1. Introduction

- Sediment quality guidelines (SQGs) are primarily developed based on ecotoxicity data obtained from laboratory-based bioassays, in which a target chemical is spiked into the test sediment as an imperfect proxy of the field exposure.
- In reality, many chemical pollutants are indeed coexisting in the sediment.

- For example, many antifouling biocide residues (e.g., copper, butyltins, phenols, Irgarol 1051, etc.) are often detected as a cocktail in water and sediment samples collected from coastal environments.

- Based on literature review of documented studies on the combined ecotoxicity of antifouling biocides, we found that both additive and synergistic effects together account for 78% of cases in which about 35% cases are synergistic [Fig. 1].

- More strikingly, Silva et al. (2002) tested the combined effect of eight estrogenic compounds and concluded that the estrogenic effects can be in additive and/or synergistic with respect to different chemical sensitivities and their no observed effect concentrations [1].

- Therefore, the ecological risk of chemical mixtures should not be overlooked. To allow more accurate risk assessment of concurrently occurring chemicals, there is a need to develop SQGs for their mixtures which are commonly coexisting in the aquatic environment.

- This poster will introduce four possible methods for deriving water quality guidelines (WQGs) or SQGs with consideration of the effect of chemical mixtures.

2. Materials and Methods

- Toxic equivalency quotient (TEQ) based approach: If all components in a chemical mixture are known to share a similar toxic mode of action, we can assume that the combined toxicity of the mixture would follow a simple concentration addition model, and the TEQ of the chemical could be applied to derive the hazardous or lethal concentration associated with the mixture.

- The standard method has been widely applied to various chemical groups such as polychlorinated biphenyls (PCBs), dioxins, dioxin-like compounds and environmental estrogenic compounds.

- Multidimensional species sensitivity distribution (m-SSD) approach: If the mixture contains chemicals with different toxic modes of action, it is possible to explore the use of the m-SSD approach. Here, binary mixtures of copper (Cu) and zinc pyrithione (ZnPT) are used as an example to illustrate the method. Standard acute toxicity tests have been conducted with an array of marine organisms for each chemical alone, and for their mixtures [2].

- The mixtures show a strong synergistic toxic effect to all nine test organisms. By utilizing the toxicity data, a two-dimensional SSD in form of a response surface is constructed to derive any specific hazard concentration for the two compounds.

- This novel method can be potentially applicable to a more complex mixture.

- Field-based SSD approach: This method is integrated with the quantile regression method, can be used to derive SQGs for any target chemical with consideration of the presence of chemical mixtures and biological interaction. The method is described in Leung et al. (2005) & Kwok et al. (2008) [3,4].

- Field-based community sensitivity distribution (f-SSD) approach: This is a novel nonparametric approach that standard Bayesian Methodology to model the toxic effect of chemicals on species density of benthic infauna. Each point along the CSD represents the hazardous concentration for a drop in species density by a proportion (γ) and thus the percentage (100－γ%) of species density being protected under this concentration can be adopted as a SQG [7].

3. Results and Discussion

3.1. The TEQ-based approach

- In this method, the concentration of PCB congeners and mixtures are converted to TCDD-TEQ using the toxic equivalent factors [5]. All toxicity data are converted to TCDD-TEQ values and thus, the WQG or SQG would be expressed as μg TCDD-

- TEQ/L [Fig. 2].

- However, the assumption of all PCBs to follow "concentration addition" model could be questionable and uncertainty exists. Usually, toxicity equivalency factors (TEFs) are only derived for a proportion of congeners, and thus surrogate TEFs would be applied to unlisted congeners with a similar structure.

- Although this method has been successfully applied for polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and PCBs, it is not universally applicable to other groups of compounds. Peters and Gonzalez (2011) [6] discovered that this method cannot be used for perfluoroalkyl chemicals, because they can activate and/or interfere with other receptors, and different chemical species can trigger different receptors leading to different toxicities.

3.2. The m-SSD approach

- The results show that ZnPT-Cu mixtures have strong synergistic effects to test organisms even at Cu as low as 2 μg/L. An example is shown in Fig. 3 (left), concentration-response relationships (Left): non-parametric response surface is constructed to model the toxicity (Middle): and isoconcentration downward indicate synergistic effect (Right) [2].

- This is only applicable to known mixtures that commonly exist in the environment.

- Nonetheless, this method can only deal with existing chemical pollutants, and requires a massive database of concurrently obtained biodiversity and chemical concentration data.

3.3. The f-SSD approach

- The application of quantile regression in the f-SSD approach can account for the effects of chemical mixtures with some empirical examples [Fig. 5a].

- The results of the f-SSD approach can serve as a check-and-balance of the laboratory driven SQGs while it can enhance ecological realism in the SQG values.

- Nonetheless, this method can only deal with existing chemical pollutants, and requires a massive database of concurrently obtained biodiversity and chemical concentration data.

3.4. The f-CSD approach

- Like the f-SSD approach, the f-CSD method also requires a large dataset of concurrently obtained biodiversity and chemical concentration data, and sophisticated computation [Fig. 6].

- The SQGs derived by this approach can be directly linked to species loss (or species protection) in relation to sediment quality and thus provide additional valuable informational for ecological risk assessment and environmental remediation [7].

4. Concluding Remarks:

- Chemical mixtures do matter as reflected by the fact that 78% cases for mixtures of antifouling biocides would result in additive or synergistic effects to marine organisms.

- It is possible to use TEQ-based approach to derive SQGs for mixtures consisting chemicals with a similar mode of toxic action.

- For mixtures containing chemicals with different modes of toxic action, the multidimensional SSD approach maybe adopted. But this method is time-consuming and not cost-effective.

- Field-based approaches such as f-SSD and f-CSD potentially serve as an alternative way to derive SQGs and account for interacting effects of chemicals and biological interaction.

- There is no perfect solution but we can always find a better one.

5. Cited References:

- Biocides would result in additive or synergistic effects to marine organisms.
- For mixtures containing chemicals with different modes of toxic action, the multidimensional SSD approach maybe adopted. But this method is time-consuming and not cost-effective.
- Field-based approaches such as f-SSD and f-CSD potentially serve as an alternative way to derive SQGs and account for interacting effects of chemicals and biological interaction.
- There is no perfect solution but we can always find a better one.