammarus toletanus* exposed to 5.1 ppm $\text{NO}_2\text{-N}$ through seven different exposure times (hours) and at four different chloride concentrations (ppm Cl^-)



Appréciation	Nitrites [mg/L N] ¹ (<10 mg/L Cl ⁻)	Nitrites [mg/L N] (10 à 20 mg/L Cl ⁻)	Nitrites [mg/L N] (>20 mg/L Cl ⁻)
Très bon	jusqu'à < 0,01	jusqu'à < 0,02	jusqu'à < 0,05
bon	0,01 à < 0,02	0,02 à < 0,05	0,05 à < 0,10
moyen	0,02 à < 0,03	0,05 à < 0,075	0,10 à < 0,15
médiocre	0,03 à < 0,04	0,075 à < 0,10	0,15 à < 0,20
mauvais	0,04 et plus	0,10 et plus	0,20 et plus

Système Modulaire Gradué

Inorganic pollutants

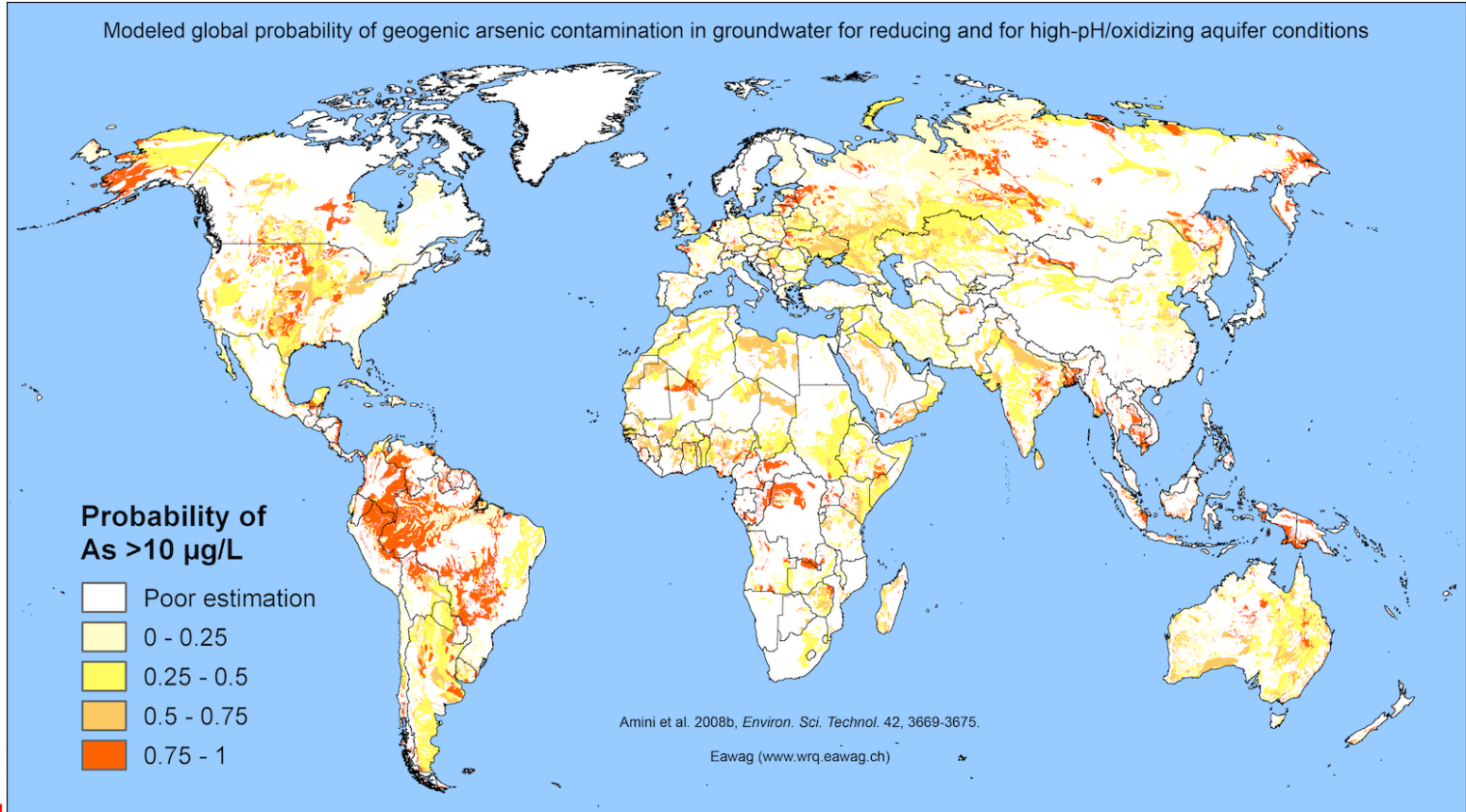
“Heavy” metals, metalloids (Al, As, Cd, Cr, Cu, Pb, Hg,...)

- **Natural contamination:** Bangladesh, Vietnam...
- **Agriculture:** pesticides, sluges,...
- **Runoff water:** streets, railways,...
- **Industry, mines**

Caution: they will not degradate but they can be transformed!

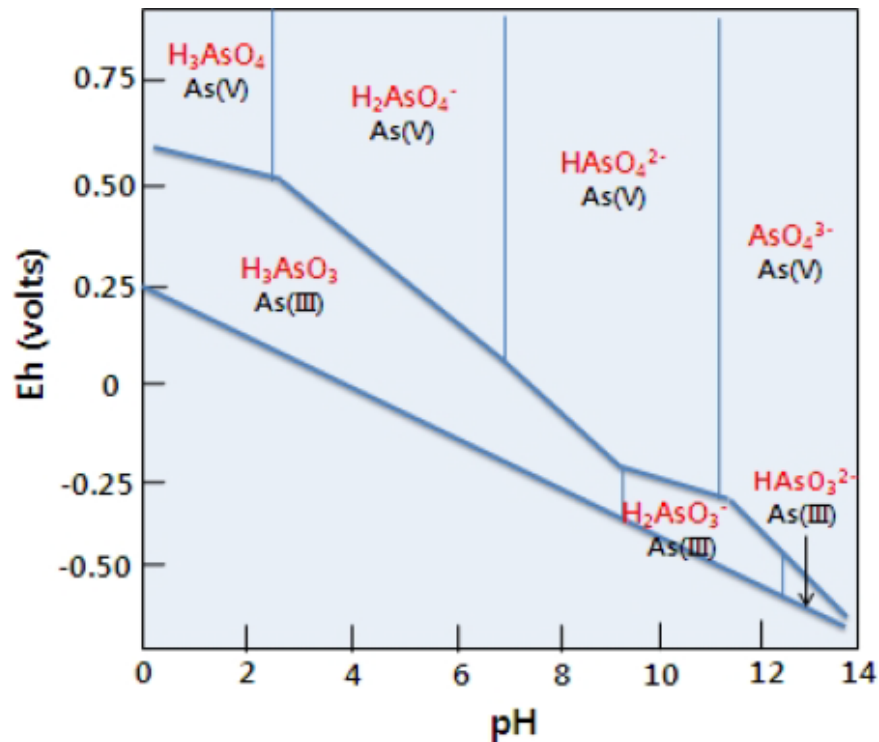
Inorganic pollutants

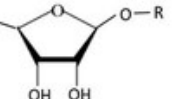

Speciation and toxicity of arsenic



Inorganic pollutants

Speciation and toxicity of arsenic

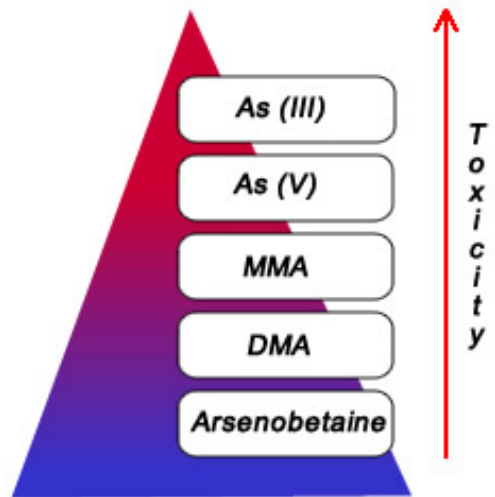


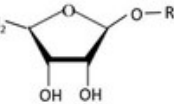
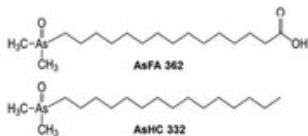
Arsenic compound	Formula	Abbreviation
<u>Arsenous acid, arsenite</u>	H_3AsO_3	As(III)
Arsenic acid, arsenate	H_3AsO_4	As(V)
<u>Monomethylarsinic acid</u>	$CH_3AsO(OH)_2$	MMA
Dimethylarsinic acid	$(CH_3)_2AsO(OH)$	DMA
Trimethylarsine oxide	$(CH_3)_3AsO$	TMAO
Arsenobetaine	$(CH_3)_3AsCH_2COOH$	AsB
Arsenocholine	$(CH_3)_3AsCH_2CH_2OH$	AsC
Tetramethylarsonium ion	$(CH_3)_4As^+$	TETRA
<u>Arsenosugars</u>	$(CH_3)_2AsOCH_2$  $O-R$	As-sugars
<u>Arsenolipids</u>		As-lipids

R = glycerol, phosphate, sulphonate or sulphate

Inorganic pollutants

Speciation and toxicity of arsenic

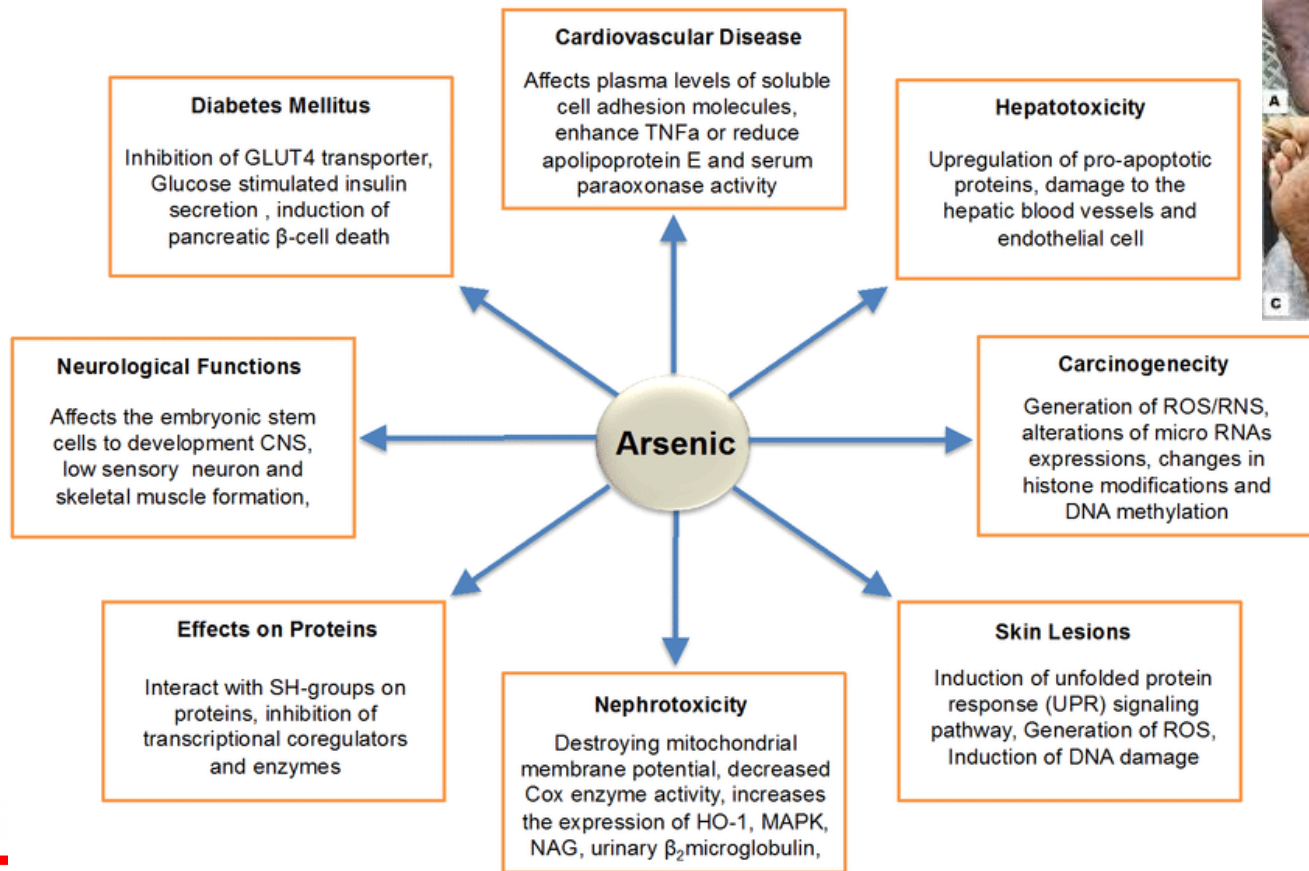


Arsenic compound	Formula	Abbreviation
<u>Arsenous acid, arsenite</u>	H_3AsO_3	As(III)
Arsenic acid, arsenate	H_3AsO_4	As(V)
<u>Monomethylarsinic acid</u>	$CH_3AsO(OH)_2$	MMA
Dimethylarsinic acid	$(CH_3)_2AsO(OH)$	DMA
Trimethylarsine oxide	$(CH_3)_3AsO$	TMAO
Arsenobetaine	$(CH_3)_3AsCH_2COOH$	AsB
Arsenocholine	$(CH_3)_3AsCH_2CH_2OH$	AsC
Tetramethylarsonium ion	$(CH_3)_4As^+$	TETRA
<u>Arsenosugars</u>	$(CH_3)_2AsOCH_2$ 	As-sugars
<u>Arsenolipids</u>		As-lipids

R = glycerol, phosphate, sulphonate or sulphate

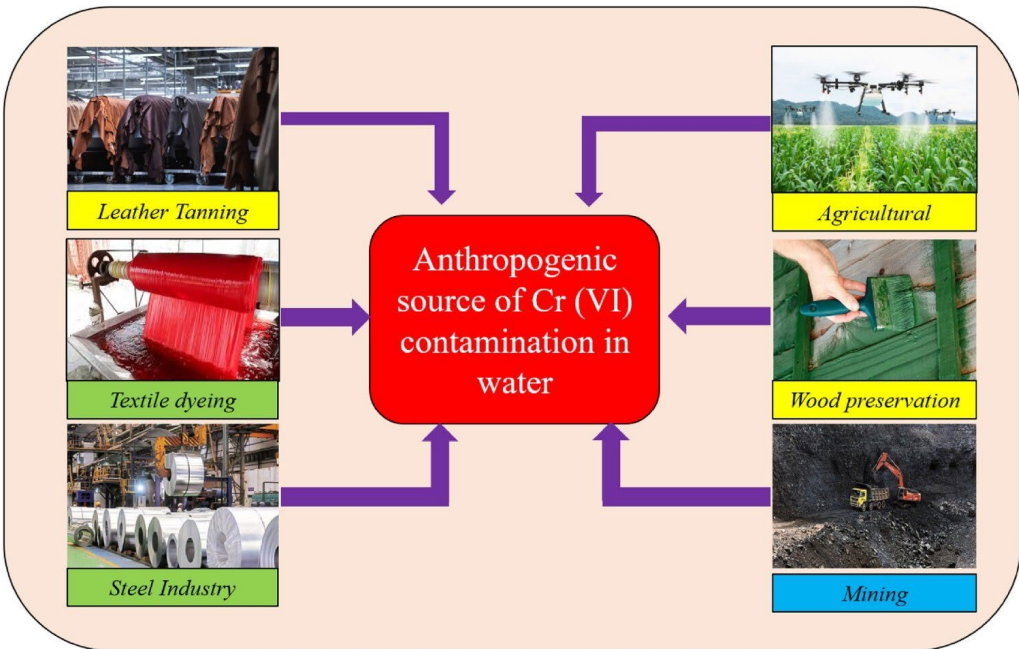
Inorganic pollutants

Speciation and toxicity of arsenic



Inorganic pollutants

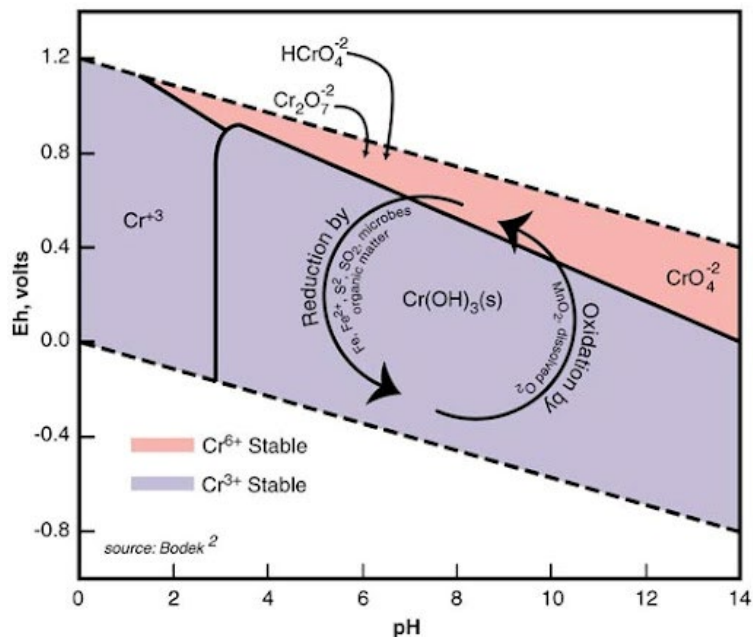
Speciation and toxicity of chromium



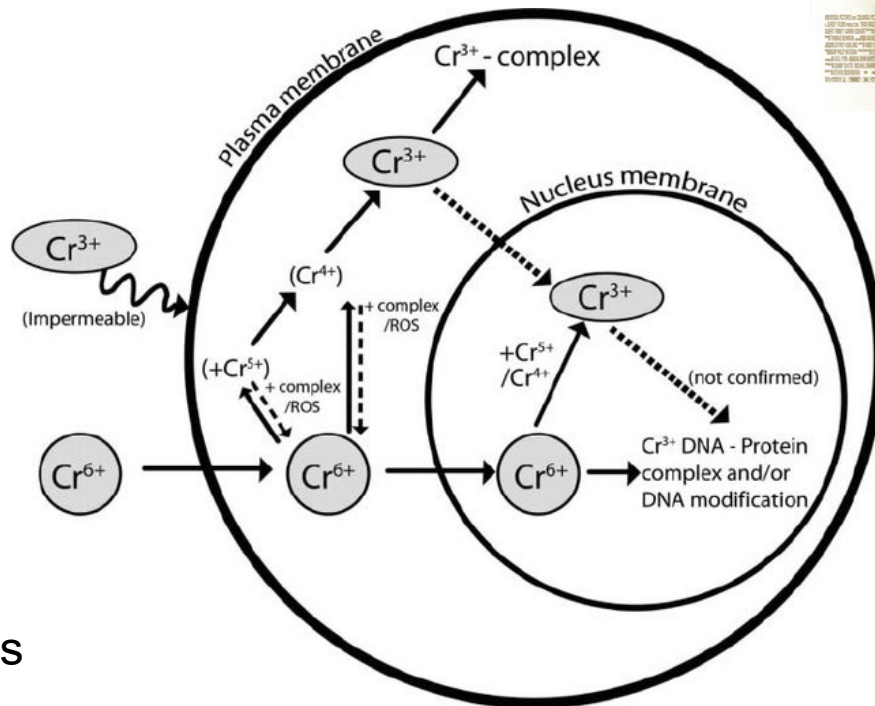
Geogenic and anthropogenic sources

Inorganic pollutants

Speciation and toxicity of chromium



Cr⁶⁺ is more toxic than Cr³⁺



Geogenic and anthropogenic sources

Organic Micropollutants

Micropollutants

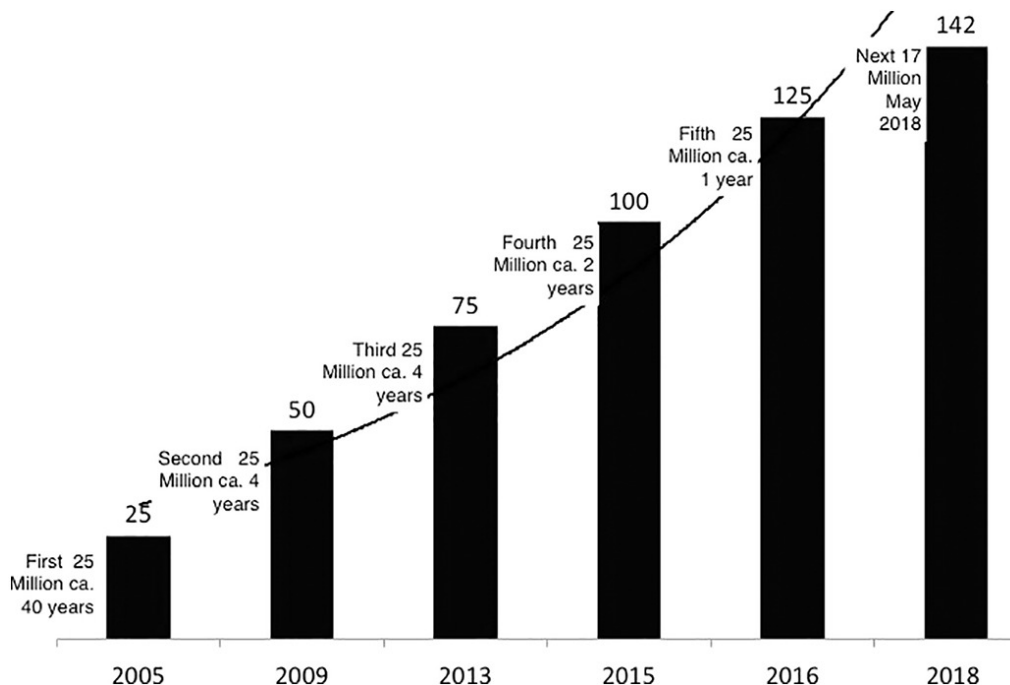
Diversity of micropollutants

More than **142,000** chemical substances are in commerce in the EU (2018).

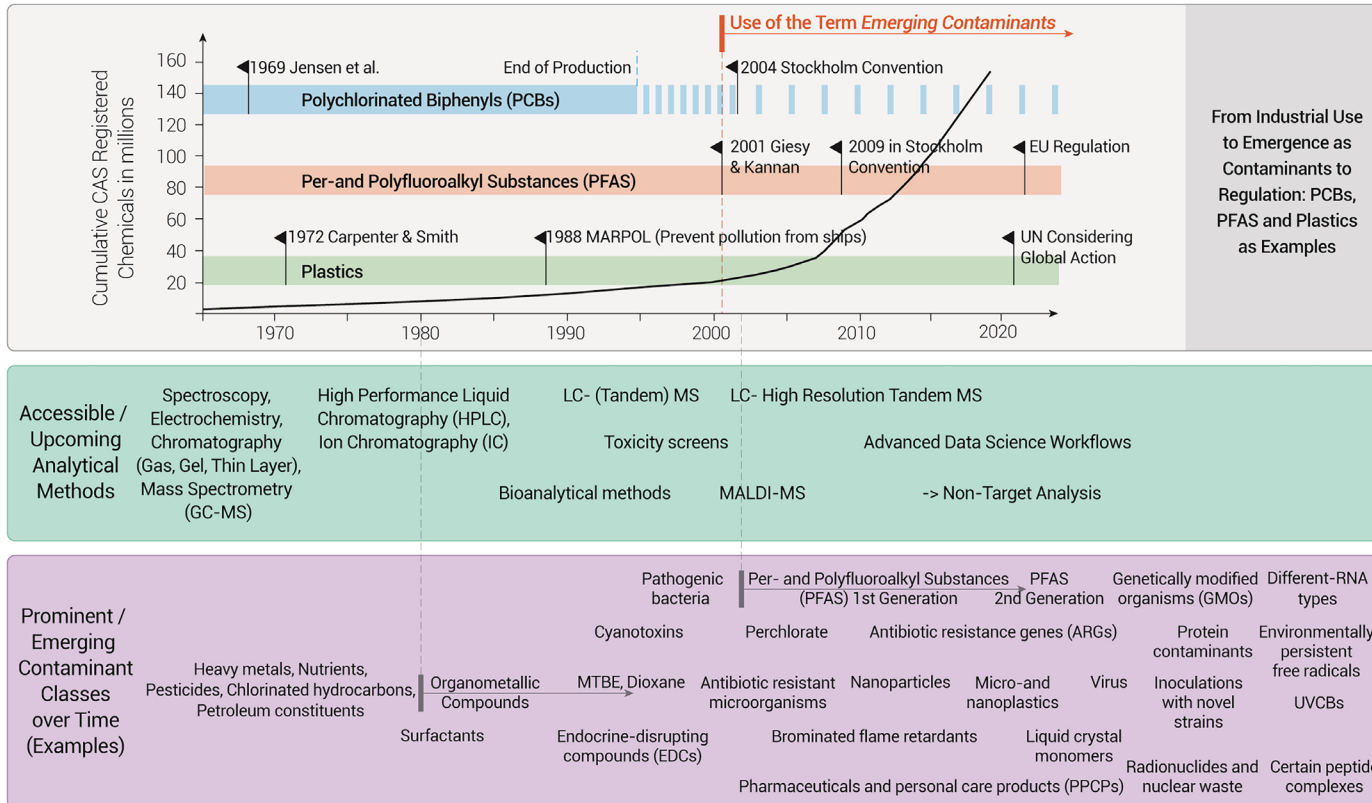
There are over **180 million** unique chemical substances registered with CAS (Chemical Abstracts Service)

15,000 to 25,000 new substances are added to this list (CAS) every day.

ACS www.cas.org



Micropollutants



Wang et al., Emerging contaminants: A One Health perspective, The Innovation, Volume 5, Issue 4, 2024,100612, ISSN 2666-6758, <https://doi.org/10.1016/j.xinn.2024.100612..>

Micropollutants

Sources of micropollutants

- Cosmetic
- Pharmaceutical
- Perfumes
- Dyes
- Pesticides, herbicides, fungicides
- Plastics
- Additives
- Non-stick substances
- Flame retardants

...

The multifaceted pathways of environmental contaminant (EC) production, utilization, and environmental release



Wang et al., Emerging contaminants: A One Health perspective, The Innovation, Volume 5, Issue 4, 2024, 100612, ISSN 2666-6758, <https://doi.org/10.1016/j.xinn.2024.100612..>

Micropollutants

Fate of micropollutants

ECs can originate from various sources:

- industrial discharges
- agricultural runoff
- wastewater effluents
- Urban emissions
- Etc.

Once released, ECs can undergo transformation processes such as **degradation, volatilization, and bioaccumulation**.

Pathways through which ECs enter the environment and their subsequent fate



Wang et al., Emerging contaminants: A One Health perspective, The Innovation, Volume 5, Issue 4, 2024, 100612, ISSN 2666-6758, <https://doi.org/10.1016/j.xinn.2024.100612..>

Micropollutants

Strategies for controlling ECs encompass various measures, including:

- pollution control at the source
- sustainable remediation
- clean up contaminated sites
- Sustainable management practices to prevent contamination.



Wang et al., Emerging contaminants: A One Health perspective, The Innovation, Volume 5, Issue 4, 2024,100612, ISSN 2666-6758, <https://doi.org/10.1016/j.xinn.2024.100612..>

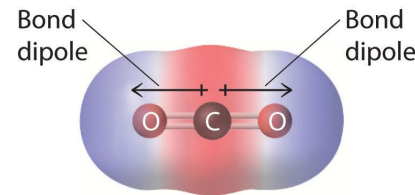
Definition

Ionic, polar and non-polar substances

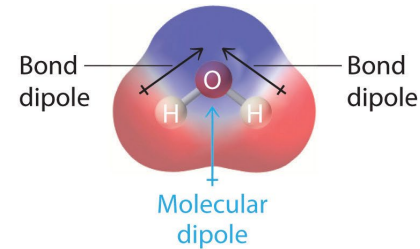
In chemistry, polarity is a characteristic describing the **distribution of negative and positive charges in a dipole**. The polarity of a bond or molecule **is due to the difference in electronegativity between the chemical elements that compose it, the differences in charge it induces, and their distribution in space**. The more asymmetrically the charges are distributed, the more polar a bond or molecule will be, and conversely, if the charges are distributed in a totally symmetrical way, it will be non-polar.

Polar: water, sucrose, ... → hydrophilic

Non-polar: hydrocarbons, ... → hydrophobic / lipophilic



(a) No net dipole moment



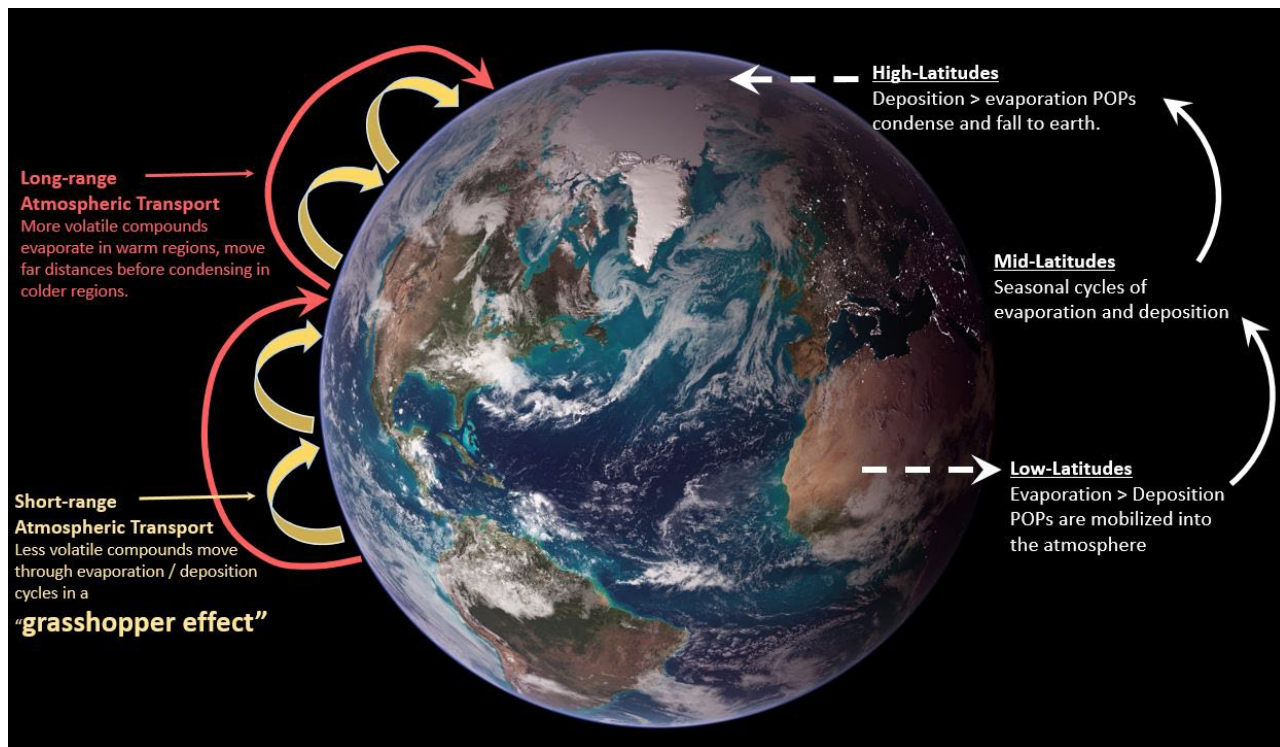
(b) Net dipole moment

Non-polar micropollutants & persistent organic pollutants (POPs)

Non-polar micropollutants & Persistent organic pollutants (POPs)

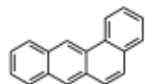
Problematic properties of certain micropollutants

- Degrade poorly in the environment (POPs)
- Have a short-term and/or long-term toxic effect
- Disperse in the environment (LRT: long range transport)
- Accumulate in food chains

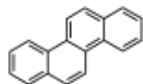


Non-polar micropollutants & Persistent organic pollutants (POPs)

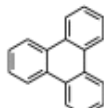
Polycyclic aromatic hydrocarbons (PAHs)



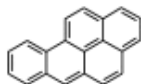
Benz[a]anthracene



Chrysene

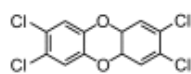


Triphenylene

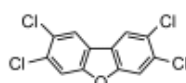


Benzo[a]pyrene

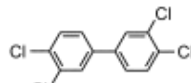
Chlorinated aromatic compounds



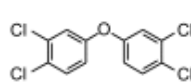
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)



2,3,7,8-Tetrachlorodibenzofuran

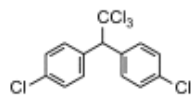


3,3',4,4'-Tetrachlorobiphenyl

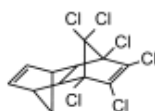


3,3',4,4'-Tetrachlorodiphenylether

Pesticides



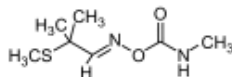
p,p'-DDT



Aldrin

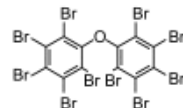


Mirex

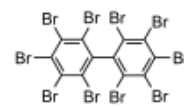


Aldicarb

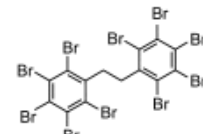
Brominated flame retardants (BFRs)



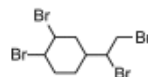
Polybrominated diphenyl ethers (PBDEs)
(decaBDE shown)



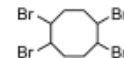
Polybrominated diphenyls (PBBs)
(decaBBD shown)



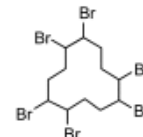
Decabromodiphenylethane (DBDPE)



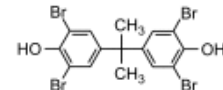
Tetrabromoethylcyclohexane
(TBECH, α , β , γ , and δ stereoisomers)



Tetrabromoethylcyclooctane
(TBCO, α , and β stereoisomers)

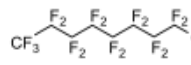


Hexabromocyclododecane
(HBCD, α , β , γ stereoisomers)

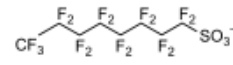


Tetrabromobisphenol A
(TBBPA)

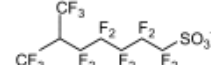
Perfluoroalkyl compounds (PFCs)



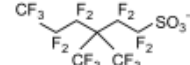
Perfluorooctanoic acid
(PFOA)



Perfluorooctane sulfonate
(PFOS)



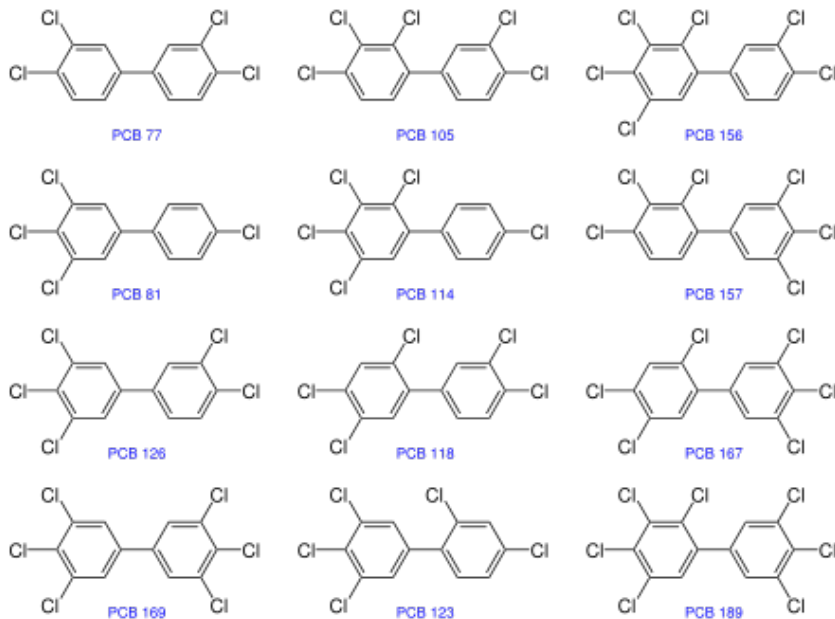
6-CF₃-PFOS



3,3-CF₃-PFOS

Non-polar micropollutants & Persistent organic pollutants (POPs)

PCBs – Polychlorinated Biphenyls



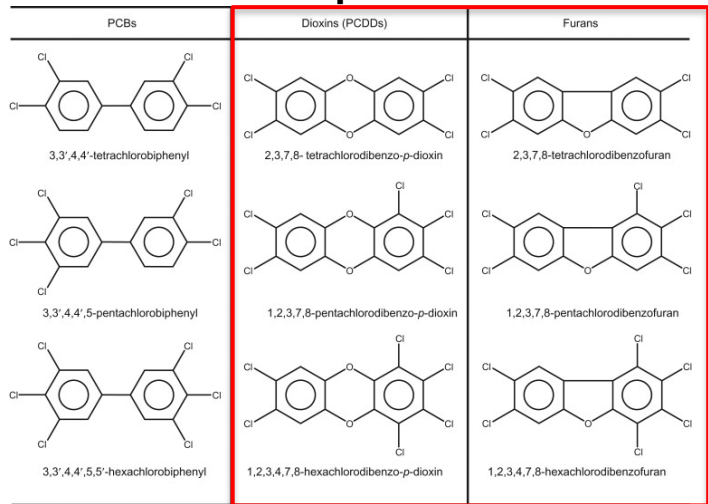
Switzerland: First regulations in 1972, ban in 1986

- Persistent organic pollutants
- 209 PCB congénères
- Fat soluble
- Classified dioxin-like PCBs as human carcinogens
- Endocrine disruptors
- Bioaccumulation



Non-polar micropollutants

Dioxins & furans pollution in Lausanne



<https://doi.org/10.1016/B978-0-12-800159-2.00019-1>

75 dioxin and 135 furan congeners

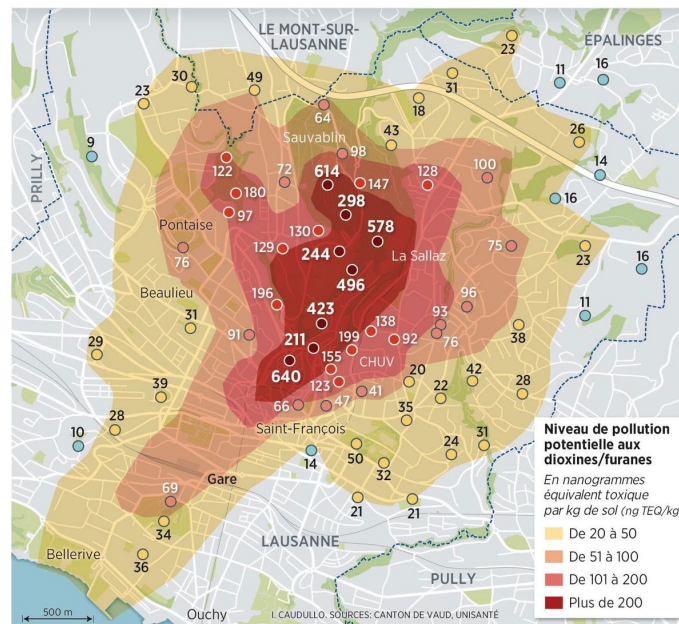
unintentionally formed pollutants

Sources: incineration, combustion, industrial...

Effects: cancer, respiratory, cardiovascular, neurological and reproductive disorders

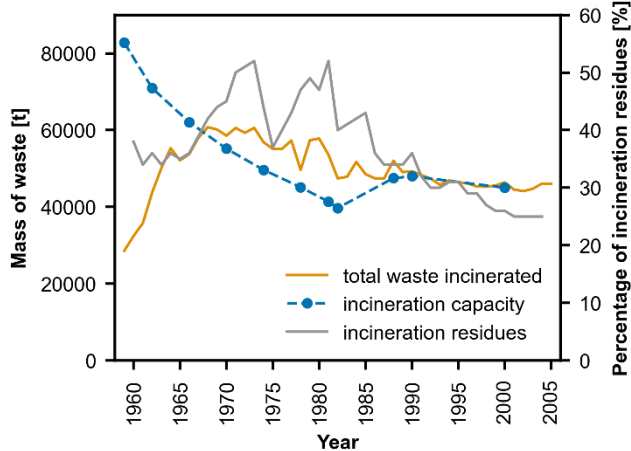
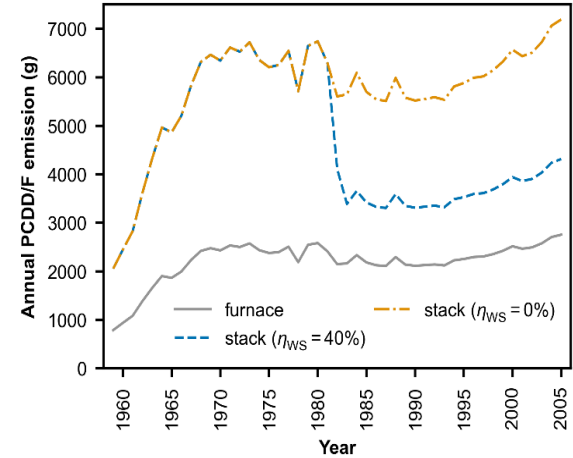
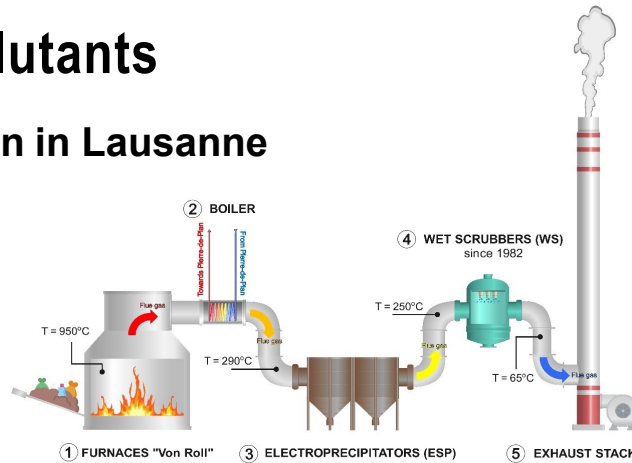


État de la pollution aux dioxines à Lausanne et dans ses environs

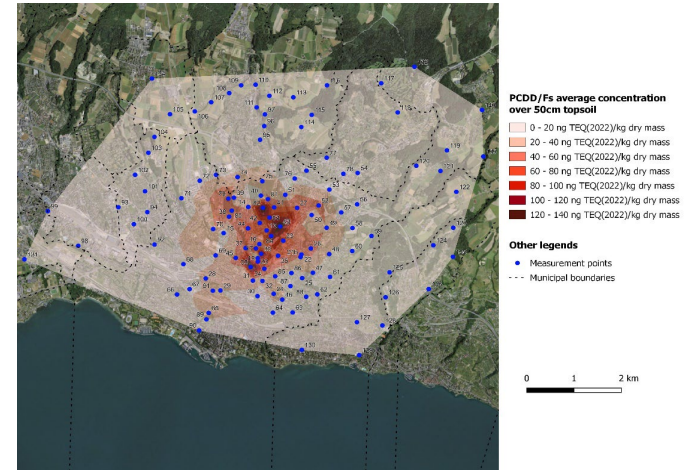


Non-polar micropollutants

Dioxins & furans pollution in Lausanne



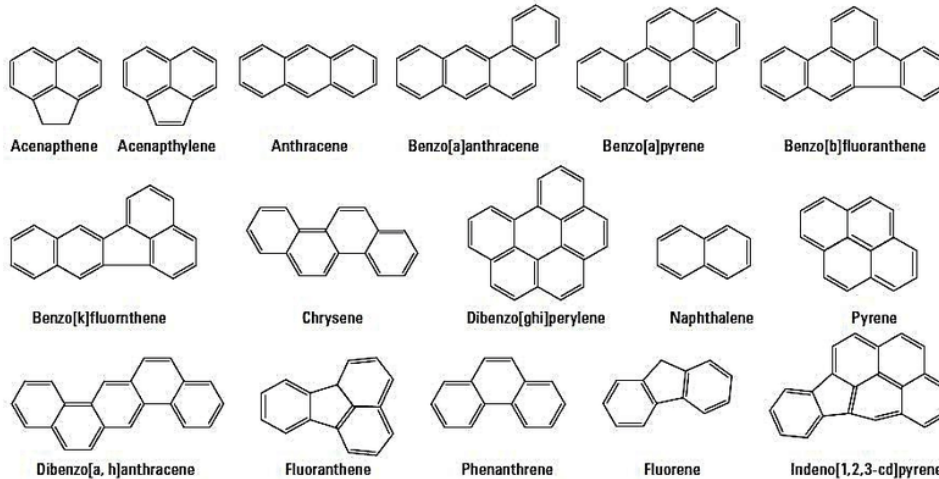
Modeling



Non-polar micropollutants

PAHs – PolyAromatic Hydrocarbons

HAP – Hydrocarbures aromatiques polycycliques



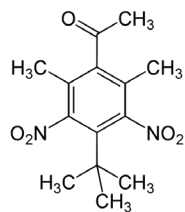
- Persistent organic pollutant
- Linked to skin, lung, bladder, liver, and stomach cancers
- Cardiovascular disease
- Developmental impacts



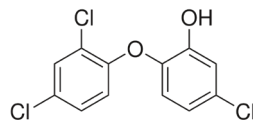
Polar micropollutants

Polar micropollutants

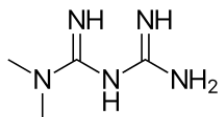
PPCP – Pharmaceutical and Personal Care Products



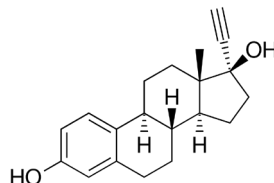
Musk ketone



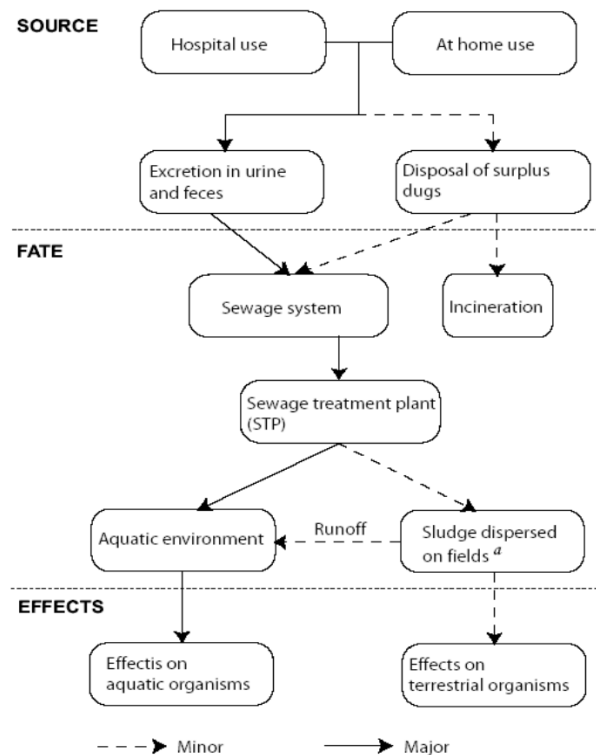
Triclosan



Metformin

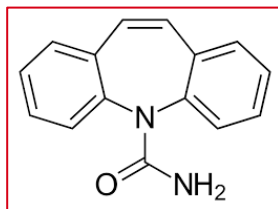


Ethinylestradiol

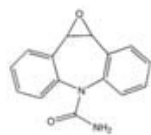


Polar micropollutants

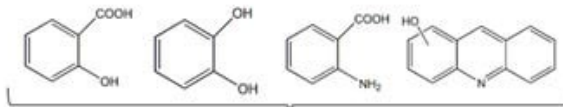
PPCP – Pharmaceutical and Personal Care Products



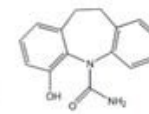
Carbamazepine an antiepileptic and a mood stabilizer, is often detected in the environment primarily through its metabolite, carbamazepine-10,11-epoxide



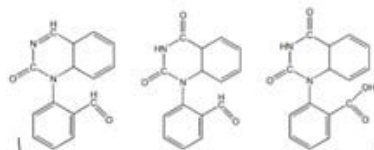
(a) Ozonation



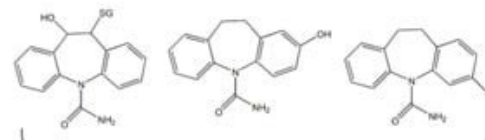
(b) UV/H₂O₂



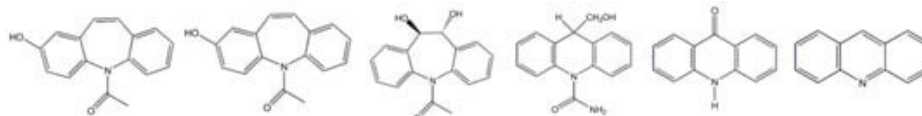
(c) Fungal degradation



(d) UV photolysis



(e) Human liver



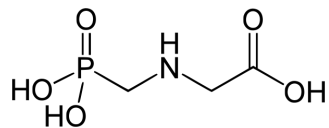
(f) Activated sludge process

Polar micropollutants

Agrochemical substances



Glyphosate (herbicide)



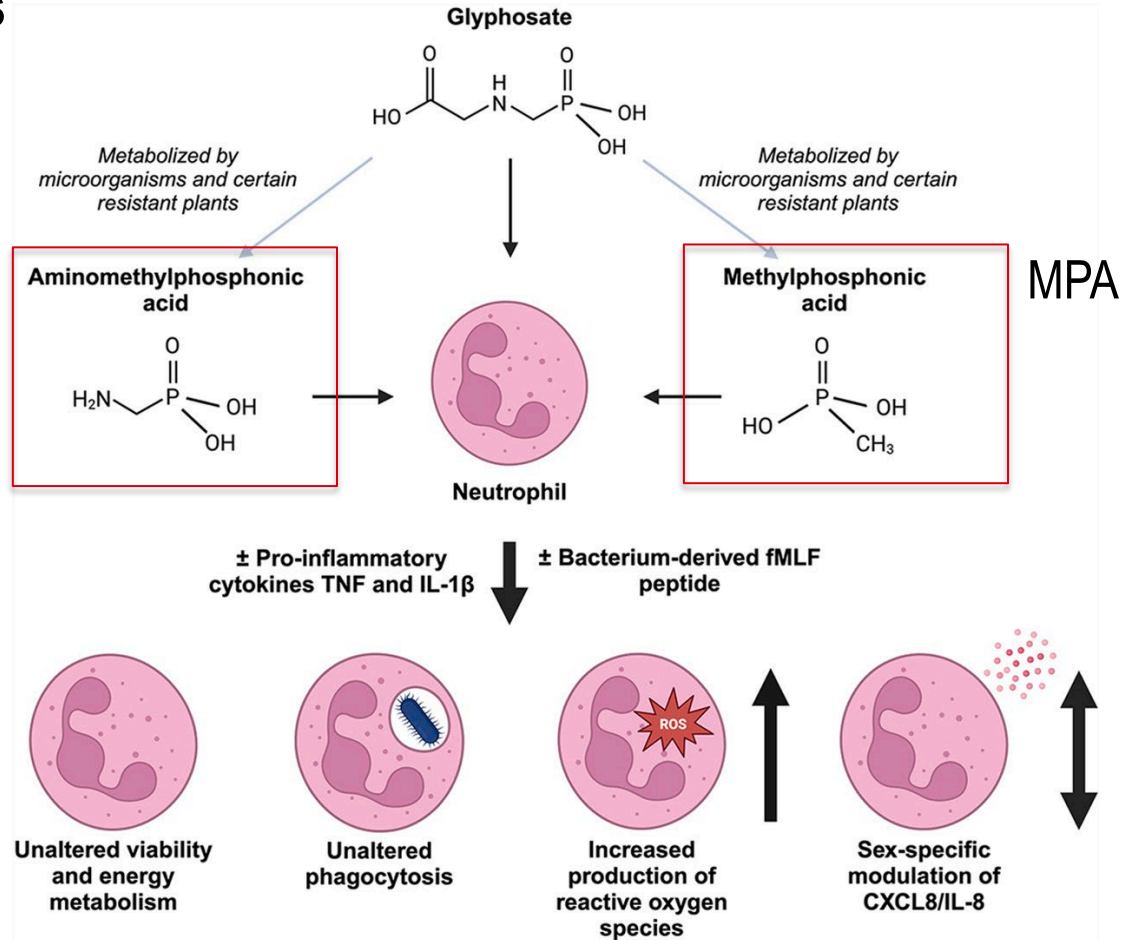
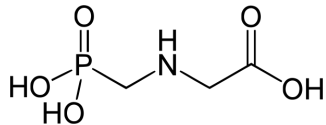
Polar micropollutants

Agrochemical substances



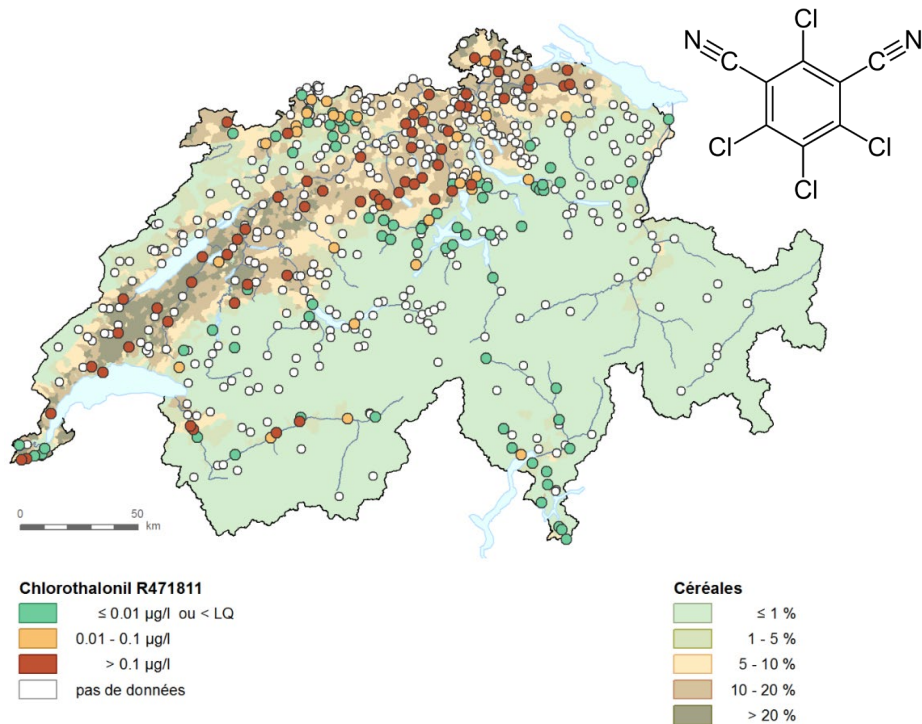
AMPA

Glyphosate (herbicide)



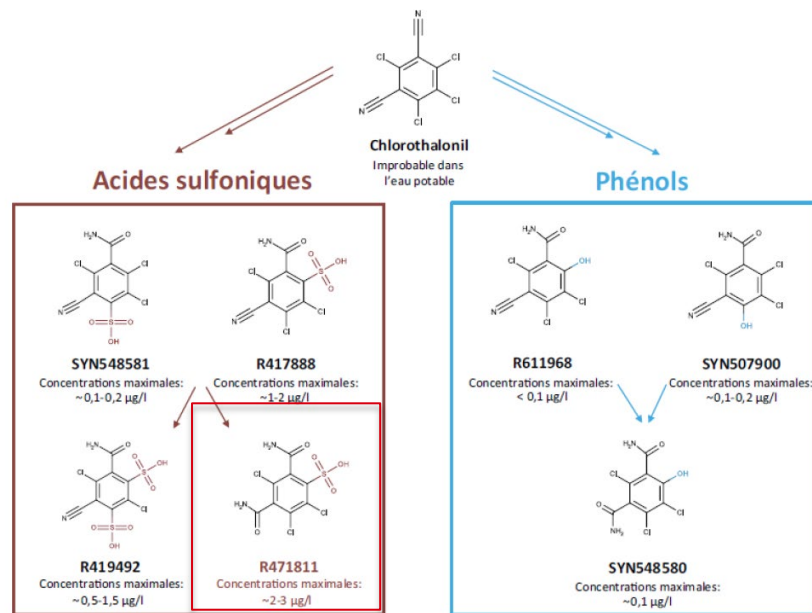
Polar micropollutants

Agrochemical substances

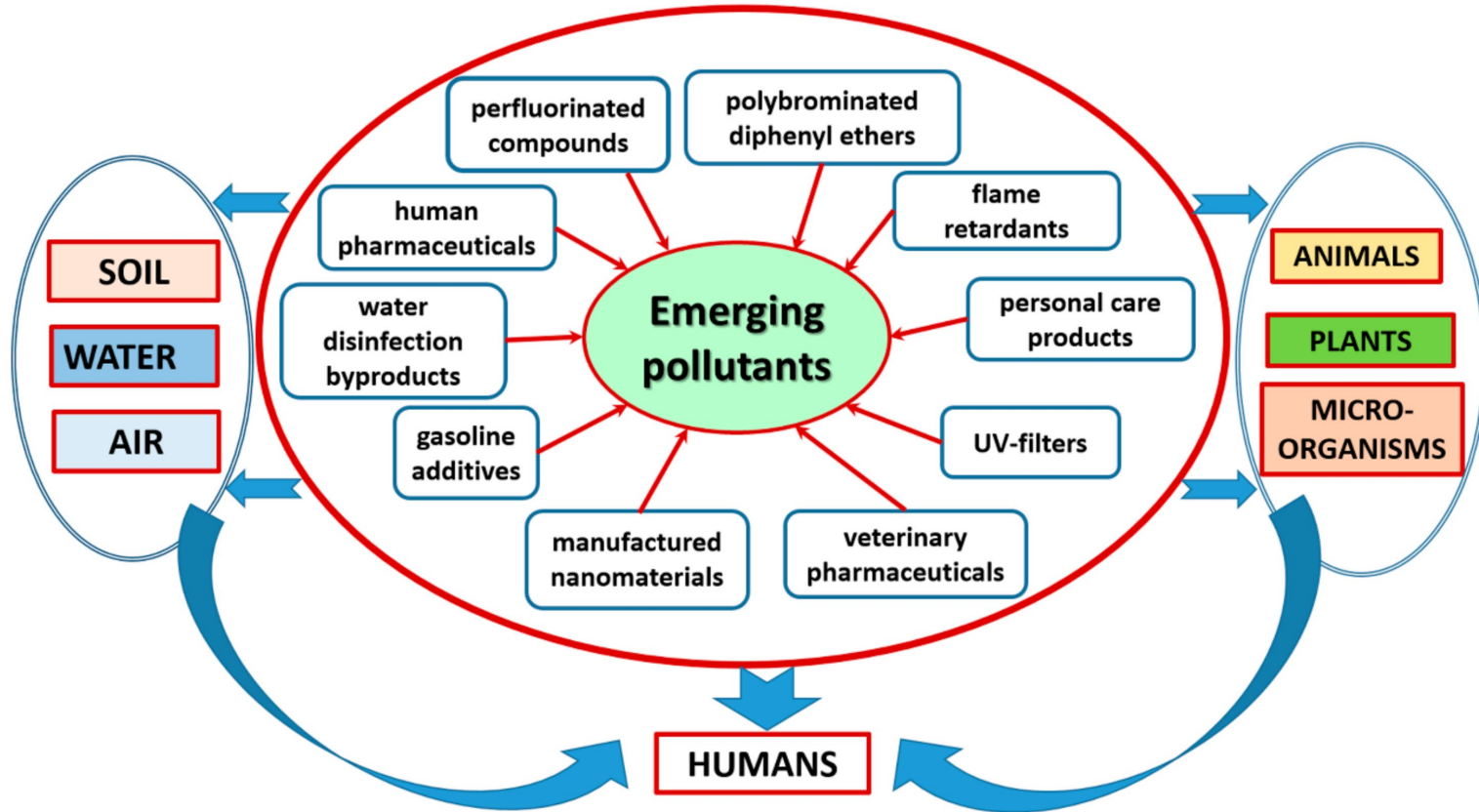


Chlorothalonil was registered by the Federal Office for Agriculture (FOAG) in the 1970s. It was used on cereals, vegetables, potatoes, vines and ornamental plants to combat diseases such as mildew

Chlorothalonil (fongicide)
probable carcinogen



Emerging micropollutants



Emerging micropollutants

Quaternary ammonium compounds (QACs)

QAC Exposure From Products to Our Bodies

PRODUCTS:

Cleaners, Disinfectants, Personal Care, Furniture, Clothing, & more



HUMAN EXPOSURE:

Ingestion, Inhalation, Dermal Absorption



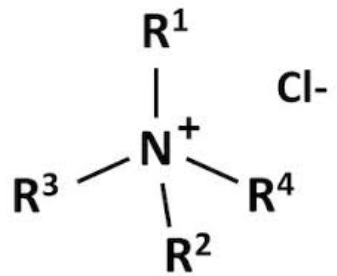
USED IN:

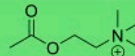
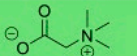
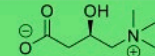
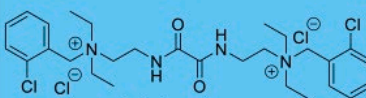
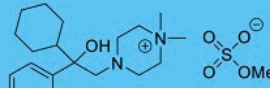
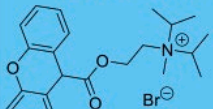
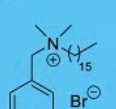
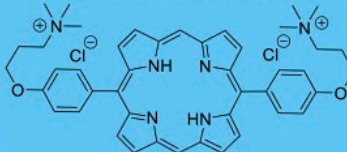
Homes, Offices, Schools, Hospitals, Food Service, etc.



ENVIRONMENT:

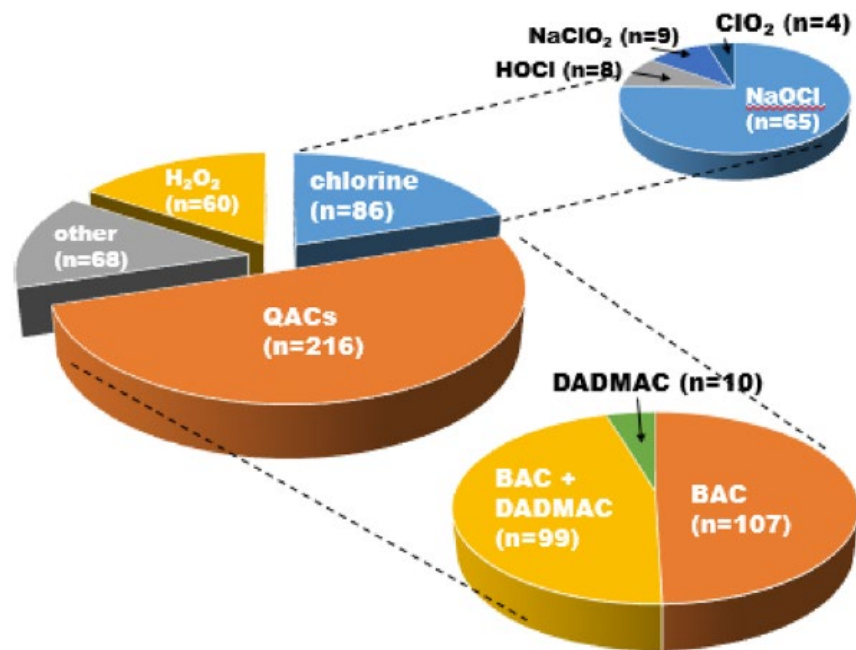
Wastewater, Biosolids, Water, Soil, Sediments, Food



 1: Acetylcholine <i>Applied in cataract surgery, enetrating keratoplasty and iridectomy</i>	 2: Betaine <i>The treatment of homocystinuria</i>	 3: Levocarnitine <i>Applied in carnitine deficiency or hyperlipoproteinemia</i>
 4: Ambenonium <i>The treatment of myasthenia gravis</i>	 5: Hexocyclium methylsulfate <i>The treatment of gastric ulcer or diarrhea</i>	
 6: Propantheline bromide <i>Applied in urinary incontinence, hyperhidrosis</i>	 7: Cetalkonium bromide <i>A preservative or to treat certain topical infections</i>	 8: Exeporfinium chloride (XF-73) <i>Anti-microbial drugs (Phase II ongoing)</i>

QAC exposure routes from products and other sources, via pathways indoors and outdoors.

Emerging micropollutants



Quaternary ammonium compounds (QACs)

pubs.acs.org/journal/estlcv

Review

Increased Use of Quaternary Ammonium Compounds during the SARS-CoV-2 Pandemic and Beyond: Consideration of Environmental Implications

Priya I. Hora, Sarah G. Pati, Patrick J. McNamara, and William A. Arnold*

Cite This: *Environ. Sci. Technol. Lett.* 2020, 7, 622–631

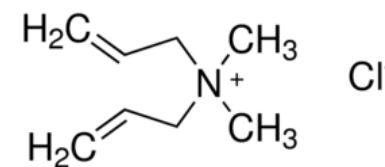
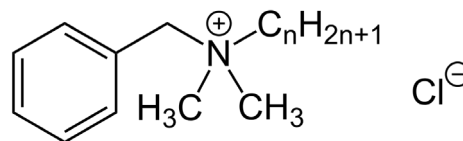
Read Online

ACCESS |

Metrics & More

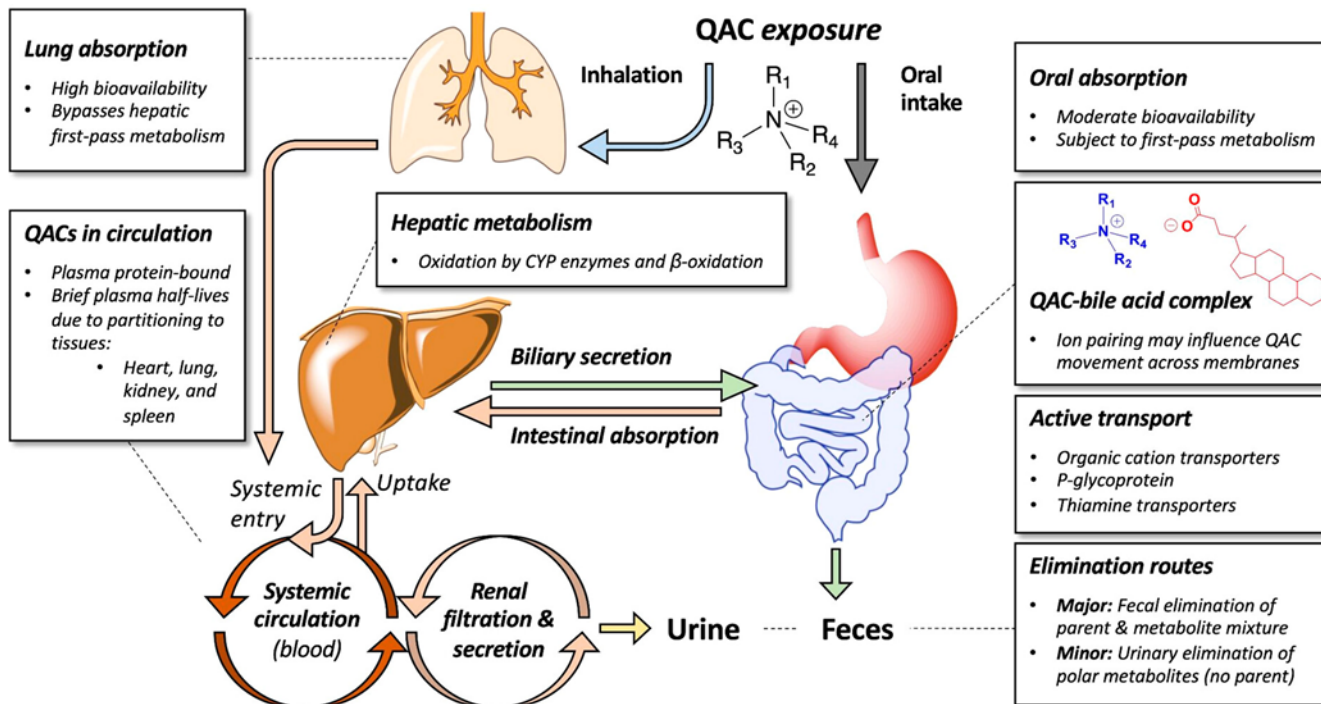
Article Recommendations

ABSTRACT: Quaternary ammonium compounds (QACs) are active ingredients in over 200 disinfectants currently recommended by the U.S. EPA for use to inactivate the SARS-CoV-2 (COVID-19) virus. The amounts of these compounds used in household, workplace, and industry settings has very likely increased, and usage will continue to be elevated given the scope of the pandemic. QACs have been previously detected in wastewater, surface waters, and sediments, and effects on antibiotic resistance have been explored. Thus, it is important to assess potential environmental and engineering impacts of elevated QAC usage, which may include disruption of wastewater treatment unit operations, proliferation of antibiotic resistance, formation of nitrosamine disinfection byproducts, and impacts on biota in surface waters. The threat caused by COVID-19 is clear, and a reasonable response is elevated use of QACs to mitigate spread of infection. Exploration of potential effects, environmental fate, and technologies to minimize environmental releases of QACs, however, is warranted.



n = 8, 10, 12, 14, 16, 18

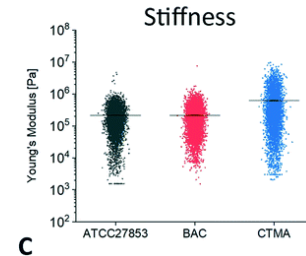
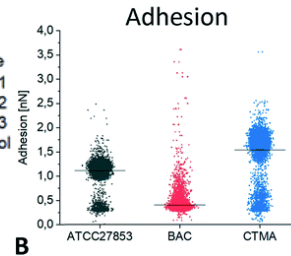
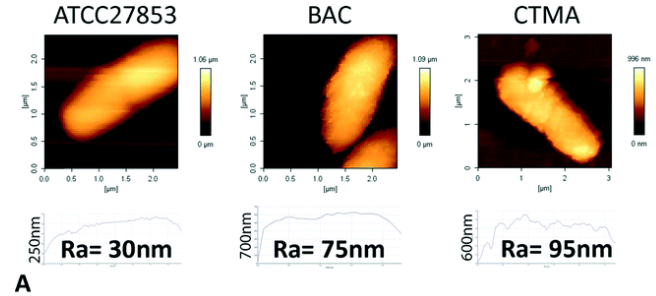
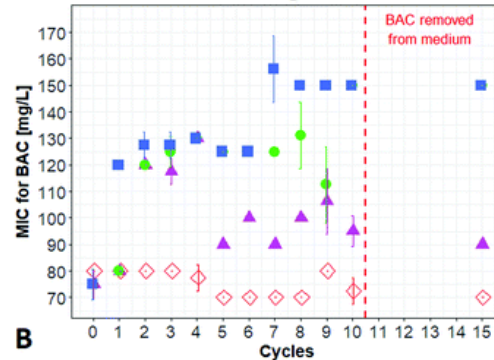
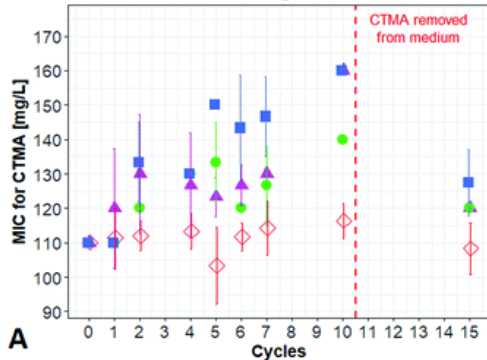
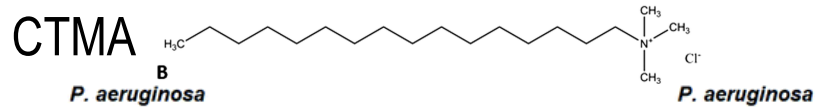
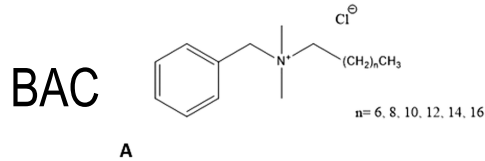
Emerging micropollutants



Proposed ADME routes for QACs based on in vitro and in vivo data on some subgroups of QACs in humans and animals.

Emerging micropollutants

Development of bacterial resistance to QACs and antibiotics



A constant exposure to 88% of the minimum inhibitory concentration (MIC) of benzalkonium chloride (BAC) led to an increase of the MIC of *P. aeruginosa*

Voumard et al. 2020

Emerging micropollutants

Environmental
Science
Processes & Impacts



COMMUNICATION

View Article Online
View Journal | View Issue



High-throughput wastewater analysis for substance use assessment in central New York during the COVID-19 pandemic

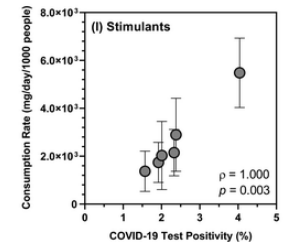
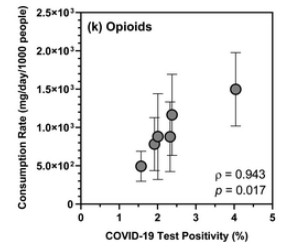
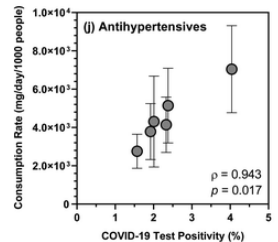
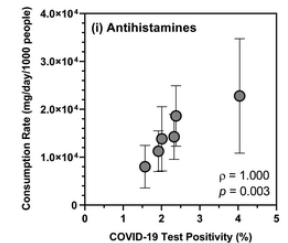
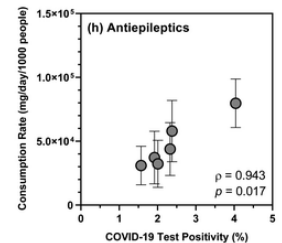
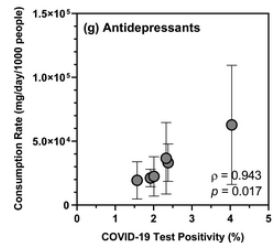
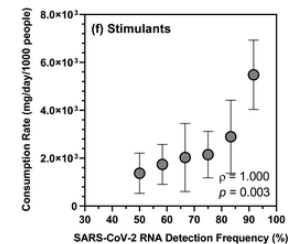
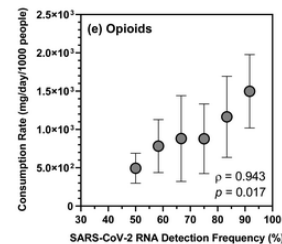
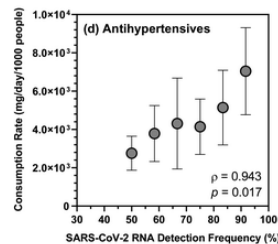
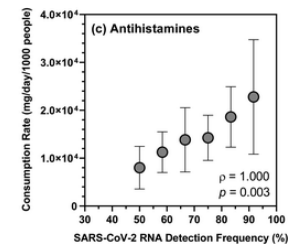
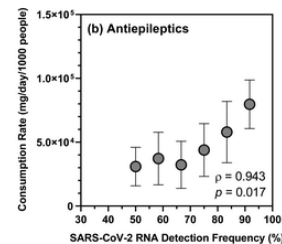
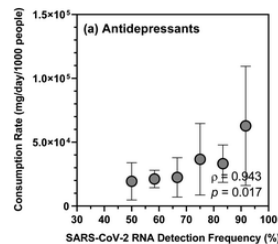
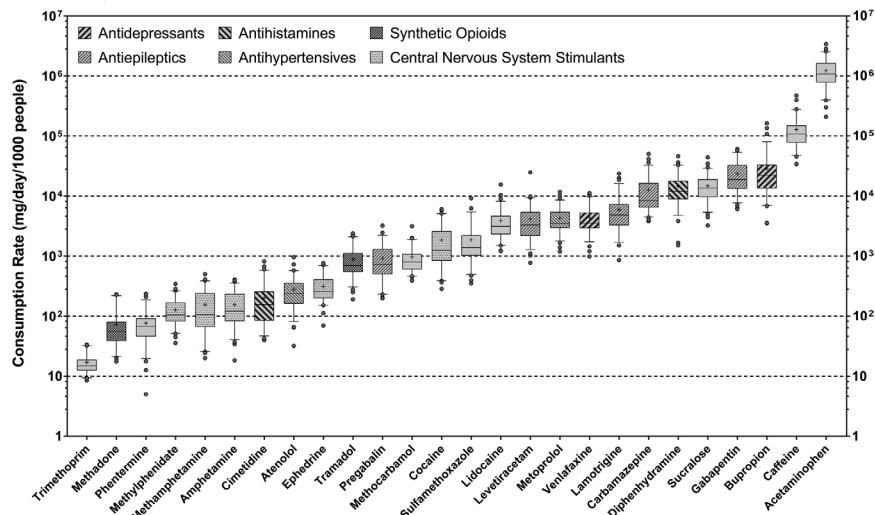
Shiru Wang,^a Hyatt C. Green,^b Maxwell L. Wilder,^b Qian Du,^c Brittany L. Kmush,^d Mary B. Collins,^a David A. Larsen^d and Teng Zeng^{a,*}

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rsc.li/epsi



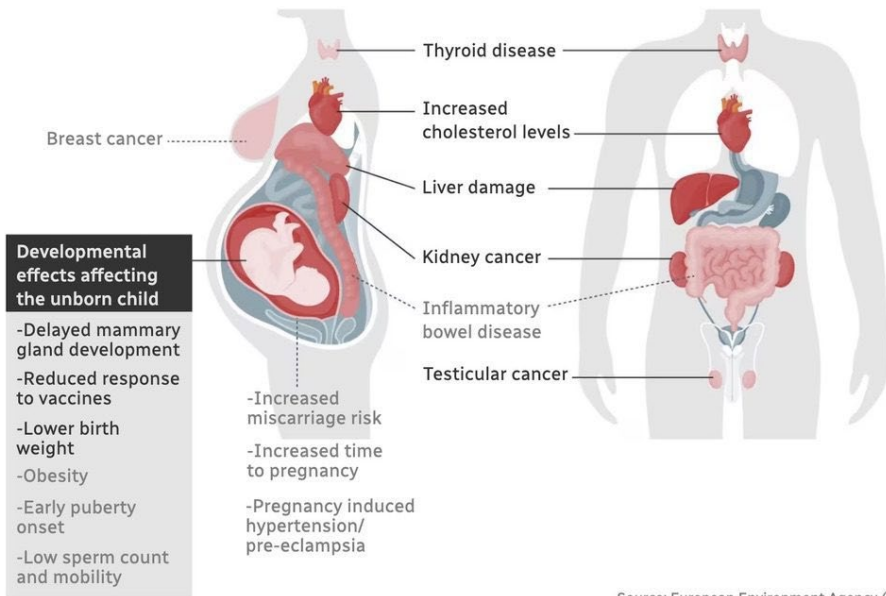
Emerging micropollutants

Per- and polyfluoroalkyl substances (PFAS)

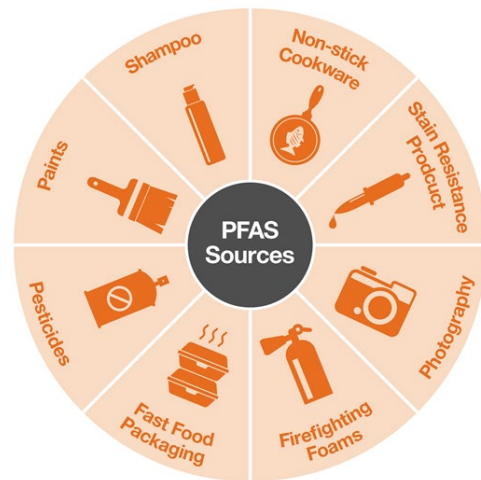
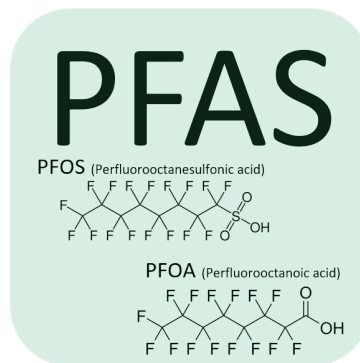
How per- and polyfluoroalkyl substances (PFAS) affect human health

PFAS are commonly used, long-lived chemicals; some are known to be toxic

—— High certainty Lower certainty



Source: European Environment Agency (CBC)



Emerging micropollutants

Per- and polyfluoroalkyl substances (PFAS)

Banks et al., 1994 Perfluoro, Perfluorinated

Kyoto Protocol, 1997 PFC's = Perfluorocarbons (C_nF_{2n+2})

Hekster and Voogt, 2002;
Hekster et al., 2003 Perfluoroalkylated Substances

n = 982 OECD 2007 Lists of PFOS, PFAS, PFOA, PFCA Related Compounds and Chemicals that Degrade to PFCAs

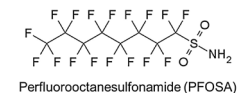
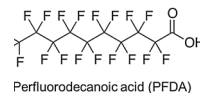
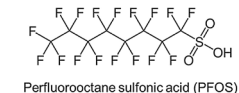
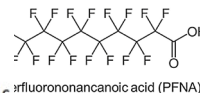
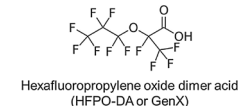
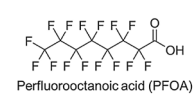
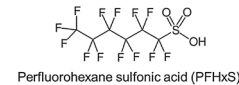
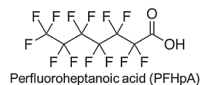
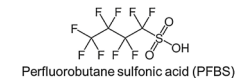
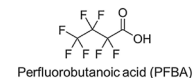
Buck, 2011

n = 4,730 OECD 2018 PFAS: $-C_nF_{2n}-$ where $n \geq 3$ and $(-C_nF_{2n}OC_mF_{2m}-, n \text{ and } m \geq 1)$

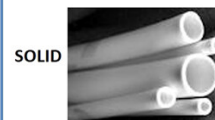
ITRC 2018 PFAS: $C_nF_{2n+1}-R$ where $n > 2$

n = > 8,000 ECHA, 2020 PFAS: all substances with $-CF_3$ or $-CF_2-$

Integr Envir Assess & Manag, Volume: 17, Issue: 5, Pages: 1045-1055, First published: 14 May 2021, DOI: (10.1002/ieam.4450)



Fluorocarbons, C-F Substances Also, A Big Universe of Very Different Substances



SOLID
Polytetrafluoroethylene
PTFE, $F(CF_2CF_2)_nF$
A Fluoropolymer

LIQUID
6:2 Fluorotelomer Alcohol
 $C_6F_{13}CH_2CH_2OH$



GAS
HFC-134a
 CF_3CH_2F
A Refrigerant

We should not group these together, because they are not the same.

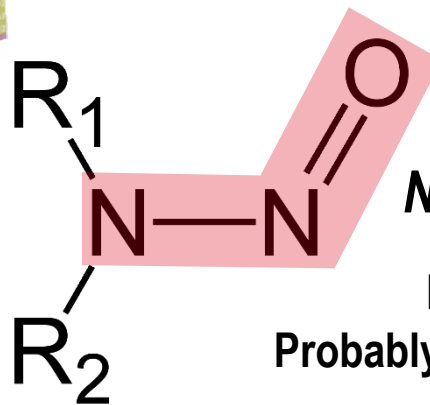
Emerging micropollutants



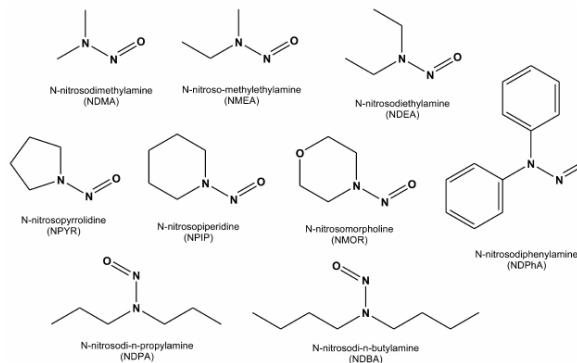
International Agency
Research on Cancer



World Health
Organization

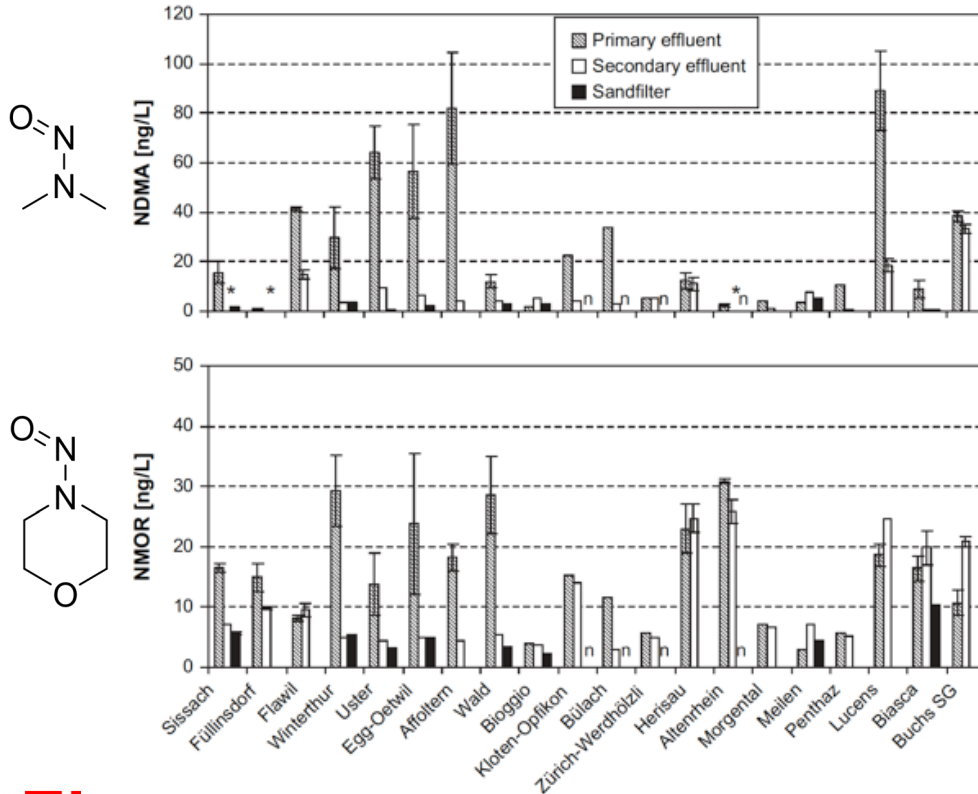


Highly mutagenic
Probably carcinogenic to humans

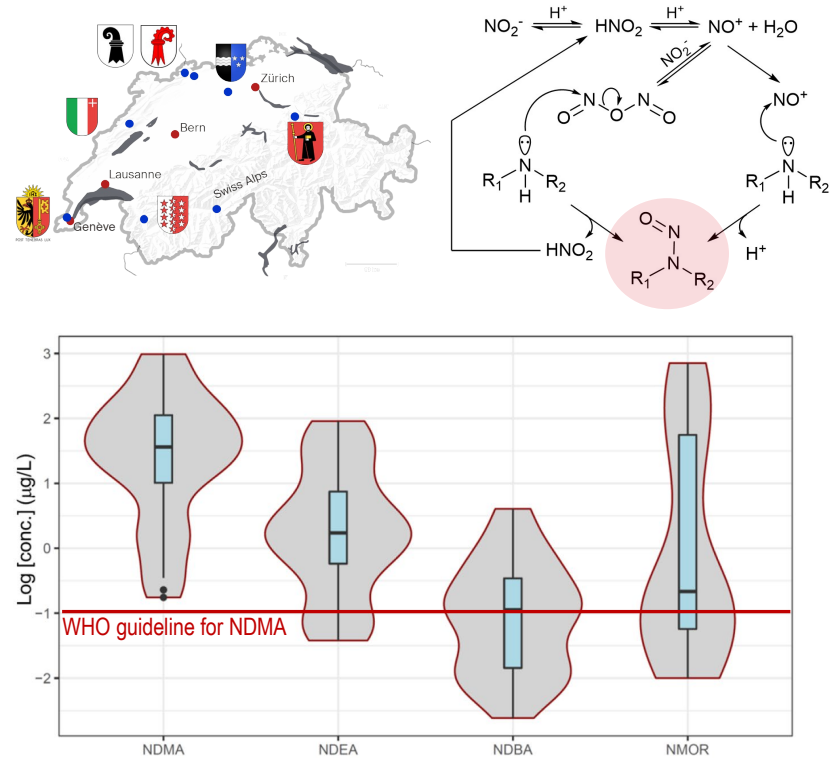


Emerging micropollutants

N-nitrosamines in **municipal** wastewater



N-nitrosamines in **industrial** wastewater



Emerging micropollutants

Plastic Pollution

Macro/meso-plastics >5mm

Microplastics <5mm – 1 μ m

Nanoplastics <1 μ m – 1nm

Primary Microplastics

Primary microplastics are small pieces of plastic that are purposefully made.

Secondary microplastics

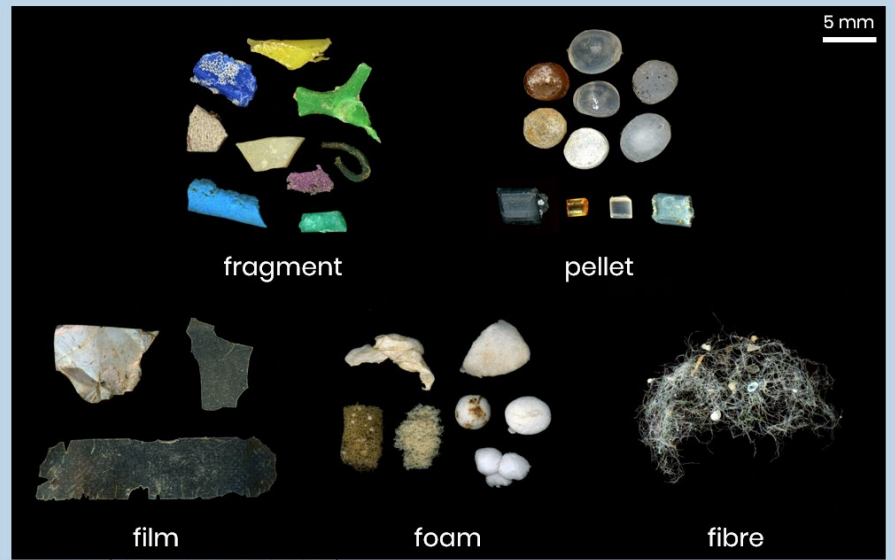
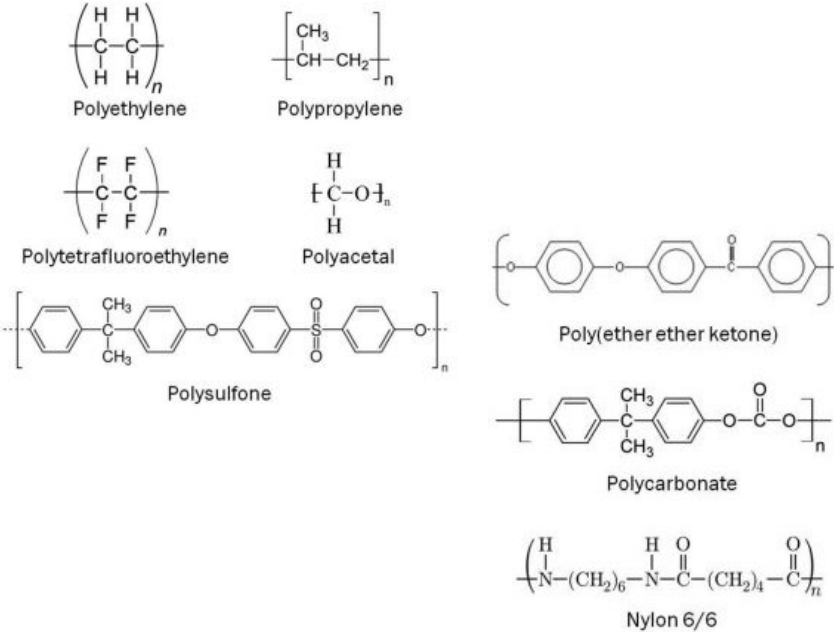
Secondary plastics are small pieces of plastic derived from the decomposition of large pieces of plastic debris, both in water and on land.



Emerging micropollutants

Plastic Pollution

Different shapes, sizes, polymers (also copolymers), colors, additives, texture density...



Alexander Kunz (Microplastic Research in Taiwan)

Emerging micropollutants

Plastic additives

Intentional additives

Added during manufacturing processes:
~10,550 chemicals possibly used.
(4,300 just for packaging)

Family: plasticizers, solvents, antioxidants, biocides, dyes, flame retardants, light stabilizers, fragrances, etc.

Provide additional properties to polymers (shape, longevity, color, gloss).

Little or no toxicological data and little regulation.

Unintentional contaminants

Degradation products or by-products during
Manufacturing processes

Deep Dive into Plastic Monomers, Additives, and Processing Aids

Helene Wiesinger,* Zhanyun Wang* and Stefanie Hellweg

Cite This: *Environ. Sci. Technol.* 2021, 55, 9339–9351

Read Online

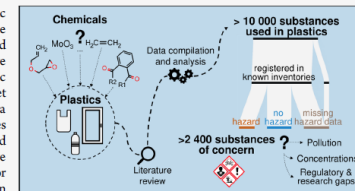
ACCESS |

Metrics & More

Article Recommendations

Supporting Information

ABSTRACT: A variety of chemical substances used in plastic production may be released throughout the entire life cycle of the plastic, posing risks to human health, the environment, and recycling systems. Only a limited number of these substances have been widely studied. We systematically investigate plastic monomers, additives, and processing aids on the global market based on a review of 63 industrial, scientific, and regulatory data sources. In total, we identify more than 10'000 relevant substances and categorize them based on substance types, use patterns, and hazard classifications wherever possible. Over 2'400 substances are identified as substances of potential concern as they meet one or more of the persistence, bioaccumulation, and toxicity criteria in the European Union. Many of these substances are hardly studied according to SciFinder (266 substances), are not adequately regulated in many parts of the world (1'327 substances), or are even approved for use in food-contact plastics in some jurisdictions (901 substances). Substantial information gaps exist in the public domain, and this review aims to address these gaps.



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Review

Overview of known plastic packaging-associated chemicals and their hazards



Ksenia J. Groh^{a,*}, Thomas Backhaus^b, Bethanie Carney-Almroth^b, Birgit Geueke^a, Pedro A. Inostroza^b, Anna Lennquist^c, Heather A. Leslie^d, Maricel Maffini^e, Daniel Slunge^f, Leonardo Trasande^g, A. Michael Warhurst^h, Jane Muncke^a

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^e Independent Consultant, Germantown, MD, USA

^f Centre for Sustainable Development (GMV), University of Gothenburg, Gothenburg, Sweden

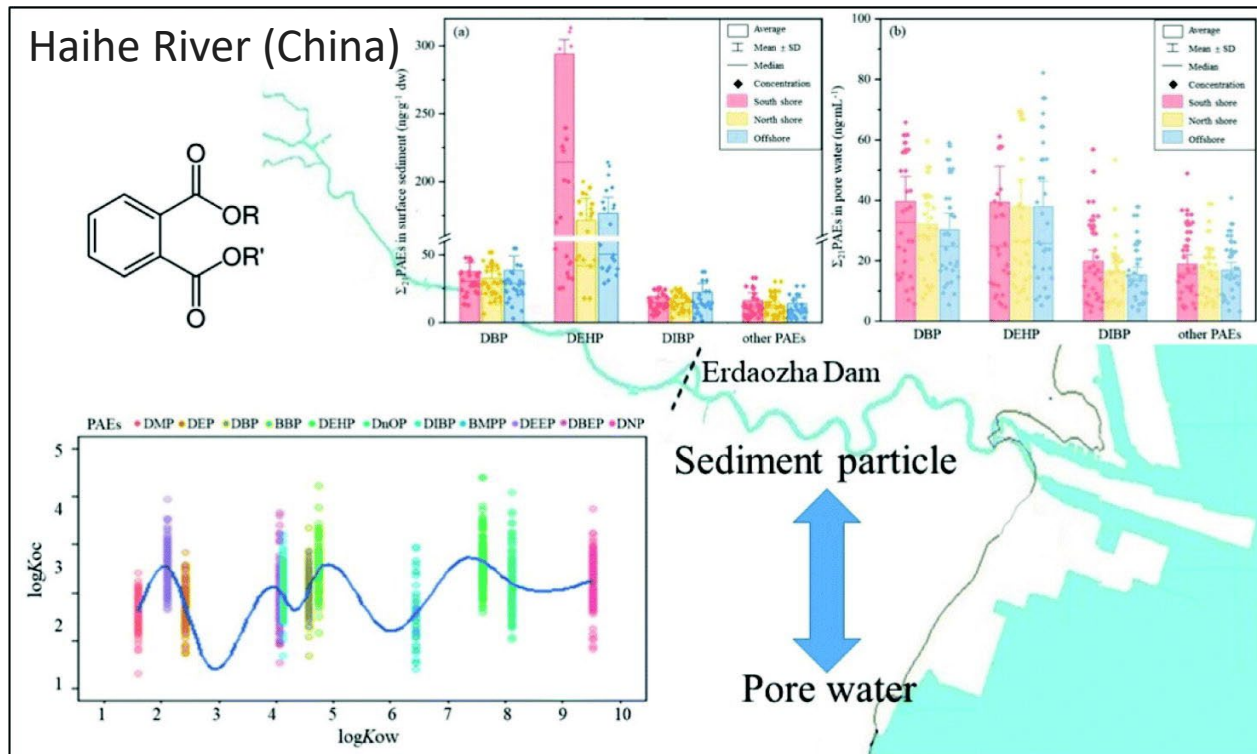
^g School of Medicine, New York University, New York, USA

^h CHEM Trust, London, United Kingdom

Emerging micropollutants

Plastic additives

Phthalate esters (PAEs) are a group of chemicals used to improve the flexibility and durability of plastics.



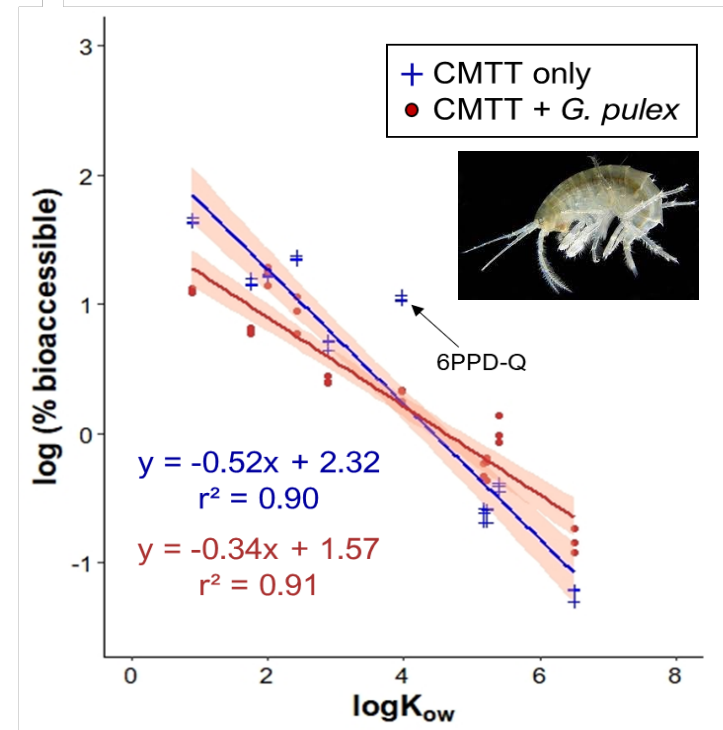
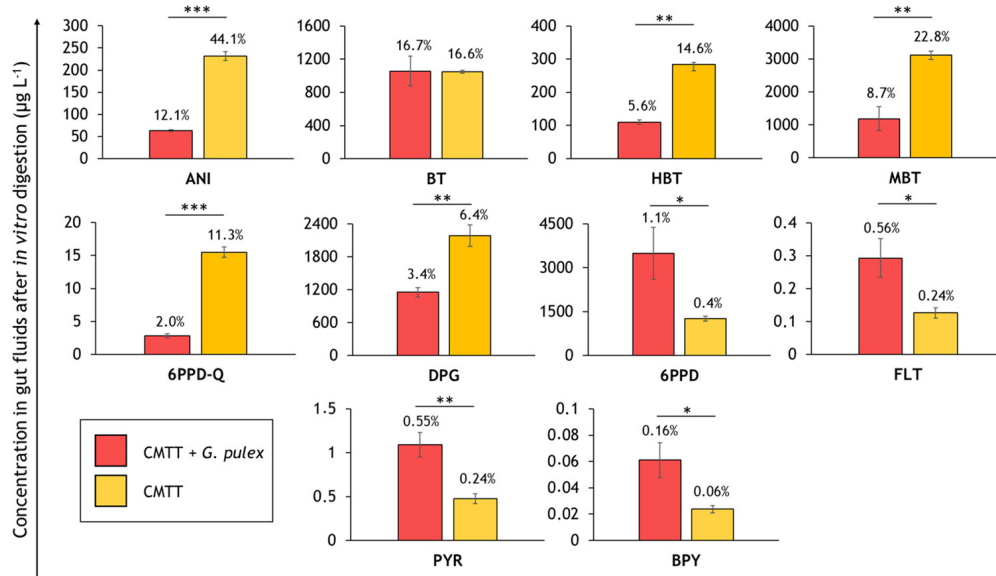
DEHP, DBP, and DIBP were the dominant species in surface sediment and pore water.

Notable differences in PAEs concentrations were observed between urban reaches and non-urban reaches.

Partitioning of PAEs between surface sediment and pore water was not significantly affected by K_{OW} .

Emerging micropollutants

Rubber materials & Tire Particles



Masset et al. (2022)

International treaties and conventions on pollutants

International treaties and conventions

Stockholm Convention on Persistent Organic Pollutants



Adopted on 22.05.2001, entered into force in May 2004, ratified by 150 countries in February 2008

Persistent organic pollutants (POPs) are organic compounds that are toxic and are not readily degradable.

The initial 12 POPs of the Stockholm Convention

Initially, twelve POPs were recognized as causing adverse effects on humans and the ecosystem.

Chemical	Pesticides	Industrial chemicals	By-products
Aldrin	+		
Chlordane	+		
DDT	+		
Dieldrin	+		
Endrin	+		
Heptachlor	+		
Mirex	+		
Toxaphene	+		
Hexachlorobenzene		+	+
Polychlorinated Biphenyls (PCBs)		+	+
Chlorinated Dioxins			+
Chlorinated Furans			+

International treaties and conventions

Stockholm Convention on Persistent Organic Pollutants



Adopted on 22.05.2001, entered into force in May 2004, ratified by 150 countries in February 2008

Persistent organic pollutants (POPs) are organic compounds that are toxic and are not readily degradable.

Bans and restrictions on the manufacture and use of the following commercial products

Annex A: Elimination

- Aldrin
- Alpha-hexachlorocyclohexane
- Beta-hexachlorocyclohexane
- Chlordane
- Chlordecone
-

Annex B: Restriction

- DDT
- Perfluorooctane sulfonic acid (PFOS), its salts and perfluorooctane sulfonyl fluoride

The unintentional production of the following substances, which for example may occur and be released in the course of incineration processes, should be minimised or eliminated wherever possible:

- Hexachlorobenzene
- Hexachlorobutadiene
- Pentachlorobenzene
- Polychlorinated biphenyls (PCBs)
- Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs)
- Polychlorinated naphthalenes

International treaties and conventions

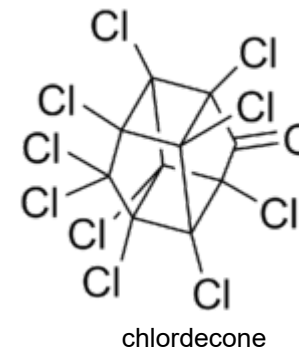
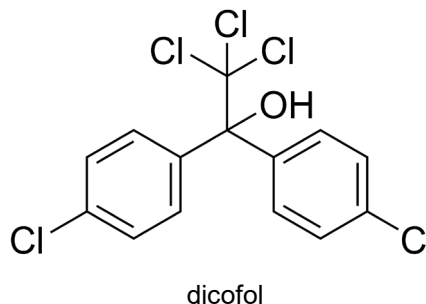
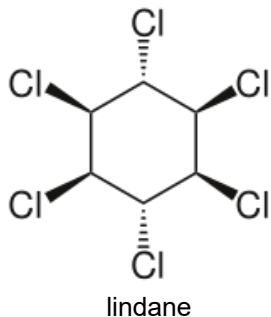
Stockholm Convention on Persistent Organic Pollutants

Adopted on 22.05.2001, entered into force in May 2004, ratified by 150 countries in February 2008

Persistent organic pollutants (POPs) are organic compounds that are toxic and are not readily degradable.

The new POPs of the Stockholm Convention

a-hexachlorocyclohexane, b-hexachlorocyclohexane, chlordane, dicofol, lindane, PFOA, PFOS, polychlorinated naphthalenes, short-chain chlorinated paraffins (SCCPs)...



International treaties and conventions

Stockholm Convention on Persistent Organic Pollutants



**Basel Convention on the Control of Transboundary Movements
of Hazardous Wastes and their Disposal**

**Rotterdam Convention on the prior informed consent
procedure for certain hazardous chemicals and
pesticides in international trade**

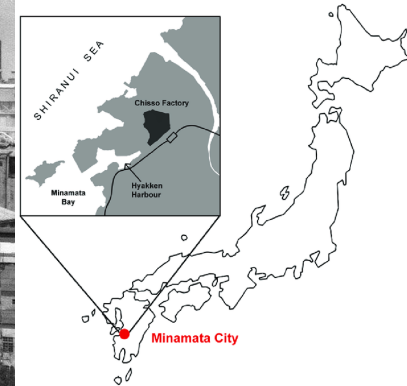
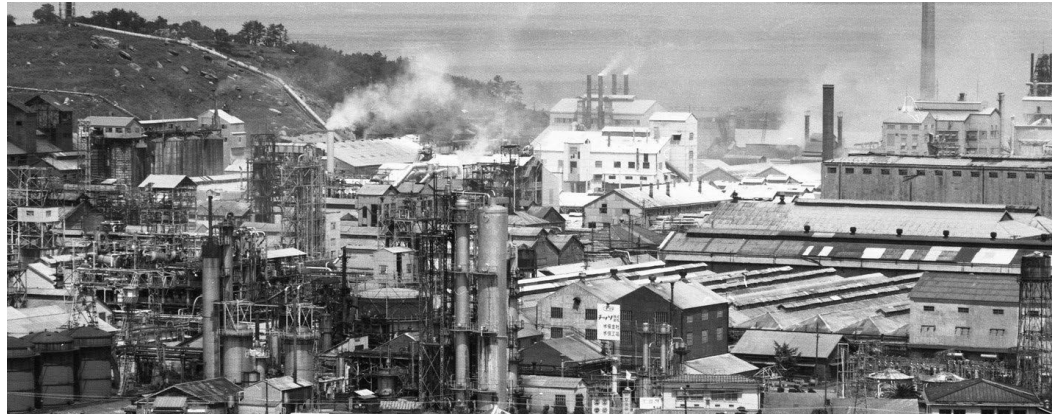


**BASEL
CONVENTION**



**ROTTERDAM
CONVENTION**

International treaties and conventions



Minamata disease was first discovered in the city of Minamata, (Japan) in 1956, hence its name. It was caused by the release of **methylmercury** in the industrial wastewater from a chemical factory owned by the Chisso Corporation, which continued from 1932 to 1968.

International treaties and conventions



MINAMATA CONVENTION ON MERCURY



Operational provisions describing the obligations for Parties to reduce anthropogenic emissions and **releases of mercury and mercury compounds** to the environment, with controls on all their lifecycle stages:

- Controls on mercury supply sources and trade (Article 3)
- Phase-out and phase-down of mercury use in products and processes (Articles 4, 5 and 6, Annexes A and B)
- Controls on artisanal and small scale gold mining where mercury is used (Article 7, Annex C)
- Controls on air emissions and releases to land and water (Articles 8 and 9, Annex D)
- Storage, waste and contaminated sites (Articles 10, 11 and 12)

International treaties and conventions

UN Global Plastics Treaty

End Plastic Pollution: Looking forward



International treaties and conventions

UN Global Plastics Treaty

Some key points the treaty may include are:

- Determining where the life cycle of plastic production begins, and potentially capping primary plastic polymer production.
- The "Zero Draft" of the plastics treaty aims to promote better the sustainable production of plastics for packaging through product design and environmentally sound waste management
- The treaty may aim to advance national and international cooperative plastic reduction measures aimed at pollution in marine environments.
- Specifying national reporting to the INC, when appropriate, and assessing the progress and effectiveness of the agreement.
- Initiating a multi-stakeholder action agenda, including the private sector, to promote cooperation at the local, national, regional and global levels.
- The treaty may aim to specify arrangements for capacity-building and technical assistance, mutually agreed technology transfer terms and financial assistance.

These are key points that may not be in the finalized treaty, however, are areas of interest in the negotiation process.

Thank you for your
attention

