Boston College Environmental Affairs Law Review

Volume 11 | Issue 1 Article 2

10-1-1983

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John Cairns, Jr.

REGULATING HAZARDOUS CHEMICALS IN AQUATIC ENVIRONMENTS

*John Cairns, Jr.**

"It is the mark of an instructed mind to rest satisfied with the degree of precision which the nature of the subject permits and not to seek an exactness where only an approximation of the truth is possible." Aristotle

I. INTRODUCTION

Dr. Joshua Lederberg, president of Rockefeller University and Nobel Laureate scientist, addressed the urgent need for new approaches to testing toxic chemicals in a speech made in February, 1981, at the World Environmental Center.[1] He felt that finding ways to assess and control the environmental health risks posed by toxic substances is one of society's major scientific challenges. Serious questions about the efficacy of both our scientific and regulatory approaches exist; consequently, the quote from Aristotle is particularly appropriate in this context because we must now make regulatory decisions with an inadequate scientific base. The economic benefits of producing a new chemical or technology (e.g., a power plant) may be quite clear, but the indirect costs, in terms of hazard to human health and the environment, are not.

Most of the earlier regulatory standards for discharge of potentially hazardous chemicals into the environment allowed fixed concentrations that were not to be exceeded. This strategy proved inappropriate for several reasons. (1) Some chemicals produce adverse biological effects at concentrations below present analytical

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*University Distinguished Professor at Virginia Polytechnic Institute & State University; Director, University Center for Environmental Studies; Chairman, Committee to Review Methods for Ecotovicology, National Research Council.

1. Anon, *Improve Toxic Testing Nobel Scientist Urges,* in CHEMECOLOGY (1981).

capabilities. (2) Environmental quality parameters, such as water hardness, temperature, pH, and dissolved oxygen concentration, mediate the toxic response—the same concentration of zinc would produce a different toxicological response in the hard water of the Guadaloupe River in Texas than in the soft water of the Savannah River between Georgia and South Carolina. (3) Toxic chemicals may act differently in combination than they do individually.

Unfortunately, there is no instrument devised by man that will measure toxicity. Only living material can be used for this purpose. This immediately produces both scientific and regulatory difficulties because living material is complex, regionally differentiated, often highly variable, and may act differently in laboratory test containers than in natural systems. This paper examines current regulatory and scientific approaches to the presence of hazardous substances in an aquatic environment. Implementation of a specific hazard evaluation process is recommended to ameliorate the inadequacies of present approaches.

II. Regulating Toxic Substances

Although most toxic substance regulations are designed to protect human health and the environment against deleterious concentrations of chemicals, they differ strikingly in protection strategy, statement of goals, allocation of costs, and responsibility for generating appropriate data and means of implementation. Unfortunately, the scientific underpinnings for almost all regulatory objectives are inadequate. Although concern about this problem had been growing for years, it was probably first crystalized by the water quality criterion documents for sixty-five classes of pollutants that were designated as toxic in section 307(a)(1) of the Clean Water Act of 1972[2] and next by the premanufacture testing policy enunciated under section 5 of the Toxic Substances Control Act of 1976[3] (TSCA). The scientific problems inherent in toxic substance regulations were matters of concern and discussions.[4]

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2. Originally Federal Water Pollution Control Act of 1972 as amended in 1977, the Clean Water Act, 33 U.S.C. §§ 1251-1376 (1976 & Supp. IV 1980).

3. 15 U.S.C. §§ 2601-2629 (1976 & Supp. IV 1980).

4. Cairns, Jr. & Maki, *Hazard Analysis in Toxic Materials Evaluation,* 51(4) J. WATER POLL. CONTROL FED. 666-71 (1979); Deland, *EPA "Policy" for Testing Toxics,* 15(4) ENVT'L SCIENCE & TECH. 385 (1981); Schaeffer, Park, Kerster, & Janardan, *Sampling and the Regulatory Maze in the United States,* 4(6) ENVT'L MGT. 469-81 (1980); Christman, *Clear Water Goals,* 15(3) ENVT'L SCIENCE & TECH. 233 (1981).

TSCA gives the Environmental Protection Agency (EPA) control over the manufacture of chemicals that may or may not prove to be toxic well before they are likely to enter the environment; TSCA thereby differs from earlier legislation such as FIFRA,[5] which regulates substances that were designed to be toxic, and the Clean Water Act, which regulates the discharge of toxics into the environment. The administrator of the EPA has the authority under TSCA to prohibit or restrict the use of any chemical that may present an unreasonable risk to human health and/or the environment. In Section 2(b) of TSCA, Congress places responsibility for providing scientifically justifiable evidence of the probability of harm to organisms on the producers of these chemicals. If the evidence presented is inadequate, the EPA has the authority to require additional toxicity testing. Congress also indicated that the EPA must use its regulatory authority "in such a manner as not to impede unduly or create unnecessary economic barriers to technological innovation while fulfilling the primary purpose of this Act to assure that such innovation and commerce in such chemical substances and mixtures do not present an unreasonable risk of injury, to health or the environment"[6] (Section 2(b)TSCA).

Within this context it is important to define terms such as "risk" and "concentration."

> *Risk* is the probability of harm from an actual or predicted concentration of a chemical in the environment. *Safe concentrations* are those for which the risk is acceptable to society. As a consequence, the assessment of hazard requires both a scientific judgment based on evidence and a value judgment of society and/or its representatives. Evidence for a scientific judgment must cover (a) toxicity—the inherent property of the chemical that will produce harmful effects to an organism (or community) after exposure of a particular duration at a specific concentration, and (b) *environmental concentration*—those actual or predicted concentrations resulting from all point and nonpoint sources as modified by the biological, chemical, and physical processes acting on the chemical or its byproducts in the environment.[7]

The balancing of risk and benefit in environmental law was addressed relatively recently by Ricci et al.,[8] who emphasized that con-

5. Federal Insecticide, Fungicide and Rodenticide Act, as amended by the Federal Environmental Pesticide Control Act of 1972, 7 U.S.C., § 135 (1972 & Supp. IV 1980).

6. Toxic Substances Control Act of 1976, 15 U.S.C. §§ 2601-2629 (1982).

7. Cairns, Jr., *Estimating Hazard*, 30 (2) BIOSCIENCE 101-07 (1980).

8. Ricci & Moltan, *Risk and Benefit in Environmental Law*, 214 (4525) SCIENCE 1096-1100 (1981).

sideration of the technical complexity of the assessment of health risks leads to understandable judicial caution about interposing legal judgments on these unresolved scientific issues.

The determination of adequacy of scientific evidence for estimating hazard is a difficult problem. Evidence indicates that commonly used toxicity tests do not provide adequate data for estimating hazard to the environment. For the moment, consider a situation in which an industry feels it has provided scientifically adequate evidence and the EPA does not. Section 5 of TSCA does not require that particular environmental tests be documented on all new chemical substances before submission of premanufacture notices.[9] A recommended data base is set, for which the ecotoxicity data are based entirely on short-term single species laboratory toxicity tests. These ecotoxicity data are not mandatory but are for "guidance." Yet when industry uses a multispecies laboratory toxicity test or actual field evidence and the EPA disapproves, significant conflict results. Estimation of hazard to man and his environment is clearly a highly technical question which the courts alone are not qualified to decide, and there is no impartial "science court" of highly qualified experts specially charged with this responsibility (although the National Academy of Sciences might serve in this capacity). Since ecotoxicology is a very new and rapidly developing field, only a well qualified expert will have the necessary background to judge the scientific validity of the evidence provided. Since, at the very least, toxicological information must be coupled with information about the environmental fate and partitioning of chemicals and both assessed for statistical reliability, a panel of experts will be needed.

Biological evidence is essential to estimate hazard to the environment. Alternative ways of abating pollution have been tried, however, reliance solely on chemical/physical measurements was not scientifically justifiable for the reasons already mentioned. Technology-based standards, such as Best Applicable Technology (BAT) and Best Practicable Technology (BPT), were also employed, based on the assumption that the "practical approach" was the best way to abate pollution.[10] Problems occur with this approach.[11] From

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9. *See* 15 U.S.C. §§ 2601-2629 (1976 & Supp. IV 1980); 44 Fed. Reg. 8986 (1981).

10. *See* 33 U.S.C. §§ 301-304 (1976 & Supp. IV 1980).

11. Cairns, Jr., *Comment on "Desirable Characteristics of Environmental Quality Standards and General Considerations Involved in Their Development,"* in PROCEEDINGS OF THE SEMINAR ON DEVELOPMENT AND ASSESSMENT OF ENVIRONMENTAL STANDARDS (1983).

an ecological standpoint, technology-based standards ignore: (1) the size of the receiving system; (2) the well-established fact that environmental quality (e.g., pH, water hardness, temperature, etc.) may markedly influence toxicity; and (3) that the total impact of all stresses on natural systems must be considered, not just the impact of a single discharge. From an industrial standpoint, use of BAT and BPT may be unsuitable because: (1) a small industry on a large river may be forced to spend money on technological improvements which produce no demonstrable biological or ecological benefits; (2) long-range financial planning is difficult when the rate of technological development is difficult to predict (but would undoubtedly accelerate if this law were enforced); and (3) operators with new equipment that they cannot use properly may produce poorer quality effluents than they would with old equipment they understand. Biological evidence must be combined with chemical/physical measurements to produce an effective hazard evaluation process.

A. Biological Evidence

Since the primary objective of environmental legislation is to prevent harm to the biota (including humans), the most reliable estimates of hazard should be based on direct measurements of living organisms rather than indirect chemical/physical measurements from which biotic condition is inferred. As previously mentioned, no instrument will measure toxicity—this can only be done with living material. Yet, without chemical/physical data, determining what caused the biological response in the living material is difficult or impossible. Therefore, a scientifically justifiable estimate of hazard requires a mixture of biological/chemical/physical data.

The intent of environmental regulation is to prevent harm to the environment rather than to document the cause and extent of damage after an ecological perturbation (although this is undeniably important). Predictive tests carried out in surrogates of natural systems are essential to accomplish this purpose. In designing such test systems, a conflict or tension exists between the desire for *environmental realism* that incorporates both the complexity and variability of natural systems and the need for *replication* (ability to reproduce results) that is most easily achieved in simple systems with only one variable. This tension is presently relieved by providing four steps in the hazard evaluation process: (1) screening tests; (2) predictive tests; (3) confirmative tests; and (4) monitoring. Screening toxicity tests are designed to determine quickly, inexpensively, and simply whether or not a chemical substance is very toxic or less so relative to other chemicals. The predictive tests are generally more sophisticated laboratory toxicity tests also normally carried out with single species. There is considerable concern that single species toxicity tests cannot be used to accurately predict responses at higher levels of biological organization.[12] The basis for this concern is that new important properties are evident at higher levels that cannot be studied at lower levels of biological organization (cell-tissue-individual-population-multispecies-community-ecosystem). This is merely a restatement of the old phrase "the whole is more than the sum of its parts." Because most estimates of hazard are based on single species laboratory tests (screening or predictive tests) lacking in environmental realism, confirmative tests are recommended as well.[13] To ensure that potentially dangerous situations do not go undetected, surveillance must be carried out with a variety of methods.[14] These various biological tests provide the necessary basis for any effective hazard evaluation process.

B. Implementation

To implement a hazard evaluation process one needs: (1) professionally endorsed parameters representing key responses; (2) formal identification of the methods most suitable to measure these parameters; and (3) certification of either individuals or laboratories capable of making the measurements accurately. Unfortunately, although the use of biological responses to predict and assess pollution is both scientifically justifiable and plausible to the layman, the means of implementing fully this course of action are not in place. Of course, both scientists and laymen agree that fish should not die. But they may not agree on other desirable parameters such as the ability of fish to spawn.[15] *Detroit Free Press* staff writer Thomas BeVier quotes William Gregory, President of Edison Sault Electric Co., as saying that trying to establish spawning beds is impractical. "We can plant fish instead and all have a damn good time."[16] Conversion

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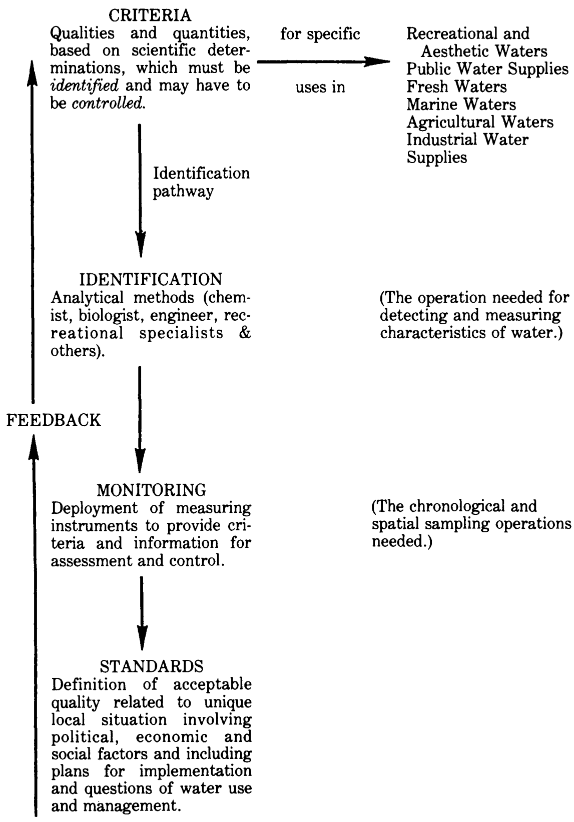
12. Cairns, Jr., *Guest Editorial: Beyond Single Species Testing,* 4 MARINE ENVT'L RES. (1980). NAT. RES. COUN., TESTING FOR EFFECTS OF CHEMICALS ON ECOSYSTEMS xii (1981).
13. Kimerle, *Aquatic Hazard Assessment—Concepts and Application*, Workshop On Hazard Assessment, Int'l Jt. Comm'n 221-230 (1979).
14. Cairns, Jr. & van der Schalie, *Biological Monitoring, Part I: Early Warning Systems,* 14 WATER RESEARCH 1179-96 (1980).
15. BeVier, *It's Fish vs. Electricity on the St. Mary's River*, Detroit Free Press, Aug. 1, 1982, at 1 col. 2.
16. *Id.*

of scientifically justifiable criteria into legal standards should consider a number of non-scientific parameters (Figure 1).[17] Even if there were general agreement on the scientific component, there would be disagreement on these. Yet, even among scientists there is no widespread strong endorsement of a multispecies, community, or ecosystem parameter to assess pollution[18] or of underlying ecological principles.[19] While statistically sound ecological comparisons by respected ecologists do exist,[20] it is unlikely that community and/or ecosystem parameters will be frequently used by regulatory agencies and industry until they acquire formal professional endorsement.

FIGURE 1

Conceptual framework for developing standards from criteria.



17. NAT. ACAD. OF SCIENCES, WATER QUALITY CRITERIA OF 1972 (1973).

18. Cook, *Quest for an Index of Community Structure Sensitive to Water Pollution*, 11 ENVT'L POLL. 269-88 (1976).

19. Gilbert, *The Equilibrium Theory of Island Biogeography: Fact or Fiction*? 7 J. BIOGEOGRAPHY 209-35 (1980).

20. Green, *Multivariate Approaches in Ecology: The Assessment of Ecological Similarity*, 11 ANN. OF REVISED ECOLOGY AND SYSTEMATICS 1-14 (1979).

Although it would be best to endorse parameters and methods to measure them separately, formal endorsement of a standard method is an indirect endorsement of the parameter it measures as well. This may be accomplished by consensus developed through publications such as *Standard Methods for the Examination of Water and Wastewater*[21] or by a group of experts representing a group of professional societies such as the American Society for Testing and Materials, Philadelphia, Pa.. The standard methods formally endorsed in this way have so far been limited to single species toxicity tests. At the 1981 annual meeting of The Society for Environmental Toxicology and Chemistry, it was asked of the plenary session attendees (about 600) if anyone knew of a standard method for toxicity testing at a higher level of biological organization than single species—there was no response. Although directly assessing the health of the biota in a "receiving system" (the one into which wastes are discharged or other anthropogenic stresses occur) is the most plausible approach for preserving environmental quality, and although methods have been available for years to study a variety of environmental parameters, biologists have to date formally endorsed only parameters and methods for single species toxicity tests. The report by the Committee to Review Methods for Ecotoxicology of the National Research Council, the operating arm of the National Academy of Sciences and the National Academy of Engineering, clearly stated: "Single species tests, if appropriately conducted, have a place in evaluating a number of phenomena affecting an ecosystem. However, they would be of greatest value if used in combination with tests that can provide data on population interactions and ecosystem processes."[22] In short, the legislation is in place in TSCA and the scholarly journals have contained a significant number of methods for years, adding to them at an impressive rate. Nevertheless, professional ecologists have not formally endorsed either parameters or methods particularly suited for hazard evaluation and pollution abatement.

In addition to endorsed parameters and measurement methods, professional certification is a necessary element to an adequate hazard evaluation process. A number of societies now have some form of professional certification (e.g., The American Fisheries

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21. AM. PUB. HEALTH ASS'N, AM. WATER WORKS ASS'N & AM. FED. OF WATER POLL., STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER (14th ed. 1976).
22. NAT. RES. COUN., TESTING FOR EFFECTS OF CHEMICALS ON ECOSYSTEMS xii (1981).

Society and The Ecological Society of America). The certification requirements, however, do not include a substantial number of publications on toxicity testing or any other substantive evidence of skill in this field. This is by no means a denigration of either of these reputable organizations or their certification processes; rather it is a recognition that present certification does not explicitly require proficiency in the most common formally endorsed standard methods for pollution assessment and hazard evaluation—single species toxicity tests. Perhaps the next phase in the development of professional certification will include more explicit indications of capabilities. Environmental Science and Ecology are such diverse fields that it is unlikely that one person could be proficient in all areas.

Gloyna, et al.[23] have pointed out the need to determine the kinds and numbers of specialists required to implement environmental legislation. Quality control systems of all kinds are only effective when a continuous monitoring system is in place—environmental quality control is not an exception to this rule. The process of hazard evaluation or risk analysis should be based on an adequate data base generated for that purpose rather than whatever can be obtained from the open or semi-open literature. These articles were almost always designated to fill other, often quite different, needs. The cost of reducing risk, including monitoring, can then be estimated and an informed decision made about the acceptable level of toxic substances to be discharged into the environment.

III. CONCLUSION

It is my conviction that we are now in a major transitional phase comparable to the agricultural revolution. The latter resulted from society's belief that the unmanaged environment was not capable of producing food in either the quantity or quality desired. Now there is unmistakable evidence that the unmanaged environment cannot always assimilate or recover from the anthropogenic stresses including toxic wastes, surface mining, and acid rain. Our attitudes and actions are more attuned to a frontier society which no longer exists than to a society where moving on is no longer a solution to

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23. GLOYNA, E. F., R. MCGINNIS, L. ABRON-ROBINSON, P. R. ATKINS, M. S. BARAM, J. CAIRNS, JR., C. W. COOK, H. H. FOLK, J. H. LUDWIG, M. T. MORGAN, J. D. PARKHURST, E. T. SMERDON & G. W. THOMAS, 5 MANPOWER FOR ENVIRONMENTAL POLLUTION CONTROL 427 (1977).

problems. Solutions to all of the major problems of our time require the collaboration of a diverse array of disciplines that are typically isolated from each other and unaccustomed to substantive interactions. A major factor in this impasse is the university where each department is an independent entity with a different approach to problem solving. Young faculty wishing to engage in interdisciplinary research do so at considerable peril since tenure and promotion committees often credit only those contributions cast in a particular disciplinary mode. Interdisciplinary articles generally are not welcomed by traditional journals, and articles in the new interdisciplinary journals will probably not be given much weight. The reemergence of integrative science characteristic of the period before the era of specialization is essential. At the same time, we must relearn how to communicate the essence of this information to laymen, use it to make decisions, and convert these, where appropriate, to useful regulation.