Time Integrative Passive sampling combined with Toxicity Profiling (TIPTOP): an effect based strategy for cost-effective chemical water quality assessment

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TIPTOP hypotheses

Hypothesis 1: Risk assessment based on toxicity profiles of complex mixture is
• toxicologically more relevant
• ecologically more relevant
• more protective
than risk assessment based on individually, target-analyzed compounds (Fig 1).

Hypothesis 2: For chemical status monitoring, a combination of time-integrative passive sampling and toxicity profiling is more cost-effective than target-analysis of a continuously expanding suite of individual compounds in grab-samples.

TIPTOP objectives

1. Passive sampling at well-defined WFD sites and in WWTP effluents
2. Toxicity profiling of extracts using mechanistic in vitro bioassays and ecologically relevant in vivo bioassays
3. Collecting and determining compound concentrations in passive samplers and in water
4. Making ecologically relevant interpretations of chemical concentrations and toxicity profiles
5. Evaluating the TIPTOP strategy by SWOT analysis, comparison to similar approaches and suggestion of improvements and validity tests;
6. Proposing a protocol for combined passive sampling and toxicity profiling, which is cost-effective, technically feasible, and acceptable

Passive sampling at WFD sampling sites

Figure 2: TIPTOP sampling sites include six well-defined WFD sites in the Dutch Delta, of which live in a downstream gradient of River Meuse. Each WFD sampling site represents a different water body with a matching color on the map. WFD sampling sites are benchmarked against effluent from two WWTPs (yellow).

Chemical analyses

Figure 4: Overview of all chemical data available to TIPTOP. All grey shaded fields and bold arrows will be performed within TIPTOP. White fields and narrow arrows indicate the flow of additional data. Data from the WFD locations are monitored within the WFDL monitoring program. They are made available by Rijkswaterstaat (RWS) through the DONAR database. Data from the WWTP locations are monitored within the E-PRTR monitoring program. They are made available through public STCMA reports.

Toxicity profiling

Sample-specific toxicity profiles (Fig. 4) will be obtained by testing the extracts from passive samplers in a battery of in vitro and in vivo bioassays. The in vitro battery measures different mechanisms of action:
• Dioxin-like activity (DR-LUC)
• Estrogenic activity (ER-LUC)
• Androgenic activity (AR-LUC)
• Thyroid hormone mimic (TR-LUC/TTR-binding)
• AChE inhibition (Elman)
• Mutagenicity (Ames)

The in vivo battery consists of acute toxicity tests with six different species representing different taxonomic groups and trophic levels (Fig 6):

Interpretation and evaluation of results

Classical approach
0. Compare concentration with EQS (compound-by-compound)

To what extent do individual priority compounds exceed their EQS?

Based on chemical data
1. Compare calculated toxicity with observed effect
2. Compare concentration of narcotics with critical bodyburden (CBB)
   To what extent is CBB reached for narcotic compounds?
3. Calculate msPAF for narcotics
   How many species are potentially affected by polar and non-polar narcotics?
4. Calculate msPAF by target analyzed compounds
   How many species are potentially affected by target analyzed compounds?

Based on toxicity profiles
5. Benchmark toxicity profile surface water to WWTP effluent
   How do toxicity profiles at WFD sites compare to a positive reference site?
6. Compare in vitro bioassay responses to trigger values
   To what extent do in vitro bioassay responses exceed trigger values?
7. Determine NEC (chronic) using EC₅₀ (acute) and ACR = 10
   How many times should water be censored for chronic effects?
8. Determine msPAF based on SSD in vivo bioassays
   How many species are exposed above NOEC/EC₅₀ in undiluted sample?

Effect-directed analysis

If chemical analyses explain only a minor part of the observed toxicity, responsible compounds will be identified by EDA (Fig 7). Demonstrating the applicability of EDA in passive samplers is especially relevant for investigative monitoring within the WFD. Figure 7 EDA is an iterative procedures of biological analysis, fractionation and chemical analysis to identify toxics in environmental samples

TIPTOP evaluation

Can toxicity profiling of passive samplers be regarded as a “safety net” for chemical status monitoring? Can we characterize this net? Number and size of mazes in the net? How to reduce mazes? Price? Acceptability?