Aquatic Ecotoxicology

Yuan Zhao and Michael C Newman

Ecotoxicology, the science of contaminant fate and effects in the biosphere, emerged as a distinct discipline in the 1960s. Initial ecotoxicological concepts and methods were adopted from classic toxicology, ecology, and geochemistry. Ecotoxicology is now an interdisciplinary science encompassing effects from biomolecules to the entire biosphere, and contaminant fates from chemical speciation to global cycling.

Aquatic ecotoxicology has always been a central component of ecotoxicology because many of the first pollution issues involved the hydrosphere. Early applications of aquatic ecotoxicology included identifying and quantifying point source toxicity in support of water quality regulation. Standard toxicity testing protocols were generated based primarily on effects to individuals but also included some descriptive metrics of ecological community structure. Research in this important field contributed insights needed to formulate key US laws such as the Clean Water Act (CWA) and the Toxic Substances Control Act (TSCA).

In the early 1990s, the activities of ecotoxicologists expanded to support the ecological risk assessment paradigm. Aquatic ecotoxicologists established the conceptual underpinnings for hazard identification and risk characterization, and the data for characterizing exposure and ecological effects. Such knowledge now supports regulatory activities related to federal acts such as the Marine Protection Research and Sanctuaries Act (MPRSA), the Comprehensive Environmental Response, Compensation, Liability Act (CERCLA), and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

Currently, much aquatic ecotoxicological prediction is based on laboratory testing in which organisms are exposed to a contaminant for a specified time and effects are estimated for either lethal or sublethal impacts to individual organisms. Regression models are commonly applied to acute exposure data to predict effect metrics such as the LC_{50} (concentration killing 50% of exposed individuals by the end of the exposure) or EC_{50} (concentration having an effect on 50% of exposed individuals by the end of the exposure). Metrics derived from analysis of variance (ANOVA) and post-ANOVA tests are applied for more chronic exposures or subtle effects that are more difficult to model. The lowest exposure concentration with a statistically significant effect (lowest observed effect concentration or LOEC) and the highest exposure concentration with no statistically significant effect (no observed effect concentration or NOEC) are the most common such effect metrics. Notionally, the LOEC and NOEC bound an effect threshold concentration for the tested contaminant.

Laboratory experiments quantifying contaminant effects commonly involve either exposure via water or sediments; exposure via food is addressed less frequently. The most common laboratory tests expose individual organisms directly to contaminant present at a range of concentrations in water. In experiments assessing effects of sediment-associated contaminants, benthic organisms are exposed directly to sediments or a nonbenthic species are exposed to sediment elutriate. Elutriate tests are designed to provide data on exposure that occurs during sediment disturbances such as that resulting from storm or dredging activities. Other types of experiments include bioaccumulation or bioavailability tests that determine the potential for contaminant accumulation in organisms. In the absence of specific knowledge of the effects or bioaccumulation potential for a specific chemical, the magnitude of effect or bioaccumulation is sometimes predicted with quantitative structure–activity relationship (QSAR) models that relate contaminant molecular qualities for a class of contaminants such as polychlorinated biphenyls to their bioactivity (i.e., effect or potential for bioaccumulation).

Augmenting results of laboratory experiments, mesocosms, and field studies are commonly used to study the structure and function of impacted aquatic communities. Mesocosms are experimental ponds or streams designed to simulate, in a simplified manner, aquatic ecosystems. Relative to laboratory systems, mesocosms are normally located outdoors and less controlled, but can achieve more ecological realism. Field studies include surveys and natural system manipulations. The former provide relatively inexpensive observation of the consequences of contamination to communities and, although affording the least controlled observation, are the most often used type of study. Used less frequently because of increased costs, the latter involve manipulation of an entire ecosystem such as a lake or a portion of it. Intelligent combining of conclusions from laboratory tests, mesocosms, and field studies allows aquatic ecotoxicologists to assess hazard or risk due to contamination.

Current trends in the aquatic ecotoxicology literature suggest several possible changes in the near future. More insights about population consequences will be gained during assessments through the application of emerging molecular techniques, and of population-based metrics and methods. Conventional, laboratory-generated effect metrics such as the LC_{50}, NOEC, and LOEC will be used with more balance with metrics of community and population effects. This will be required to meet the demands of modern ecological risk assessment. To more directly address the needs of ecological risk assessment, more emphasis will also be placed on methods of quantifying the uncertainty in effect estimates.

See also: Environmental Toxicology (00374); Pollution, Water (00782); Risk Assessment, Ecological (00850).

Further Reading

Boudou A and Ribeyre F (1997) Aquatic ecotoxicology: from the ecosystem to the cellular and molecular levels. *Environmental Health Perspectives* 105(Suppl 1): 21–35.

Caquet T, Lagadic L, and Sheffield SR (2000) Mesocosms in ecotoxicology (1): Outdoor aquatic systems. *Reviews of Environmental Contamination and Toxicology* 165: 1–38.

Preston BL (2002) Indirect effects in aquatic ecotoxicology: implications for ecological risk assessment. *Environmental Management* 29(3): 311–323.

Snape JR, Maund SJ, Pickford DB, and Hutchinson TH (2004) Ecotoxicogenomics: The challenge of integrating genomics into aquatic and terrestrial ecotoxicology. *Aquatic Toxicology* 67(2): 143–154.