Risk-based water quality assessment through bioanalytical tools

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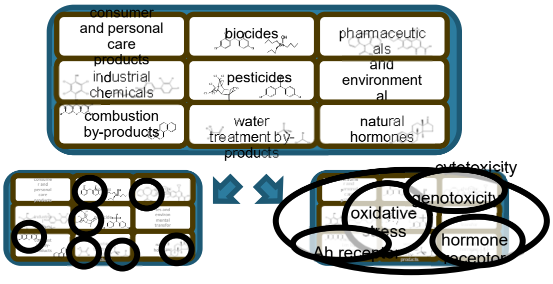
Water quality monitoring of chemicals

Countless organic contaminants enter waterways from industry, agriculture, households, *etc*.

Conventional water treatment does not always remove all chemicals. Disinfection processes (*e.g.*, chlorination, ozonation) eliminate many unwanted pathogens/chemicals but transformation products can form.

Chemical analysis and bioassays provide complementary information and together may serve as a comprehensive screening tool.



Chemical analysis
- Quantitative detection of targeted compounds
- May overlook non-target contaminants such as disinfection by-products and unknown chemicals

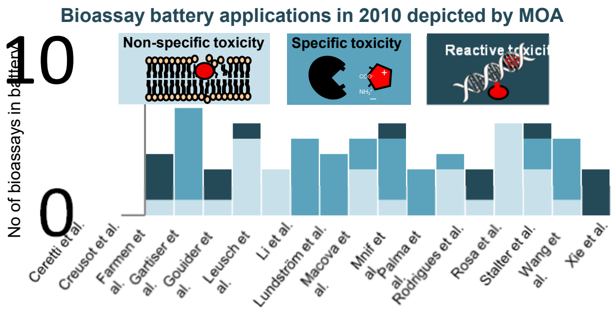
Bioanalytical tools
- Capture mixture effects
- Risk-scaled, *i.e.*, toxic potency determines response magnitude
- Provide information on the mode of action, *i.e.*, the cause of toxicity

Current applications of bioanalytical tools

Assays span across various modes of toxic action:

- **Non-specific toxicity** - overall cytotoxicity (often by Microtox®), important to rule out interference with specific response (QA/QC)
- **Specific toxicity** – *e.g.*, binding to nuclear receptors (*e.g.*, estrogen and aryl hydrocarbon receptors) and enzymes (*e.g.*, acetylcholinesterase inhibition for neurotoxicity), often reporter gene assays
- **Reactive toxicity** - all MOAs that involve chemical reactions (*e.g.*, protein/DNA damage, oxidative stress), common assays include, *e.g.*, Ames test (mutagenicity), Comet assay (genotoxicity)

Few studies cover multiple MOA categories:



Poulsen et al. (2011) Urban Water Security Research Alliance Technical Report No. 41.

Considerations for the design of bioanalytical tools

Take into account ultimate protection goal - human and ecosystem health.

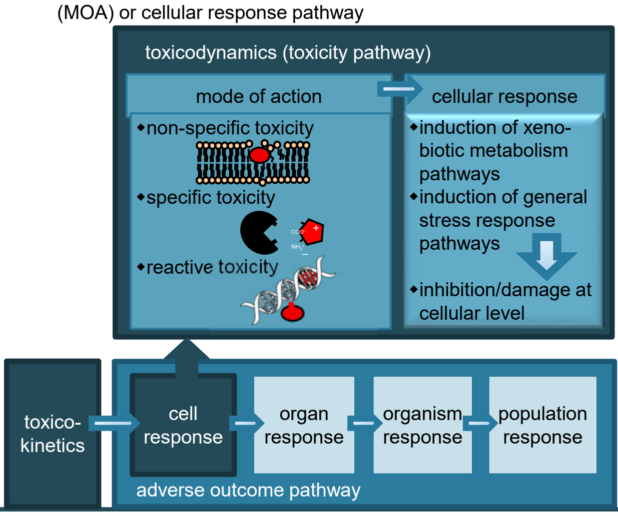
Early indicators of chemical hazard potential before manifestation of adverse effects.

Detect early cellular triggers that may result in toxicity and cellular response (defence and repair mechanisms).

Account for mixture effects (additive, synergistic, antagonistic).

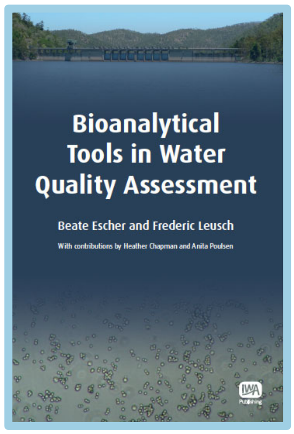
Conceptual framework: **adverse outcome pathways**

- The bioassay system should mimic toxicokinetics (uptake and elimination as well as metabolism)
- The bioassay should target and be selective for a mode of action (MOA) or cellular response pathway



The future of bioanalytical tools

The application of bioanalytical tools for water quality assessment is still in its infancy, however, has already proven useful for both benchmarking of water quality and assessment of water treatment efficacy. Yet, the road to acceptance as a regulatory tool is long.



Current limitations include a lack of:

- Standardised validated methods
- Elimination of experimental artefacts such as matrix effects (*e.g.*, by organic matter)
- Link between bioassays and chemical analysis
- Link between *in vitro* and *in vivo* assays

Potential for improvement

- Assays to detect adaptive cellular stress response pathways (*e.g.*, inflammation, oxidative stress, DNA damage)
- Improved cellular assays for developmental and reproductive effects
- Advancement of genomics, transcriptomics, proteomics and metabolomics to enable mixture assessment, water testing
- Three-dimensional cell models (*e.g.*, Caco-2 colon cancer cell line grown on microporous membrane)
- Automation for surveillance monitoring (*e.g.*, online-extraction, automatic high-throughput screening)
- Development of tiered approach, where bioassays act as pre-screening tools to assess need for further chemical analysis

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Beate Escher and Frederic Leusch, with contributions by Heather Chapman and Anita Poulsen
(2011) Bioanalytical tools in water quality assessment. IWA Publishing, London, UK.
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