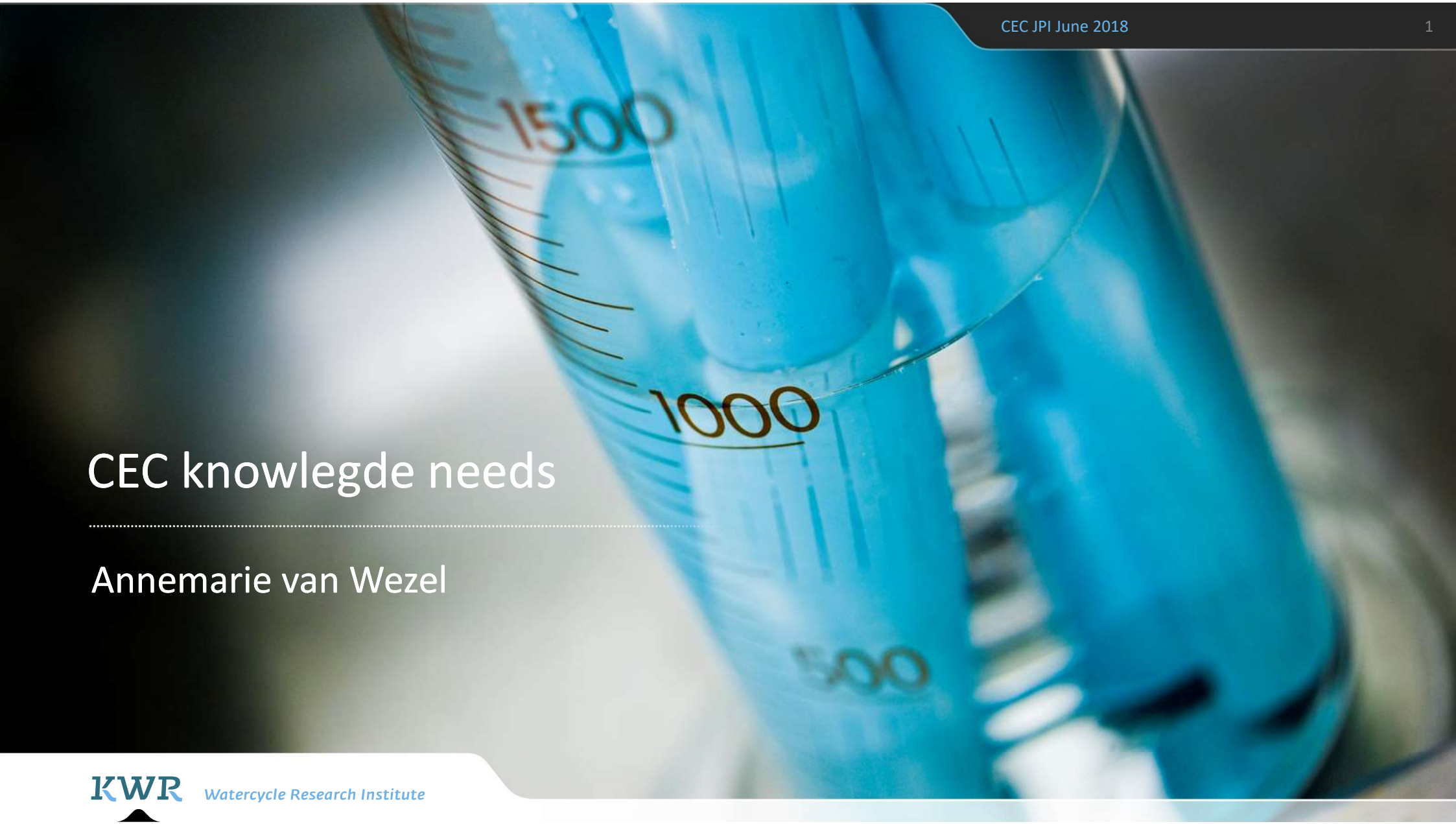


CEC knowlegde needs

Annemarie van Wezel

KWR Watercycle Research Institute

CEC knowledge needs

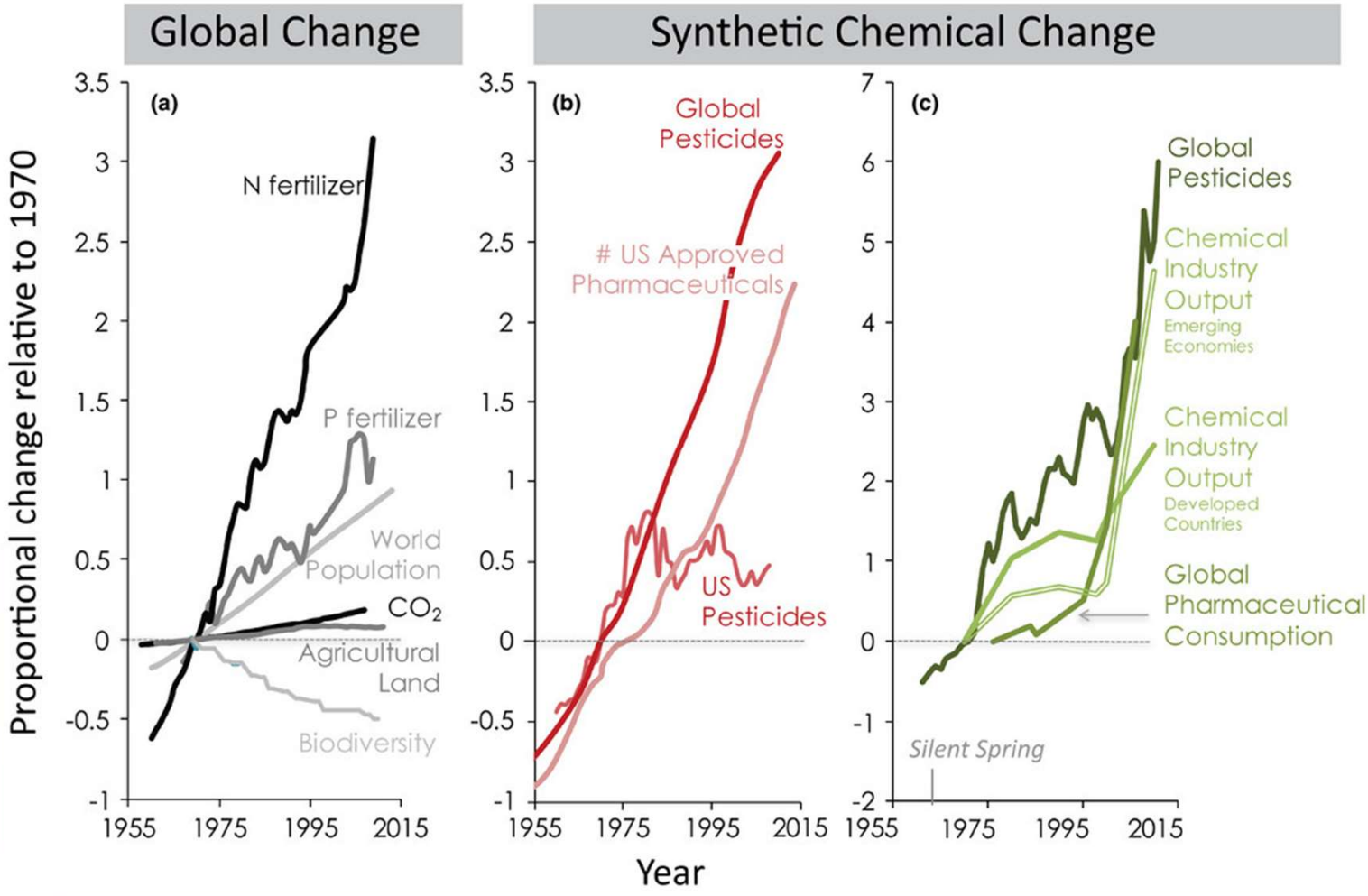
CECs in global change context

One Health – One Watercycle

Solutions-oriented risk assessment

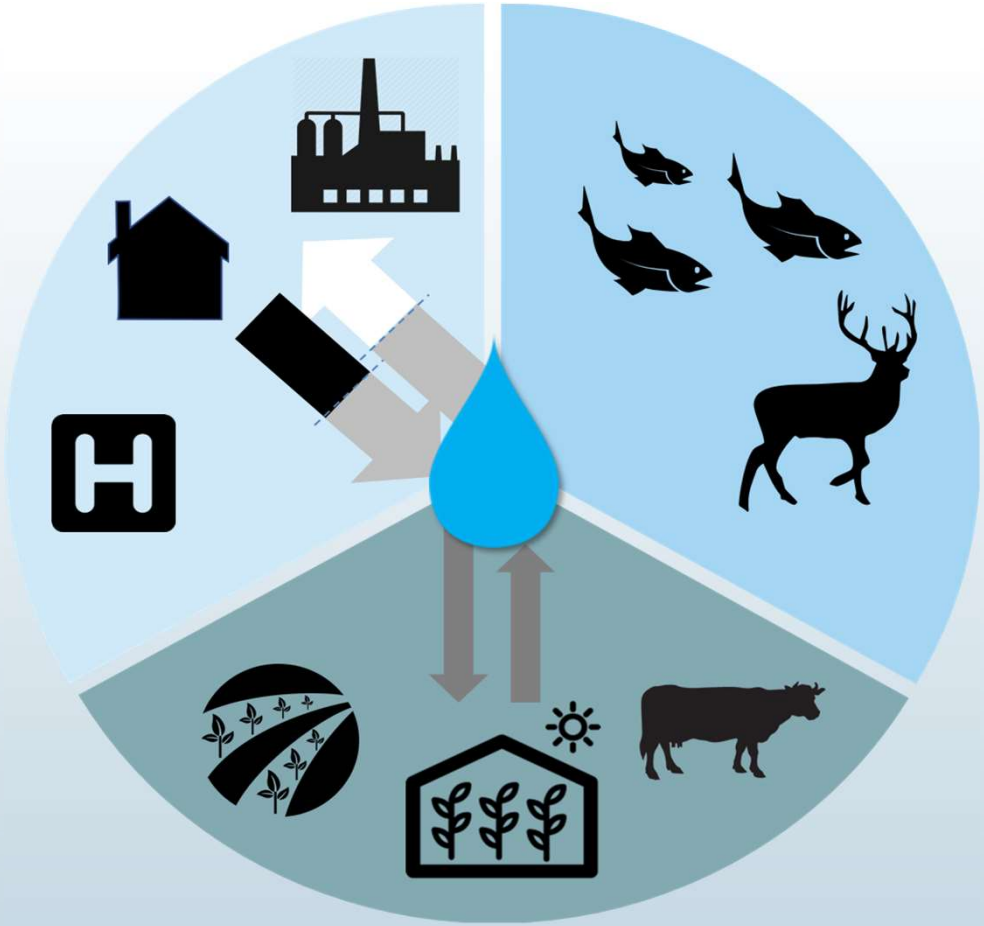
Prevent regrettable subsitution

Synthetic chemicals outpace other factors of global change



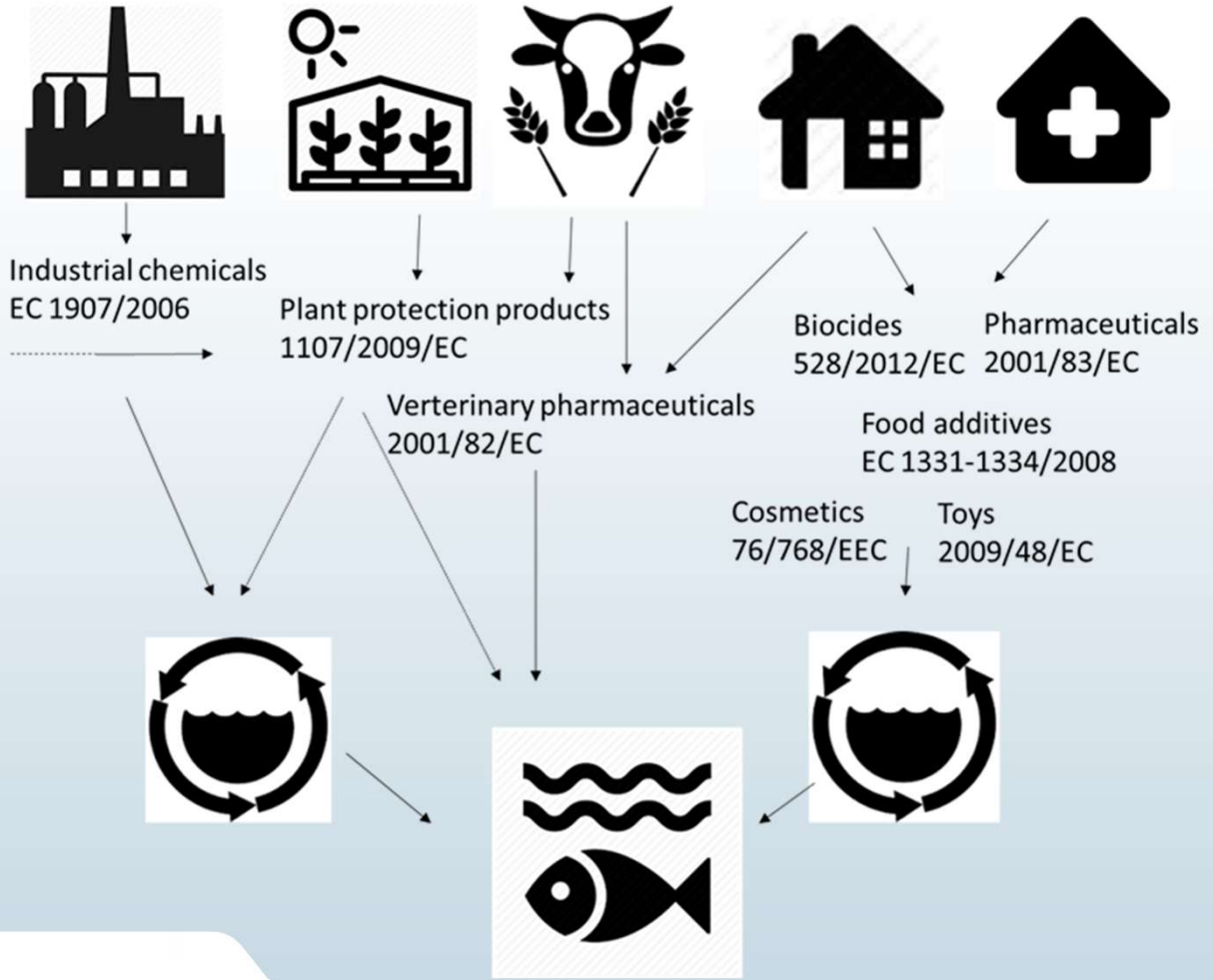
Bernhardt et al 2017 Front Ecol Environ

Water system integrates urban and rural water withdrawals and returns, sectors demand fit-for-purpose water quality



Van Wezel et al 2017

Sectors, policy frameworks and pathways



(STARE)

One Watercycle - One Health

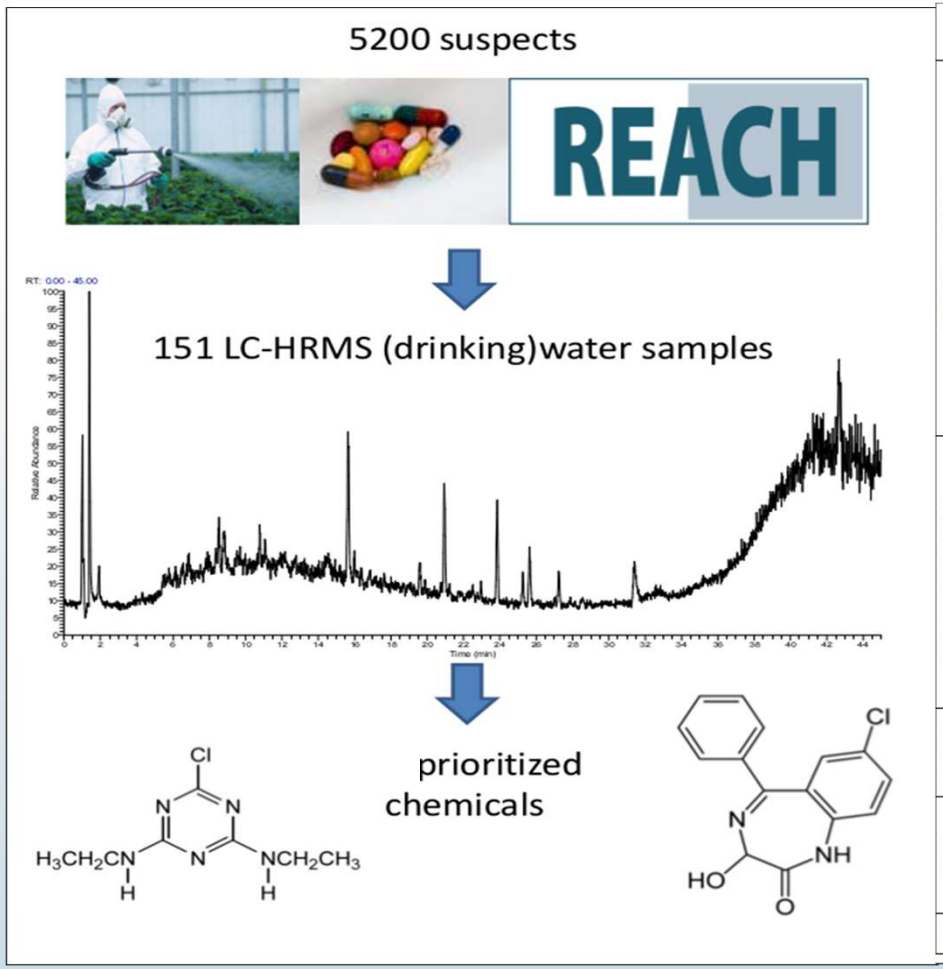
Sources

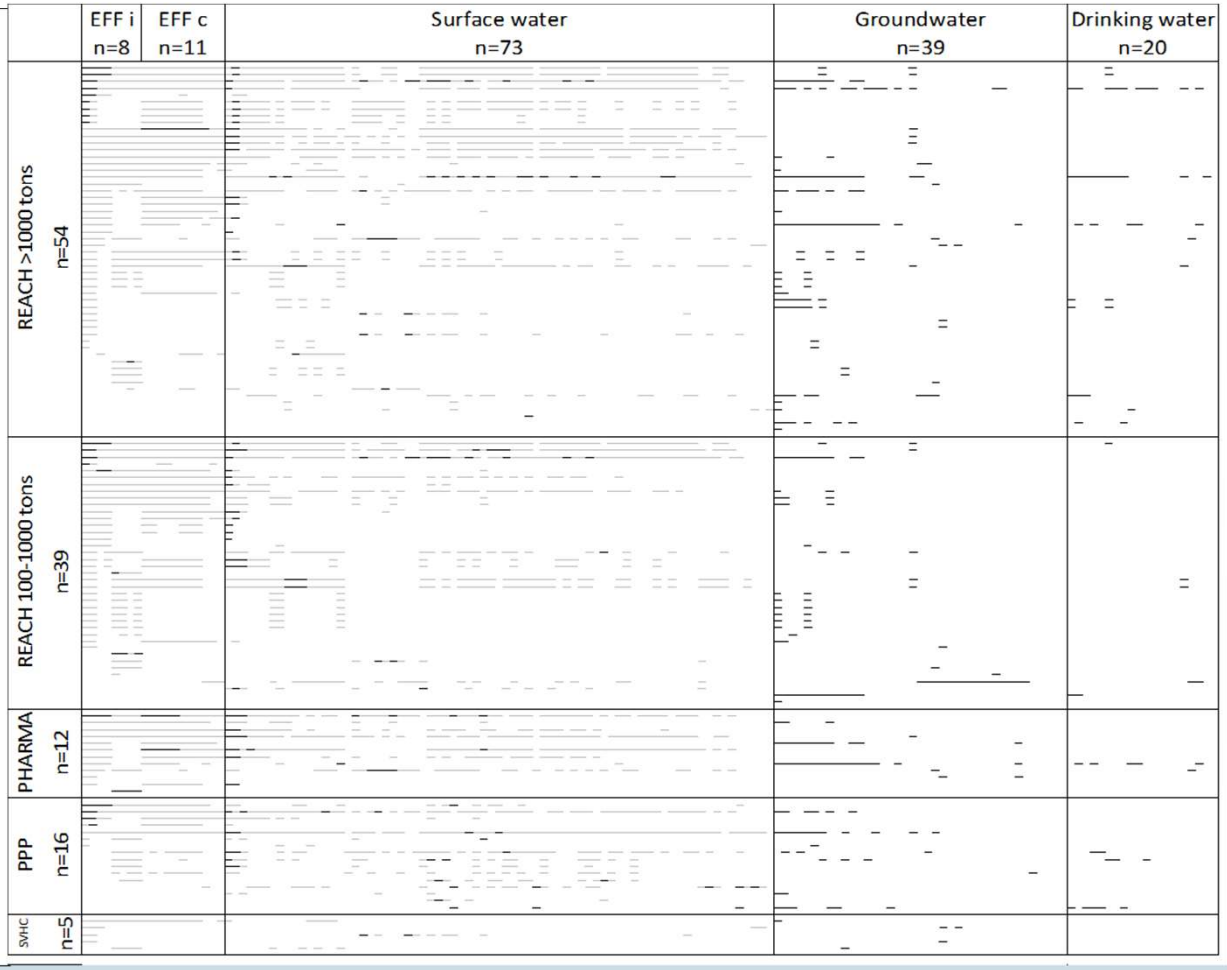
Effects – humans & ecosystems

Data on occurence and effects chemicals, pathogens, genes

Mitigation measures

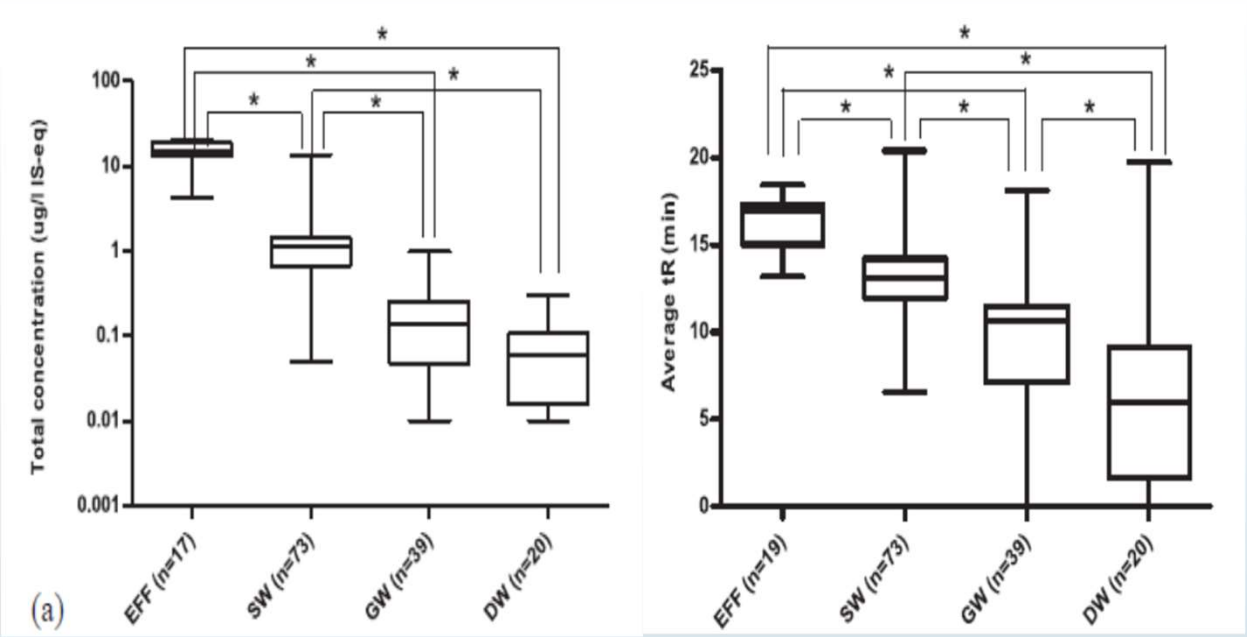
Suspect screening





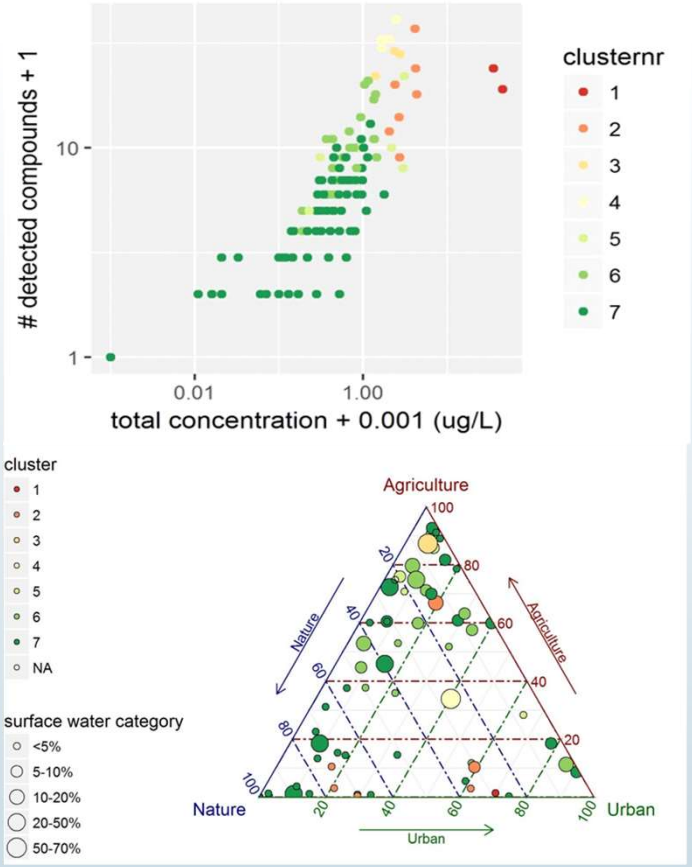
Sjerps et al 2016

Concentrations decrease in water cycle, mobile substances remain

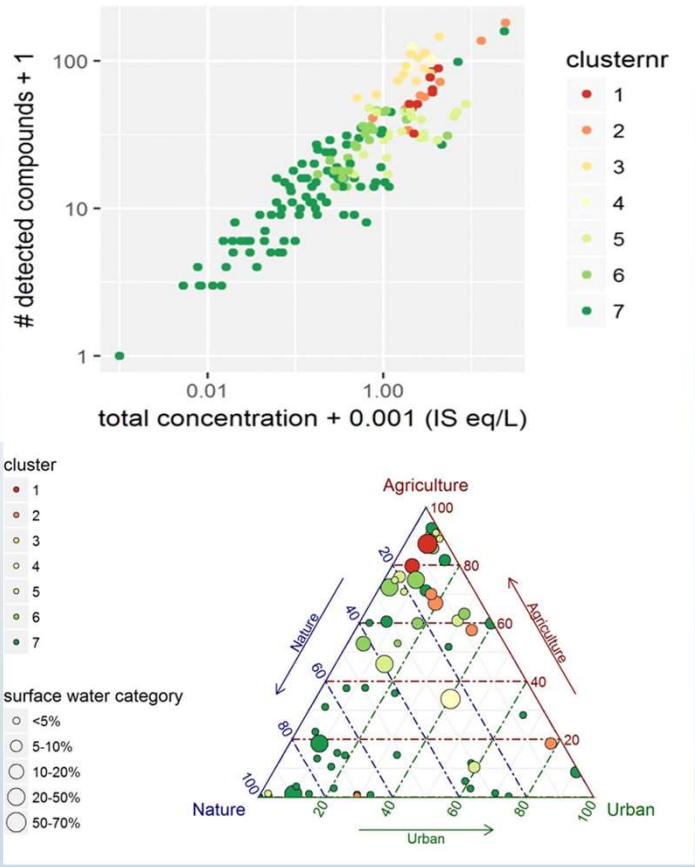


Relation occurrence in groundwater sources with land-use and surface water infiltration

Target

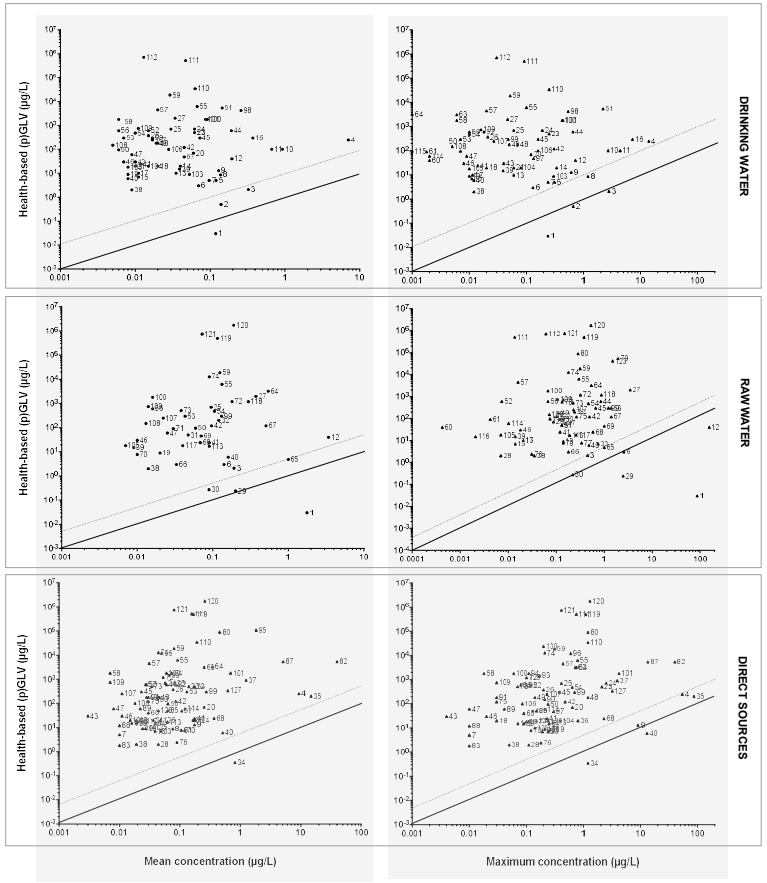


Suspect



(PERSIST)

Majority of evaluated substances detected in drinking water (sources) do not occur in concentrations posing an appreciable risk to humans



- For 142 out of 163 drinking water relevant substances (p)GLVs could be derived
- For 88 of the 163 substances,
  health risk assessment could not be performed due to lack of toxicity data or drinking water concentrations

A chemical is never alone…
Choice of bioassays to assess mixtures

Dutch drinking water utilities & water management authorities use bioassays to evaluate human & environmental health

Toxicity endpoints relevant for drinking water monitoring	Specific pathway	Most promising bioassay(s)
Xenobiotic metabolism	PXR receptor agonists AhR receptor agonists	HG5LN PXR assay, PXR HepG2 assay DR CALUX, AhR geneblazer
Hormone-mediated mode of action	(anti)estrogenic activity (anti)androgenic activity (anti)glucocorticoid activity	ERα CALUX, YES assay AR CALUX, AR-MDA-kb2 GR CALUX, GR-MDA-kb2
Reactive mode of action	Gene mutations Chromosomal mutations DNA damage response	Ames fluctuation assay, ToxTracker Micronucleus assay, ToxTracker UMUc assay, Vitotox, p53 CALUX, BlueScreen
Adaptive stress response	Oxidative stress pathway	Nrf2 CALUX, AREc32 assay
Developmental toxicity	Focus point endocrine distruption	Various nuclear receptor activation assays, H295R assay

EDA EMERGE DEMEAU

From research to implementation on the water cycle

GWRC 2008 to 2017
Endocrine Toolbox
- Estrogenicity
- Beyond Estrogenicity (ER)
- ER, AR, TR, GR, PR, MR, RXR

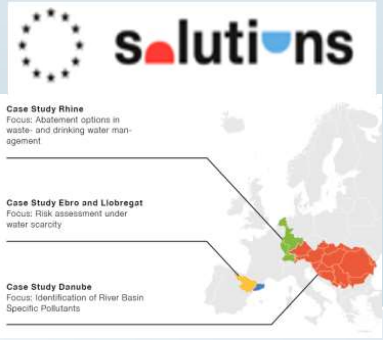
Applied to WW, SW, DW

International projects 2011 to 2016
Biological tools for µpollutants mixtures transformation-products?
Applied to conventional & Water REUSE schemes

Demonstration projects

FP7 European projects

From 2012 to 2018



Future research needs

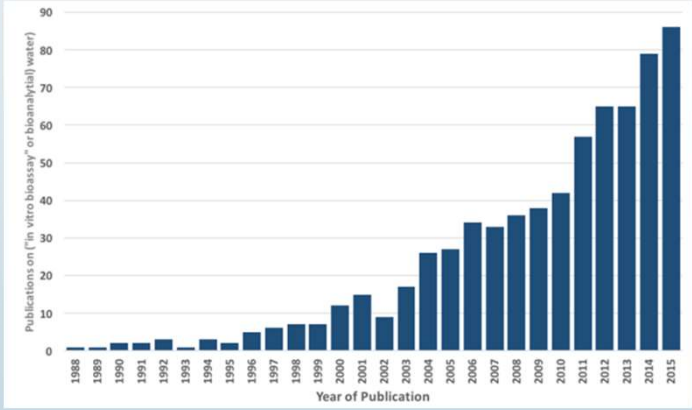
Mindset shift → Merge into 'One-Health' system for safe watercycle planning, by integrating human and ecological risks

'One-Health' system for Watercycle

World Health Organization

Framework implementation & acceptance

- Choice of assays in AOP framework
- Guidance for interpretation of data & consensus on EBTs
- Not in drinking water regulation thusfar (but… Risk Based Monitoring)
- Possibly in revision of the EU WFD and Guidelines on Integrating Water Reuse into Water Planning and Management



Stakeholder in the water sector are more aware on presence of contaminants of emerging concern

→ a strong drive for measures to reduce exposures and effects.

Chemical life-stages based overview of mitigation options

Phase in chemical life cycle	Mitigation option	Relevant stakeholder	Technological character	Large spatial scale	Efficiency to reduce chemical load to water system
Development					
	Green chemistry	Industry Education	+	+	+
Registration and authorization					
	Legislation and guidance	Government Industry	−	+	±
Production					
	Implement best available techniques	Industry Government	+	−	±
Use and consumption					
Professional	Emission prevention during professional use	Agriculture Health sector Government	±	−	+
Non-professional	Increase consciousness consumers	Education Industry Consumers	−	+	+
Water treatment					
	Upgrade sewage treatment plants with advanced technologies	Water manager	+	−	See Table 2
	Advanced drinking water treatment	Drinking water utility	+	−	

Removal efficiencies of CEC by advanced water treatment technologies; Criteria for reporting and assessment

No homogenous approach to test (advanced) water treatment technologies

A set of 52 reliability criteria and 9 relevance criteria is developed, to select, evaluate and compare CEC removal efficiency of water treatment technologies

Treatment technology	*CEC characteristics*	*Water matrix characteristics*	*Treatment process conditions*	*References*
Granular activated carbon	Molecular charge/pKa	**pH**	**Surface area/grain size**	(De Ridder et al. 2011, Jeirani et al. 2017, Mailler et al. 2016, Nam et al. 2014, Rossner et al. 2009, Verlicchi et al. 2010)
	Log K_{ow} /Log D_{ow}	**DOC content**	**Pore volume**	
	Molecular weight/size	**Temperature**	Surface charge	
	Functional groups (H-bonds, aromaticity etc.)		**Biological activity**	
	Concentration		**Contact time/EBCT**	
			Column length	
			Flow	
			Backflush routine	
			Scale of testing (bench, pilot, full)	
			Prior carbon use (if any)	
Powdered activated carbon	Molecular charge/pKa	**pH**	**Surface area**	
	Log K_{ow} /Log D_{ow}	**DOC content**	**Pore volume**	
	Molecular weight/size	**Temperature**	**Contact time**	
	Functional groups (H-bonds, aromaticity etc.)		**Concentration**	
	Concentration		Surface charge	
			Scale of testing (bench, pilot, full)	
Ozone (+H_2O_2)	Reactivity	**pH**	**Dosage of O_3 (and H_2O_2)**	(Lee et al. 2013, von Sonntag and von Gunten
	Concentration	**DOC content**	**Design reactor (mixing regime)**	
		Nitrite/nitrate	**Contact time**	

Evaluating literature data

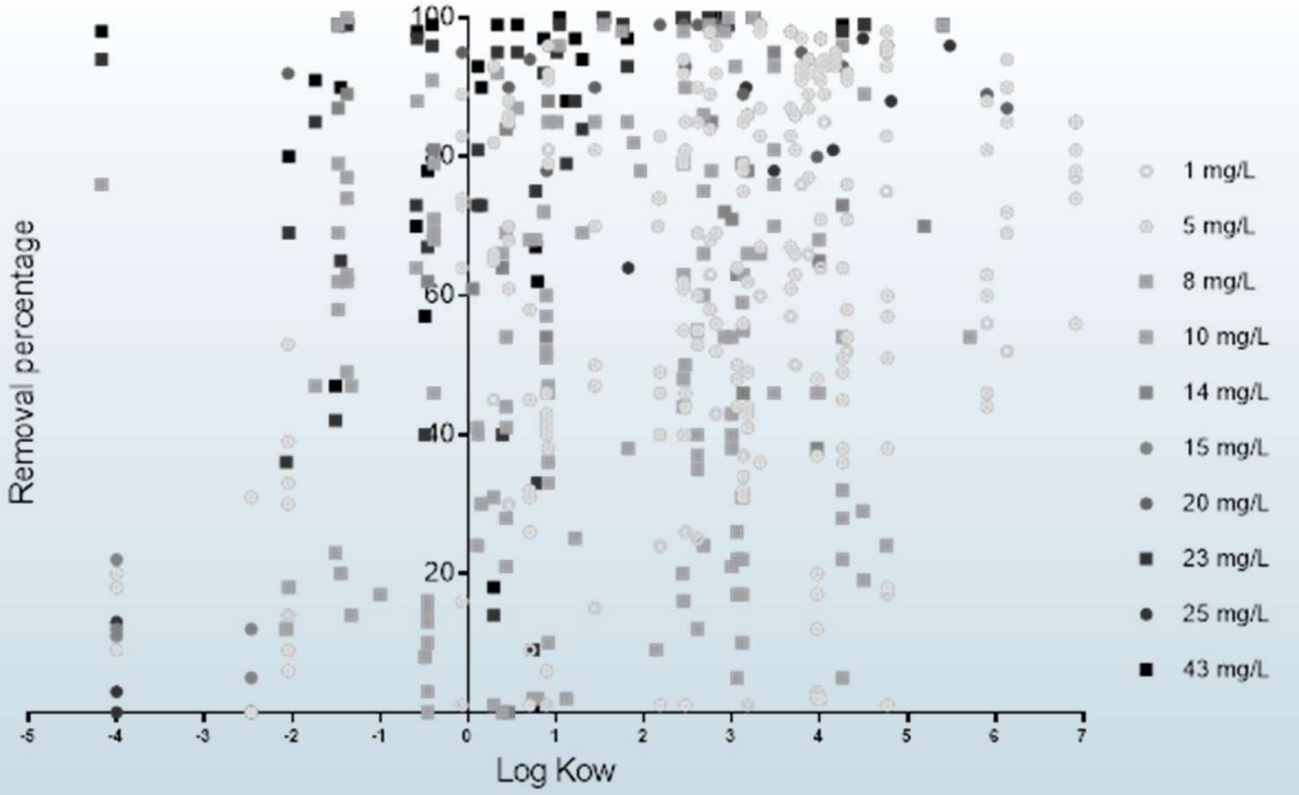
A dataset was built containing removal efficiency percentages and the defined reliability criteria.

231 papers reporting on water treatment techniques PAC, ozone/UV ± H_2O_2 and nano- and reverse osmosis membranes were evaluated of which 53 fulfilled the criteria

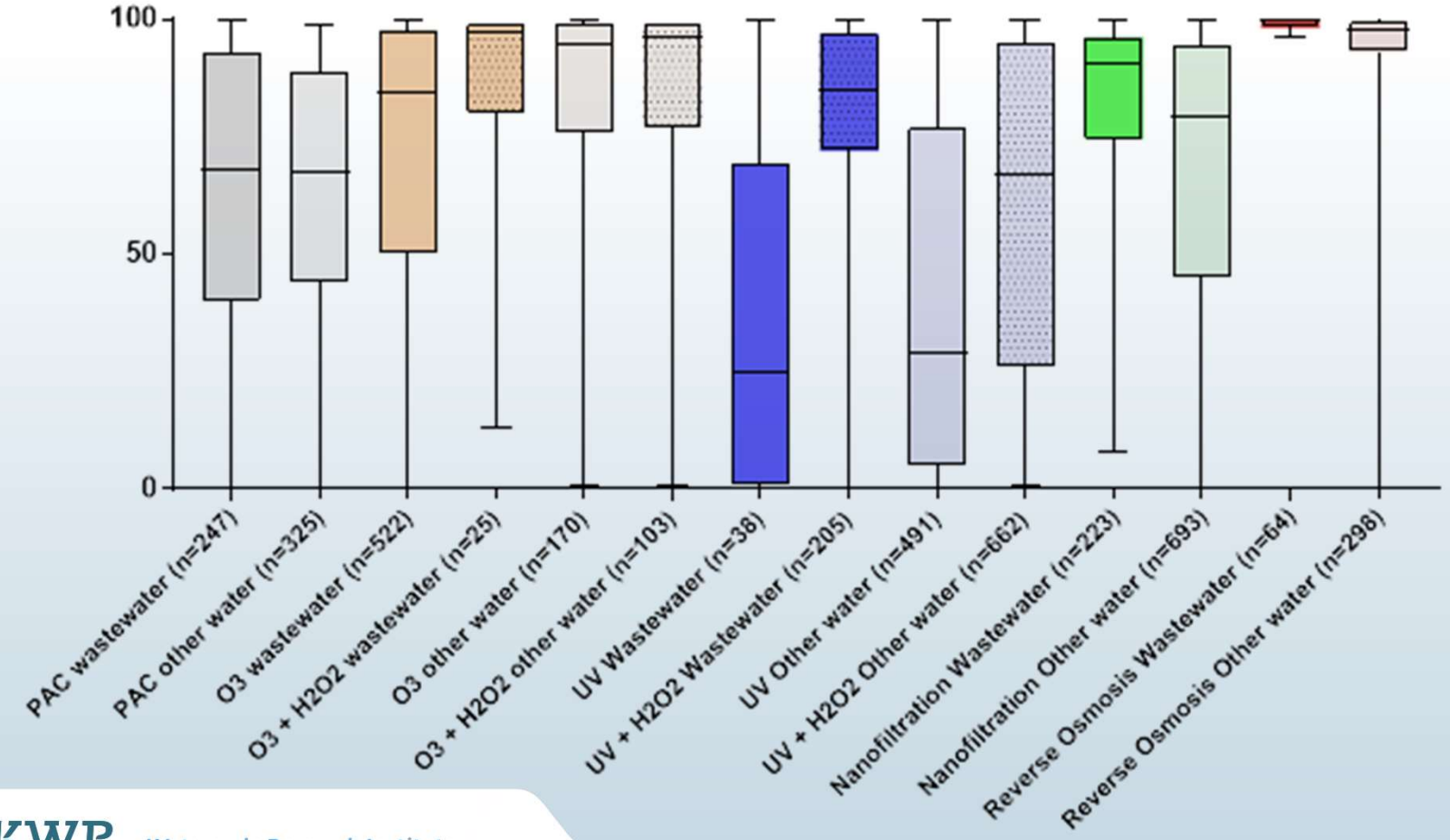
Treatment	**PAC**	**O_3 ± H_2O_2**	**UV ± H_2O_2**	**NF**	**RO**
# of papers	39	61	83	62	28
After criteria	7	15	20	14	7
# of CECs	119		74	111	51
# of data points	595	997	1396 (529 UV, 867 UV±H_2O_2)	916	322
Treatment dose	1-43 mg/L	0,5-16,3 mg/L O_3 (0,0625-10 mg/L H_2O_2)	(0-100 mg/L H_2O_2)		
Contact time	10 min-2 days	13 sec-30 min	1-120 min	2-48 hrs	30 min-24 hrs
DOC content	0-7,5 mg/L	0,8-33,3 mg/L	0-16,4 mg/L	0-3,7 mg/L	0-3,7 mg/L
CEC concentration	1 ng/L - 3353 µg/L	0,18 ng/L – 3353 µg/L	3 ng/L-118 mg/L	1,1 ng/L-308,24 mg/L	100 ng/L-15 mg/L

PAC

Influential parameter	p-value	R^2	Data points
Log K_{ow}	<0,0001	0,06262	539
DOC content	<0,0001	0,03307	574
Surface area (Wastewater[ii])	<0,0001	0,1995	247
Contact time	<0,0001	0,05114	582
Concentration (Wastewater)	<0,0001	0,1897	247
Concentration (surface water, other water)[i]	<0,0001	0,1781	306

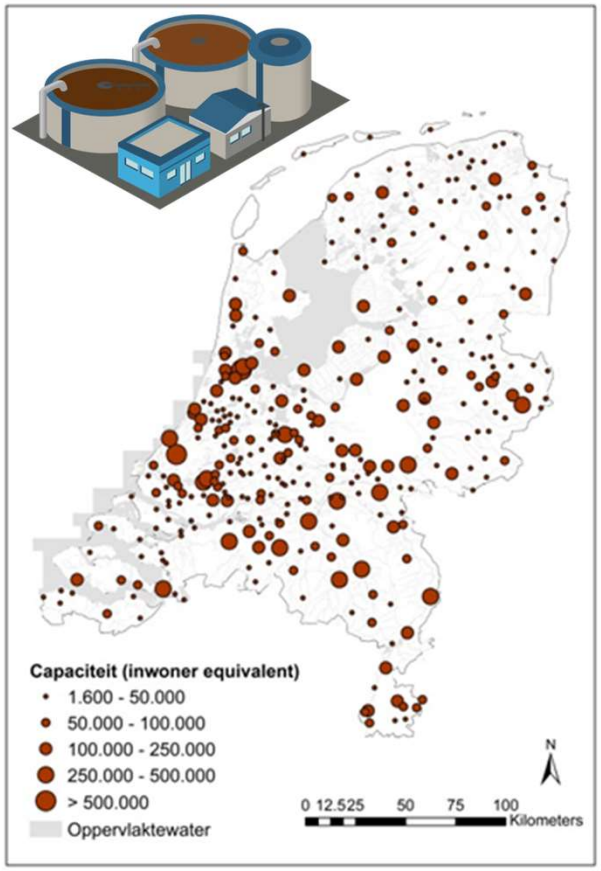


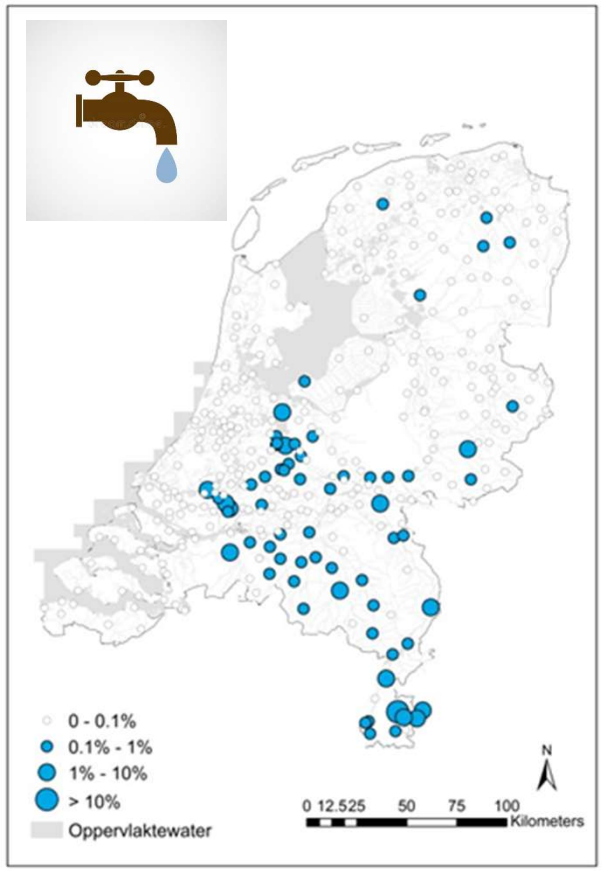
Overall efficiency of selected techniques

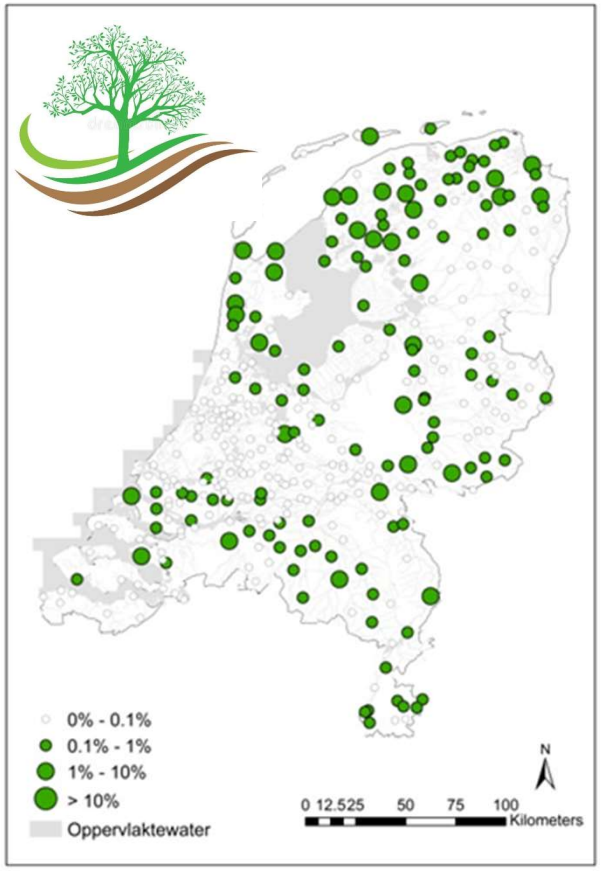


(MOTREM)

Increasing the effectivity by placement of treatment
Impact per STP on drinking water or nature

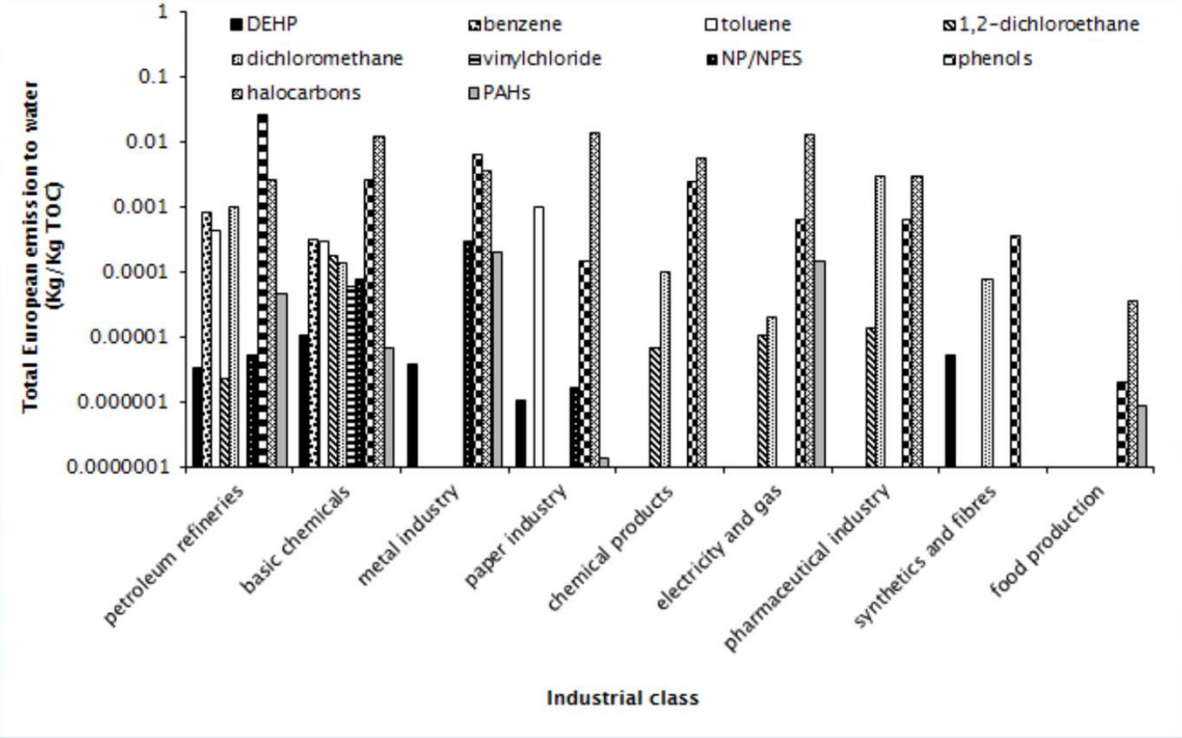


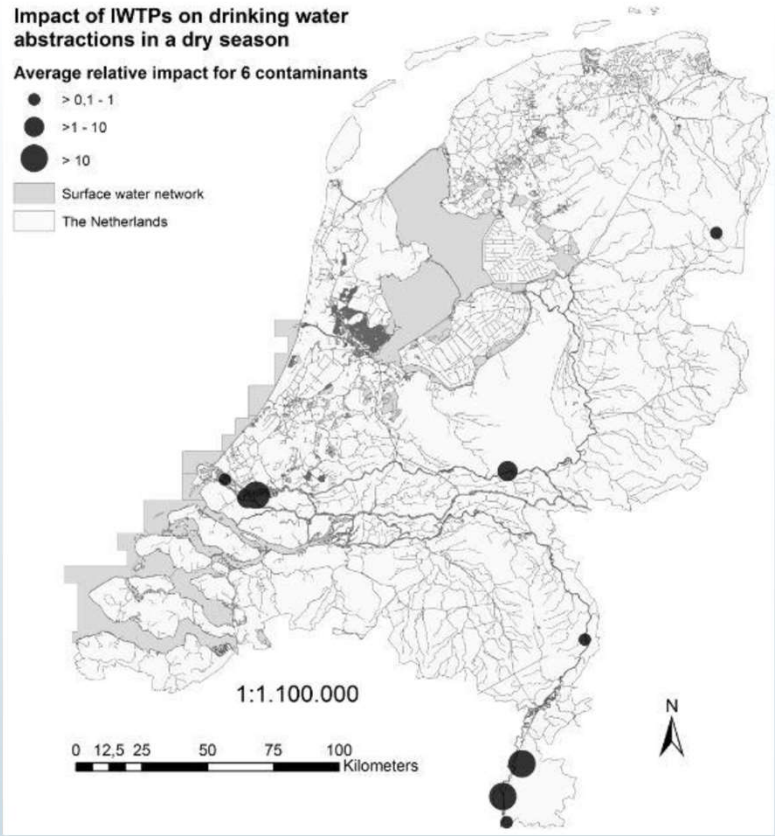




Emissions based on E-PRTR normalized to TOC

Systematic information on many CECs of interest in IWTP effluent is lacking





solutions focused perspective

- Research on chemical water quality focuses on problem and risk analysis, little attention to mitigation options
- Solution-focused assessments connect the perspectives of the water cycle and the chemical life cycle
- Solution-focused assessments can be supported by a mitigation database to prioritize mitigation options
- Currently no uniform approach to test and report CEC removal efficiencies, hampering informed decision making. Therefore set of relevance and reliability criteria was developed. Many studies did not include information to assess all criteria
- Modelling the impact of STP or IWTP on susceptible functions allows spatially smart implementation of mitigation options

Case; GenX emission by Chemours Dordrecht

Ban on PFOA → GenX

Indirect emission via STP

Province gives license

GenX;

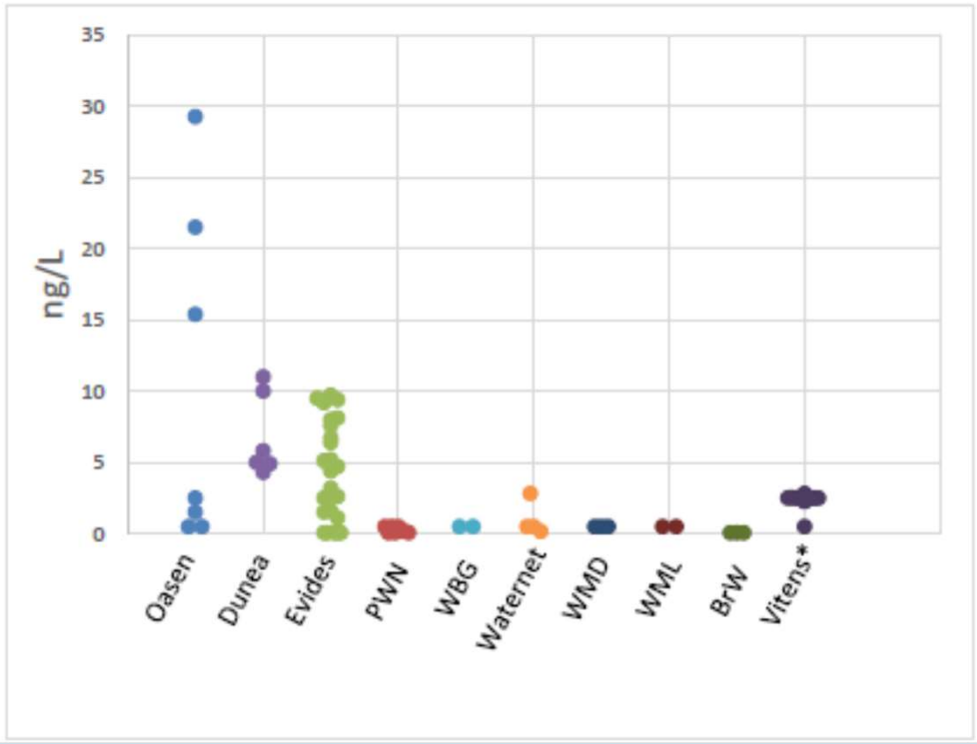
FRD 902 (salt, REACH registred)

FRD 903 (acid)

E1

Measurements in surface and drinking water

November 2016: 0,15 µg/l as indicative safe drinking water level



More technologies can be installed….

..but we might better think of ways to:

- Not to create a market pull for new substances when banning
- Use nature-based solutions for removal
- Create (non-)chemical alternatives that combine less hazardous properties with good functionaly
- More integrated and less sectoral chemical registration and authorization
- Co-development knowlegde MS → JPI
- Reach a non-toxic environment given future projected changes