FRAME

A novel framework to assess and manage **contaminants of emerging concern** in **indirect potable reuse**

Kevin S. Jewell, Jörg E. Drewes, Christian Dietrich, Uwe Hübner, Stefano Polesello, Giuseppe Mascolo, Mario Carere, Kevin V. Thomas, Daniel Pierre, Wolfram Kloppmann, Marie Pettenati, Géraldine Pico-Colbeaux, Nina Hermes, Johann Müller, Sapia Murgolo, Sara Valsecchi, Axel Aurouet, Loïc Thomas, Aurore Hertout, Karina Petersen, Soňa Fajnorova, Meriam Muntau, Saer Samanipour, Ailbhe L. Macken, Thomas A. Ternes

Rationale

- Overexploitation of water resources calls for increased application of indirect potable reuse (IPR)
- Management strategies for IPR in the European context are currently lacking

Aims

- Develop new strategies to manage CECs and pathogens in IPR for drinking water augmentation
- Overall evaluation procedure for IPR

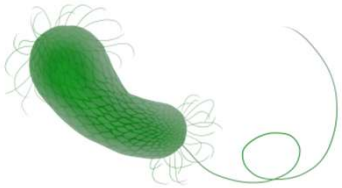
FRAME Handbook

Chapters:

- Regulation, guidelines – EU, USA, WHO, …
- Evaluation scheme – Indicator parameters
- Monitoring – Methods, examples
- Treatment barriers – Innovative solutions
- Decision support – Software

Analysis methods

- Biological contaminants
  - FIBs
    - Escherichia coli and total coliform bacteria – ISO 9308-2:2012
    - Pseudomonas aeruginosa – EN ISO 16266:2008
    - Enterococci – DIN EN ISO 7899-2
  - Antibiotic resistant bacteria, resistance genes
    - Ampicillin
    - Imipenem
    - Vancomycin
    - Erythromycin
    - Sulfamethoxazole

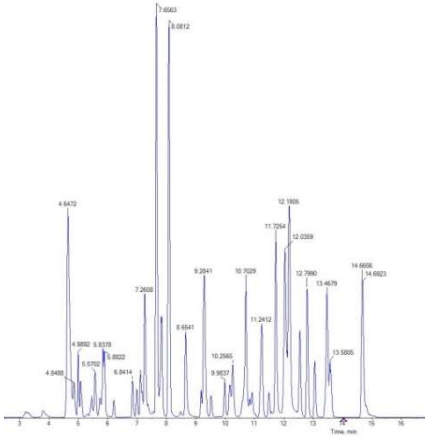


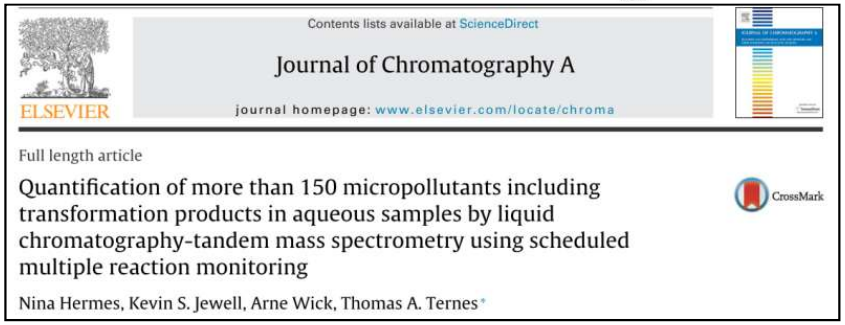
Wikimedia-commons

Hampton T. (2013)

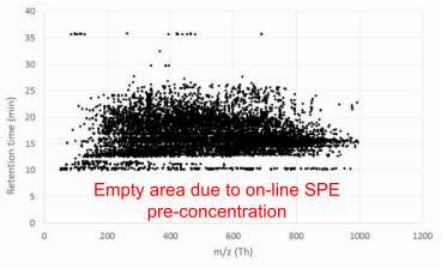
Analysis methods

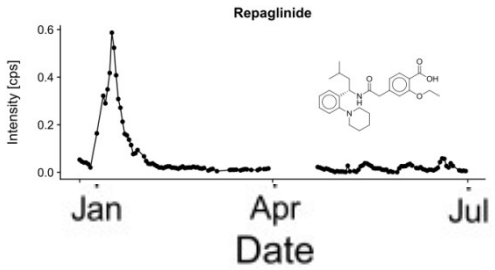
- Chemical contaminants
  - Target analysis methods
    - 166 CECs incl. 12 PFAS, 70 transformation products (biological, ozone)
    - **Three** multi-residue methods
  - Non-target analysis

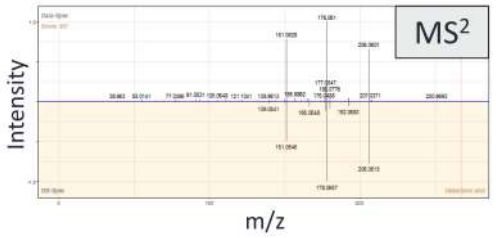




Hermes et al. 2018

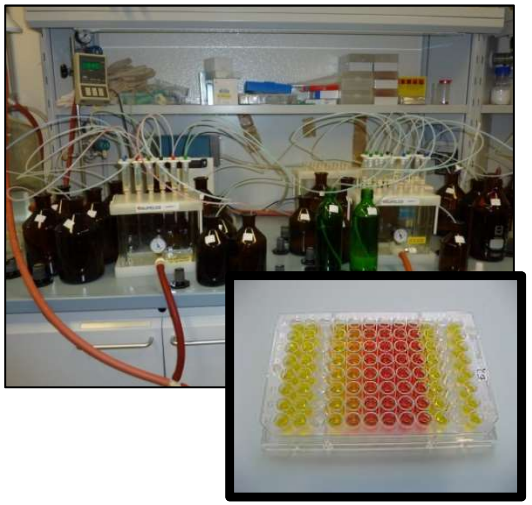




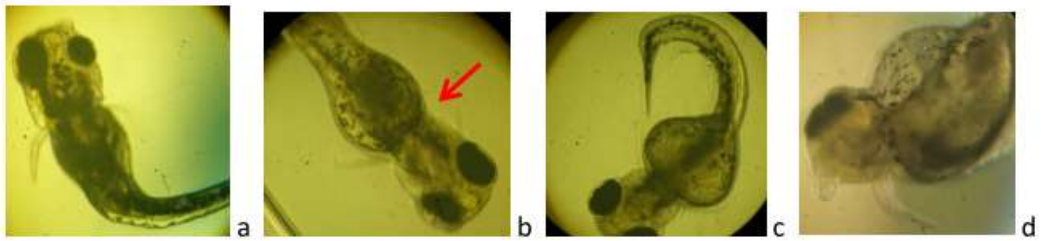


Analysis methods

- Chemical contaminants (cont.)
  - Effect-based monitoring *in vitro*
    - Ames test – mutagenic/carcinogenic activity
    - GeneBLAzer® – endocrine activity

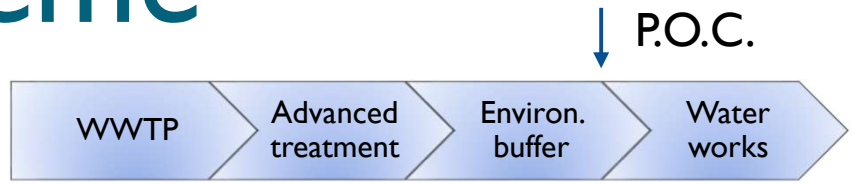


  - Effect-based monitoring *in vivo*



Evaluation scheme

- Point of compliance:



Health-based

- Threshold limits
  - CECs
  - Pathogens
- Effect-based
  - Zebrafish embryo test (lethal)

Below threshold

Performance-based

- CEC removal: Comparative treatment process evaluation incl. TPs
- Treatment targets for pathogens
- Effect-based
  - Zebrafish embryo test (sub-lethal)
  - Receptor assays (*in vitro* effects)

Evaluation scheme

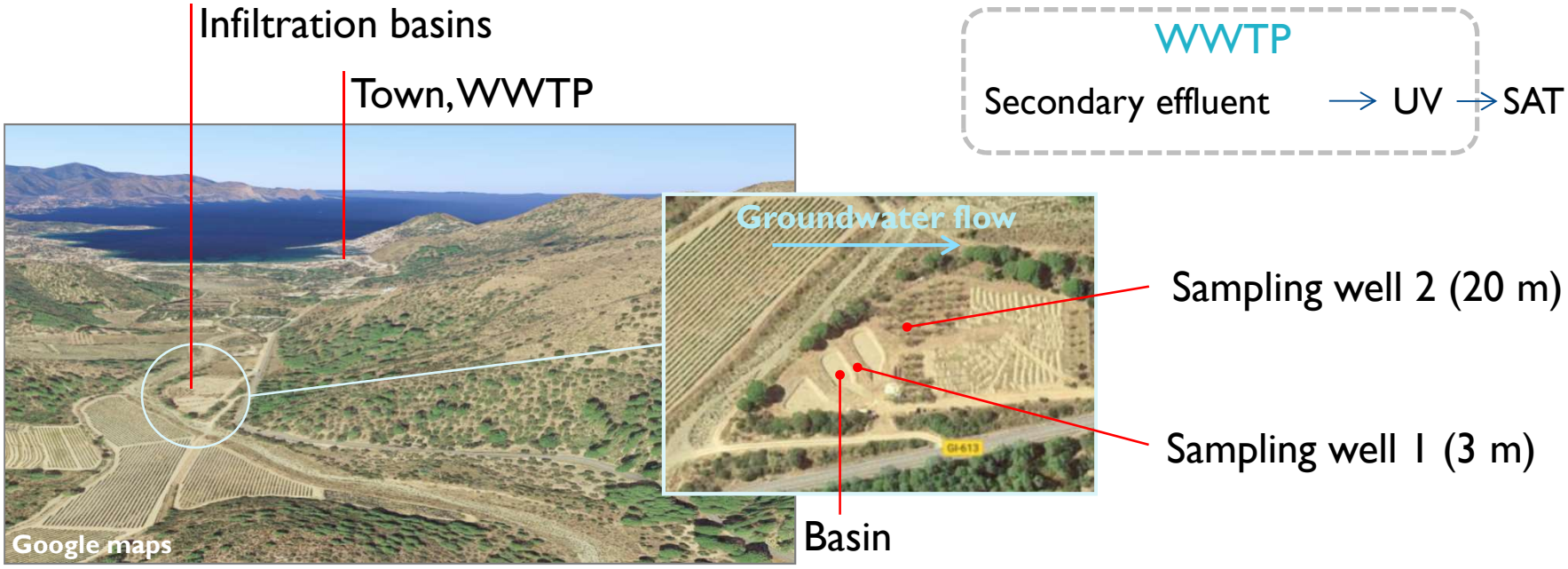
- Selection of CECs for health-based targets
  - Cat. A: Health-related compounds (e.g. GOW of UBA)
  - Cat. B: Health-related compounds WFD
  - Cat. C: Ozonation by-products

Example of Cat. B:

Name	Type or use	Regulatory values	IPR
Terbutryn	Biocide	0.065 µg/L (WFD)	< 65 ng/L
Isoproturon & …	Herbicide	0.1 µg/L (DWD 98/83/EC)	< 100 ng/L
PFOS	Industrial	0.65 ng/L (WFD)	< 0.65 ng/L
PFOA	Industrial	0.1 µg/L (proposal DWD revision)	< 100 ng/L
PFASs – Total	Industrial	0.5 µg/L (proposal DWD revision)	< 500 ng/L

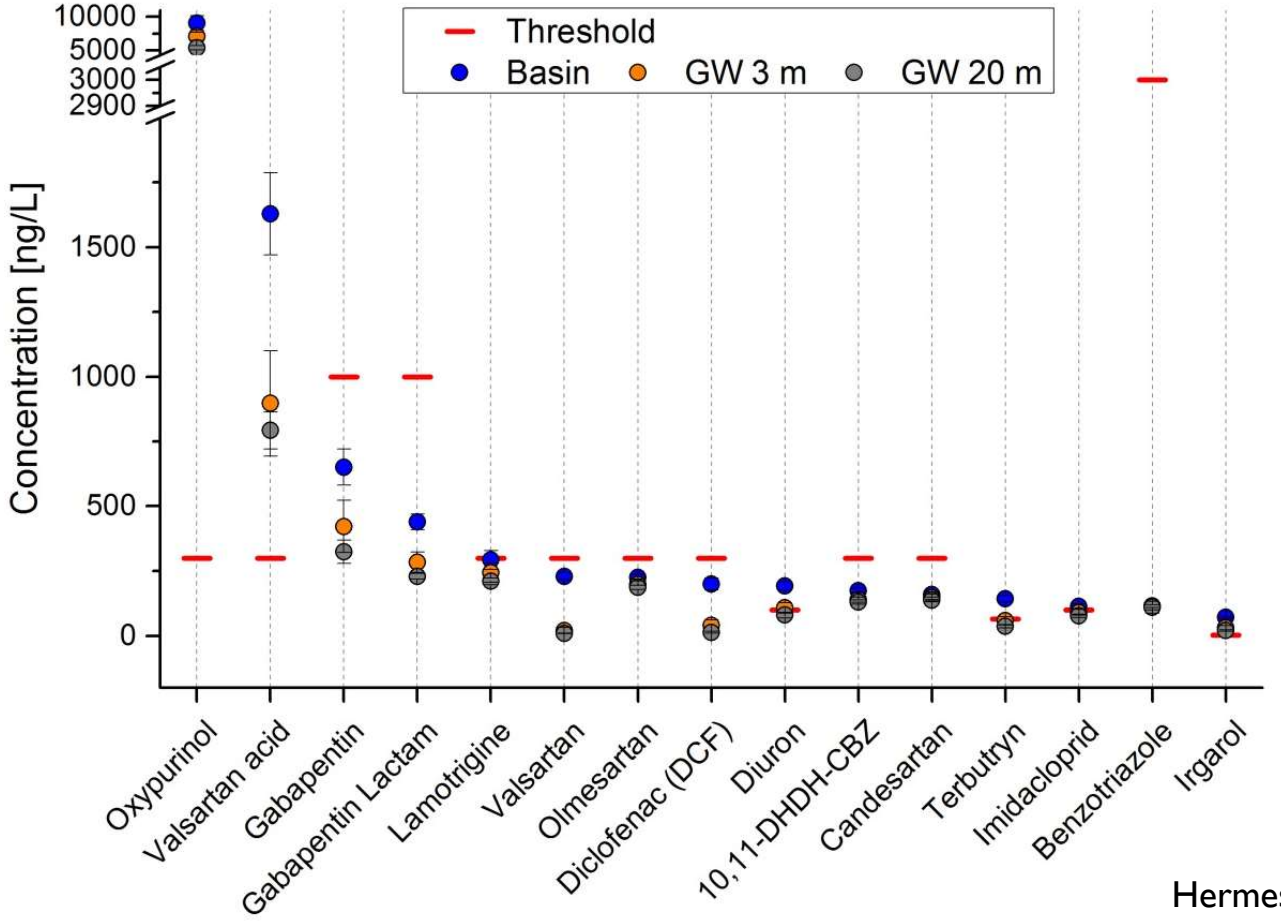
Monitoring studies

- El Port de la Selva, Spain – Indirect Potable Reuse
  groundwater augmentation, prevent sea-water intrusion



Monitoring studies

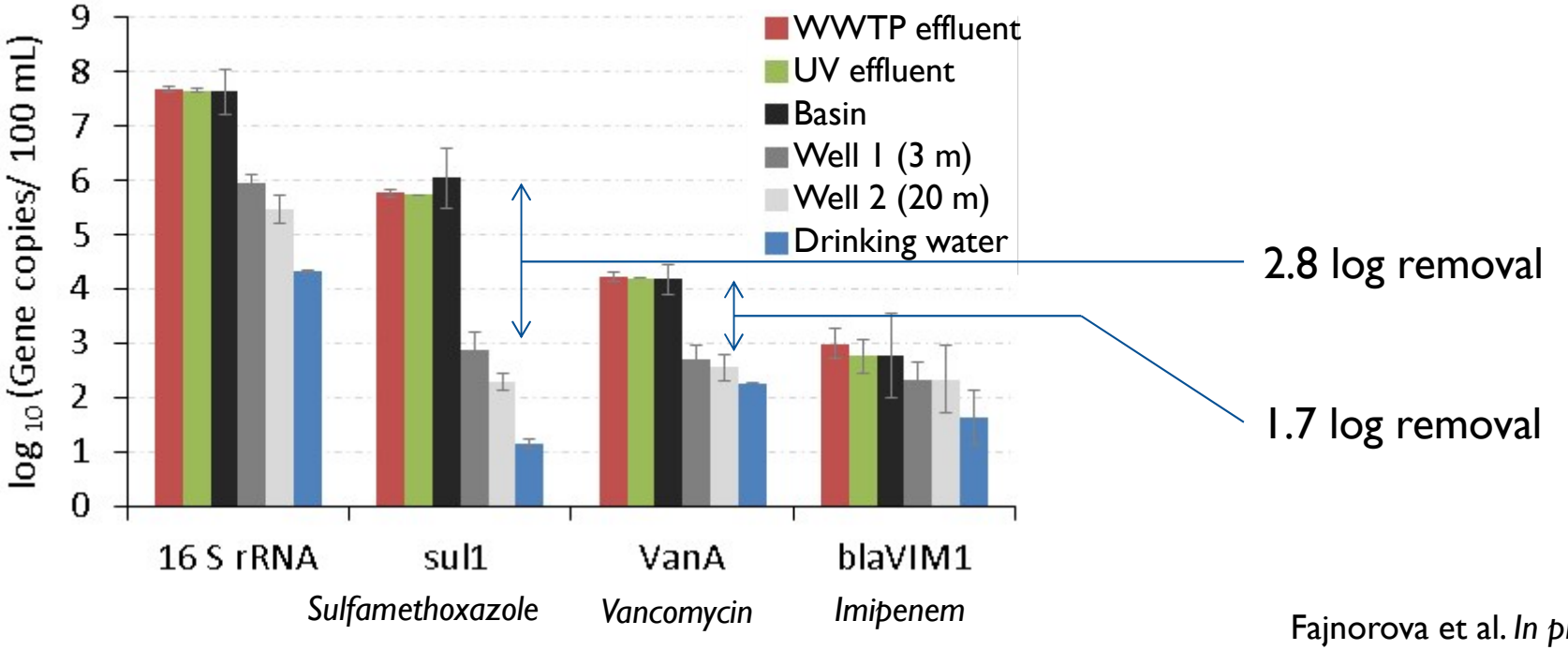
- CEC removal measurements



Hermes et al. *in prep.*

Monitoring studies

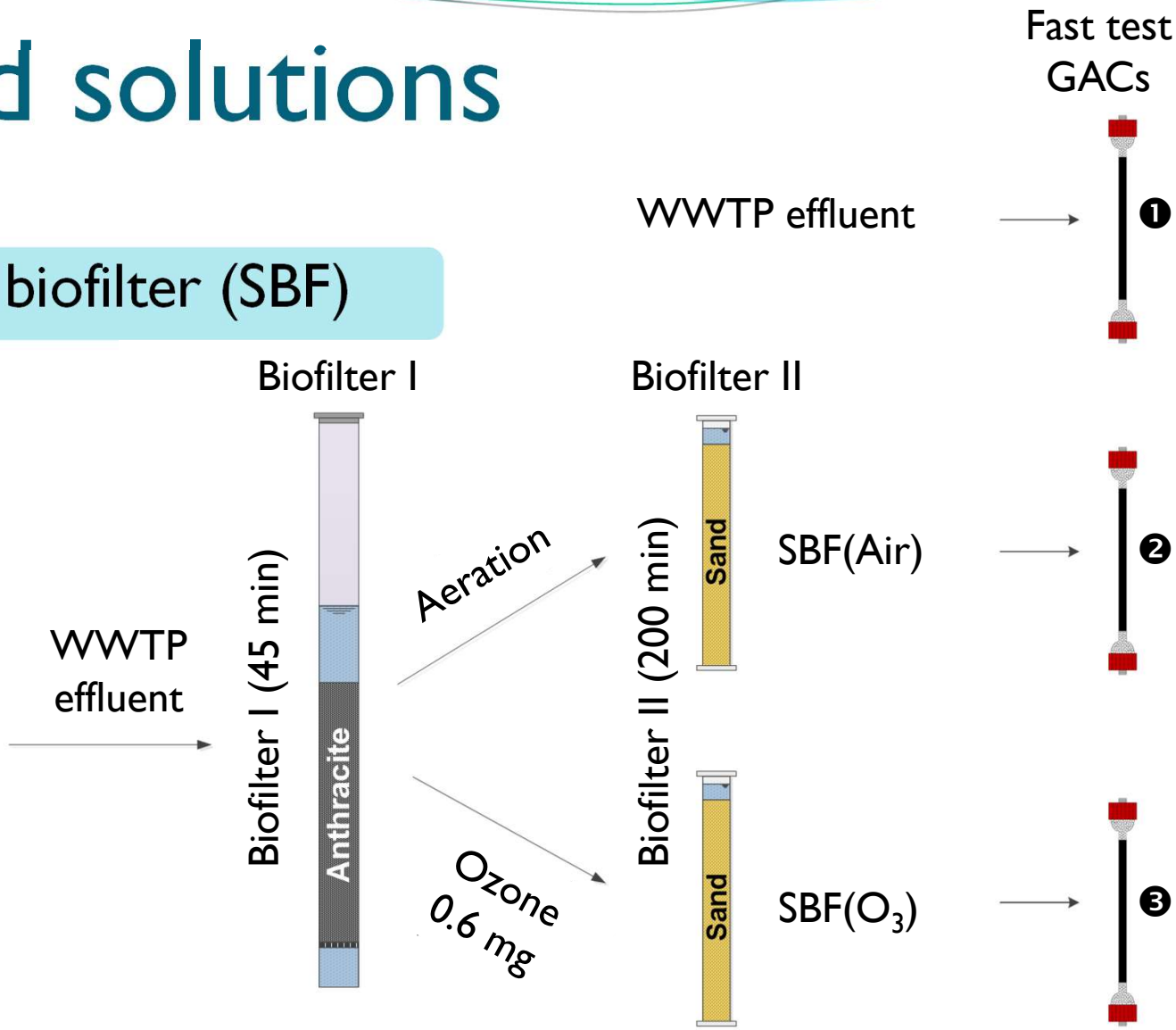
- Antibiotic resistance: removal of A.R. genes



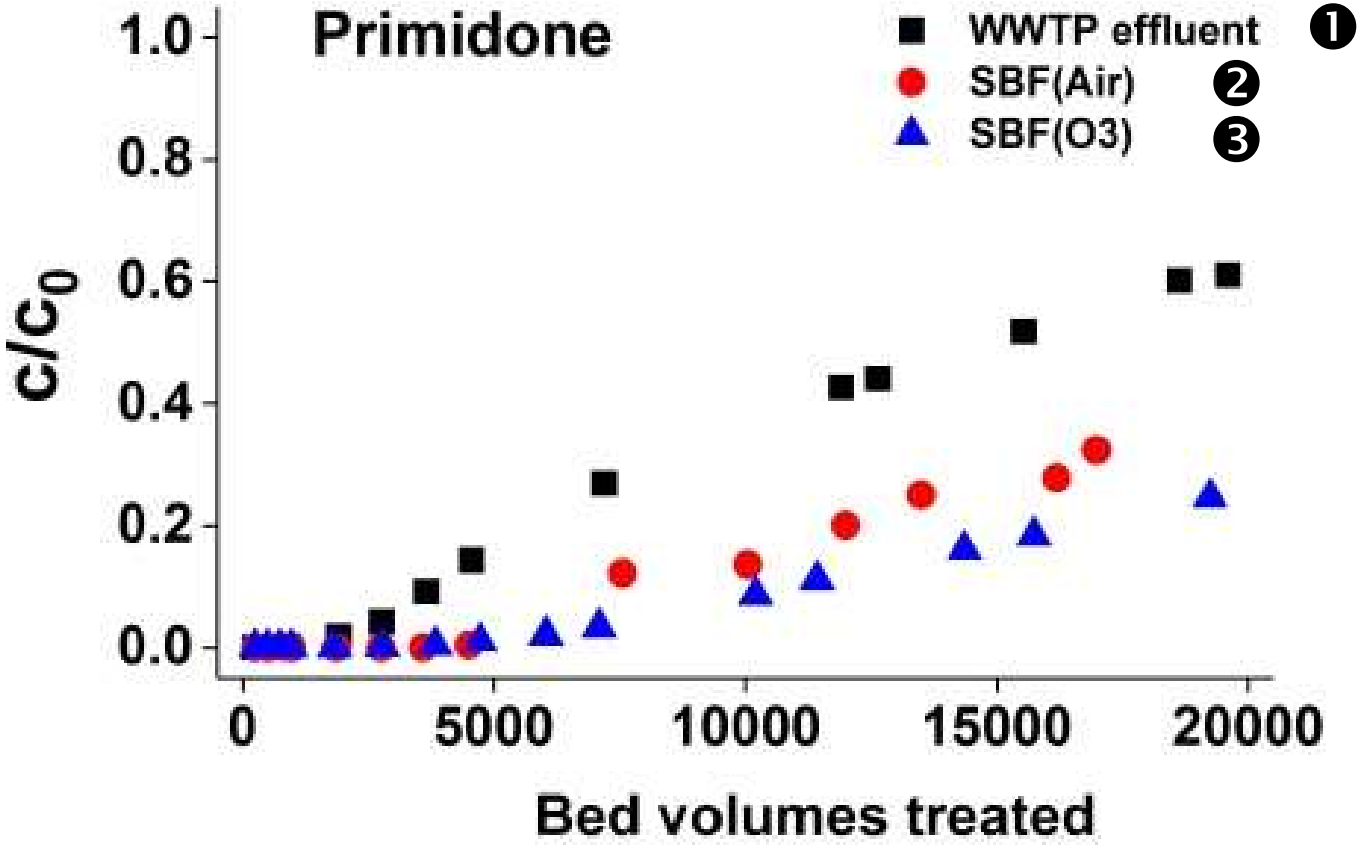
Fajnorova et al. *In prep.*

Advanced solutions

- Hybrid sequential biofilter (SBF)
  - Biofilter I (short)
  - Biofilter II (long)
  - Interstitial aeration or ozonation
  - Post-column GAC



Advanced solutions



Müller et al. *In prep.*

Conclusion, outlook

- Take home messages:
  - **Mitigation:** Multi-barrier systems (Ozone, Activated Carbon, Soil passage) are the most effective options[1]
  - **Evaluation/control:** A small range of indicator substances and pathogens, supplemented with effect-based measures
  - **Modelling/decision support:** Useful tool to assist process understanding and decision making
    - Link: [http://www.geo-hyd.net/install/Frame_DSS]

[1] cf. Muntau et al. *Sci. Tot. Environ.* 2017

Stakeholder engagement

- Input/consultation in the development of the evaluation strategy
  - Point of compliance & regulatory values

- Final workshop included presentations and discussion sessions with stakeholders from Europe and overseas
  - Panel discussions
  - Outputs fed into FRAME Handbook

Impact and knowledge output

- Handbook tailored to decision-makers
- Sensitive multi-residue analytical methods
- Impact on monitoring and evaluation strategies, EU policy implementation and future research
- CEC mitigation strategies, e.g. SMART concept

Collaboration, coordination, mobility, synergies

- Six exchange visits within the consortium
- Nine consortium or bilateral meetings at different institutes
- Links gained between all groups of the FRAME consortium, e.g. treatment design and CEC analysis
- Most institutes are continuing to work together

Future work

- Linking effect-based results with responsible contaminants
- Development of non-target strategies for contaminant prioritization
- Up-scaling of pilot-scale technical solutions, e.g. SMART system
- Further development of decision support tools and online resources

Acknowledgement

- Representatives at the field sites
- Partners, institutions
- www.frame-project.eu

GEFÖRDERT VOM

Bundesministerium für Bildung und Forschung

ONEMA
Office national de l'eau et des milieux aquatiques

The Research Council of Norway

MINISTERO DELL'ISTRUZIONE, DELL'UNIVERSITÀ E DELLA RICERCA

Last slide