

Scientific abstract in English

The abstract (max 8 000 characters including spaces) shall be written as an abstract for a scientific paper, i.e. it shall summarise the various parts of the work:

- Introduction with objective and hypothesis
- Material and methods
- Results
- Discussion and conclusions
- List of scientific papers, if any, which were written during the project period

Introduction

SafeDrink comprised an interdisciplinary research team from SLU, Uppsala Univ. (UU), Mid Univ. of Sweden, National Food Agency, and the drinking water (DW) sector including chemists, toxicologists, engineers and social scientists. We have carried out interdisciplinary, demand-driven research in collaboration with water producers, enterprises, and international colleagues. The objectives of SafeDrink were to:

- develop screening techniques for chemical analysis and toxicological effects of known and unknown organic micropollutants present in drinking water (DW)
- integrate screening tools for hazard identification at an early stage to prevent adverse health effects
- apply these methods for the evaluation of DW treatment plant (DWTP) processes and the impact of dissolved organic carbon (DOC) on contaminant levels and toxicity from source to tap
- search for hazardous chemicals in human serum with links to DW exposure
- analyze how the public makes sense of everyday life risks, in particular from tap water, to improve risk communication by stakeholders

Materials and Methods

SafeDrink developed an integrated chemical-biological framework for improved detection of toxic chemicals in DW. High volume water samples (up to 10 L) or exposed passive samplers are treated and concentrated to low volume (~1 mL) extracts for analysis using mass spectrometry (LC-MS/MS and LC-HRMS) and cell-based bioassays^{1,2,4,5,8-10}. A battery of bioassays were developed to investigate toxic activities of the extracts^{2,5,9,11,12,13,16,17}. We also created a software tool for selection of relevant hazardous substances (suspects) to screen for in DW (SusTool)³.

Effects of water treatment techniques including the impact of DOC were studied experimentally^{1,2,11,14,15}, and screenings were conducted in field studies^{4,5,7,8-10}. The methodology for the sense-making studies was interviews with parents living in two Swedish cities with previous challenges with water quality.

Results

Our results are summarized in 17 peer-reviewed research articles¹⁻¹⁷.

Discussion and Conclusions

The main findings from the project are:

- Concentrations of micropollutants were low in the DW¹⁰. However, bioassays revealed metabolic and estrogen activities, as well as oxidative stress^{2,9}. The effects were not related to the detected micropollutants, and thus due to unknown chemicals.
- Conventional DWTPs are generally inefficient in removing micropollutants^{1,8-10,14}. After treatment steps, the bioactivities were either reduced⁹, remained^{2,9} or increased² in the outlet water.
- Granulated active carbon (GAC) filters efficiently removes per- and polyfluoroalkyl substances (PFASs), but efficiency and column breakthrough time is dependent on chain length, functional groups and DOC levels and type^{14,15}. In contrast, PFASs are well removed by anion-exchange independent of DOC concentrations¹⁴.
- DOC has some impact on in vitro bioactivities¹¹.
- Bioassays are useful tools for the detection of chemical threats in source and DW to protect consumers from exposure to hazardous chemicals^{2,9,11,16,17}.
- Human exposure to PFASs through DW may be significant even at relatively low levels, as shown from serum levels of exposed individuals⁷.
- People make sense of risks based on previous personal experiences (e.g. water contamination), local images of water quality (e.g. related to unspoiled nature) and current life situation (e.g. having an infant). Effects of risk communication vary accordingly.

In conclusion, being our most important food, DW needs to be extensively monitored for hazardous chemicals. As proposed in the new EU drinking water directive, a risk-based approach is required, where bioanalysis is combined with chemical analysis (effect-directed analysis) to identify chemical(s) causing toxic effects.

SafeDrink has led to a proposal to the government for a national Competence Center on Chemical Hazards in DW, initiated by the Governor of the Uppsala County Board and signed by 10 other regional stakeholders (water producers, national authorities, Vice Chancellors of SLU and UU). SafeDrink also constituted the platform for Ready2Drink, a joint academy-stakeholder proposal for a Vinnova Competence Center 2020 focusing on DW quality and quantity (88 million SEK) submitted in Jan 2019.

Dissemination

We have published 5 reports (see Popular Science Report) and 17 peer-reviewed articles in international journals, and 11 manuscripts are under way. Members of SafeDrink organized workshops and sessions on DW production challenges, and we contributed with >80 national/international conference, workshop, and seminar presentations, frequently as invited speakers. Media has frequently acknowledged our work (see Popular Science Report) and we have educated 15 master students and 4 postdocs, and 1 PhD student graduation is under way. We have also taught classes in environmental and water science/technology in academia as well as in courses for staff at treatments plants.

Peer-reviewed publications

- 1 **Pohl J et al.** Embryotoxicity of ozonated diclofenac, carbamazepine, and oxazepam in zebrafish (*Danio rerio*). *Chemosphere*, in press
- 2 **Lundqvist J et al.** Innovative drinking water treatment techniques reduce the disinfection-induced oxidative stress and genotoxic activity. *Water Res* 155:182-192, **2019**
- 3 **Dürig W et al.** Development of a suspect screening prioritization tool for organic compounds in water and biota. *Chemosphere* 222:904-912, **2019**
- 4 **Gobelius L et al.** Calibration and application of passive sampling for per- and polyfluoroalkyl substances in a drinking water treatment plant. *J Hazard Mater* 362:230–237, **2019**
- 5 **Rosenmai AK et al.** Effect-based assessment of recipient waters impacted by on-site, small scale, and large scale waste water treatment facilities – combining passive sampling with *in vitro* bioassays and chemical analysis. *Sci Rep* 21;8(1):17200, **2018**
- 6 **Probert PM et al.** Identification of a xenobiotic as a potential environmental trigger in primary biliary cholangitis. *J Hepatol* 69, 1123-1135, **2018**
- 7 **Gyllenhammar I et al.** Perfluoroalkyl acids (PFAAs) in serum from 2-4-month-old infants – influence of maternal serum concentrations, gestational age, breastfeeding and contaminated drinking water. *Environ Sci Technol* 52:7101-7110, **2018**
- 8 **Gobelius L et al.** Per- and polyfluoroalkyl substances in Swedish groundwater and surface water: Implications for Environmental Quality Standards and drinking water guidelines. *Environ Sci Technol* 52:4340-4349, **2018**
- 9 **Rosenmai AK et al.** In vitro bioanalysis of drinking water from source to tap. *Water Res* 139:272-280, **2018**
- 10 **Tröger R et al.** Micropollutants in drinking water from source to tap - method development and application of a multiresidue screening method. *Sci Total Environ* 627:1404–1432, **2018**
- 11 **Rosenmai AK et al.** Impact of natural organic matter on bioactivity of water samples. *Chemosphere* 200:209-216, **2018**
- 12 **Niss F et al.** Short communication: Toxicity bioassays with concentrated cell culture media - a methodology to overcome the chemical loss by conventional preparation of water samples. *Environ Sci Pollut R*, 12:12183-12188, **2018**
- 13 **Rosenmai AK et al.** Relationship between peroxisome proliferator-activated receptor alpha activity and cellular concentration of 14 perfluoroalkyl substances in HepG2 cells. *J Appl Toxicol* 38:219–226, **2018**
- 14 **Kothawala DN et al.** Influence of dissolved organic matter concentration and composition on the removal efficiency of perfluoroalkyl substances (PFASs) during drinking water treatment. *Water Res* 121:320-328, **2017**
- 15 **McCleaf P et al.** Removal efficiency of multiple perfluoroalkyl substances (PFASs) in drinking water using granular activated carbon (GAC) and anion exchange (AE) column tests. *Water Res* 120:77-87, **2017**
- 16 **Lundqvist J et al.** Microcystins activate nuclear factor erythroid 2–related factor 2 (Nrf2) in human liver cells in vitro – Implications for an oxidative stress induction by microcystins. *Toxicol* 126:47-50, **2017**
- 17 **Lundqvist J et al.** Fungicide prochloraz induces oxidative stress and DNA damage *in vitro*. *Food Chem Toxicol* 91: 36-41, **2016**