

Does the dose make the poison? The influence of biotic and abiotic factors on the toxicity of copper in mussels

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Paracelsus stated in the 16th century that “*the dose makes the poison*”. Modern marine environmental risk assessment (ERA) is still primarily based on this principle through the use of tightly controlled laboratory experiments performed according to international standards. Previous research has indicated that several biotic and abiotic factors may influence the toxicity of pollutants or the sensitivity of various species. Therefore, the relationship between the dose and effect may not be straightforward and current ERA could therefore not accurately reflect the actual risk of chemical contaminants.

To address this issue we evaluated the effect of both biotic and abiotic variables on the toxicity of Cu. The blue mussel was selected as - Cu sensitive - model organism and the influence of the following variables was assessed:

- Local adaptation by using 3 different populations (Adriatic, North and Baltic Sea);
- Life stage variability by performing the experiments on mussel larvae and on settled mussels;
- Environmental variability by changing the salinity and dissolved organic carbon (DOC) concentration of the seawater;
- Presence of other pollutants by changing the Ni or Zn concentration.

Furthermore, these variables were not assessed one by one but in combination. For example: the influence of salinity and DOC was assessed for both larvae and settled mussels and for different populations.

The results indicated that the sensitivity of the different populations to Cu was nearly identical but all other variables had a significant effect on Cu toxicity. Furthermore, interactions between biotic and abiotic variables were frequently observed. As expected, mussel larvae (currently the life stage most commonly used to generate mussel sensitivity data for usage in ERA) were more sensitive to Cu compared to settled mussels when assessed in artificial seawater. However, DOC had a profound protective effect against Cu toxicity in mussel larvae but not in settled mussels. This implies that settled mussels are more sensitive to Cu than larvae in seawater with a high DOC concentration. An increase in the salinity increased the toxicity of Cu in both larvae and adult mussels, although this effect was more prominent in larvae. No interactions between salinity and DOC on Cu toxicity were found. Finally when mussel larvae are exposed simultaneously to Cu and either Ni or Zn this increased the toxicity of Cu, although the magnitude of the effect was higher when Cu was combined with Ni than with Zn. Furthermore, the influence of Ni and Zn on Cu toxicity was more pronounced for the North Sea population compared to the Baltic Sea population. This implies that even if both populations have an equal Cu sensitivity when simultaneously exposed to other metals their response might be different.

To conclude we now know that for mussels:

- The larvae are more sensitive than the settled mussels at low DOC, but vice versa at high DOC;
- Local (geographical) adaptation does not change the inherent sensitivity;
- DOC and salinity have a profound, life stage dependent, effect on the toxicity of Cu;
- Simultaneous exposure to other metals increases the Cu sensitivity, but the magnitude varies with the metal and the population investigated.

Keywords: copper; mussels; ocean; mixture; toxicity; nickel; zinc; salinity