

Drinking water production – What are the risks from dumping RO - concentrates and antiscalants into the aquatic environment?

Carolin Bertold¹, Florian Gigl¹, Anja Rohn², Gerhard Schertzinger², Beat Schmutz³, Sebastian Egner³, Dominic Armbruster³, Oliver Happel³, Henner Hollert¹, Sarah Johann^{1*}, Sabrina Schiwy^{1*}

¹Department Evolutionary Ecology & Environmental Toxicology (E²T), Faculty Biological Sciences, Goethe University Frankfurt, Max-von-Laue-Str. 13, 60438 Frankfurt am Main, Germany

²IWW Water Centre Moritzstr. 26, 45476 Mülheim an der Ruhr, Germany

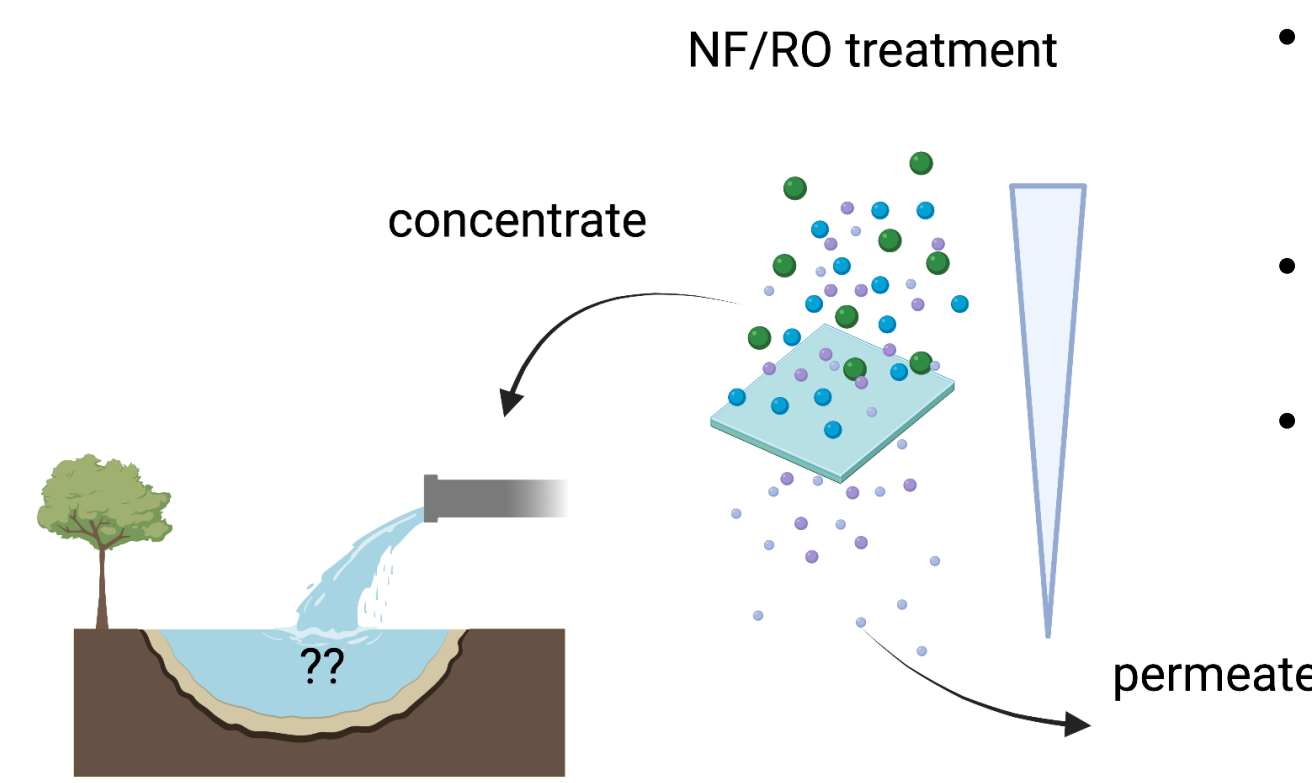
³TZW: DVGW Water Technology Center, Karlsruher Str. 84, 76139 Karlsruhe, Germany

*contributed equally to senior authorship

Correspondence: johann@bio.uni-frankfurt.de / bertold@bio.uni-frankfurt.de

Background

- Reverse Osmosis (RO) plants are used for drinking water purification and water softening
- RO products: permeate (for drinking water production) and concentrate
- Concentrates**
 - Directly discharged into rivers or indirectly via WWTP → regarded with increasing concern
 - Concentrated salts and antiscalants (AS), may contain anthropogenic trace substances (e.g., PFAS)
- Antiscalants**
 - Additives used in RO plants to reduce membrane fouling
 - Based on phosphonates or polyacrylates
 - Environmental risk: low biodegradability; possible contribution to the migration of trace metals; phosphonates could lead to eutrophication [1]



Aims and objectives

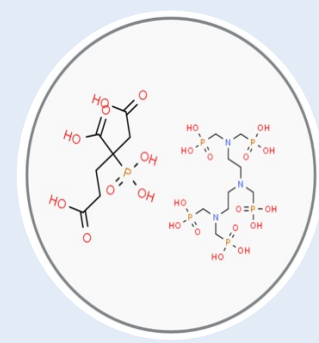
- Developing a comprehensive bioassay battery for the ecotoxicological assessment of AS and concentrates
- Evaluating the effect of AS active ingredients in complex mixtures (concentrates and technical products)
- Evaluating different concentrate treatment strategies (data not shown)
- Contributing to a holistic evaluation of NF/RO technology in drinking water treatment

Samples

Antiscalants*

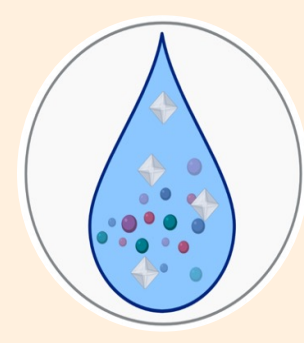
Standards and technical products of

- ATMP
- DTPMP
- PBTC
- Polyacrylic acid



RO Concentrates

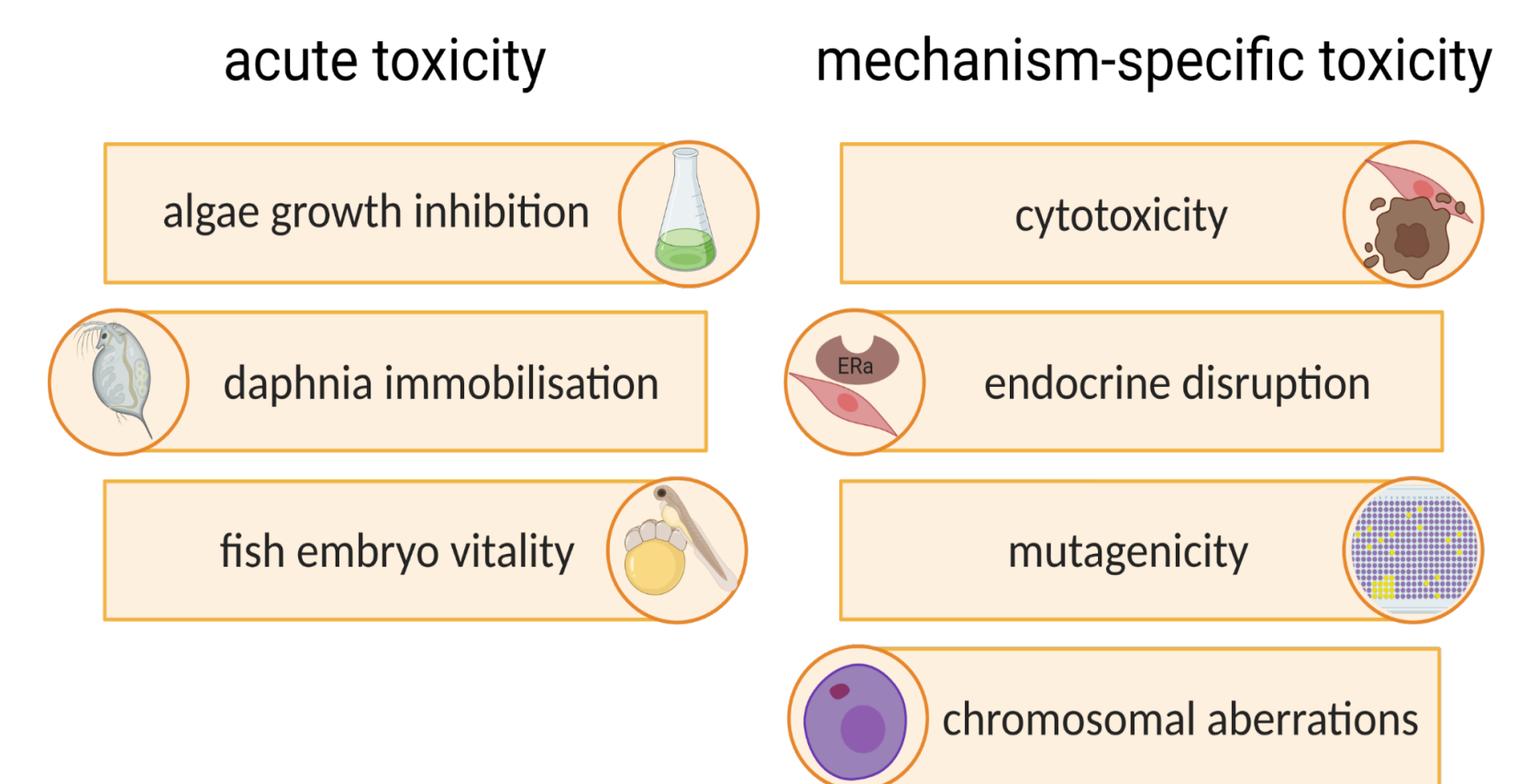
- Con A ATMP
- Con B Polyacrylate/DTPMP
- Con C DTPMP
- Con D Polyacrylate and without AS



*Ca-saturation (20 mmol functional groups/L)

Methods

Ecotoxicological assessment:



Chemical characterisation of phosphonates:

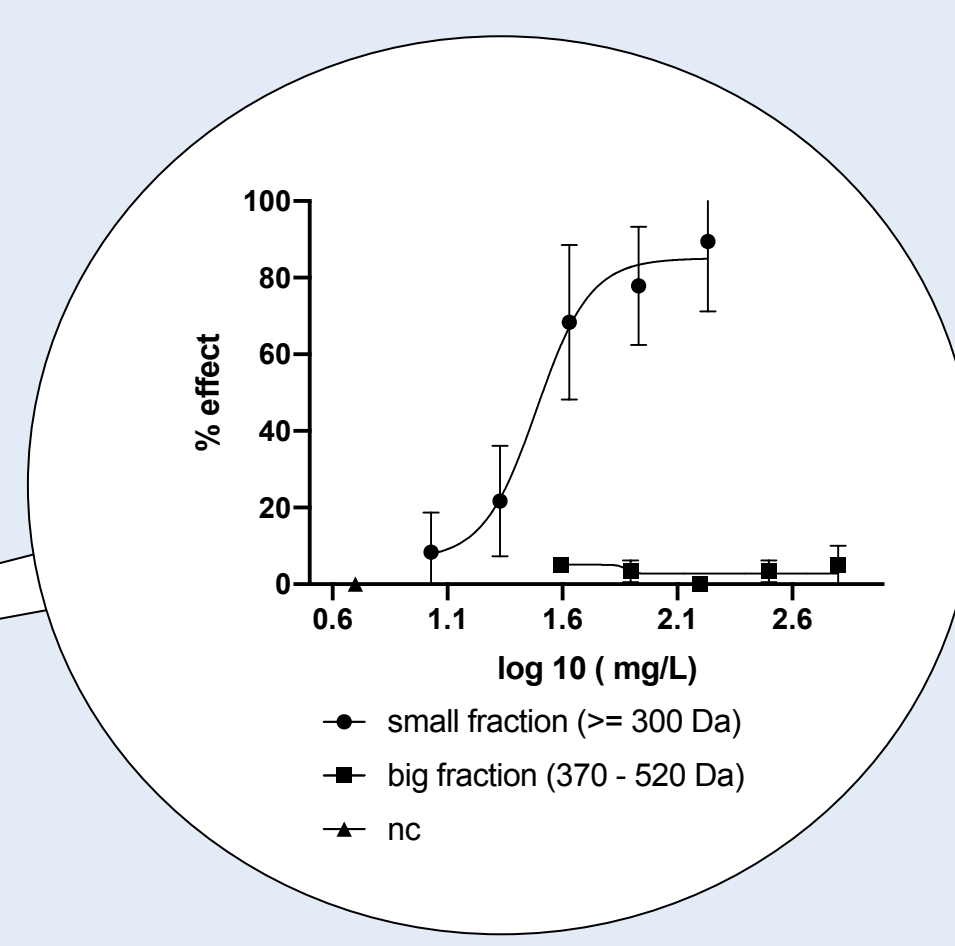
Determination of AS concentrations in standards, technical products and concentrates via IC-IC-MS, IC-ESI-TOF and IC-ESI-MS/MS

Results and Discussion

Antiscalants

Table 1: Overview of ecotoxicological effects from AS technical products and standards in a comprehensive bioassay battery. All biotests were performed in 3 valid independent replicates (* less than 3 replicates performed).

	algae growth inhibition	daphnia immobilisation	fish embryo vitality	cytotoxicity	endocrine disruption	mutagenicity	chromosomal aberrations
Standards							
ATMP	no	no	no	high	no	no	no
DTPMP	no	no	no	high	no	no	no
PBTC	no	no	no	high	no	no	no
Polyacrylic acid	no	no	no	no	no	no	no
Technical products							
Technical product ATMP	no	no	no	high	no	no	no
Technical product DTPMP	no	no	no	high	no	no	no
Technical product PBTC	no	no	no	high	no	no	no
Technical product polyacrylic acid 1	no	no	no	no	no	no	no
Technical product polyacrylic acid 2	no	no	no	no	no	no	no
Technical product polyacrylic acid and DTPMP	no	no	no	high	no	no	no



Acute toxicity:

- AS partly induce toxicity in laboratory model organisms- especially toward algae
- Algae toxicity is possibly due to nutrient complexation [2]
- ATMP and DTPMP show effects in the range of potentially environmentally relevant concentrations
- Big fraction (370-520 Da) of technical product polyacrylic acid 2 is not toxic to daphnids, whereas the fraction with smaller polymers (<=300 Da) shows a significant toxic effect

Mechanism-specific toxicity:

- No toxic effects

RO Concentrates

Table 2: Overview of ecotoxicological effects from RO concentrates in a comprehensive bioassay battery. All biotests were performed in 3 valid independent replicates (grey boxes = experiments not yet performed; * less than 3 replicates performed).

	algae growth inhibition	daphnia immobilisation	fish embryo vitality	cytotoxicity	endocrine disruption	mutagenicity	chromosomal aberrations
Concentrate A (ATMP)	no	no	no	high	no	no	no
Concentrate B (polyacrylic acid and DTPMP)	no	no	no	high	no	no	no
Concentrate C (DTPMP)	no	no	no	high	no	no	no
Concentrate D (with polyacrylic acid)	no	no	no	high	no	no	no
Concentrate D (without antiscalants)	no	no	no	no	no	no	no

→ **Low acute toxicity toward daphnids and fish** (here: premature hatching observed) could be due to the high salt content of the concentrates [3]

→ endocrine activity was detected in concentrate A,B,C

→ Measured concentrations of ATMP and DTPMP in the concentrates below the acute toxicity threshold of the standards and technical products

Highlights

- AS standards and technical products induced **no to moderate toxicity in environmentally relevant concentrations**
- Preliminary toxicity ranking of phosphonate-based AS:
PBTC < ATMP < DTPMP
- AS technical products can be more toxic than the active ingredient alone (potentially due to unknown additives)
- First results show **low to moderate toxicity of concentrates**



Outlook

- Further ecotoxicological investigations will be performed concerning
 - Swimming behavior alterations in AS exposed zebrafish larvae
 - Impact of high salinity in concentrates
 - Complete Biotest battery on concentrates
- Further chemical profiling of trace substances in concentrates