Aquatic Risk Assessment of Chemicals: Is It Working?

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Amid rising doubts that aquatic organisms are being fully protected from the harmful effects of toxic chemicals, opportunities to improve this situation are being neglected. This failure is due in large measure to widespread misperceptions about the capabilities of environmental risk assessment techniques: Few people question risk assessment benefits, and most believe that use of the method provides the best practical approach for ecosystem protection.

The major thrust of current scientific effort mirrors this view. Ever more complex assessment strategies are being developed that are refining knowledge of hazard, as well as predictions of environmental exposure, and are combining them in increasingly sophisticated ways to produce risk estimates. Much of this undertaking has been driven by public concern, such as that which arose in response to environmental disasters caused by poor management practices and imperfect knowledge of chemical modes of action and behavior. Ecotoxicologists and environmental chemists responded to these emergent problems by developing improved testing regimes designed to eliminate or better manage future uses of harmful materials. Although far from being a reliable science, there is no doubt that the assessments are screening out some undesirable chemicals, or at least their risky uses.

But is this approach actually preventing significant environmental degradation, and is the trend toward development and use of more sophisticated testing programs justified by results that have been achieved? Unfortunately, these questions are difficult to address. Few environmental investigations and monitoring programs are explicitly designed to test whether chemical risk assessments are working as intended. Most lack the feedback loop that regulators need to objectively evaluate whether assessments are effective, and reliable field data required for validating the assessments are generally unavailable.

Do these shortcomings matter if predictions of exposure concentrations and no-effect levels err heavily in a precautionary direction, as they appear to do? Through the adoption of a precautionary approach it is presumed that issues not explicitly accounted for in the risk assessment process will de facto be addressed implicitly. Given this current practice, it appears unlikely that new highly toxic, persistent, or bioaccumulative substances will be permitted knowingly to enter the environment in individually harmful amounts. However, this approach may not suffice: A number of significant fallacies are undoubtably embedded in the risk assessment models, and at least one important area, the significance of environmental mixtures, is ignored altogether.

Possibly the most critical issue of concern associated with this neglect is that of accounting for the anthropogenic chemical environment into which new substances are likely to be discharged. Risk assessors, by default, generally assume scenarios in which new chemicals enter a pristine ecosystem—one into which anthropogenic chemicals have not previously been discharged. By analogy, this is equivalent to a doctor prescribing a hepatotoxic drug without first inquiring about a person's drinking habits.

It is difficult to account for the effects of chemical mixtures in the environment. Aquatic monitoring data are generally of poor quality and rarely involve more than the reactive reporting of mass freshwater fish kills. Kills of aquatic invertebrates or, more importantly, invertebrate community declines, are usually unreported or are not linked to particular inputs. Causes of one-third of the freshwater chemical pollution incidents (mainly fish kills) reported by the United Kingdom (U.K.) Environment Agency are either unclassified or unknown (*1*), mainly because diagnostic chemical and biological assays are not yet widely used. As a result, freshwater data cannot be employed to assess whether chemical risk assessments are working.

Toxicity information about the surrounding marine waters of the United Kingdom is more instructive (see figure on next page). Sensitive bioassays and biomarkers have been applied in marine monitoring programs since the early 1990s. Biological monitoring tools have the advantage that they can integrate the effects of many of the bioavailable contaminants present at a given location, thus reveal-

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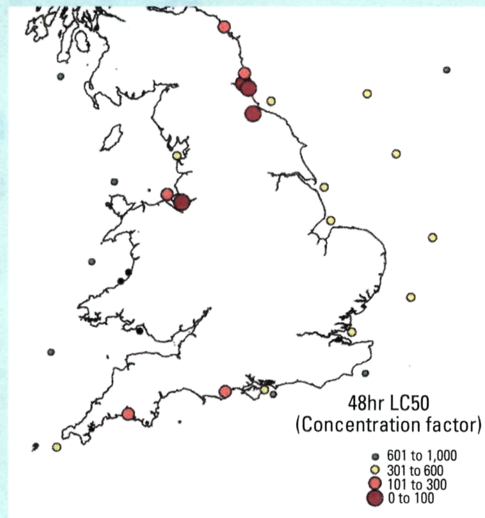
Toxicity of marine waters

Sampled waters in estuaries and near the coastline of the United Kingdom (U.K.) contain higher concentrations of toxicants than those offshore. The acute toxicity of hexane-water extracts to an indicator organism, the copepod *Tisbe battagliai* was evaluated. The largest circles correspond to water samples in which organic contaminants required the least concentration before being able to cause acute toxicity. In some instances the raw seawater itself was found to be acutely toxic. Data are courtesy Mark Kirby, Centre for Environment, Fisheries, and Aquaculture Science.



ing possible effects of complex mixtures that cannot easily be characterized according to their individual chemical constituents.

Conclusive data gathered in the United Kingdom demonstrate that many estuarine waters and surficial sediments are acutely toxic, or nearly so, to a range of invertebrates (*2*). The bioassays controlled for such factors as low dissolved oxygen and elevated hydrogen sulfide and ammonia, are responding primarily to chemical contaminants and not to the consequences of organic enrichment. The aquatic contaminants (and many of the sedimentary ones) are primarily of recent origin and that many different anthropogenic substances are present in the waters of the more industrialized estuaries (*3*). Use of techniques involving fractionation and bioassay of complex samples to identify causative chemicals has shown that water in the Tyne estuary, for example, is acutely toxic primarily due to the joint action of at least seven different organic substances (*4*). In no case has it been found that toxicity in estuaries or offshore is due solely to a single contaminant (*3–6*).

The consistent and more or less ubiquitous nature of water and sediment toxicity in industrialized estuaries suggests that it cannot generally be attributed to occasional accidental spills, but must be largely the result of routine contemporary discharges of a mixture of mainly synthetic chemicals. Substances that are usually being discharged in individually harmless concentrations are acting together in discharges and receiving waters to produce lethal and sublethal consequences. A proportion of this toxicity must be caused by chemicals that have never received any risk assessment or management, but modern, contemporarily used substances are partly responsible. This observation suggests that reliance upon currently formulated risk assessments is not entirely an effective measure for preventing environmental impacts.

Although this is an unacceptable situation, I do not believe the logical consequence is to argue for comprehensive bans on the discharge of synthetic chemicals. I believe a pragmatic response is to employ sentinel organisms to warn us of potential ecological deterioration. Only biological systems can provide the integrated information that tells us whether a particular effluent or waterway contains a harmful mix of chemicals, and only bioassay-led chemical fractionation investigations can identify which substances are responsible for the observed effects.

Environmental risk assessments of chemicals have flaws that probably cannot be addressed by tinkering with models. Rather than relying solely on increasingly sophisticated risk assessments, we in Europe should consider the merits of concentrating more effort on performing direct toxicity assessment (DTA) of complex discharges and quality assessment of receiving waters. This practice has been successfully employed in the United States. The use of DTA responds to the insufficiency of chemical risk assessment and monitoring for preventing environmental impacts. DTA detects and identifies major pollutant problems before they have a chance to cause extensive damage.

Whereas widespread implementation of DTA can lead to pressure for more discharges to be cleaned up, it can also make possible the avoidance of unnecessary treatment of innocuous effluents. In view of the evidence for chemical toxicity in some estuarine waters, failure to employ DTA methodology will lead to chemophobic bans on all discharges of anthropogenic materials. Environmental risk assessment of chemicals is working, but only up to a point. We must recognize its limitations and emplace additional measures that can identify substances that are slipping through the net.

References

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