AFS Policy Statement #6:
EFFECTS OF TOXIC SUBSTANCES IN SURFACE WATERS
(Full Statement)

A. Issue Definition

As a result of daily activities, man has been altering the environment since before recorded history. Increased urbanization, the Industrial Revolution, and an overall larger population base have accelerated the process considerably. While providing numerous societal benefits, modern chemical technology has also brought about a marked increase in the number and variety of chemicals ultimately entering natural surface waters. The last century has witnessed a substantial growth of the chemical industry and it is estimated that there are presently over two million known, chemical compounds in existence, with nearly 250,000 new compounds currently synthesized each year. Of this number, it is estimated that approximately 1,000 new chemicals each year will find their way into the environment as the end result of marketing, use, and disposal.

As our understanding of the structure and functioning of the aquatic environment grew, it became obvious that the capacity of our rivers, lakes, and oceans to assimilate chemical wastes and toxic materials discharged into them was not at all infinite and that serious degradation of water quality was the inevitable result of misuse and mismanagement of this invaluable resource.

As techniques of analytical chemistry became increasingly more sophisticated and discerning, it became evident that most waste waters contain small amounts of chemical substances that with inadequate dilution and/or treatment may significantly impair the survival potential of resident aquatic life. The persistence and accumulation of hazardous substances such as pesticides and recalcitrant organics have resulted in the need for new and useful manufacturing containment and waste treatment procedures that will help protect aquatic life from the problems associated with materials such as DDT, PCB's and kepone. It is some significance to note that the initial indications of adverse ecological effects of many of these global pollutants came from the aquatic environment

In defining the issue of toxic substances in the environment, it is important to develop an initial understanding of what is meant by "toxic substances." In today's society, the classification of all chemicals as either distinctly 'harmful or distinctly safe is not warranted and we recognize that it is not feasible to describe a strict line of demarcation between harmful and beneficial. It is more relevant to recognize that there exist degrees of risk or safety for all chemicals since even the most innocuous of chemicals can create distinctly harmful environmental effects when present in high concentrations. In contrast, even the most toxic chemical substances can be assimilated by the aquatic environment provided the concentrations are sufficiently low. Therefore, it is evident that all chemical substances can be considered to have potential for toxic effects on surface water communities but that the degree of risk or safety of a chemical substance must be related to the amount potentially reaching the aquatic environment and a consideration of relative toxicity and persistence of that chemical.

To provide for societal needs now and into the future, it is evident that man will continue to affect and alter the environment. Along with the future societal benefits from technological developments, we must be able to predict changes in water quality and quantify impacts on aquatic life and efficiently minimize the impacts. An immediate need exists to develop further expertise and understanding of existing freshwater and marine aquatic communities so that an unacceptable risk to the survival potential of resident aquatic life will not be imposed. There is also a need to predict, assess, and separate, unimportant and trivial impacts of toxic substances on these communities from those changes and impacts that are significant and degrading.

B. Impacts on Aquatic Environment

The impacts of chemical substances on the aquatic environment have been as many and as diverse as the number of beneficial purposes for which these chemicals were initially created. The spread of manufacturing, consumer use, and distribution patterns for this myriad of chemical substances has become so general that there remain essentially no natural surface water communities currently untouched at least to some degree by man-made chemical substances. Measurable residues of persistent organics have been reported from fish and aquatic mammals from all corners of the earth, obviously thousands of miles from any known use or application site of these organics. Frequently the concentration of a particular toxic substance is sufficiently high so as to leave no doubt of the negative impact on aquatic life as was the case with kepone in the James River or PCB's in the lower Hudson. However, it is much more common to encounter lower concentrations of a particular chemical with no obvious or immediate effects but with far-reaching and potentially more significant secondary effects on aquatic communities and consumer species. The well-known example of the bioconcentration of chlorinated organic pesticides, particularly endrin, resulting in the deaths of literally millions of sport and forage fish species in the lower Mississippi River during the early 1960's demonstrated that persistent organic chemical could cause significant impacts on aquatic life in areas far removed from their discharge point if all aspects of manufacture, use, and disposal were not carefully considered. Since this specific example, the problem of a persistent, toxic chemical with subsequent impacts on higher tophic levels or other communities has been repeated on numerous occasions.

There is little value in attempting to identify industrial processes or list specific products with potential for impact on aquatic communities since, almost without exception, all manufactured chemical substances possess the potential to enter surface waters sometimes with and sometimes without man's specific intent. While all chemicals have this potential, is a basic understanding of general chemical and physical properties-such as molecular structure, water solubility, vapor pressure etc. and knowledge of anticipated uses and quantities to be produced can give early insights into which specific chemicals are most likely to become a problem. Comparison with lists of previous problem chemicals and/or processes also allows for some evaluation of relationships that results in the past problems.

In order to bring about a reduction in distribution or abundance of specific aquatic life, these toxic substances need not be present in acutely toxic concentrations. Species reductions can be caused by significantly lower concentrations of the chemical, which either directly or indirectly affect survival, growth, reproduction or behavior. Thus it becomes important to develop relevant criteria for the protection of the biological integrity of surface waters considering aspects of the structure and function of the biological community prior to the manufacture and distribution of new and expanded use chemicals.

C. Effects on Fish, Shellfish and Related Organisms

Results of numerous monitoring and survey programs suggest that most surface waters of the United States and many ground water sources contain measurable amounts of potentially harmful chemical substances. Consequently, resident fish and shellfish populations have been exposed to these chemical substances often with significantly deleterious effects. These exposures have typically resulted in direct and indirect toxic impacts on aquatic biota or in more subtle effects such as rendering these resources inedible for consumers. In the classic investigation of New York State lake trout mortalities in the late 1950's, Burdick and co-workers demonstrated that concentrations of DDT could cause fry mortalities via transmittal of DDT from female lake trout to their offspring through the egg. The promising commercial salmon fishery in the upper Great Lakes was abruptly terminated in the early 1970's when it was observed that these fish contained residues of DDT and PCB's in excess of the Food and Drug Administration recommended guideline of 5 ppm. More recently, large sections of the James River estuary in Chesapeake Bay have been closed for the taking of fish and shellfish due to manufacturing discharges and subsequent bioconcentration of the pesticide ketone.

Surface water pollution by heavy metals has been widespread and in some instances has caused significant human health problems due to bioconcentration of metals by fish and shellfish used as human food resources. The aqueous chemistry of metals in trace concentrations is extremely complex and can involve many biological, physical, and chemical parameters to activate or detoxify the particular form of metal in question. The classic Japanese "Minamata disease" associated with human consumption of fish and shellfish laden with high concentrations of methylmercury clearly focused concerns on the environmental distribution and transformation of metals in aquatic ecosystems.

Numerous investigators in the recent literature have reported behavioral modifications or alterations in fish exposed in laboratory situations to sub-acute concentrations of many test chemicals. Sublethal concentrations of pesticides can alter fish physiology, behavior, learning and ability to escape natural predation. Similarly, trace concentrations of mercury, zinc, and other metals reduce the swimming rate of crab and fish larvae thus reducing their ability to escape predation.

The significance of these sublethal responses, typically observed under controlled laboratory conditions, is extremely difficult to project to natural populations existing in receiving waters. However, the impact of these behavioral changes could potentially be more significant than survival or reproduction related effects observed at higher concentrations.

The inshore estuarine ecosystem is another area of particular concern with respect to the effects of toxic substances on aquatic biota. The estuary serves a vital function in the life history of most commercially important shellfish and many fish species. Anadromous fishes such as shad and several salmonids spend significant portions of their life histories in these areas. Many human population centers are also located in coastal areas and as a result the estuarine ecosystems in and around these cities have often been significantly affected by discharge and accumulation of toxic substances. Because of their unique physical and chemical characteristics, estuaries can trap and concentrate toxic chemicals in sediments and clehitus. The National Pesticide Monitoring Program in the United States, analyzing fish samples from 15 coastal states, found DTT residues ubiquitous, occurring in 63% of all samples analyzed. PCB's and other halogenated hydrocarbons are equally as widely distributed with typical concentrations in fish tissues between 0.5 and 1.0 ppm (wet wt. basis) and with occasional residues as high as 15 ppm.

Although data on effects of chemicals on marine organisms are not so extensive as those for the freshwater environment, pesticides, PCB's, phthalate esters, and many other chemical substances have been shown in numerous published investigations to adversely affect the survival, growth, behavior, and reproduction of marine fish and shellfish. Therefore, the effects of chemicals on marine and estuarine biota must also be considered in safety testing programs for new and expanded use chemicals.

A fundamental problem with current technology for aquatic toxicity testing and environmental hazard evaluation is our inability to test materials in the actual chemical forms and concentrations most likely seen in the environment. The additional extrapolation of laboratory results obtained for a single species existing in isolated test aquaria makes projection of laboratory results to actual environmental exposures uncomfortably uncertain.

This problem of real-world projection and validation of laboratory toxicity data has direct impact on several areas of immediate concern. These concerns include laboratory toxicity data and their use in establishing acceptable water quality criteria, determination of effluent guidelines and acceptable daily discharges, establishment of safety factors in hazard evaluation programs, and assessing overall benefit and risks associated with decreasing Or increasing discharge rates of chemicals.

In developing laboratory toxicity data and attempting to project results to natural receiving water communities, aquatic toxicologists and individuals concerned with risk assessments of new and expanded-use chemicals are typically confronted with the complex characterization of these receiving waters. Acute and chronic toxicity data currently developed using standardized testing procedures typically do not take into account the numerous interactions of pollutants with each other such as synergisms and antagonisms and interactions with natural environmental variables such as temperature, water hardness, pH, and salinity, all of which can significantly alter the impact of chemicals in surface waters. Therefore, if programs to evaluate effects of chemicals are to be most meaningful and predictive of real-world impacts, additional research consideration must be given to these environmental variables and their impact on a chemical's fate and effects in natural waters.

D. Needed Actions

As the preceding short summary of impact and effects of toxic chemicals in the aquatic environment indicates, these effects are often complex and far-reaching. The simplest counter to a chemical use that produces immediate and obviously deleterious environmental effects is to impose a ban on its use before the effects become irreversible. However, many of the less obvious and subtle environmental effects of toxic substances discussed above are not readily recognized and therefore become considerably more difficult to handle. Therefore, the effects of toxic substances in surface waters then becomes an issue requiring the development and enhancement of methodology to predict the fate and effects of chemical substances in aquatic environments prior to their manufacture, use and distribution. Methods to derive these needed data are currently evolving as procedures for hazard evaluation. This is defined as the development of methods for measuring risk to the aquatic environment associated with the use of chemical substances through an objective and probabilistic exercise based on empirical data and scientific judgment. The results of the integrated hazard evaluation procedure can then be used in a uniform manner to provide a means of estimating the limiting concentrations of chemical substances that will produce no negative effects on aquatic life potentially exposed to the chemical.

In view of the above and with respect to the issue of toxic substances and their effects on fisheries resources of North America, the American Fisheries Society recognizes the need for cooperative action among government, industry, and university scientists supporting efforts in the following areas:

(1) Aquatic scientists must become more active in establishing and reviewing the policies of government, industry, and the private sector in the area of chemical manufacture, control, and use to ensure that provisions for the protection and enhancement of fishery resources are included.

(2) Aquatic scientists need to become familiar with the existing and evolving programs for hazard evaluation of new and expanded-use chemical substances. It is imperative that meaningful aquatic hazard evaluation programs be developed and applied to chemicals by competent researchers as part of the premanufacturing notification and review processes evolving under federal, state, and local regulations.

(3) The AFS Water Quality Section should become the forum for fisheries and aquatic scientists interested in the relationships between water quality and aquatic resources. The image of the Water Quality Section must be expanded and enhanced through increased membership, support of relevant and timely publications, and a larger voice in the establishment of AFS environmental policies.

(4) Aquatic scientists should encourage the development of well-designed research programs in the following areas:

a. We must develop an overall better understanding of physical, chemical, and biological environmental processes and their interactive effects on distribution and removal of chemical substances.

b. Cost-effective methods are needed to predict the concentration of a chemical substance that will have no chronic effects on exposed aquatic species in receiving waters.

c. Cooperative programs and an overall higher degree of coordinated research activities are needed to ensure that impact of limited funds for environmental research into toxic substances are maximized. Interdisciplinary efforts to characterize chemical/physical kinetics and biological effects of chemical substances will ensure early positioning of environmental concerns for new chemicals.

(5) The Water Quality Section of AFS should initiate an education program to provide the public a balanced, realistic assessment of current water quality issues and their potential impact on aquatic resources. Such an education program will ensure that public pressure can be focused on timely water quality issues thus lending support to environmentally sound decisions.