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Future water quality monitoring — Adapting tools to deal with mixtures of pollutants in water resource management

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Abbreviations: AA, annual average; AOP, adverse outcome pathways; BQE, biological quality elements; CIS, Common European implementation strategy; DG SANCO, Directorate General for Health and Consumer Protection of the European Commission; EDA, effect-directed analysis; EQS, environmental quality standards; EROD, ethoxyresorufin-O-deethylase; EU, European Union; GC–MS/MS, gas chromatography coupled with double mass spectrometry; GFP, green fluorescent protein; GST, glutathione sulfotransferases; HPCCC, high performance counter current chromatography; KE, key event; LC–HRMS/MS, liquid chromatography of high resolution coupled with double mass spectrometry; MAC, maximum allowed concentrations; MIE, molecular initiating event; MoA, mode of action; PAH, polycyclic aromatic hydrocarbons; PNEC, predicted no-effect concentration; RBSPs, river basin specific pollutants; TU, toxic units; WFD, Water Framework Directive.

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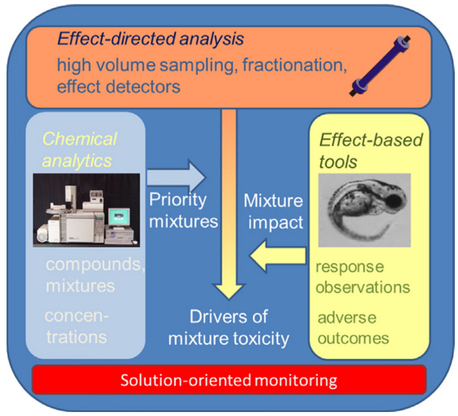
HIGHLIGHTS

- Future water contamination monitoring can address the detection of priority mixtures.
- Effect-based tools will help to assess the impact of mixture on water quality.
- Drivers of mixture toxicity can be identified using effect-directed analysis.

GRAPHICAL ABSTRACT



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ABSTRACT

Environmental quality monitoring of water resources is challenged with providing the basis for safeguarding the environment against adverse biological effects of anthropogenic chemical contamination from diffuse and point sources. While current regulatory efforts focus on monitoring and assessing a few legacy chemicals, many more anthropogenic chemicals can be detected simultaneously in our aquatic resources. However, exposure to chemical mixtures does not necessarily translate into adverse biological effects nor clearly shows whether mitigation measures are needed. Thus, the question which mixtures are present and which have associated combined effects becomes central for defining adequate monitoring and assessment strategies. Here we describe the vision of the international, EU-funded project SOLUTIONS, where three routes are explored to link the occurrence of chemical mixtures at specific sites to the assessment of adverse biological combination effects. First of all, multi-residue target and non-target screening techniques covering a broader range of anticipated chemicals co-occurring in the environment are being developed. By improving sensitivity and detection limits for known bioactive compounds of concern, new analytical chemistry data for multiple components can be obtained and used to characterise priority mixtures. This information on chemical occurrence will be used to predict mixture toxicity and to derive combined effect estimates suitable for advancing environmental quality standards. Secondly, bioanalytical tools will be explored to provide aggregate bioactivity measures integrating all components that produce common (adverse) outcomes even for mixtures of varying compositions. The ambition is to provide comprehensive arrays of effect-based tools and trait-based field observations that link multiple chemical exposures to various environmental protection goals more directly and to provide improved in situ observations for impact assessment of mixtures. Thirdly, effect-directed analysis (EDA) will be applied to identify major drivers of mixture toxicity. Refinements of EDA include the use of statistical approaches with monitoring information for guidance of experimental EDA studies. These three approaches will be explored using case studies at the Danube and Rhine river basins as well as rivers of the Iberian Peninsula. The synthesis of findings will be organised to provide guidance for future solution-oriented environmental monitoring and explore more systematic ways to assess mixture exposures and combination effects in future water quality monitoring.

1. Introduction

The monitoring of freshwaters with the goal of safeguarding environmental water quality in Europe so far has focused on the evaluation of the ecological and chemical status of water bodies. For the ecological status biological and hydromorphological quality elements are considered, while the chemical status is judged based on consideration of a few selected compounds (EU Dir, 2000/60; EU Dir, 2013/39). The established techniques for the biological quality elements rely on phytoplankton, macrophytes, phytobenthos, benthic invertebrate, and fish fauna recordings (EU Dir, 2000/60). These monitoring efforts are carried out on a wide scale and at regular intervals, such that the ecological status is the aggregate of occurrence and abundance information. The chemical status, on the other hand, is derived from information on analytically determined concentrations of priority pollutants in different compartments such as water, sediment and biota, which are compared against Environmental Quality Standards (EQS) (EU Dir, 2008/105; CIS GD 27, 2011). Complementary efforts include emission monitoring, effluent testing for acute toxic effects, and risk management measures for specific products, such as buffer zones for pesticide application or product labelling for pharmaceuticals or consumer products.

Despite the enormous efforts, the picture that emerges regarding ecological and chemical status is still incomplete, fragmented, and with contradictory assessments of the situation. There is general consensus that the target of “good ecological status” defined in the Water Framework Directive (WFD) will not be reached for the majority of European water bodies within the anticipated timeframes (EEA, 2012). Among the causes for this failure the contribution of chemical contamination, however, remains unclear, although efforts to assess chemical monitoring results point to a contributory role of chemical contamination (Malaj et al., 2014). Overall, about 40% of European