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<th>Can we possibly derive sediment quality guidelines for chemical mixtures?</th>
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<td>Author(s)</td>
<td>Leung, KMY</td>
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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, butyltin, phenols) and polycyclic aromatic hydrocarbons (PAHs) are often detected as a cocktail in water and sediment samples collected from coastal environments.

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 concept of TEQ could be applied to derive the additivity based on lethal concentrations proposed in terms of TEQ and/or exposure concentration. This “standard” method has been widely applied to various chemical groups such as polychlorinated biphenyls (PCBs), dioxins, dioxin-like compounds and environmental estrogens.
- Multiple stressors approach: Standardized SSD (95% protection level) approach: If the mixture consists of 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 hazardous 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) & Kowok et al. (2008) [3,4].
- Field-based community sensitivity distribution (f-SSD) approach: This is a novel nonparametric approach that combines Bayesian Methodology to model the toxicity effect of chemicals on species density of bentic 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 TCDQ-TEQ using the toxic equivalent factors [5]. All toxicity data are converted to TCDQ-TEQ values and thus, the WQG or SQG would be expressed as μg TCDQ-TEQ/L. [Fig. 2].
- However, the assumption of all PCBs to follow “concentration addition” model and the concept of TEQ could be applied to derive the additivity based on lethal concentrations proposed in terms of TEQ and/or exposure concentration. This “standard” method has been widely applied to various chemical groups such as polychlorinated biphenyls (PCBs), dioxins, dioxin-like compounds and environmental estrogens.
- Multiple stressors approach: Standardized SSD (95% protection level) approach: If the mixture consists of 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 hazardous concentration for the two compounds. This novel method can be potentially applicable to a more complex mixture.
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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 0.1 μg/L. An example is shown in Figure 3. The concentration-response relationships (Left; non-parametric response surface is constructed to model the toxic effect (Middle); and isobols bowing downward indicate synergistic effect (Right) [2].
- The SQGs values derived by this approach can be directly linked to species loss (or species protection) relative to sediment quality and thus provide additional valuable information for ecological risk assessment and environmental remediation [7].

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-SSD 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 values derived by this approach can be directly linked to species loss (or species protection) relative to sediment quality and thus provide additional valuable information 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 might be applicable. 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:
- Drs. Apostolos Koutsaftis and Bao, Vivien (2004) The Swire Institute of Marine Science and School of Biological Sciences, The University of Hong Kong, Hong Kong, China. Email: knyleung@hku.hk

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