For our Environment

Stockholm Water Week 2017

Contaminants of Emerging Concern and Water Reuse – Approaches to Risk Management and Regulation

Christoph Schulte & Manuela Helmecke

Department II 2 “Water and Soil“
Federal Environment Agency (UBA)
Germany

Example Per- and Polyfluoroalkyl Substances (PFAS)

Source: (1) Jürgen Fälchle (2) Norman Chan, (3) industrieblick, (4) Stillfx, (5) Luisa Leal, (6) Kzeno, (7) demarco, (8) Tobilander/Fotolia.com

PFAS - Main concerns

- Environmental persistence
- Findings and distribution in surface water
  - one source: waste water
- Long-range transport and findings in remote areas
- Findings and accumulation in food webs and top predators
- Uptake in plants (wheat, maize, vegetables) and enrichment in edible parts
- Findings in food and drinking water
- Occurrence in blood samples and breast milk of the general population (and long elimination half life)
- Toxicological profile (e.g. PFOA Reprotoxic Cat. 1 B)

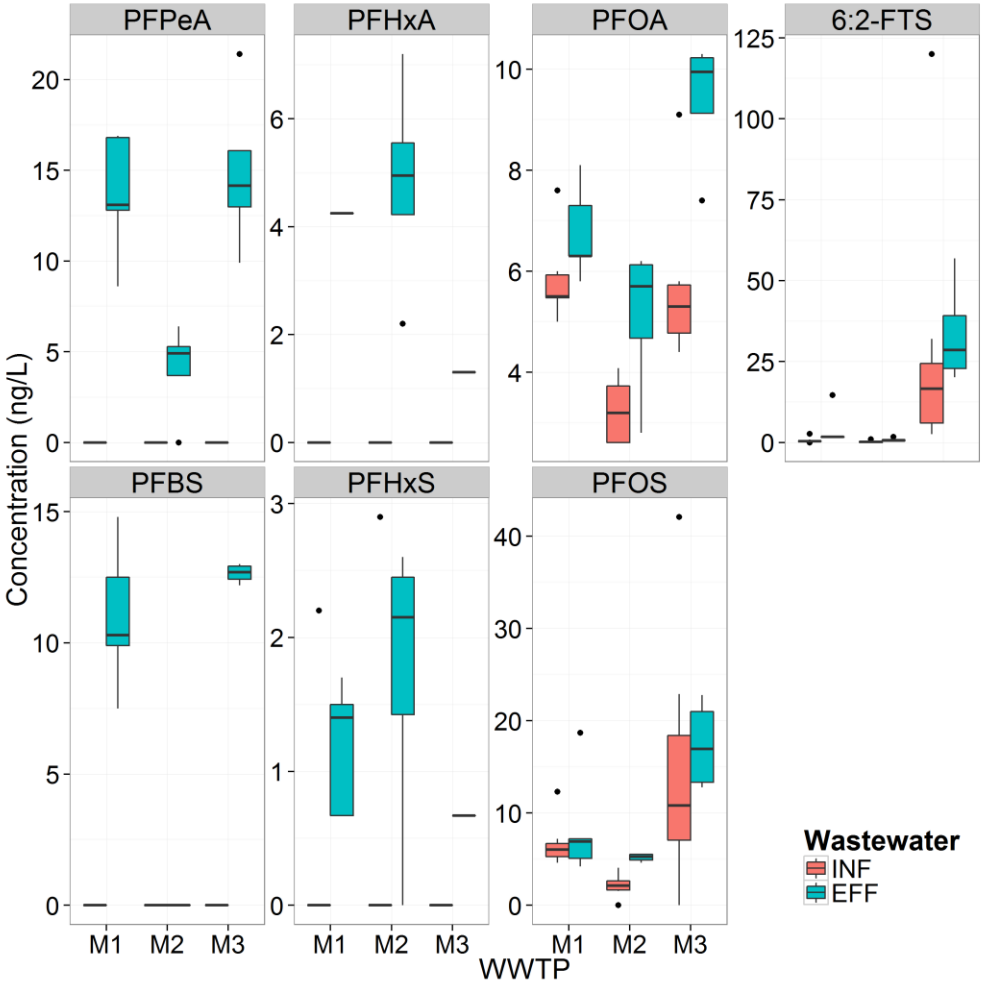
Fotolia_942152

Fotolia_2770439

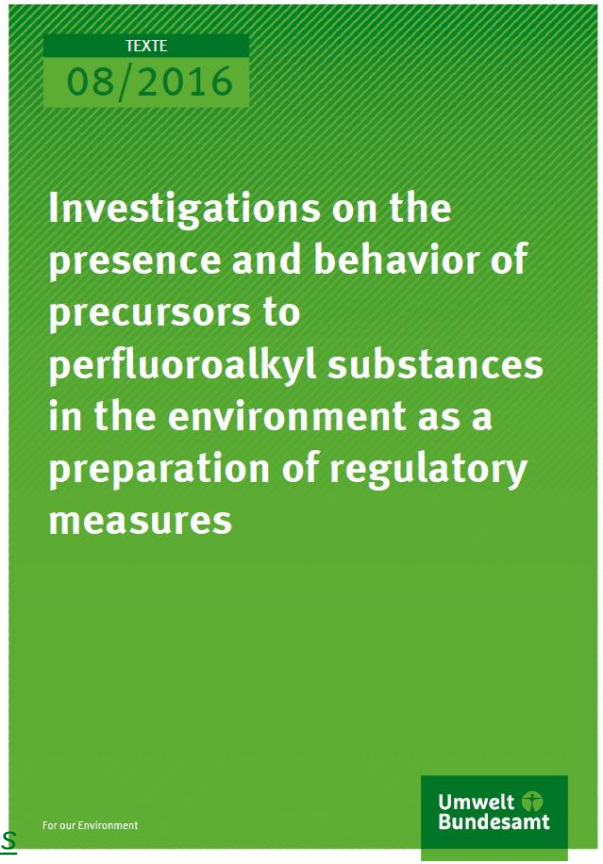
Marc Rathman\ fotolia.de

e.g. Vierke L. et al. 2012 Environmental Sciences Europe 24:16.

PFAS in Municipal Waste Water Treatment Plants



Box plots of influent and effluent concentrations of PFBA, PFPeA, PFHxA and PFBS, PFHxS and PFOS in municipal WWTPs M1-M3. Concentrations of influent of WWTP-M2 were calculated as weighted average



UBA-Texte 08/2016: Investigation on the presence and behaviour of precursors to perfluoroalkyl substances in the environment as a preparation of regulatory measures

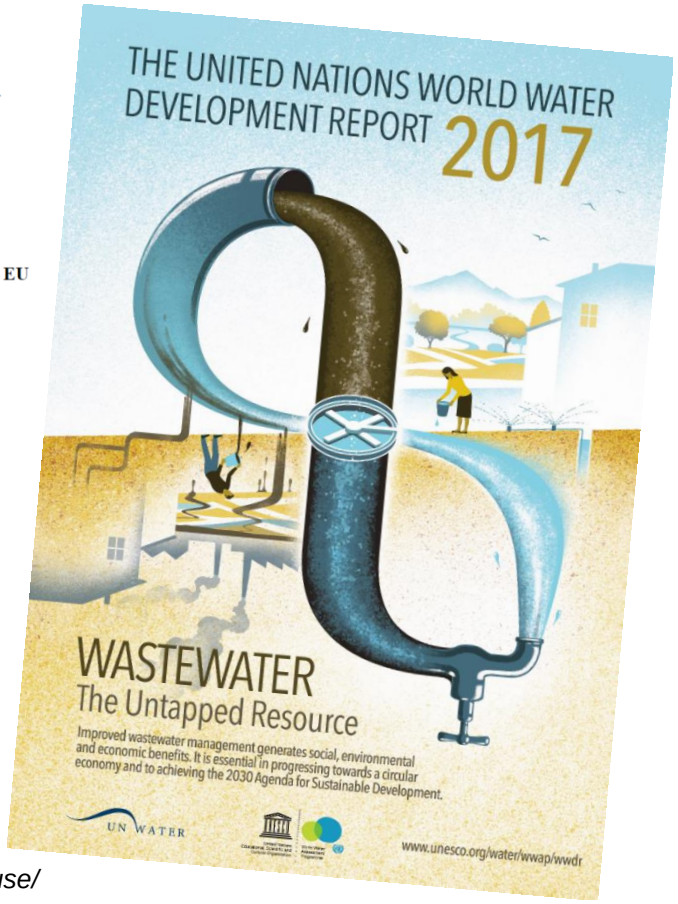
Water reuse

EUROPEAN COMMISSION

Brussels, 28.4.2017
SWD(2017) 153 final

COMMISSION STAFF WORKING DOCUMENT

Agriculture and Sustainable Water Management in the EU



http://legal-planet.org/2015/12/18/how-do-we-move-past-the-yuck-factor-in-potable-water-reuse/

Existing Guidelines

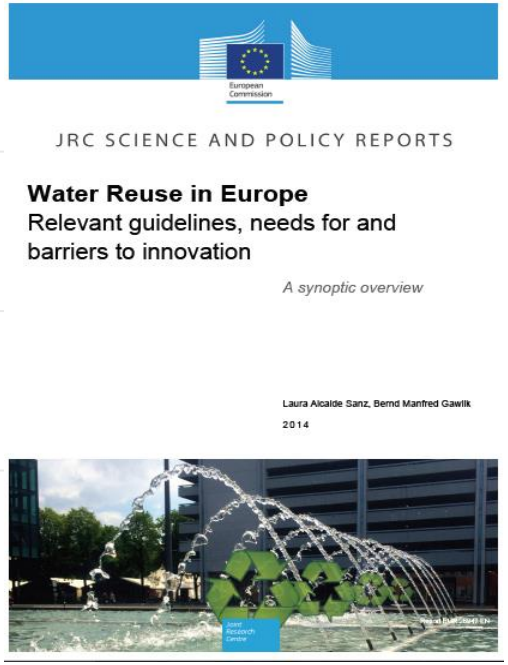
International Guidelines	
WHO	Guidelines for the safe use of wastewater, excreta and greywater Water Safety Plan, Sanitation Safety Plans. Guidelines for Potable Reuse (upcoming)
ISO	ISO/TC 282 „Water reuse“: ISO 16075 „Water reuse in irrigation“ (more in preparation)
Australia	Australian Guidelines for water recycling: managing health and environmental risk (2006, 2008)
USA	EPA: Guidelines for Water Reuse (2012), California: Regulations Related to Recycled Water (2009) (Title 22)

ISO 16075-1:2015
Guidelines for treated wastewater use for irrigation projects
-- Part 1: The basis of a reuse project for irrigation

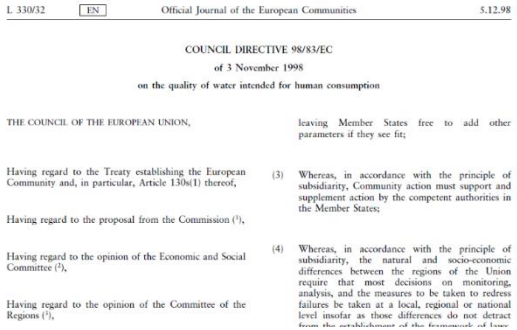
ISO 16075-2:2015
Guidelines for treated wastewater use for irrigation projects
-- Part 2: Development of the project

ISO 16075-3:2015
Guidelines for treated wastewater use for irrigation projects
-- Part 3: Components of a reuse project for irrigation

ISO 16075-4:2016
Guidelines for treated wastewater use for irrigation projects
-- Part 4: Monitoring



Regulatory context in the EU



L 330/32 EN Official Journal of the European Communities 5.12.98

COUNCIL DIRECTIVE 98/83/EC

of 3 November 1998

on the quality of water intended for human consumption

THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community and, in particular, Article 130s(1) thereof,

Having regard to the proposal from the Commission (1),

Having regard to the opinion of the Economic and Social Committee (2),

Having regard to the opinion of the Committee of the Regions (3),

leaving Member States free to add other parameters if they see fit;

(3) Whereas, in accordance with the principle of subsidiarity, Community action must support and supplement action by the competent authorities in the Member States;

(4) Whereas, in accordance with the principle of subsidiarity, the natural and socio-economic differences between the regions of the Union require that most decisions on monitoring, analysis, and the measures to be taken to redress failures be taken at a local, regional or national level insofar as those differences do not detract

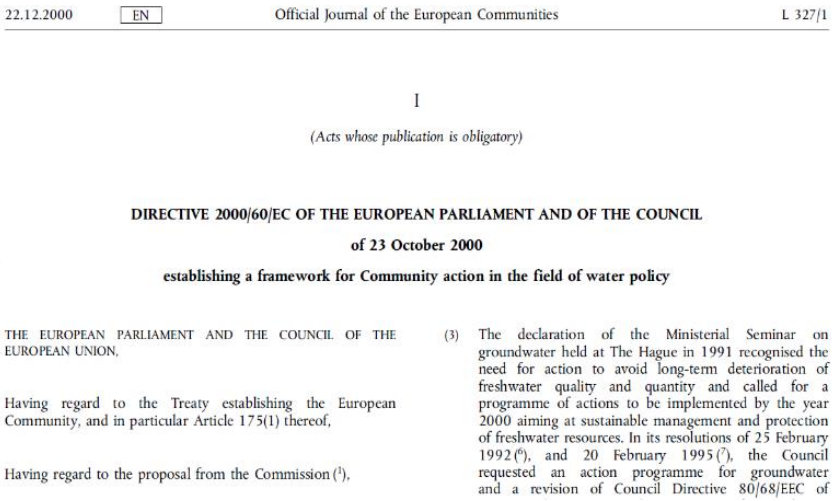
- Water Framework Directive (Directive 2000/60(EC)
- Groundwater Directive (Directive 2006/118/EC)
- Environmental Quality Standards Directive (Directive 2008/105/EC, amended by Directive 2013/39/EU)
- Urban Wastewater Treatment Directive (Directive 91/271/EEC)
- Nitrates Directive (Directive 91/676/EEC)
- Drinking Water Directive (Directive 98/83/EC)
- Regulation (EC) No 852/2004 on the hygiene of foodstuffs
- Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs

Water Framework Directive 2000/60/EC

Art.4 (1) a) … Member States shall implement the necessary measures to prevent the detoriation of the status of all bodies of surface waters

Art.4 (1) b) … prevent the detoriation of the status of all bodies of groundwater

Art.11 (3) j) prohibition of direct discharges of pollutants into groundwater



22.12.2000 EN Official Journal of the European Communities L 327/1

I

(Acts whose publication is obligatory)

DIRECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 23 October 2000

establishing a framework for Community action in the field of water policy

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 175(1) thereof,

Having regard to the proposal from the Commission (1),

(3) The declaration of the Ministerial Seminar on groundwater held at The Hague in 1991 recognised the need for action to avoid long-term deterioration of freshwater quality and quantity and called for a programme of actions to be implemented by the year 2000 aiming at sustainable management and protection of freshwater resources. In its resolutions of 25 February 1992 (6), and 20 February 1995 (7), the Council requested an action programme for groundwater and a revision of Council Directive 80/68/EEC of

Groundwater Directive (Directive 2006/118/EC)

27.12.2006 EN Official Journal of the European Union L 372/19

DIRECTIVE 2006/118/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 12 December 2006

on the protection of groundwater against pollution and deterioration

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 175(1) thereof,

Having regard to the proposal from the Commission,

Having regard to the Opinion of the European Economic and Social Committee [1],

Having regard to the Opinion of the Committee of the Regions [2],

Acting in accordance with the procedure laid down in Article 251

(5) In order to protect the environment as a whole, and human health in particular, detrimental concentrations of harmful pollutants in groundwater must be avoided, prevented or reduced

(6) Directive 2000/60/EC sets out general provisions for the protection and conservation of groundwater. As provided for in Article 17 of that Directive, measures to prevent and control groundwater pollution should be adopted, including criteria for assessing good groundwater chemical status and criteria for the identification of significant and sustained upward trends and for the definition of starting points for trend reversals.

Article 6

Measures to prevent or limit inputs of pollutants into groundwater

1. In order to achieve the objective of preventing or limiting inputs of pollutants into groundwater, established in accordance with Article 4(1)(b)(i) of Directive 2000/60/EC, Member States shall ensure that the programme of measures established in accordance with Article 11 of that Directive includes:

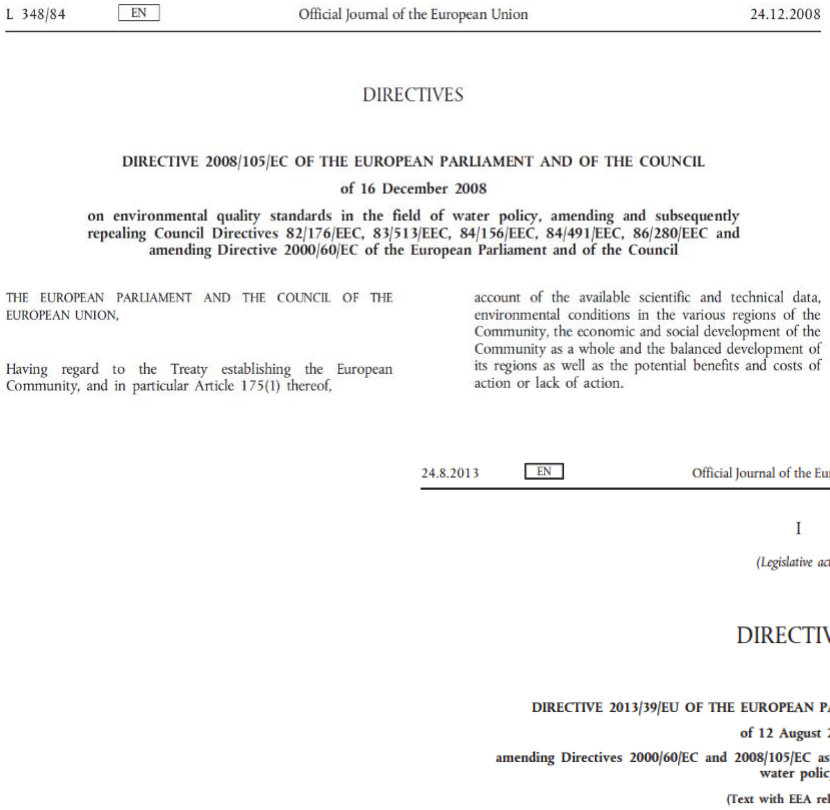
(a) all measures necessary to prevent inputs into groundwater of any hazardous substances, without prejudice to paragraphs 2 and 3. In identifying such substances, Member States shall in particular take account of hazardous substances belonging to the families or groups of pollutants referred to in points 1 to 6 of Annex VIII to Directive 2000/60/EC, as well as of substances belonging to the families or groups of pollutants referred to in points 7 to 9 of that Annex, where these are considered to be hazardous;

(b) for pollutants listed in Annex VIII to Directive 2000/60/EC which are not considered hazardous, and any other non-hazardous pollutants not listed in that Annex considered by Member States to present an existing or potential risk of pollution, all measures necessary to limit inputs into groundwater so as to ensure that such inputs do not cause deterioration or significant and sustained

- Reflecting on Annex VIII to Water Framework Directive
- Including CMR (carcinogenic, mutagenic toxic for reproduction) substances, endocrine disruptors and persistent, bioaccumulative and toxic (PBT-) substances

Environmental Quality Standards

- For certain hazardous chemicals
- Not defined for Contaminants of Emerging Concern



L 348/84 EN Official Journal of the European Union 24.12.2008

DIRECTIVES

DIRECTIVE 2008/105/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

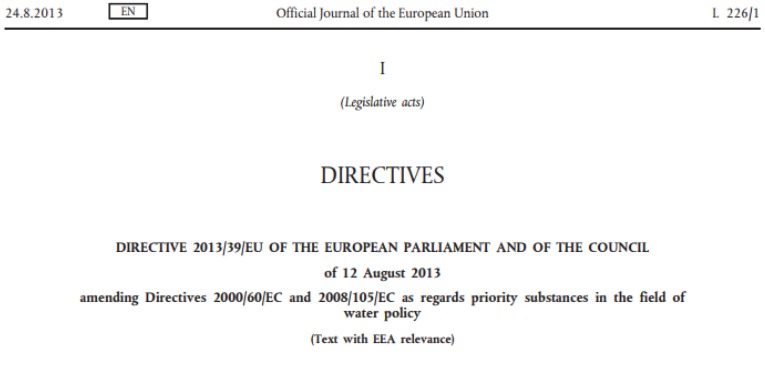
of 16 December 2008

on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 175(1) thereof,

account of the available scientific and technical data, environmental conditions in the various regions of the Community, the economic and social development of the Community as a whole and the balanced development of its regions as well as the potential benefits and costs of action or lack of action.



24.8.2013 EN Official Journal of the European Union L 226/1

I

(Legislative acts)

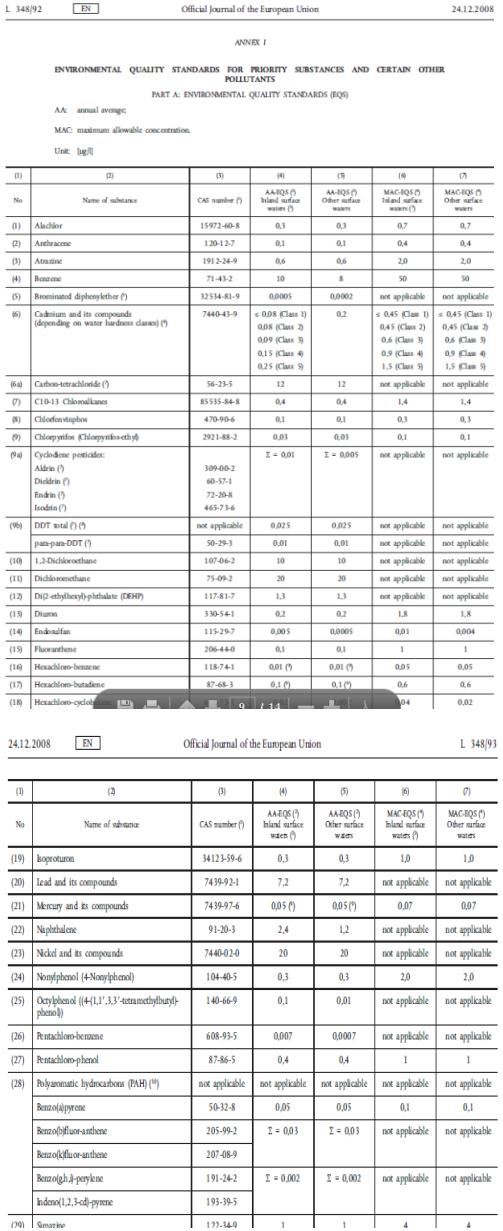
DIRECTIVES

DIRECTIVE 2013/39/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 12 August 2013

amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy

(Text with EEA relevance)



L 348/92 EN Official Journal of the European Union 24.12.2008

ANNEX I

ENVIRONMENTAL QUALITY STANDARDS FOR PRIORITY SUBSTANCES AND CERTAIN OTHER POLLUTANTS

PART A: ENVIRONMENTAL QUALITY STANDARDS (EQS)

AA: annual average;

MAC: maximum allowable concentration.

Unit: [µg/l]

(1) No	(2) Name of substance	(3) CAS number (*)	(4) AA-EQS (*) Inland surface waters (*)	(5) AA-EQS (*) Other surface waters	(6) MAC-EQS (*) Inland surface waters (*)	(7) MAC-EQS (*) Other surface waters
(1)	Alachlor	15972-60-8	0,3	0,3	0,7	0,7
(2)	Anthracene	120-12-7	0,1	0,1	0,4	0,4
(3)	Atrazine	1912-24-9	0,6	0,6	2,0	2,0
(4)	Benzene	71-43-2	10	8	50	50
(5)	Brominated diphenylether (*)	32534-81-9	0,0005	0,0002	not applicable	not applicable
(6)	Cadmium and its compounds (depending on water hardness classes) (*)	7440-43-9	≤ 0,08 (Class 1) 0,08 (Class 2) 0,09 (Class 3) 0,15 (Class 4) 0,25 (Class 5)	0,2	≤ 0,45 (Class 1) 0,45 (Class 2) 0,6 (Class 3) 0,9 (Class 4) 1,5 (Class 5)	≤ 0,45 (Class 1) 0,45 (Class 2) 0,6 (Class 3) 0,9 (Class 4) 1,5 (Class 5)
(6a)	Carbon-tetrachloride (*)	56-23-5	12	12	not applicable	not applicable
(7)	C10-13 Chloroalkanes	85535-84-8	0,4	0,4	1,4	1,4
(8)	Chlorfenvinphos	470-90-6	0,1	0,1	0,3	0,3
(9)	Chlorpyrifos (Chlorpyrifos-ethyl)	2921-88-2	0,03	0,03	0,1	0,1
(9a)	Cyclodiene pesticides: Aldrin (*) Dieldrin (*) Endrin (*) Isodrin (*)	309-00-2 60-57-1 72-20-8 465-73-6	Σ = 0,01	Σ = 0,005	not applicable	not applicable
(9b)	DDT total (*) (*)	not applicable	0,025	0,025	not applicable	not applicable
	para-para-DDT (*)	50-29-3	0,01	0,01	not applicable	not applicable
(10)	1,2-Dichloroethane	107-06-2	10	10	not applicable	not applicable
(11)	Dichloromethane	75-09-2	20	20	not applicable	not applicable
(12)	Di(2-ethylhexyl)-phthalate (DEHP)	117-81-7	1,3	1,3	not applicable	not applicable
(13)	Diuron	330-54-1	0,2	0,2	1,8	1,8
(14)	Endosulfan	115-29-7	0,005	0,0005	0,01	0,004
(15)	Fluoranthene	206-44-0	0,1	0,1	1	1
(16)	Hexachloro-benzene	118-74-1	0,01 (*)	0,01 (*)	0,05	0,05
(17)	Hexachloro-butadiene	87-68-3	0,1 (*)	0,1 (*)	0,6	0,6
(18)	Hexachloro-cyclohexane					0,02

24.12.2008 EN Official Journal of the European Union L 348/93

(1) No	(2) Name of substance	(3) CAS number (*)	(4) AA-EQS (*) Inland surface waters (*)	(5) AA-EQS (*) Other surface waters	(6) MAC-EQS (*) Inland surface waters (*)	(7) MAC-EQS (*) Other surface waters
(19)	Isoproturon	34123-59-6	0,3	0,3	1,0	1,0
(20)	Lead and its compounds	7439-92-1	7,2	7,2	not applicable	not applicable
(21)	Mercury and its compounds	7439-97-6	0,05 (*)	0,05 (*)	0,07	0,07
(22)	Naphthalene	91-20-3	2,4	1,2	not applicable	not applicable
(23)	Nickel and its compounds	7440-02-0	20	20	not applicable	not applicable
(24)	Nonylphenol (4-Nonylphenol)	104-40-5	0,3	0,3	2,0	2,0
(25)	Octylphenol ((4-(1,1',3,3'-tetramethylbutyl)-phenol))	140-66-9	0,1	0,01	not applicable	not applicable
(26)	Pentachloro-benzene	608-93-5	0,007	0,0007	not applicable	not applicable
(27)	Pentachloro-phenol	87-86-5	0,4	0,4	1	1
(28)	Polyaromatic hydrocarbons (PAH) (10)	not applicable	not applicable	not applicable	not applicable	not applicable
	Benzo(a)pyrene	50-32-8	0,05	0,05	0,1	0,1
	Benzo(b)fluor-anthene	205-99-2	Σ = 0,03	Σ = 0,03	not applicable	not applicable
	Benzo(k)fluor-anthene	207-08-9				
	Benzo(g,h,i)-perylene	191-24-2	Σ = 0,002	Σ = 0,002	not applicable	not applicable
	Indeno(1,2,3-cd)-pyrene	193-39-5				
(29)	Simazine	122-34-9	1	1	4	4

Contaminants of Emerging Concern in the WFD

- EU - Watch list defining monitoring requirements for certain Contaminants of Emerging Concern

L 78/42 EN Official Journal of the European Union 24.3.2015

ANNEX

Watch list of substances for Union-wide monitoring as set out in Article 8b of Directive 2008/105/EC

Name of substance/group of substances	CAS number (1)	EU number (2)	Indicative analytical method (3) (4) (5)	Maximum acceptable method detection limit (ng/l)
17-Alpha-ethinylestradiol (EE2)	57-63-6	200-342-2	Large-volume SPE — LC-MS-MS	0,035
17-Beta-estradiol (E2), Estrone (E1)	50-28-2, 53-16-7	200-023-8	SPE — LC-MS-MS	0,4
Diclofenac	15307-86-5	239-348-5	SPE — LC-MS-MS	10
2,6-Ditert-butyl-4-methylphenol	128-37-0	204-881-4	SPE — GC-MS	3 160
2-Ethylhexyl 4-methoxycinnamate	5466-77-3	226-775-7	SPE — LC-MS-MS or GC-MS	6 000
Macrolide antibiotics (6)			SPE — LC-MS-MS	90
Methiocarb	2032-65-7	217-991-2	SPE — LC-MS-MS or GC-MS	10
Neonicotinoids (7)			SPE — LC-MS-MS	9
Oxadiazon	19666-30-9	243-215-7	LLE/SPE — GC-MS	88
Tri-allate	2303-17-5	218-962-7	LLE/SPE — GC-MS or LC-MS-MS	670

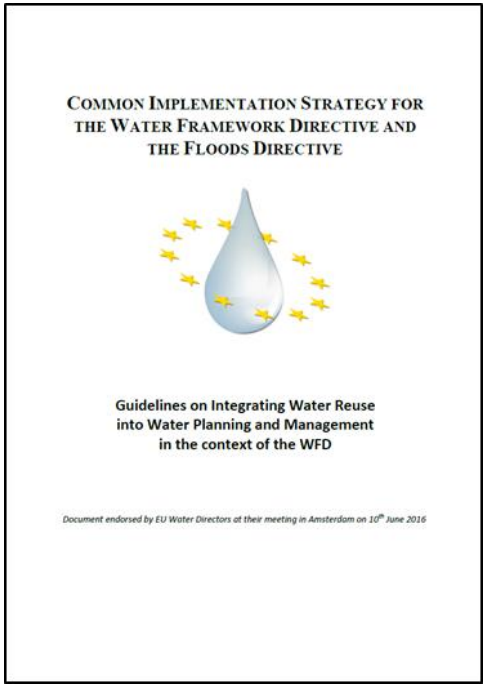
(1) Chemical Abstracts Service.
(2) European Union number — not available for all substances.
(3) To ensure comparability of results from different Member States, all substances shall be monitored in whole water samples.
(4) Extraction methods:
LLE — liquid liquid extraction

Activities of the European Commission on Water Reuse

„Blueprint to Safeguard Europe's Water Resources“ (2012):
Water reuse as important measure for water scarcity;
objective: establish a common framework for using treated wastewater

Action Plan within the Circular Economy Package (COM(2015(614)):

- CIS-Guideline on Integrating Water Reuse into Water Planning and Management (CIS Ad-hoc Task Group June 2016)
- Development of EU Minimum Quality Requirements for water reuse for irrigation and aquifer recharge (JRC, legislative proposal expected by end of 2017)
- Support for innovation and research
- EU-funds for investment in reuse



http://ec.europa.eu/environment/water/pdf/Guidelines_on_water_reuse.pdf

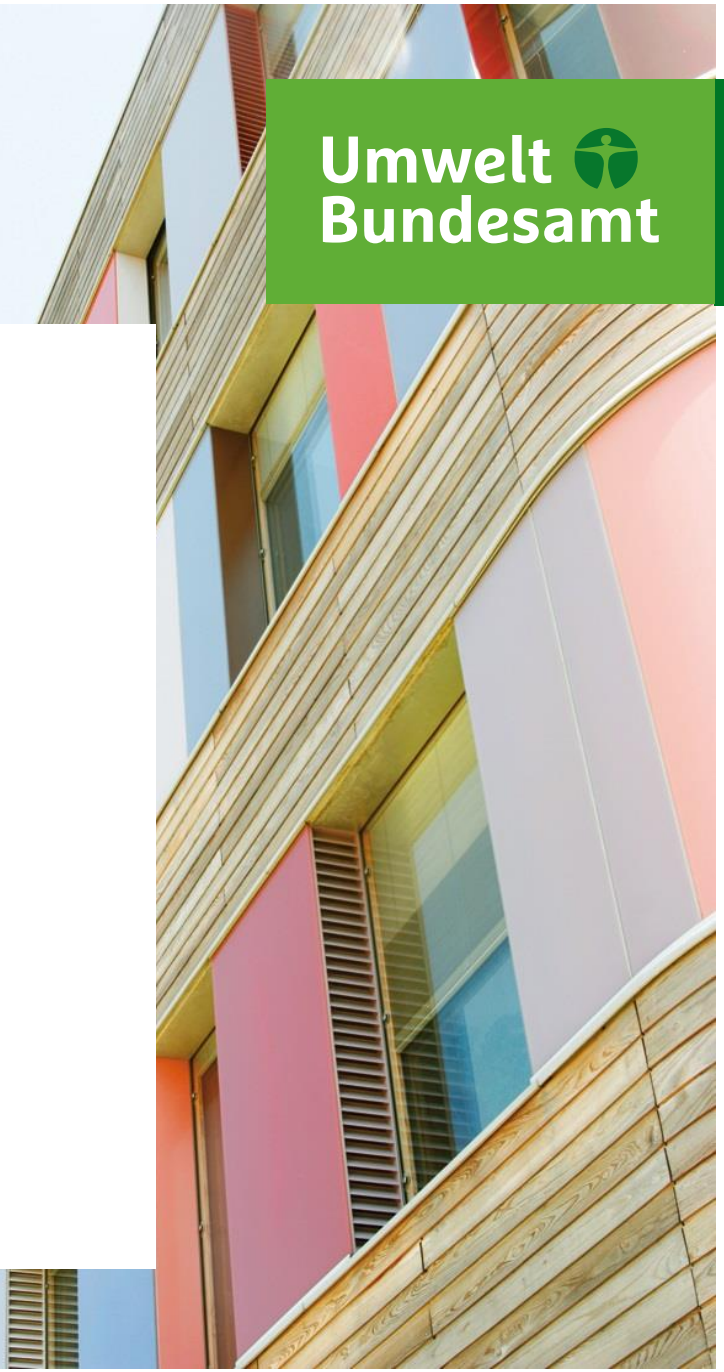
UBA Recommendations for EU minimum quality requirements

- Regional differences of water availability need to be considered
- Ensure compliance with the existing EU regulation
- Implement a systematic and comprehensive risk management approach (e.g. as WHO Water- /Sanitation Safety Plans)
- Ambitious standards for health and environmental protection are needed
- Consider the precautionary principle to address unknown risks of CECs
- Introduce monitoring of CECs and derive quality standards
- Safe reuse requires advanced wastewater treatment
- No aquifer recharge with direct injection

https://www.umweltbundesamt.de/en/topics/uba-position-on-eu-minimum-requirements-for-water

Summary

- Reuse of water is a challenging opportunity for water resource management
- One concern for water reuse are Contaminants of Emerging Concern, especially if these substances have hazardous properties
- The risk for consumers and the environment needs to be assessed in advance of reusing water
- In the EU, the Water Framework Directive and Groundwater Directive are defining the good status for surface and ground water, certain monitoring requirements, and risk management responsibilities
- We see a need for monitoring contaminants of emerging concern in waste water and to adapt treatment processes in advance of reusing water



Thank you for your attention!

Dr. Christoph Schulte
Federal Environment Agency - Umweltbundesamt (UBA)
Department II 2 „Water and Soil“
Wörlitzer Platz 1, 06844 Dessau, Germany
+49-340-2103-3162
Email: christoph.schulte@uba.de

www.uba.de

Definitions: Water Reuse (EU Context)

Water reuse: use of treated wastewater for beneficial use after treatment as necessary

Direct reuse: direct introduction of treated wastewater from a water treatment plant to a distribution system

Indirect reuse: reuse of treated wastewater placed into a water body source (e.g. lake, river, or aquifer) and partly retrieved for later use

Planned reuse: systems developed for water reuse (intended, controlled)

Unplanned reuse: uncontrolled, unintended reuse of wastewater after discharge (e.g. downstream users using water from a river which contains wastewater discharged upstream)

Urban wastewater: domestic wastewater or the mixture of domestic wastewater with industrial wastewater and/or run-off rain water

Potential exposure pathways

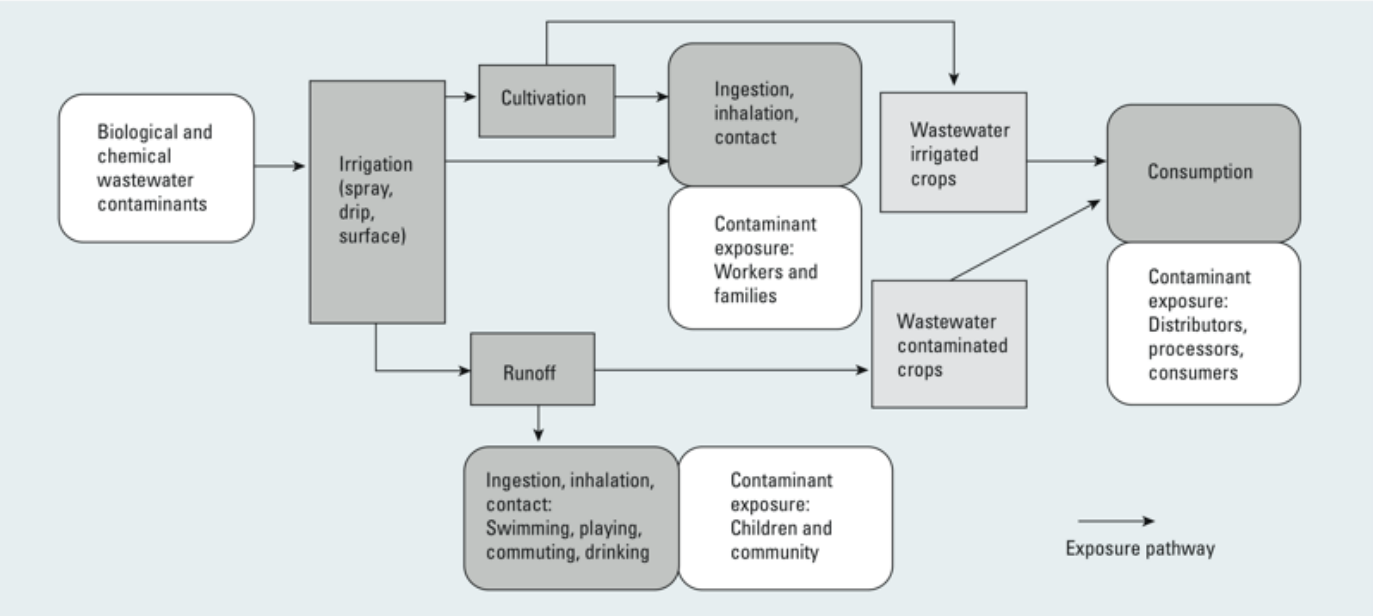


Table 2. Possible exposure pathways of chemicals to humans via agricultural irrigation

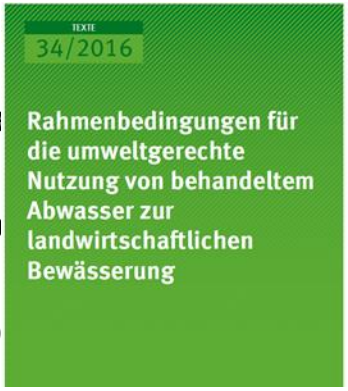
Pathway	Scenario
• Reclaimed water irrigation → soil → plant uptake → food production → human toxicity	• Ingestion of food plants cultivated on land irrigated with reclaimed water
• Reclaimed water irrigation → soil → plant uptake → animal uptake → human toxicity	• Ingestion of meat/animal products from animals pasture on land irrigated with reclaimed water
• Reclaimed water irrigation → soil → vadoze zone → groundwater → human toxicity	• Ingestion of drinking water produced from groundwater polluted by reclaimed water
• Reclaimed water irrigation → atmosphere → human toxicity	• Inhalation of volatile contaminants during irrigation process

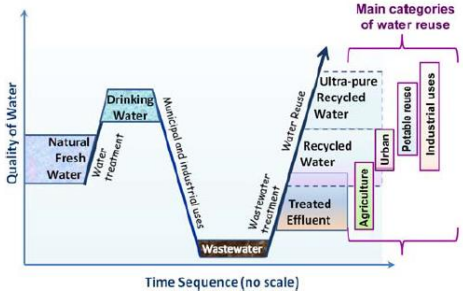
S. Weber et al. / Desalination 187 (2006) 53–64; Human risk assessment of organic contaminants in reclaimed wastewater used for irrigation

UBA Study on agricultural irrigation with treated wastewater

- No nationwide need for irrigation with treated wastewater in Germany Germany: two non-binding DIN norms for hygienic and chemical-physical quality of irrigation water (DIN 19650, DIN 19864-10)
- Relevant EU Directives: WFD, GWD, UWWTD, Nitrate directive
- Groudnwater protection: Prevent/limit input of pollutants
- Problematic:micro pollutants in groundwater (e.g. pharmaceutical residues d
  Wolfsburg, Braunschweig); evidence of accumulation in plants
- For hygienic safety indicator organisms for viruses would need to be added t
  Germany
- To meet the requirements of DIN 19650 for edible crops, conventionally treat
  („tertiary treatment“) would require additional desinfection
- Systematic and process oriented risk management is needed
- Different wastewater treatment technologies are available to reach ne
  quality – matter of cost-benefit consideration

➔ Conclusion: Due to **existing uncertainties in assessing potential h**
wastewater should only be used for irrigation íf no other local wa
(priority to efficiency measures)





Lazarova, Valentina, International Water Association; Milestones in Water Reuse: The Best Success Stories (2013)

PFAS in surface water (ng/l)

		PFBS	PFHxS	PFOS	PFBA	PFHxA	PFOA	PFNA	Reference
West Coast, 2009	**South Korea**	<0.2 – 16	<0.2 - 8.7	0.4 – 47			0.5 – 31	<0.2 - 5.9	Naile et al., 2010,
River Xi, Fuxin, 2009	**China**	7 – 445	0.2 - 0.6	0.3 - 0.5			27 - 668	0.4 – 16	Bao et al. 2011,
Rivers, 2010	**Japan**		nd - 8.4	nd – 97	<1.5 – 18	nd – 16,000	<1.5 – 360	nd – 39	Takamine et al., 2014,
Rivers, 2008	**Taiwan**			49 – 5,440			11 - 310		Lin et al., 2009
Elbe, 2007	**Germany**	3.5 - 5.3	0.3 - 0.5	4.1 -6.2	nd - 0.4	1.7 – 2.6	4.4 -4.8	0.7 -1.2	Ahrens et al. 2010.
Baltic Sea, 2007	**Baltic Sea**	0.3 - 0.9	nd - 0.6	nd - 0.4	nd – 0.4	0.1 - 0.3	0.3 – 4.6	0.1 - 0.4	Ahrens et al. 2010.
Steinbecke, 2005	**Germany**						33,900		Skutlarek et al. 2006.
Greenland sea 2007-2010		<0.001 - 0.02	nd - 0.04	<0.1 - 0.2		<0.003 - 0.1	0.004 – 0.2	<0.003 - 0.1	Zhao et al. 2012.

Concerns on certain PFAS – mobility

- Certain PFAS can occur in raw water and can therefore be transferred into drinking water
- Certain PFAS cannot be eliminated from water with the commonly applied measures

  (e. g. Lundgren et al. 2014)

Emotion\fotolia.com

Potential exposure of humans via drinking water

Examples:

- 18% of 85 Spanish tapwater samples *(Gellrich et al., 2013)*
- 23% of 26 German tapwater samples *(Llorca et al., 2012)*
- 86% of 7 tapwater samples from six EU Countries *(Ullah et al., 2011)*
- 49% of 26 waterworks along the river Rhine *(Wilhelm et al., 2010)*

Concerns of certain PFAS – Enrichment in plants

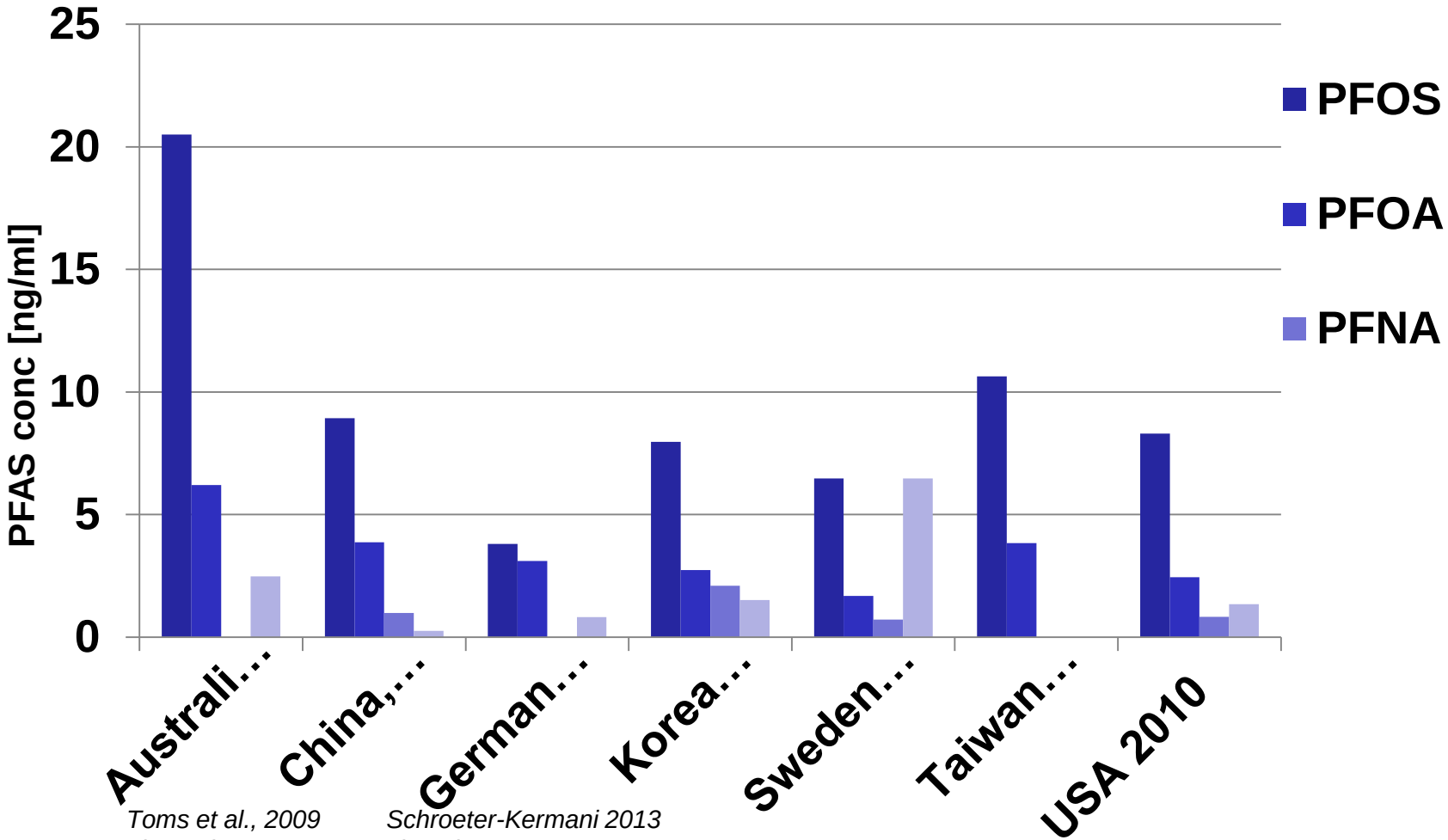
- Plant uptake shown by several studies e.g. for wheat, maize, grass and vegetables
- Enrichment in edible parts of plants
- Benchmarking with PFOA: PFHxA higher uptake and higher transfer to edible parts of plants

(Felitzeter et al. 2014; Krippner et al. 2015; Wen et al. 2014; Yoo et al. 2011)

Potential exposure of humans via food

Source: Marc Rathman\ fotolia.de

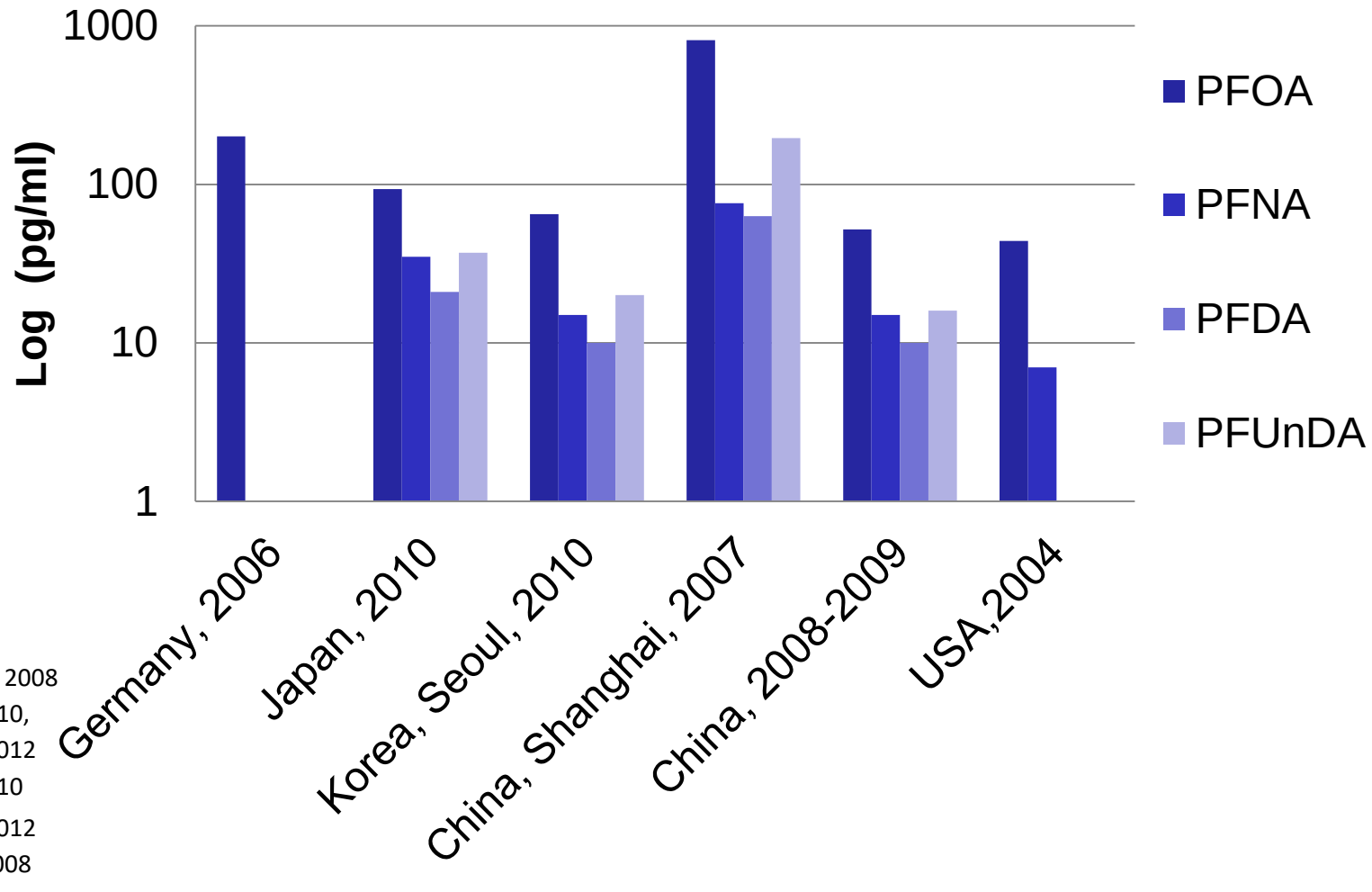
Long-chain PFASs in human blood



Toms et al., 2009
Liu et al., 2009
Guo et al., 2011
Pan et al., 2010

Schroeter-Kermani 2013
Ji et al., 2012
Glynn et al., 2012
Hsu et al., 2013
Olsen et al., 2012

Long-chain PFASs in breast milk



Völkel et al., 2008
Liu et al., 2010,
Fujii et al., 2012
Liu et al., 2010
Fujii et al., 2012
Tao et al., 2008

PFAS in Municipal Waste Water Treatment Plants

Analyte	LOD	LOQ	EFF 1	EFF 2	EFF 4	EFF 6
	ng/L					
PFPeA	2.5	5.1	14.0	9.9	21.4	14.3
PFHxA	1.3	6.6	<LOQ	<LOQ	<LOQ	<LOQ
PFHpA	1.0	4.8	<LOQ	<LOQ	<LOQ	<LOQ
PFOA	0.2	2.3	10.2	9.7	10.3	7.4
PFNA	0.3	3.1	<LOQ	n.d.	<LOQ	n.d.
PFDA	0.7	3.3	<LOQ	n.d.	n.d.	n.d.
PFBS	0.7	1.3	13.0	12.5	12.2	12.9
PFHxS	0.1	1.3	<LOQ	<LOQ	<LOQ	<LOQ
PFOS	0.4	1.8	22.8	20.4	13.5	12.8
6:2-FTS	0.1	0.3	20.1	56.9	33.3	23.8
8:2-FTS	1.3	2.5	n.d.	<LOQ	n.d.	n.d.

PFAS concentrations in ng/L in the effluent samples of a municipal WWTP. Only substances with at least one detection are shown.

Anal Bioanal Chem
DOI 10.1007/s00216-016-0072-1

RESEARCH PAPER

Sampling and simultaneous determination of volatile per- and polyfluoroalkyl substances in wastewater treatment plant air and water

Ian Ken Dimzon[1,2] · Joke Westerveld[1] · Christoph Gremmel[2] · Tobias Frömel[2] · Thomas P. Knepper[2] · Pim de Voogt[1]

Received: 7 April 2016 / Revised: 14 October 2016 / Accepted: 31 October 2016
© The Author(s) 2016. This article is published with open access at Springerlink.com

Abstract Volatile per- and polyfluoroalkyl substances (PFASs) are often used as precursors in the synthesis of non-volatile PFASs. The volatile PFASs, which include the perfluoroalkyl iodides (PFAIs), fluorotelomer iodides (FTIs), fluorotelomer alcohols (FTOHs), fluorotelomer olefins (FTOs), fluorotelomer acrylates (FTACs), and fluorotelomer methacrylates (FTMACs), are often produced starting from the telomerization process. These volatile compounds can be present in the air and water environment and can be transformed into highly persistent perfluoroalkyl carboxylic acids. detected at concentrations higher than 40 ng/m^3. The MDL in water was 10 ng/L. Direct spiking of the cartridges and analyte introduction by volatilization from the glass surface onto the SPE material had recoveries between 86 and 100%. The volatile PFASs were shown to readily partition into the air rather than into water. Consequently, large losses in the amount of PFASs were observed when these were spiked into the water.

Keywords Volatile PFAS · GC-MS · WWTP · Influents · Effluents · Air

Anal Bioanal Chem (2017) 409:1643–1655
DOI 10.1007/s00216-016-0110-z

RESEARCH PAPER

HPLC–MS/MS methods for the determination of 52 perfluoroalkyl and polyfluoroalkyl substances in aqueous samples

Christoph Gremmel[1] · Tobias Frömel[1] · Thomas P. Knepper[1]

Received: 29 July 2016 / Revised: 26 October 2016 / Accepted: 21 November 2016 / Published online: 7 December 2016
© Springer-Verlag Berlin Heidelberg 2016

Abstract Two quantitative methods using high-performance liquid chromatography (HPLC) combined with triple quadrupole tandem mass spectrometry (MS/MS) were developed to determine perfluoroalkyl and polyfluoroalkyl substances (PFASs) in aqueous samples. The first HPLC–MS/MS method was applied to 47 PFASs of 12 different substance classes substances in the environment. In one exemplary application in an industrial wastewater treatment plant, FTOHs were found to be the major substance class in the influent; in particular, 6:2-FTOH was the predominant compound in the industrial samples and accounted for 74% of the total PFAS concentration. The increase in the concentration of the trans-

UBA-Texte 08/2016: Investigation on the presence and behaviour of precursors to perfluoroalkyl substances in the environment as a preparation of regulatory measures