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How does the WFD address cumulative stress (including mixture toxicity) of pollutants to achieve good chemical and ecological status of water bodies?

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1. Introduction

It is now more than ten years ago that the Water Framework Directive (WFD) was adopted by the European Parliament. The main objectives of the WFD are (i) to achieve good ecological and chemical status for inland surface waters, transitional waters and coastal waters in EU Member States, (ii) to assess the ecological and chemical status of these water bodies by means of monitoring programmes, and (iii) to implement programmes of measures to reduce environmental stress to an acceptable level. By adopting the WFD a fundamental change in management objective was introduced in the European Union, from merely pollution control to ensuring ecosystem integrity as a whole [1].

The ecological status of WFD water bodies is assessed by monitoring of biological quality elements (e.g. fish, macroinvertebrates, macrophytes, benthic diatoms, phytoplankton), general chemical and physico-chemical quality elements (e.g. pH, alkalinity, nutrients) and hydromorphological quality elements. These quality elements monitored in water bodies are compared with the status of more or less pristine reference ecosystems. If in WFD water bodies the ecological status deviates too much from the reference condition action is needed for achieving the acceptable ecological status.

The chemical status of water bodies is assessed by comparing chemical monitoring data with Environmental Quality Standards (EQS) for *priority (hazardous) substances* and *other relevant substances*. Currently, 41 priority (hazardous) substances are listed in the European Union, but a regular update of this list with emerging substances is anticipated. If in water bodies exposure concentrations of one or more of these priority (hazardous) substances are not in compliance with the officially published EQS's for these pollutants a good chemical status is not reached and action is needed to improve this. In contrast to the EU-level priority (hazardous) substances the *other relevant substances* are river basin or Member State specific. These other relevant substances have been selected because they are believed to potentially impair the ecological status of specific WFD water bodies and/or related human health aspects. The methodology to derive the EQS's for other relevant substances is similar to that of the priority (hazardous) substances. This methodology is described in the new Technical Guidance Document for deriving Environmental Quality Standards (will be officially released in 2011). In European river basins the priority (hazardous) substances and river specific pollutants have to be measured on a regular basis.

Under the umbrella of the WFD, EQS derivation is primarily based on a single substance toxicity assessment approach. In exceptional cases EQS's for mixtures may be derived when their qualitative and quantitative composition is well-defined and/or well described (e.g. biocide preparations, PCB's, dioxins). The concentration addition (CA) concept is used as a default when setting EQS's for mixtures. Although compliance with good chemical status is primarily based on EQS's for individual substances, cumulative stress (including mixtures) of toxicants may be identified as a main pressure affecting ecological status. In that case the cumulative risks caused by pollutants have to be reduced.

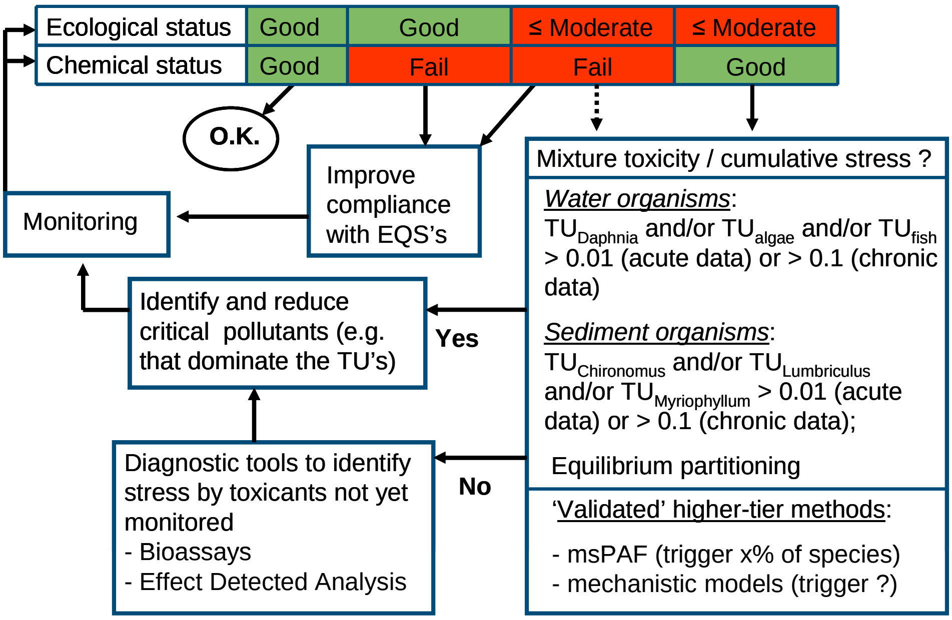
2. Discussion

An important question at stake is whether compliance to the relevant set of EQS's is sufficient to also prevent cumulative risks by different toxicants, since the derivation of EQS's for individual substances tends to follow a precautionary approach. The safety factors applied for spatio-temporal extrapolation of lowest effect values (e.g. laboratory toxicity data or threshold levels from micro/mesocosms) or HC5 values of SSDs, to obtain EQS's, partly are motivated to also address multi-stress conditions that may occur in aquatic ecosystems. Chemical monitoring data reveal that in polluted water bodies usually a limited number of toxicants dominate the mixture in terms of Toxic Units (TU's), also when many pollutants are present. Consequently when implementing restoration programmes, it seems cost-effective to focus on these (high TU) chemicals in first instance. In addition, chemical monitoring data of surface waters reveal that most measured mixtures (90%) contain ≤ 5 toxic substances [2]. For this reason it is an important research activity to construct databases for the most important simple mixtures (in water and sediment) to assess their potential hazard/risk [3]. It should be noted, however, that not all toxicants that occur in aquatic ecosystems were and will be measured due to financial constraints, so that chemical monitoring programmes may underestimate the risks of cumulative stress.

Most experimental research on aquatic risks due to multi-stress by toxicants is based on laboratory single species tests while community-level experiments are relatively scarce. Nevertheless, from micro/mesocosm experiments that addressed exposure to realistic packages of pesticides used in potato and flower bulb crops (with weekly application of either an insecticide, herbicide, fungicide or a combination) it appeared that the largest proportion of the risk was caused by one or a few active ingredients only [4, 5]. In addition, from microcosm experiments that simulated chronic exposure to two or three pesticides with a similar or dissimilar toxic mode-of-action, it appeared that the threshold level for toxic effects usually is ≥ 0.01 TU (on basis of standard acute toxicity data) and that synergistic toxic effects are rarely observed [6, 7, 8].

The lessons learned from experimental studies with pesticides indicate that it is worthwhile to make a distinction in two types of cumulative stress, viz., (i) repeated pulse exposures that may differ in toxic mode-of-action and that may be toxicologically dependent [9], and (ii) mixture toxicity of pollutants that may differ in toxic mode-of-action [8, 10]. Exposure to toxicants in the water compartment more often is time-variable in nature, while that in the sediment compartment more often is chronic. A proper assessment of mixture toxicity for sediment organisms is a challenge due to lack of toxicity data and bioavailability issues [11]. In this context also the proper linking of exposure to effects is an important issue, particularly for organisms that are exposed both via the sediment and water compartments (e.g. rooted macrophytes and invertebrates that dwell on the sediment surface). A proper evaluation of risks due to mixture toxicity of these organisms requires insight in the Ecotoxicologically Relevant type of Concentration (ERC; see [12]), which may be different for different types of organisms. This again may have consequences for monitoring programmes and the interpretation of diagnostic tools such as msPAF [13] and the SPEAR index [14].

Since the Toxic Unit concept seems to be a simple and sound first-tier method to evaluate mixture toxicity the following approach may be used to assess and manage mixture toxicity under the WFD.



Note that the TU approach described above can only be used for pollutants that are monitored, and for substances for which the basic ecotoxicological data are available (or predicted). Also note that this approach may indicate possible impairment of ecosystem status due to mixture toxicity of measured pollutants but not their cumulative effects on human health issues (which also is one of the protection objectives of EQS's). Possible (mixture) ecotoxicity of substances not included in chemical monitoring programmes may be assessed by conducting bioassays and Effect Detected Analysis [13, 15].

3. Conclusions

- Under the umbrella of the WFD, the chemical status of aquatic ecosystems is predominantly assessed by means of chemical monitoring and compliance with a set of EQS's for individual priority pollutants

> *Research needs*: Reliable analytical methods to analyse pollutants below their EQS in water and sediment, toxicity data for emerging substances and insight into the Ecotoxicologically Relevant type of Concentration (ERC) for the proper linking of exposure to effects (bioavailable fractions; relevant time-windows for exposure and effect estimates).

- Concentration addition (CA) and the TU concept may be used as a first-tier approach to assess the aquatic risk of mixtures of measured contaminants, but the relative contribution of cumulative stress originating from sediment contaminants needs more attention

> *Research needs*: Mechanistic models to evaluate the cumulative risks of pulsed exposures to different toxicants (e.g. TK/TD models) and mixture toxicity (e.g. food web models) on basis of ERC's, and 'validation' of these models by means of experimental studies with relevant mixtures.

- Realistic mixtures in aquatic ecosystems probably are dominated (in terms of TU) by a limited number of substances

> *Research needs*: Exposure and effects database of frequently occurring mixtures in the water and sediment compartment

4. References

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