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How predictable is the biological response to chemical toxicity?

To assess the impact on ecosystems of chemical contamination in aquatic environments, scientists need to measure not only the concentration of the contaminants, but also the extent to which they can disrupt biological processes at a cellular level in plants and animals and at an ecosystem level. According to a new study, considering these complex inter-relationships in combination will help improve the ecological status of waterways, in line with Water Framework Directive (WFD) commitments.

Estuaries are heavily influenced by human activities and thus can be hotspots for chemical contamination. For environmental scientists, this can make them ideal environments to look for wildlife that may show adverse effects in response to such contamination. In a comprehensive study of the Humber Estuary in the UK, researchers from the EU-funded TESS project[1] measured concentrations of a range of potentially harmful inorganic metals and organic pollutants in sediment samples taken from locations along the length of the estuary. Organic pollutants commonly arise from industrial activity, for example, in the manufacture of polymers and chemicals such as pesticides and pharmaceuticals.

Using a novel assay technology based on genetically modified yeast cells, the scientists grew yeast cultures in specially prepared extracts from the sediment samples and analysed them for signs of toxic impacts to the cell's genetic material (genotoxicity) or to the general health of the cells themselves (cytotoxicity). To represent more complex biological systems, they also measured the activity of particular enzymes (GSTs) in ragworms (*H. diversicolor*) taken from the same locations. High GST activity indicates evidence of a detoxifying biological response to contaminants in the ragworms, and this approach has been widely used in the past to detect pollution in aquatic environments.

Perhaps the most interesting result reported by the scientists, was that neither cytotoxicity nor genotoxicity in the yeast cells were consistently found in the same locations as high GST activity in ragworms. This suggested that indicators of pollution may not be visible at all levels in the ecosystem. One reason for this may be that organisms have the ability to limit the effects of chemical contamination to cell damage, without leading to detectable changes in individuals or populations, a concept known as 'environmental homeostasis'.

In areas where the scientists expected to see signs of genotoxicity or cytotoxicity in the yeast cells in response to toxic levels of some metals, they did not find them. This suggests that toxicity may be related to the combined effect of a mixture of contaminants at low concentrations, rather than to any single substance at a high concentration. With respect to the organic contaminants, the scientists also could not find a clear link between high concentrations and GST activity in the ragworms. Nor could they find a consistent relationship between concentration and toxicity.

The complexity of these results indicates that the relationships between cellular toxicity and more complex biological responses are often far from clear. The researchers point out that, for the examples given in the study, a simple assessment of contaminant concentration, biological toxicity or GST levels alone would not provide an accurate picture of the complex interactions that exist.
For these reasons, risk assessments carried out in line with the WFD[2] commitment to improve the ecological status of Europe's waterways will need to consider a wide range of factors, from the concentration and combination of contaminants through to the impact on higher organisms in the ecosystem.

1. TESS (Transactional Environmental Support System) is supported by the European Commission under the Seventh Framework Directive. See: www.tess-project.eu
2. See: http://ec.europa.eu/environment/water/water-framework/index_en.html

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