

Toxic Materials in the Aquatic Environment

Seminar Conducted by

WATER RESOURCES RESEARCH INSTITUTE

Oregon State University



Spring Quarter 1978

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Preface

Major sources of water pollution can be found in nearly every kind of industrial, municipal, or agricultural operation. There are thousands of toxic chemical compounds in use today and new chemicals are being developed every year. Chemical contaminants, such as phosphates, nitrates, pesticides, detergents, trace metals, acid from mine drainage, cyanide, phenols, radioactive substances, solvents, and hydrocarbons, are all products of our technological society and potential threats to our water resources.

Fish and wildlife are affected directly by toxic pollution. But, virtually all forms of such pollution harm people in some fashion. While much is known about the health effects of some pollutants, the total impact of pollution is difficult to measure. There is no way to determine absolutely the chronic effect of environmental pollution. It cannot be stated, unequivocally, that the continued accumulation of tiny amounts of pesticides in the fatty tissues of humans or other organisms is a direct cause of disease. Research on cause and effect goes on constantly and must continue. Much has been accomplished in recent years, but there is a great deal more to be done.

Some aspects of the problem were examined in a seminar series during Spring quarter. The weekly presentations were open to faculty, students of all ages, and the general public. The papers presented are published in this volume to reach a wider audience.

Peter C. Klingeman
Director

Corvallis, Oregon
July, 1978

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The Institute

The Water Resources Research Institute, located on the Oregon State University Campus, serves the State of Oregon. The Institute fosters, encourages and facilitates water resources research and education involving all aspects of the quality and quantity of water available for beneficial use. The Institute administers and coordinates statewide and regional programs of multidisciplinary research in water and related land resources. The Institute provides a necessary communications and coordination link between the agencies of local, state and federal government, as well as the private sector, and the broad research community at universities in the state on matters of water-related research. The Institute also administers and coordinates the inter-disciplinary graduate education in water resources at Oregon State University.

This seminar series is one of the activities regularly undertaken by the Institute to bring together the research community, the practicing water resources specialists, students of all ages and interests, and the general public, in order to focus attention upon current issues facing our state.

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Overview: Our Toxicological Dilemma

Our biosphere comprises only a fraction of one percent of the mass of our earth and, by definition, all life exists in this region. But our ability to alter our environment continues at a pace which increasingly exceeds our ability to predict the consequences of our actions. A disturbing and growing body of evidence indicates that subtle man-made hazards are replacing disease and famine as key determinants of longevity in many areas of the world.

The decision to devote this year's Water Resources Institute Seminar series to the problem of aquatic toxicology seems to be a very timely one. Major legislation dealing with toxic substances control has been enacted. We are exposed almost daily to media reports of new toxicological risks and hazards. Symposia on specific aspects of aquatic toxicology are held regularly. A large number of research reports and articles have appeared in the literature in the last four years, including approximately 15,000 on toxicity, 1000 on water toxicity, 11,000 on cancer and 100 related to carcinogens in water.

We know very little about what substances in water are doing to the exceedingly complex aquatic life systems and man. Seemingly inert materials, such as asbestos, have been determined to be potentially toxic. Controversy rages on the significance and meaning of toxicological investigations. Industry continues to generate new chemicals at the rate of about 800 per year, while over one-half million manufactured chemicals circulate in our environment. The fate and distribution of all these substances remains largely unknown.

Rapid developments in highly sophisticated and computer coupled chemical instrumentation have permitted detection and analysis of chemical substances in the part per billion level and below. This is a difficult level to conceptualize but an appreciation can be gained by considering that one part per billion (ppb) is equivalent to one second in 31.7 years. Such levels are often several orders of magnitude below what is generally regarded as safe for the occurrence of a toxic substance in water. On the other hand, many substances have been found to be either harmful, or potentially harmful, in the ppb (microgram per liter or $\mu\text{g/l}$) range, including chlorine, cadmium, mercury phthalate esters and phenol. Water quality criteria for some of the

chlorinated aromatic compounds have been established at the part per trillion level (one second in 31,700 years), including polychlorinated biphenyls, DDT, and aldrin-dieldrin. It is often quite difficult to determine such low ranges, not because of analytical limitations, but because background or "blank" levels of a substance sometimes exceed criteria or experimental values.

SOURCES AND QUANTITIES

Toxic substances arise from three primary sources: 1) wastewater effluent from domestic and industrial treatment plants, 2) runoff, and 3) spills. The magnitude of each of these with respect to toxics is very uncertain. As examples, suffice it to state that

- over 12,000 industrial plants discharge large quantities of known toxics, either directly to the sewer or to surface waters after preliminary treatment,
- the electroplating industry alone accounts for over 250,000 lbs/day of toxic heavy metal and cyanide wastes,(1)
- domestic waste treatment plants discharge between 100,000 and 400,000 lbs/day of toxic and highly reactive chlorine,(2)
- over 800,000,000 lbs of pesticide products enter the environment annually.(3)

In addition to these direct routes, over 4 million metric tons of oil enter the oceans annually from surface sources. An unknown but potentially much larger amount enters by way of the atmosphere.(4,5)

Groundwater leaching from solid waste sites and dredging provide routes for entry of toxic substances into surface waters. Toxic hazards associated with emerging energy technologies include those arising from coal gasification, coal liquification, shale oil extraction, and nuclear energy. Well documented toxic substances found in the aquatic environment are listed in Table 1 with EPA water quality criteria limits.

TOXICOLOGICAL TESTING

What kind of information is required to assess the hazards of environmental exposure to toxic substances? Before going further, we should establish the meaning of the word "toxic". As defined in Public Law 92-500, the Federal Water Pollution Control Act of 1972, section 502(13), the term toxic refers to "those substances, or combination thereof which, after discharge and exposure to living organisms, will cause, on the basis of information available

- death,
- disease,
- behavioral abnormalities,
- cancer,
- genetic mutations,
- physiological malfunctions

to such organisms or their offspring." (6)

TABLE 1

WATER QUALITY CRITERIA VALUES FOR SOME
COMMONLY DOCUMENTED AQUATIC TOXICANTS*

<u>Substance</u>	<u>EPA Recommended Limits Mg/L</u>	
	<u>Domestic</u>	<u>Aquatic Life</u>
Aldrin-Dieldrin		0.003
Ammonia		20
Arsenic	50	
Cadmium	10	0.4-1.2
Chlordane		0.01-0.004
Chlorine		2-10
2,4-D	10-100	
Chromium	50	100
Copper	1000	0.1x96HrLC ₅₀
DDT		0.001
Lead	50	
Mercury	2	0.05-0.1
Parathion		0.04
Polychlorinated biphenyls		0.001
Selenium	10	0.01x96HrLC ₅₀
Toxaphene	5	0.005

*Environmental Protection Agency. Water Quality Criteria. 1976.

Traditional kinds of information used in toxicological testing to assess hazards have been:

1. the dose response relationship in which the effect intensity usually increases with the dose;
2. the time-course of the response in which the time required for the dose to produce the effect is noted;
3. repeated dose effects in which accumulative effects, irreversibility, tolerance, withdrawal behavior or other similar effects are noted;
4. relationship between structure and activity;
5. site of action;
6. mechanism of toxic effect.

Biologic, chemical, physical and genetic factors contribute to the difficulties involved in interpretation of toxicological data and impart limitations on extrapolation of data from one species of organism to another. These factors are summarized in Table 2.

TABLE 2

SOME AQUATIC TOXICOLOGICAL VARIABLES

<u>Biologic/Genetic</u>	<u>Chemical</u>	<u>Physical</u>
	intrinsic toxin properties	temperature
species resistance	Eh	surface area
strain resistance	oxygen	adsorption
adaptation	chelating agents	light
size	complexing agents	
age	antagonistic substances	
tolerance	synergistic substances	
health	ionic activity	
membrane permeability	hardness	
transformation mechanisms	alkalinity	
distribution	pH	
absorption	ion exchange	
storage	dissolved gases	
reserve functional capacity		

There are many methods used to evaluate the hazard associated with a particular toxic substance. One of the most common is to isolate the test organism in a test chamber and introduce the toxic substance, or substances in question under rigorously controlled conditions. Such a test is often referred to as a toxicity bioassay, although is more properly called a test.

With fish, the test is normally performed for a period of 24-96 hours. No standard procedures have found wide acceptance. The present state of the art is reasonably good for predictions of toxicity in certain waters containing a limited number of inorganic and organic components. This is rarely the case, however, except in the laboratory. In addition, there are several other reasons why aquatic toxicological data must be interpreted with care, among them,

1. they apply primarily to fish which are normally not the most sensitive aquatic community representatives;
2. effects of toxics measured at high concentrations may not be valid at much lower concentrations;
3. most toxicity studies (and therefore most water quality standards) are based on total concentration of a substance irrespective of its form, i.e., electron state, physical state, degree and type of complexation, or coordination, etc.;
4. there is no uniformly applicable statistical methods for assessing the tests' confidence;(7)
5. Commonly used linear models may not properly describe non-linear relations;(8)
6. a single environmental gradient may influence a number of independent physiologic factors;(8)

The extent to which we address these and like problems will determine the measure of certainty we have in our results. Are we to accept something less than scientific certainty? We have no choice. Beyond a reasonable doubt? Or, shall we be content with the greater weight of the evidence, or perhaps only substantial evidence? At present, there is no broadly applicable or systematic way of answering these questions. There is no general agreement on how to determine how safe a substance is.

CARCINOGENS AND MUTAGENS

A tremendous effort is underway to answer a single question about carcinogens. What is safe? Investigators in Louisiana found that 51% of un-concentrated Mississippi River water caused mutations in common bacteria.(9) Forty-three percent of the Royal Ferns exposed to industrial wastes underwent mutations as compared to 1 percent in a control population.(10) These are only two recent examples of an effort being mounted to assess the risks of a class of substances known collectively as carcinogens and mutagens.

In the United States cancer kills 1 out of 5, and the rate is increasing. The economic loss in excess of 15 billion annually. Last year cancer killed almost 400,000 U.S. citizens. Another 1 million are under treatment. As many as 90% of these are thought to be environmental. (14) What proportion of these are related to the aquatic environment and what additional effects are exerted on aquatic organisms, and ultimately man, are largely unknown.

Carcinogens and mutagens are troublesome for several reasons, among these:

1. No threshold level below which a substance is "safe" has yet been demonstrated for a carcinogen;

2. Substances known to be carcinogenic are found everywhere, including air, water, soil, and food;
3. Interactions among carcinogens and other substances may, and often do, produce unexpected effects;
4. A "latency" period is usually required before the appearance of cancer or mutogenesis. This may range from hours in the case of aquatic microorganisms to 50 years or more for man.

Of the two million known chemicals, only about 6,000 have been laboratory tested for carcinogenicity.(11) Classes of organic compounds identified as carcinogens include nitrosoamines, haloaromatics, haloaliphatics, polynuclear aromatics, epoxides, aromatic amines, and halogenated alkenes. Inorganics include arsenic and asbestos. Other similar classes of substances may or may not be carcinogenic. There is simply no way that one can look at the structure of a compound with the assurance it represents no risk. Small differences in molecular structure, and/or form, can mean the difference between a carcinogen and an apparently innocuous substance. Bis-chloroethyl-ether is a 10-100 times weaker carcinogen than bis-chloromethylether. Chemicals often appear safe for human exposure after 10-20 years of use with no apparent harm. But the relatively long delay between exposure and symptoms makes it impossible to identify some carcinogens in the aquatic environment.

There are two sources of data in the assessment of carcinogenic risk: 1) animal studies, and 2) epidemiology. Some difficulties in animal studies have been discussed, including our lack of ability to accurately assess the degree of risk because of the required extrapolation to man across species and exposure levels. Epidemiologic data exists for only a few chemicals, and this is certainly an area of major neglect, but not without its attendant difficulties, including variables such as human genetic difference, geography, diet, occupation, age, and health status. Evidence now appears to be growing that many human cancers result from synergistic interaction of several factors present chronically and at low levels. It is therefore not sufficient to investigate the effects of each substance individually. The extent to which chemicals interact at detectable or undetectable levels and the extent to which they may be additive, or offset each other's effects, cannot be predicted. On the other hand, some substances are known to enhance the natural protective mechanism of the organism.

On the positive side, G. E. Schweitzer, director of EPA's Office of Toxic Substances, predicted that "within a decade. . . we should have established sound and reliable procedures and techniques for anticipating the consequences of introducing new chemicals into the environment. . . we should no longer be caught by surprise by high volume chemicals (asbestos, PCB's, vinyl chloride, aldrin/dieldrin, mercury) which. . . pose grave environmental risks after the damage is done." (examples by author) (12)

The current government evaluative programs include EPA's Carcinogen Assessment Group, the National Cancer Institute's Clearing House, and the National Institute of Environmental Health Sciences work. NCI and NIEHS are evaluating proposed short-term screening tests, including the Ames test, a DNA repair-deficient spot test, and a hemoglobin variance test. (13)

The cost of toxicity and carcinogen evaluation programs is very great, but the machinery of government, industries, and universities has begun

to respond in earnest to investigative needs. If the only cost to society involves unnecessary elaboration of expensive tests, or the occasional rejection of useful materials or processes, and safety has not been compromised, then our only sin is inefficiency. If, on the other hand, epidemiologic studies demonstrate that the exposure risks are more than we bargained for, then we have compromised the collective health of the organisms inhabiting the planet. There is little doubt that preventative measures call for increased capital expenditures and a change in basic lifestyles.

A summary of the toxicological problems confronting industrialized countries was stated by the late E. F. Schumacher when he said that the "rising rate of environmentally-induced cancers emanated not from our failures but from what we thought were our greatest successes." (13)

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Presented April 6, 1978 by W. E. MILLER, J. C. GREENE, E. A. MERWIN, and
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Algal Bioassay Techniques for Pollution Evaluation

INTRODUCTION

The recent enactment of the Toxic Substance Control Act (PL 94-469), simultaneously with amendments to the Clean Water Act and the concern for the deteriorating quality of our nation's water supplies, has led the Environmental Protection Agency to a flurry of bioassessment research activity. This research is divided into two broad categories: 1) ecological effects, and 2) health effects. The research thrust for the short-term duration centers around the validation of existing (on the shelf) protocols to define the toxic effects of any type of pollutant (whether it's a specific organic compound, complex waste, or a new chemical formulation) which can enter aquatic and/or terrestrial ecosystems.

The Algal Assay: Bottle Test (AA:BT) procedure developed, evaluated and standardized at the Corvallis Environmental Research Laboratory (CERL), is an ecological test which can be used to define the effects of toxicants in the aquatic environment. The ability of the AA:BT to define toxicity is the result of the research effort since its inception in 1967.

Algal Assay Development

The development of the algal assay began when a joint task force composed of individuals from government and industry met in 1967. The objective of the joint task force was to consider the problems associated with man-induced eutrophication in the United States, and to stimulate the development and demonstration of technical means for the management, control, or prevention of these problems.

In order to accomplish this objective, one recommendation was to encourage and promote the development of an algal assay procedure for use in predicting the impact of changed levels of nutrient elements in natural water environments, as well as of the addition of new nutrient or nutrient-synergistic compounds to the water environment.

In 1968, the Joint Industry/Government Task Force on Eutrophication sponsored a meeting between international experts from industry, government, and academic institutions, at which time an algal bioassessment technique draft outline was composed.

There was a growing interest in eutrophication in 1968, and many investigators were using a variety of tools to evaluate and predict the impact of the addition or subtraction of various materials on algal growth. Because of the proliferation of procedures, it was evident that correlation or comparison of data collected at various times and places would be most difficult.

The joint task force, as a first order priority, pressed for the rapid development and distribution to the field of a reliable, reproducible, and correlatable procedure that could be universally employed. The Corvallis laboratory was assigned the task of leading this effort.

In 1969, a Provisional Procedure was published as a first step in this direction. This enabled the interested investigators an opportunity to evaluate the bioassay techniques in their own laboratories. This document was not a "standard method". Individuals were encouraged to suggest modifications to improve or simplify the algal assay procedure.

In 1971, two documents were published by the Environmental Protection Agency. They were the product of more than two years of intensive research directed toward the development of a reliable and reproducible algal assay.

The "Inter-Laboratory Precision Test" represents a concerted effort by one government laboratory, four university laboratories, and three industrial laboratories to evaluate the precision of the "Bottle Test" of the "Provisional Algal Assay Procedure" in determining the growth response of Selenastrum capricornutum to various nutrient concentrations in synthetic culture medium and natural lake water samples.

This course of action identified elements of the test that were faulty, difficult, or questionable. As a result of this massive effort, the "Algal Assay Procedure: Bottle Test" was refined sufficiently to be offered for wider use.

We at CERL believed that the algal assay procedure was sufficiently refined to qualify as a standard method. This conviction was confirmed in 1975 when the American Public Health Association published the Algal Assay Procedure in its 14th edition of "Standard Methods for the Examination of Water and Wastewater".

This method is currently under review by the American Society of Testing and Materials and is in the subcommittee (D-19.23.02) ballot process.

Importance of Algal Assays

Algae are the basic support of the food chain in the aquatic environment. Therefore, they are important for the sustenance of the higher trophic levels within the aquatic ecosystem. Algae convert energy from the sun, through photosynthesis, into protein which is assimilated by the higher trophic

forms, many of which are consumed by man. Much of the seafood we eat and the oxygen we breath is a result of algal productivity. A balanced growth of algae within the aquatic environment is beneficial. However, extremes in productivity can create adverse conditions. An aquatic system devoid of algae because of nutrient limitation is a low productive (aquatic desert) system; whereas, excessive nutrient enrichment causes algal blooms which dominate the ecosystem and, in most cases, adversely affect the desirable sports fishery and recreational uses, such as swimming and water skiing.

ASSAY ALGAL APPLICATION

The AS:BT can be used to define growth limiting constituents within the aquatic environment; whether they are macronutrients (N, P), trace-elements (Fe, Mn) or growth inhibitors. It can be used to identify the bioreactive components of the pollutants (not necessarily those identified through chemical analysis) entering the receiving waters which are responsible for regulation of biological productivity. The significance of the Algal Assay:Bottle Test is that differentiation can be made between the constituents identified in a pollutant determined by chemical analysis from the interaction of these constituents which actually regulate algal growth, i.e., a textile waste can contain both organic and heavy metal components either of which may be in toxic concentrations. The interaction between these components (chelation of heavy metals) may detoxify the waste and, accordingly, the test alga will be limited by the nutrient and not the toxic constituents within the waste. And, it can produce information that can be applied to real-world situations. In summation, the AA:BT is simple, reproducible and utilitarian in concept and scope.

The test organism which has been the principal "workhorse" during the development of the AA:BT is the green alga Selenastrum capricornutum. This alga was selected because of its ease of culture and maintenance. It is unicellular, in which the cells are in a non-mobile condition throughout their life cycle. These attributes allow this alga to be enumerated on a daily basis, or at any point in time during the incubation period, with an electronic particle counter. The electronic particle counter is used to measure both cell density in cells/ml and changes in mean cell volume (μm^3). Cell density and mean cell volume measurements are used to indirectly calculate (on a dry weight basis) the change in biomass to a given stress over a unit of time (usually 14 days).

Basically, the assay consists of the inoculation of 1000 cells/ml of the test alga into the testwater which is incubated under standard light (400 ft-c) and temperature (24°C) conditions. The growth responses obtained reflect the interaction of the bioreactive constituents contained in the pollutant or receiving water.

Nutrient Limitation

The AA:BT protocol was developed in concert with the Joint Industry/Government Task Force on Eutrophication. Thus, early application research centered around the study of nutrient dynamics in natural waters, with principal emphasis upon lakes and impoundments. Miller, Maloney and Greene (1974) evaluated 49 lakes to ascertain the utility of the AA:BT to define their

trophic status. Four productivity (trophic response) subgroups were identified; low, moderate, moderately high and high. Growth response in these lakes was primarily limited by phosphorus (72%) and, secondarily, by nitrogen (16%). Constituents other than N and P regulated growth in the remaining 12% of the lakes studied. The ability of the AA:BT to correlate with the nutrient content of these test waters enabled its response to mirror the known trophic levels. This was substantiated by comparison of the trophic assessment assigned by the limnologists who were familiar with the lake systems to the growth response (on blind samples) obtained in the laboratory using the AA:BT.

Similar nutrient growth response interactions were obtained in 18 samples assayed from the highly regulated multiple use Snake River system (Greene, Miller, Shiroyama, and Maloney, 1975). Half of the 18 Snake River water samples supported biomass less than $0.01 \text{ mg dry wt l}^{-1}$ and were considered to be low in productivity. The remaining 9 samples reflected nutrient inflow from municipal, industrial and agricultural sources within the drainage basin. The increases in AA:BT response correlated with either the population density (municipal waste discharge) or agricultural intensity adjacent to the Snake River system.

The ability of the AA:BT to predict the algal growth potential in natural waters and its use to define limiting nutrients in these waters led to the identification and application of nitrogen and phosphorus yield factors to predict the growth of Selenastrum capricornutum (Shiroyama, Miller, and Greene, 1975). Each $\mu\text{g P l}^{-1}$ will support $0.43 \pm 20\%$ mg dry wt. l^{-1} of S. Capricornutum if other constituents are not growth limiting. Therefore, test waters containing $20 \mu\text{g P l}^{-1}$ (Ortho-P is most bioavailable) should support $8.60 \text{ mg dry wt. l}^{-1}$ (20×0.43) of the test alga depending upon the availability of other essential nutrients (primarily nitrogen as NO_2 , NO_3 , and $\text{NH}_3\text{-N}$) within the test water.

Total soluble inorganic nitrogen ($\text{TSIN} = \text{NO}_2 + \text{NO}_3 + \text{NH}_3\text{-N}$) is readily available for support of S. capricornutum. Each $\mu\text{g TSIN l}^{-1}$ will support $0.038 \text{ mg dry wt l}^{-1}$ of the test organism providing other nutrients are not growth limiting. These phosphorus and nitrogen yield factors are used to predict the assay response of natural waters.

The ratio of TSIN to Ortho-P content in test waters can be used as a "guide" to nutrient limitations in natural waters. Waters containing N:P ratios greater than 11:1 may be considered phosphorus limited. Those containing N:P ratios less than 11:1 can be considered nitrogen limited for algal growth. Confirmation of a nitrogen or phosphorus limitation prediction is obtained by analysis of the assay response to singular and combined nutrient (N,P) and/or chelator additions.

No singular chemical test or biological measurement can be used to define all the interactions regulating biological productivity in natural waters. The relationship between AA:BT assays to measurements of indigenous phytoplankton in Long Lake, Washington, has been reported (Greene et al., 1976). A high correlation ($r = 0.95$) between both mm^3 indigenous phytoplankton l^{-1} and mg m^3 chlorophylla ($r = 0.93$) and $\text{mg dry wt. S. capricornutum l}^{-1}$ was achieved when consideration was given to whether the reservoir was stratified or homothermal.

In most cases, the trophic status of lakes and impoundments is based on their bioavailable nitrogen and phosphorus content. Those waters containing

greater than 0.015 mg bioavailable P l⁻¹ and 0.165 mg bioavailable N l⁻¹ are generally eutrophic.

Failure of a test water to attain the predicted yield or nutrient limitation status is usually indicative of the presence of toxicants. The standard addition of 1.0 mg Na₂ EDTA l⁻¹ to these test waters prior to assay is used to define the extent of heavy metal toxicity (Miller et al., 1976).

Heavy Metal Toxicity

The study of heavy metal interaction in natural waters is complicated by uncertainty of the form, concentration, and biological reactive state of the metal. Thus, with few exceptions, the chemically analyzed heavy metal content of a test water may not reflect the resultant biological interactions and productivity in natural waters. The growth response of S. capricornutum to conditions of heavy metal stress in natural waters is in essence a "biological response model" of complex physical and chemical interactions. The resultant biological response (maximum standing crop) is an integration of the combined effects of solubility, ionic strength, metal concentration, and contact time which regulate toxicity of the heavy metal to the test organism.

Miller, Greene, and Shiroyama (1976b), have reported that the inhibition of specific heavy metals upon the growth of S. capricornutum may be linear (0-100%) with the increase in zinc content of test waters, but non-linear for the increase in copper and cadmium content beyond 20 and 40%, respectively. These growth responses have established the sensitivity of S. capricornutum to the bioreactive state of these heavy metals. The >95% I₁₄ algistatic (inhibitory) response of the test alga in these test waters is similar to that of sensitive indigenous species to accidental or recent discharges of heavy metals (an algicidal response is verified when a subculture from an algistatic test water fails to grow in assay medium). However, this inhibited response does not necessarily reflect the growth potential of indigenous algae which have evolved from long-term chronic exposure to heavy metals.

The response of the standard laboratory algal test organism to the addition of Na₂ EDTA, singly and in combination with nitrogen and phosphorus, to heavy metal laden test waters, has been shown to correlate (r = 0.82) with indigenous phytoplankton standing crop (Greene et al., 1978). The indigenous phytoplankton growth in these waters can be attributed to: 1) adaptation to their environment; 2) natural decomposition, and/or complexing of the heavy metals by both organic and inorganic ligands; and 3) the presence of adequate nutrients.

Complex Wastes

The advent of the Toxic Substance Control Act (TSCA) outlined in Public Law 94-469 (October 11, 1976), and the resulting need to establish test procedures and effluent guidelines for pollutants, has stimulated a flurry of bioassessment activity. This activity is relevant since only the bioreactive components of the pollutants are responsible for the regulation of biological productivity in natural waters.

TABLE 1
COMPARATIVE BIOTEST RESPONSES FOR TEXTILE EFFLUENTS*†

Textile Plant	Freshwater ecology series			Recommended interpretation		Marine ecology series		
	Fathead minnow (96-hr LC ₅₀), % secondary effluent	Daphnia (48-hr EC ₅₀), % secondary effluent	Selenastrum (14-day EC ₅₀), % secondary effluent	Selenastrum 20% secondary effluent % I ₁₄ % S ₁₄		Sheepshead minnow (96-hr LC ₅₀), % secondary effluent	Grass shrimp (96-hr LC ₅₀), % secondary effluent	Algae (96-hr EC ₅₀), % secondary effluent
A	19.0	9.0	11.3	53	----	62.0	21.2	f
B	NAT ^b	NAT	----	--	83	NAT	NAT	9
C	46.5	41.0	----	--	187	69.5	12.8	90
D	NAT	NAT	----	--	100	f	f	f
E	NAT	7.8	< 2.0	95 ^e	----	NAT	NAT	10 to 50
F	NAT	81.7	----	--	598	NAT	NAT	85
G	64.7	62.4	----	--	390	NAT	NAT	59
H	c	40% dead at 100% concentration	7.8	92	----	f	f	f
J	NAT	NAT	----	--	76	f	f	f
K	NAT	NAT	----	--	57	NAT	NAT	77
L	23.5	28.0	12.0	81	--	NAT	NAT	1.7
M	NAT	60.0	----	--	149	f	f	f
N	48.8	100% dead at all dilutions	< 2.0	95 ^e	--	47.5	26.3	2.3
P ^a	NAT	NAT	----	--	38	f	f	9.0
R	16.5	8.0	8.8	95	--	f	f	f
S	NAT	NSA ^d	----	--	382	NAT	NAT	9
T	46.5	NAT	----	--	1911	68.0	34.5	70
U	NAT	12.1	----	--	377	NAT	NAT	9
V	36.0	9.4	----	--	232	f	f	94
W	55.2	6.3	1.0	95	--	37.5	19.6	50
X	NAT	NAT	----	--	163	NAT	NAT	9
Y	NAT	NAT	----	--	261	f	f	f
Z	NAT	42.6	15.5	84	--	f	f	f

*Sample inadvertently collected prior to settling pond. ^bNo acute toxicity. ^cDiseased batch of fish nullified this analysis. ^dNo statistical analysis because heavy solids concentration obscured the analysis; the sample does not appear to be acutely toxic. ^e95% growth inhibition in 2% solution of secondary effluent. ^fAnalysis not performed on this sample. ^gGrowth inhibition < 50% in 100% solution of secondary effluent. ^hNo chemical mutagen was detected by the 10 microbial strains. ⁱNo rat mortality after 14 days due to maximum dosage of 10⁻⁵ m³/kg body weight (LD₅₀). However, six samples (B, C, F, L, N; and S) showed potential body weight effects, and sample R resulted in eye irritation.

The continued acceptance of chemical analysis of specific constituents within the complex waste (i.e., Zn, Cu, Cd, phenol, PCB, analine) as the primary reference standard for the legislation of ecological response criteria is both unwise and misleading. Only concurrent evaluation of both chemical analysis and bioassay results will provide the scientific base necessary to establish realistic water quality criteria.

The AA:BT can be used to define the potential stimulatory and/or inhibitory properties of complex wastes introduced into receiving waters. It is important to consider the following factors when designing an assay protocol to evaluate the environmental impact of complex wastes:

1. The method of entry into the receiving water (i.e., direct discharge after primary, secondary, or advanced waste treatment; percolation thru soils; etc.)
2. The anticipated final concentration of the complex waste within the receiving water.
3. The degree to which the test waters are representative of those receiving the candidate complex wastes.

Twenty-three textile waste samples, representing eight manufacturing processes, were evaluated by seven assay techniques to define their toxic properties. The bioassessment organisms included freshwater and marine algae, crustacea, fish, and mammals. A comparison of the sensitivity of these bioassays (Table 1) showed that the AA:BT, using *S. capricornutum*, was one of the most sensitive tests used in the textile waste survey. This test not only identified toxic wastes, it also identified those that were stimulatory (Shiroyama, et al., in preparation).

ASSAY UTILITY

The AA:BT is a viable tool for the study of nutrient limitation and heavy metal toxicity. It also shows great potential for the evaluation of complex wastes. The validation of the test to define its sensitivity to broad classes of industrial wastes is of prime importance. The biggest stumbling block in this validation is the evaluation of the toxic and/or stimulatory effects of organic compounds. The reasons for this are: 1) the safety factor in handling the compounds; 2) the volatility and insoluble nature of these compounds; 3) the lack of knowledge about the mode of interactions causing the toxicity; and, 4) the expense of chemical identification of both the parent compound and its degradation products within the test system.

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Relationship to Water Resources , Terrestrial Laboratory Microcosms:

For over 100 years scientists have been putting parts of the world into boxes, then studying the consequences of various manipulations---chemical exposure, changes in environmental conditions, etc. Plant growth chambers and aquaria have evolved into controlled laboratory model ecosystems or microcosms, which are now being applied to ecological research and chemical evaluation. Ironically, the first plant growth chambers (Ward, 1852) were used to protect plants from the noxious London smog. Now we not only use them to study the effects of smog on crops, but also apply them to evaluate pesticides and a host of other pollutants.

Focus in this paper is directed at terrestrial systems and their outputs to aquatic systems; however, many of the concerns about microcosm technology and its application are shared by both terrestrial and aquatic systems. Terrestrial microcosm technology was recently reviewed at a Symposium here at Oregon State University (Gillett and Witt, in press), so that the state-of-the-art can be presented as currently viewed.

TERRESTRIAL MICROCOSM SYSTEMS

Microcosms are controlled, reproducible laboratory systems which attempt to simulate the processes and interactions of components in a portion of an ecosystem. The microcosm may be either open or closed, but has a definite boundary which determines the physical structure and scope of studies. Because a particular microcosm is being used as a physical laboratory model of a specific type or portion of the environment, it must be excised from that environment, or composed of representative materials and biota from the system. Environmental conditions and other "driving variables", such as chemicals, can then be controlled. Microcosm technology focuses on the accurate modeling of real world situations, so that observations in the microcosm can be extrapolated to the larger environment. For terrestrial microcosms, most of the current interest is in evaluating the fate and effects of chemicals introduced into the system.

Microcosms are intermediate in scale, complexity, and degree of operator control between the test tube and the field. As a physical model they are a means for explicitly testing hypotheses about chemical fate and effects, changes in environmental conditions, or the interactions of species and processes. There are thus a number of advantages and limitations to the microcosm approach (Table I). Perhaps one of the most important questions one might ask about microcosm experiment is: Do the results of the measurements in the microcosm apply generally to environments other than that specifically represented in the test system, or are they limited to just that system? We know that test tube measurements apply generally to all systems, but do not represent any system very well. The same may be said for single species toxicity tests in cages or aquaria. Experience has provided caution to extrapolation from these studies, but we have yet to learn how cautious to be about microcosm technology.

For a number of situations microcosms are uniquely suited as test systems. Van Voris, et al. (1978) have demonstrated this most forcefully in an excellent study that used excised grassland microcosms to show that ecosystem complexity (as measured by patterns of community CO₂ uptake and release) could be quantitatively related to the ecosystem stability and resistance (as measured by the rate of onset and return to normal of elutriate calcium ion loss from the soil) to cadmium as a pollutant. These properties cannot be measured in less than an ecosystem, but quantitation in the field is impractical and the results often inconclusive. Although the microcosms came from the same field species, diversity as an index was much more erratic. In order to make these measurements, environmental conditions were maintained constant for several months in the laboratory.

A different practical aspect of microcosm technology is that evidenced by the work of Nash, et al. (1977) on toxaphene losses from cotton. Although this pesticide has been used for years, the studies in the agroecosystem changer (Figure 1) provided the first quantitative view of toxaphene disposition into air and soil from the application onto plants. Similarly, although aldrin and dieldrin have been used on corn for decades, inhibition of early plant growth was first discovered (Cole, et al., 1976b) in a terrestrial physical model ecosystem (Cole, et al., 1976a) shown in Figure 2. In sum, single species exposure trials can provide highly accurate evaluation of toxicologic effects, but do not provide the gestalt of chemical insult that occurs with transport, transformation and bioaccumulation in the field.

Table II gives data about the various terrestrial microcosm systems which have been applied to the study of pesticides and other toxic substances. The physical systems are illustrated in Figures 1-8. Each of the systems has provision for water inputs (potentially bearing pollutants), and all but one can be related to outputs into water for examining terrestrial contributions to water quality. The first microcosm applied to pesticides studies (Metcalf, et al., 1971) was an aquatic/terrestrial model of a "farm pond" (Figure 3), and the physical model ecosystem or "terrestrial monoculture system" can be modified from the configuration shown in Figure 2 to employ an aquatic phase, with the soil as sediments. (Cole and Metcalf, 1977).

The systems employed by Lichenstein's group at the University of Wisconsin have even more direct connections between the "farm" and receiving waters. Their first system (Lichtenstein, et al., 1974) examined the pesticide

TABLE I: Advantages and Limitations of Terrestrial Microcosms^a

Advantages

1. Provide for demonstration of interactions without risk to larger (e.g., field or population) systems.
2. Provide indices of distribution of chemical (temporal, spacial, relative mass) and thus indicate where and what to look for regarding fate and effects in the environment.
3. Practical and cost-effective for examining thousands of chemicals (as compared to only dozens per year in the field).
4. Provide a higher level of verification from simple laboratory tests to what might be expected in the field.
5. Provide indication of effects within complex systems, especially by comparison between chemicals, conditions and systems.
6. Lead to fundamental analysis of processes and problems, giving a broader perspective to interactions and potential effects of classes of chemicals.
7. Provide information more useful to guide "safe" manufacturing, handling, use and disposal practices than laboratory tests alone and in a manner that may be more understandable to the lay public.

Limitations

1. Are not self-sustaining and are too short-lived to demonstrate a number of significant ecological processes (e.g., succession).
2. Simple properties are better measured in less complex systems.
3. Biological effects can be measured or indicated, but not determined accurately.
4. Not all significant processes of a given environment or ecosystem may be included in a particular microcosm.

^aGillett and Witt (in press).

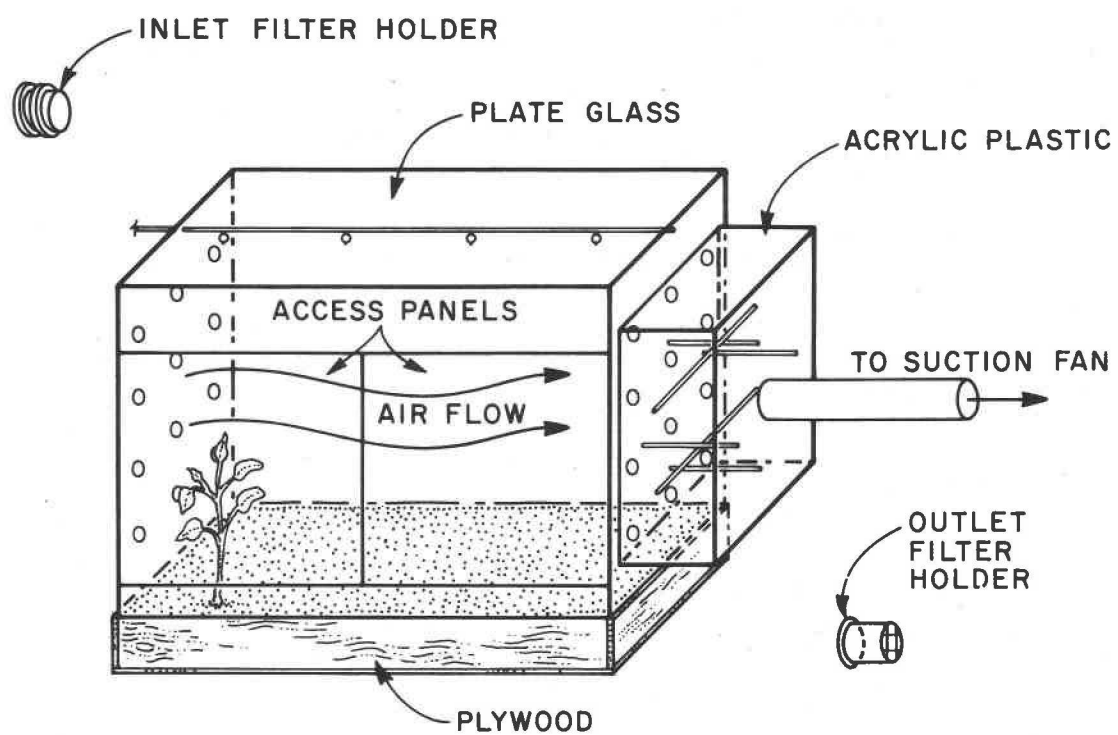


Figure 1. Microagroecosystem chamber. (Nash and Beall, 1977).

TABLE II. Chief characteristics of terrestrial microcosms used to study fate and effects of chemicals in the environment.^a

Characteristic	System					
	Plant/soil ^b	Terrestrial monoculture system ^c	Microagro-ecosystem ^d	Terrestrial Microcosm Chamber ^e	Soil core ^f	Soil/litter ecosystem respirometer ^g
Unit size	1.0 liter	19 l.	863 l. (1.5x0.5x1.15m)	458 l. (1.0x0.75x0.6m)	40 cc	500 cc
Mass of soil (kg)	0.7	0.4 (vermiculite) 3.0 (Drummer)	165	150	80g	100g
Type of soil(s)	silty loam; sandy; quartz sand	vermiculite; silty clay loam	sandy loam	synthetic potting mix; silty clay loam	various forest and grassland types	(Douglas fir, red alder litter)
Temperature (C)	28/20	26/19	ambient ^h	30/19	26/20	19
Light/dark (hrs)	12/12	12/12	ambient	16/8	12/12	0/24
Air flow rate (l./min)	ambient	ambient	2500	10, 50	ambient	O ₂ by demand
Water inputs	Addition to weight; per- colation	addition to weight; post- terrestrial aquatic study	"rain" to set humidity or excess for percolation	"rain" to set humidity; "spring"	fixed volume on weekly basis for percolation	none
Plants	Corn	Corn; soybeans	Corn; cotton; tomatoes; tobacco; cereals and grasses	Alfalfa/ryegrass; Douglas fir/red alder/ryegrass	Endemic plant types (e.g., fescue meadow plants)	None
Invertebrates added	None	Caterpillar, slugs, pillbugs, earthworms	None	<u>Tenebrio</u> larvae, snails, pillbugs, earthworms, crickets, <u>Collembola</u> spp., nematode spp.	None (endemic fauna)	None (endemic fauna)
Vertebrates	None	Prairie vole	None	Gray-tailed vole	None	None
Microbiota	Ambient	Ambient	Ambient	Ambient	Ambient	Ambient
Operating time (per experiment)	up to 200 days	30 days as terrestrial; 27 days as aquatic	60-90 days	60-90 days	6 to 9 weeks (including pre-equilibra- tion time of 5 to 7 weeks)	60 days (including pre-treatment equilibration of about 30 days)

^aGillett and Witt (in press).

^bLichtenstein, et al., 1974.

^cCole, et al., 1976^a; Cole and Metcalf, 1977.

^dBeall, et al., 1976; Nash and Beall, 1977.

^eGile and Gillett, 1977.

^fDraggan, 1976; Ausmus, et al., 1977.

^gBond, et al., 1975; Lighthart, et al., 1977a,b.

^hGreenhouse with supplemental lighting available.

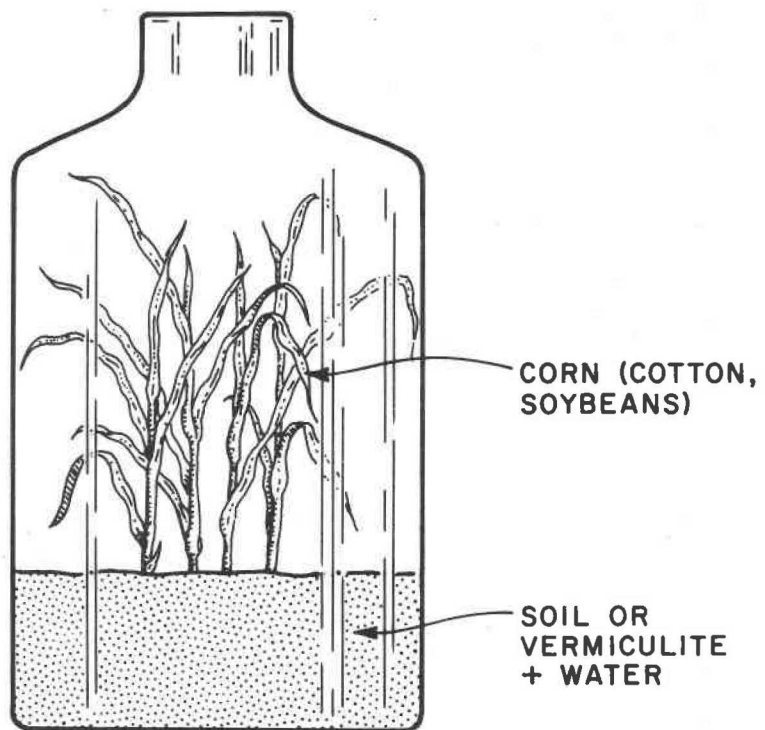


Figure 2. Physical model ecosystem. (Cole, et al., 1976a).

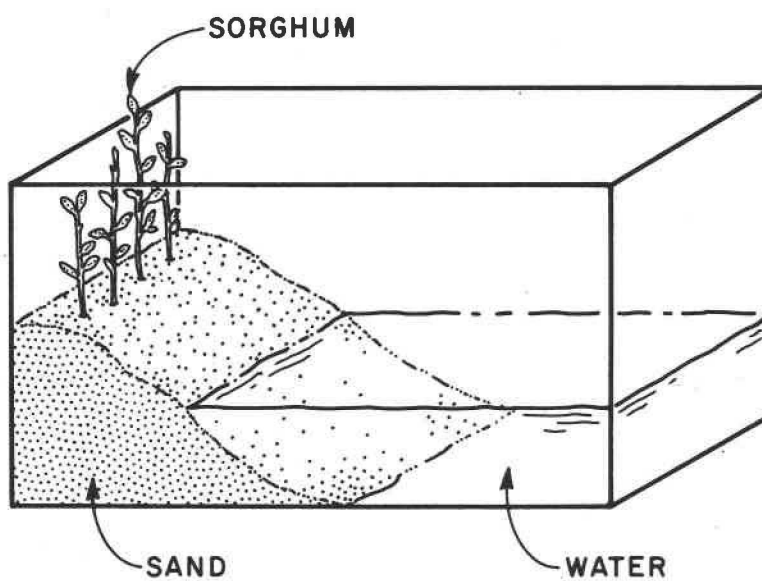


Figure 3. "Farm pond" or aquatic-terrestrial microcosm, the first used in pesticide studies. (Metcalf, et al., 1971).

leached through a "plant-soil" system (Figure 4). Later this was developed into a compartmentalized system (Figure 5) with an aquarium as the receiving waters (Lichtenstein, 1977). Thus, either run-off or soil percolation can be assessed in a modular form.

The soil core microcosm (Figure 6) developed at Oak Ridge National Laboratory (Draggan, 1976; Ausmus, et al., 1977) is a smaller scale version that preceded the system used by Van Voris, et al. (1978). These soil core microcosms are used to examine the soil nutrients lost during leaching and can be employed to study the fate of chemicals in the soil as well. The approach has been used for excised microcosms as large as one meter on a side and containing a young red maple ("treecosm"). The ORNL studies are particularly important because they are tied to measurements of nutrient export from watersheds, which may be untreated or located at sites of heavy pollution. Thus, they may be useful in evaluating toxic substance effects which contribute to apparently unrelated problems, such as non-point source pollution by nitrate and phosphate.

The Bond-Lighthart soil/litter ecosystem respirometry microcosm (Figure 7) is the only terrestrial microcosm without a water output, since it is a closed system (Bond, et al., 1975). However, the same chamber could be used for a variety of tests, such as sediments, that relate directly to aquatic systems. It is now being used to examine waste treatment sludge effects in agricultural land disposal and similar problems of heavy metal pollution (Lighthart, et al., 1977).

The CERL Terrestrial Laboratory Microcosm (TMC) (Figure 8) was developed to provide a system in which both fate and effects of pesticides could be measured (Gillett and Gile, 1975, 1976; Gile and Gillett, 1977). Inputs include both "rain" and a "spring" from which the vole and other animals drink, while leachate is collected for residue studies.

These systems differ so markedly in how they are employed and exactly what is measured that they are not easily compared. Table III shows the types of studies performed and what data the proponents believe could be obtained, along with the approximate costs. Currently, microcosm technology is expensive, in terms of facilities, personnel, and operating costs. One of the major objects of research in the field is to optimize that cost in relation to other means of obtaining the necessary data.

PESTICIDE FATE AND EFFECTS IN A TMC

The nature and volume of output data from a microcosm experiment can be illustrated with the results from a study with ^{14}C -dieldrin in the TMC. (Gile and Gillett, 1977). Briefly, the TMC is a glass box (1 m. x 0.75 m. x 0.61 m) with a plexiglas lid. It is in an environmentally controlled room and has clean air supplied to each box. For this experiment, the soil was a synthetic mixture of sea sand, a commercial potting mixture, and a clay soil amendment. Reverse-osmosis purified water was added to the soil mixture; each longitudinal half of the TMC was planted with alfalfa and ryegrass, and nematodes (*Pristionchus iheringii* and *Cephalobus perseghis*) and earthworms (*Lumbricus* spp.) were added at Day Zero. On Day 10 pillbugs (*Armadillarium* and *Porcellio* spp.), mealworm larvae (*Tenebrio molitor*), garden snails (*Helix pomata*), and common brown crickets (*Achetus domesticus*) were added to the TMC, which had a

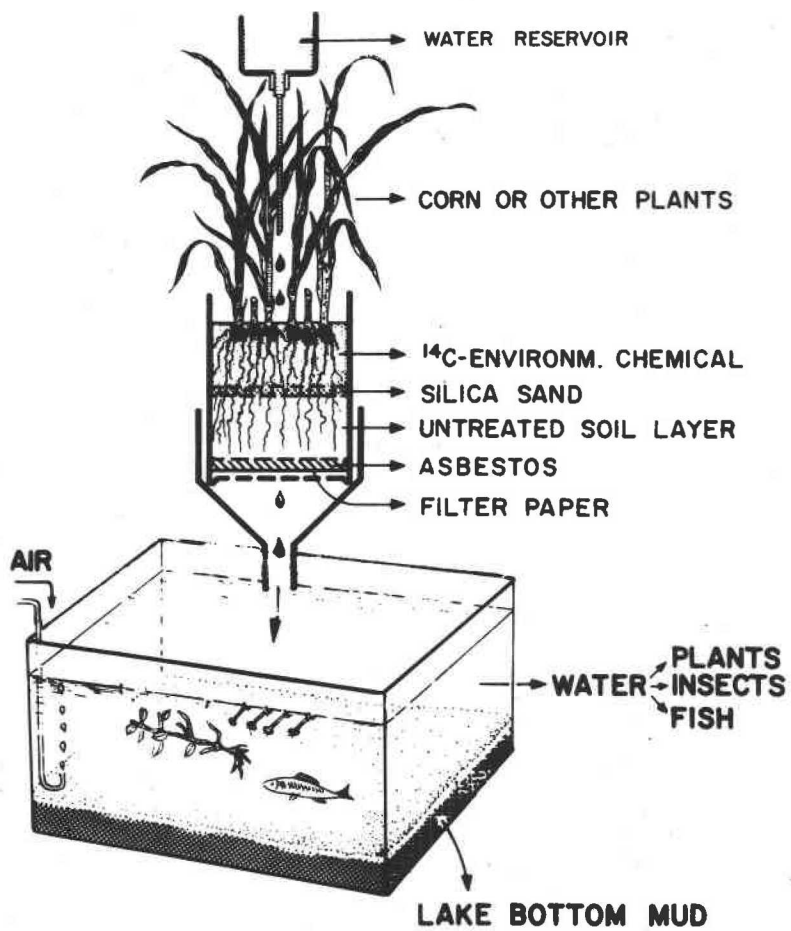


Figure 4. The "plant-soil" microcosm for percolation studies (Lichtenstein, et al., 1974).

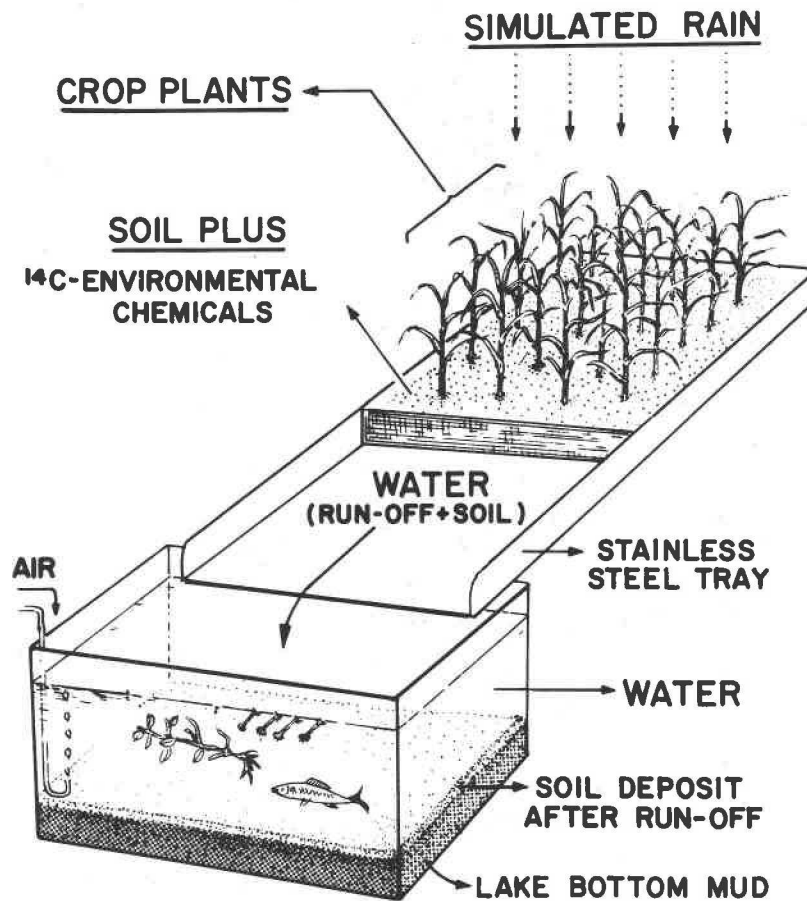


Figure 5. The "plant-soil-water" system for run-off studies (Lichtenstein, 1977).

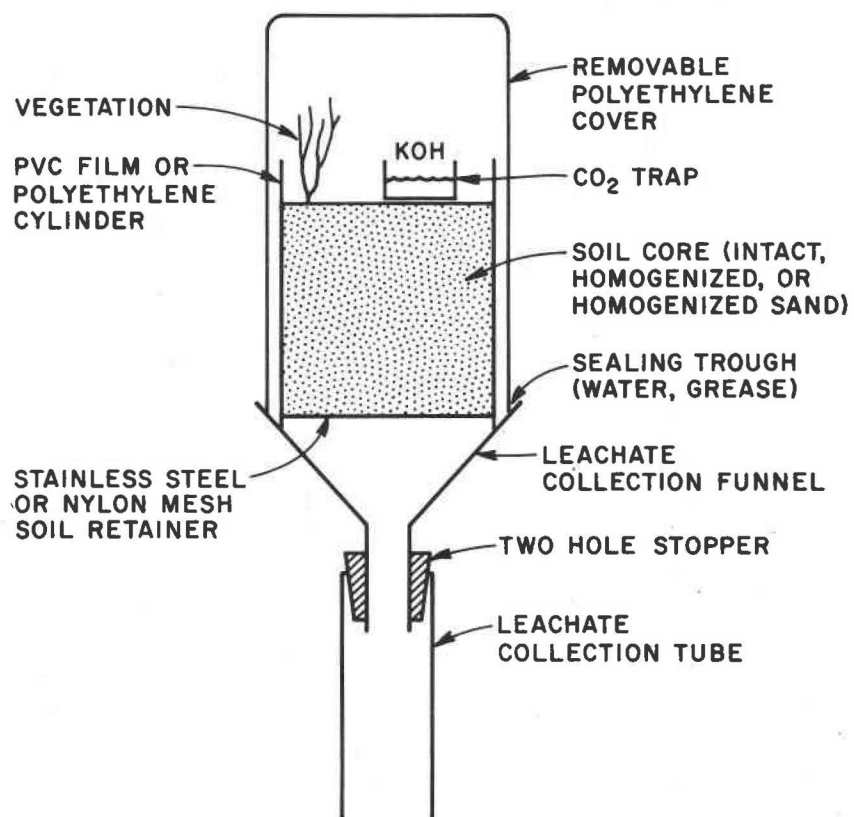


Figure 6. Soil core microcosms (Draggan, 1976; Ausmus, et al., 1977).

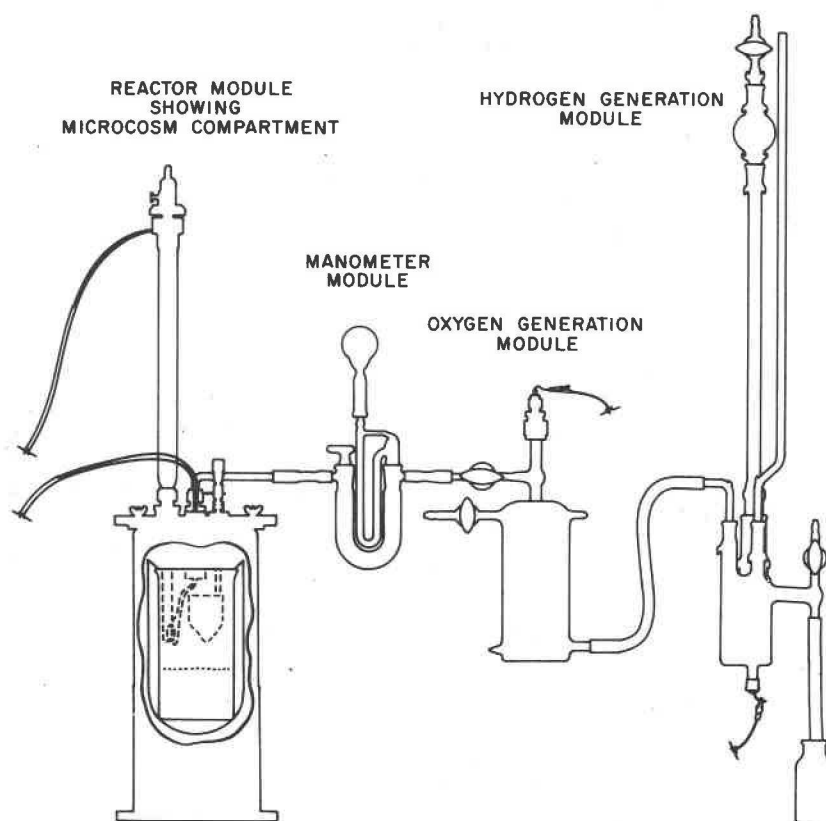


Figure 7. Soil/litter ecosystem respirometer (Lighthart, et al., 1977^a).

SCHEMATIC OF TMC AIR AND WATER SYSTEMS

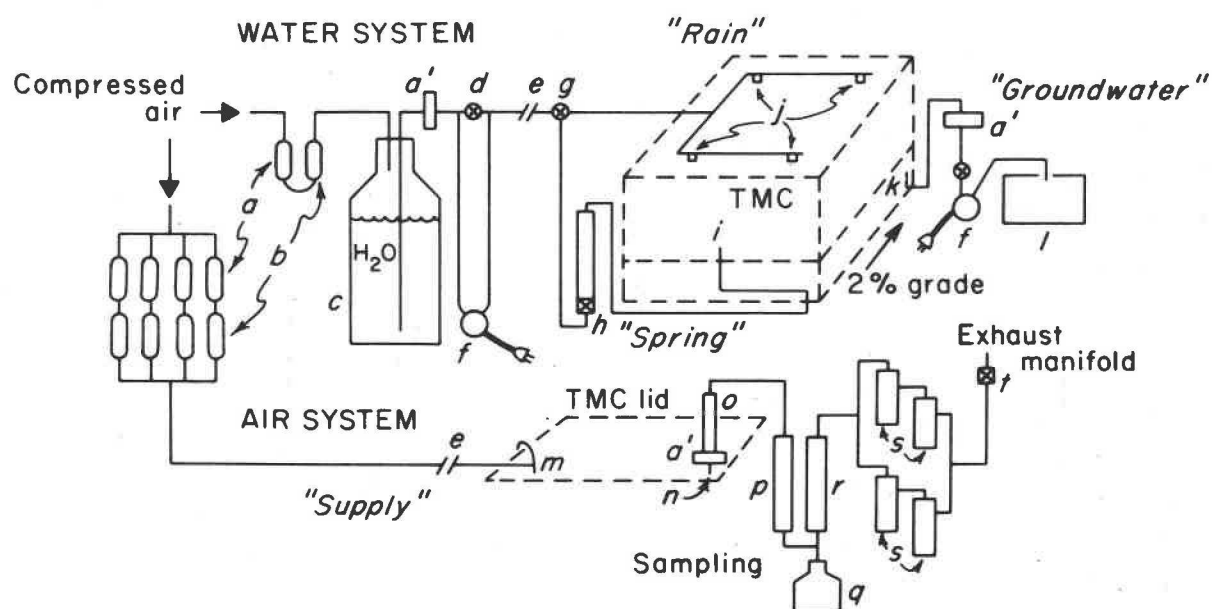


Figure 8. Terrestrial microcosm chamber (TMC) (Gillett and Gile, 1976).

TABLE III. Cost/capabilities claimed for various microcosm systems.^a

Parameter measured	Plant/soil	Terrestrial monoculture	Agroecosystem	Terrestrial Microcosm Chamber	Soil Core	Soil/litter
Leaching/mobility in soil	X(*)	X	X(*)	X(*)	X	
Soil binding	X	X	X	X	X	(X)
Transformation products bound residues ^b	X* X*	X X	X* (X*)	X* X(*)	(X*) (X*)	(X*) (X*)
Plant uptake	X	X	X*	X*	(X*)	
Phytotoxicity	(X)	X	X	(X)		
Mammal and Insect toxicity		(X)		X*		
Bioaccumulation		X		X*		
Volatility		X(*)	X*	X*	(X*)	
Soil respiration					X*	X*
Nutrient cycling	(X)		(X*)	(X*)	X*	
Calorimetry						X*
Cost/compound ^c (\$1000)	3-5	15	100	50-250	2-4	25
Cost/unit ^d (\$100)	0.25	0.5	15	15	0.002	0.5
Time/compound (man-mo.)	6	6	18	20-40	2	6

^aItems in parentheses are anticipated as feasible, but not tested; items starred indicate rates determined (Gillett and Witt, in press).

^bIf radiolabeled chemical used.

^cThrough-put expense only and not including parenthetical items.

^dCost without environmental controls, facilities, etc.

good growth of both crops. On Day 40 three of the TMCs were treated with 103.5 mg of ^{14}C -dieldrin (50 μCi) in 4 ml of acetone (1.38 kg/ha or 1.12 lbs/acre) and the fourth was sprayed with 4 ml of acetone as a negative control. On Day 48 a gravid female vole (*Microtus canicaudus*) was added to each TMC. When the initial voles died, TMC VIII was terminated and new voles added to TMCs V and VII. On the death of these voles, TMC VII was terminated and a female that had just whelped the night before was added to TMC V. On Day 67, both TMCs V and VI were terminated at the death of vole Vc. The control vole survived in good condition through the entire experiment.

Observations included: daily censuses of visible animals, weekly soil cores for nematode enumeration, weekly samples of plants and crickets for ^{14}C analysis, daily air filter samples, samples of air scrubbers and condenser every third day, and periodic collection of leachate after rain events. At termination, the biota were enumerated and stored at -20°C for analysis, the soil was divided into vertical and horizontal zones for subsampling, and all remaining plant material was collected. The voles, where possible, were dissected and individual tissues analyzed.

A combination of extraction and thin-layer chromatography was used on each of the samples to provide data on the composition of the organic- and water-soluble extractables, then the samples were combusted for estimation of bound ^{14}C residues. Where necessary, concentrations of dieldrin were confirmed by gas-liquid chromatography. ^{14}C -Content was determined by liquid scintillating counting.

This experiment was designed to examine three principle points: (1) Did the methodology provide a satisfactory measurement of the fate of the mass of material added? (2) Were effects in the system reasonably comparable to results from field studies and other microcosm systems? and (3) Were the rates and extents of movement, transformation and bioaccumulation consistent with other experience?

Results

Table IV shows that the average accountability was 88.6%, which is better than can be achieved in the field (40-60%) and approaches that in the test tube (90-100%). Note that only a trace of material was recovered in the water from any of the TMCs, and that only a small fraction of the applied dose was recovered in the fauna. Although the dieldrin was applied to the foliage, the soil became a repository. The TMCs were not direct replicates and behaved differently in terms of the temporal profile of air concentrations, so that the masses shown in Table IV do not represent time-dependent changes. For example, one might gather that dieldrin was being transferred from the soil to the plants if one examined only the masses recovered at termination. The results of weekly sampling, however, showed that there were markedly different rates of residue dissipation between the three TMCs. The parallel declines in plant residues and air concentrations (Figure 9) infer that this transfer from plants to soil was mediated through the air.

The soil profiles of TMCs VII and V are as expected for a chemical that is poorly metabolized and strongly bound to soil, in good agreement with much experience with dieldrin. Residue decline in the soil, however, was

TABLE IV: ^{14}C Mass Balance (10^6 dpm)^a

Item	Terrarium		
	VIII (12 days)	VII (20 days)	V (27 days)
Sprayer content	111.00	111.00	111.00
Spray losses	2.23	6.53	1.87
Applied to TMC	108.77	104.47	109.13
Soil	78.13	43.66	44.32
Plants	14.34	24.91	49.96
Air	0.84	1.04	0.27
Water	nd ^g	nd	0.03
Fauna			
Voles	1.32	3.34	2.34
Snails	1.30	1.16	1.78
Invertebrates	0.59	0.85	0.49
Other ^b	4.44	1.04	0.82
Total Recovered	100.97	76.00	100.01
Loss estimates:			
Voles ^c	0.12	0.49	0.25
Plants ^c	--	2.68	0.22
Soils ^c	2.0	---	---
Nematode ^d	0.08	0.05	0.04
Air ^e	0.82	1.23	0.26
Total estimated	3.72	4.45	0.77
Percent recovered	92.8	72.7	91.6
Percent accounted for	96.2	77.0	92.3

Mean:
85.7 [0.132]^f
88.5 [0.115]^f

^aGile and Gillett, 1977.

^bIncludes nesting materials, vole and snail feces, algal swipes from walls, and terminal clean-up of TMC.

^cSamples lost or spilled, est. from equivalent samples.

^dBased on est. soil residues.

^eBased on est. of scrubber-trapped material after first 4 days, prior to which scrubber samples were handled improperly.

^fCoefficient of variation in brackets.

^gnd = less than 10^3 dpm/l.

VIII

VII

V

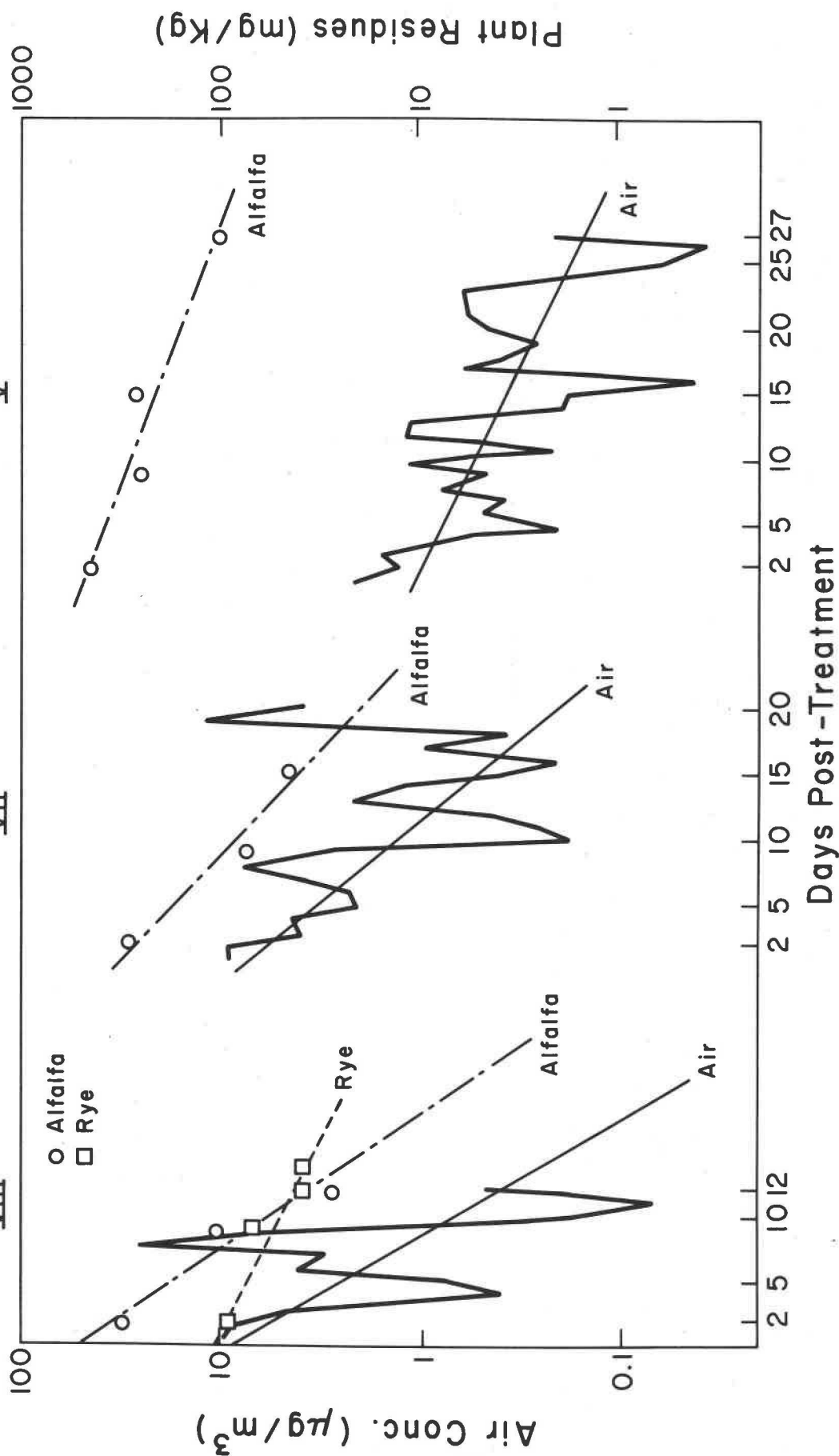


Figure 9. Comparison of daily ^{14}C activity in the air to alfalfa and rye residues. (Solid lines connect daily total radioactivity. Light solid lines are L.M.S. estimates of rate of decline in daily air output. Broken (alfalfa) and dashed (rye) lines are L.M.S. estimates of residue decline on crop. (Gile and Gillett, 1977).

estimated from the terminal residues to be on the order of 10 days for loss of one-half the concentration, whereas most studies demonstrate half-lives of weeks to months. This low value may be misleading if one does not take into account that it is the result of both gain and loss at different rates in the several TMCs.

Residues in invertebrates (Table V) were very much higher than found in association with soils of the same level as the TMCs. Snails are particularly good accumulators of the poorly metabolized organochlorine pesticides, such as dieldrin. Most of the material was as parent compound, but *Tenebrio* adults in TMCs VII and VIII had more bound residue than dieldrin and bound residues were a significant portion of the total activity in crickets (19%), earthworms (11%) and pillbugs (8.3%).

The residue distribution by organ in the voles was as expected and amazingly consistent. (Table VI) The brain residues (avg. 17.7 ppm fresh wgt.) were the most consistent and reinforce the conclusion, based on observation of convulsions in some animals, that dieldrin intoxication was the cause of death. This is supported further by examination of the total exposure time of the animal plotted against the time since treatment that that exposure began. As shown in Figure 10, the longer after dieldrin treatment that the vole enters the field, the longer it can be expected to survive. For example, we would have had to wait 42 days after treatment to add the vole to this system to obtain the same survival as the control. This analysis suggests that repeated mortality of the voles could be used as a measure which might be related to such significant functions as the re-entry time for workers in treated fields.

One approach to evaluating the results of the microcosm test is to examine various indices of chemical behavior. The Ecological Magnification (Metcalf, et al. 1971) is the ratio of the concentration of parent material in the whole animal to that in the media, which in this case was taken as the average soil concentration at termination. In Table VII, the values are much lower than those obtained against water as the medium, since the soil attenuates the concentration considerably. Thus, Sanborn and Yu (1973) found EM values of 6,000 to 40,000 for dieldrin in an aquatic system. If the concentration in water (less than 1.5 ppb) were taken as the reference in the TMC, the EM values would be greater than 17,000.

A second value is the Biodegradation Index (ratio of concentration of metabolites to concentration of parent material), which is not similarly affected by choice of substrate, but may vary considerably between species. Dieldrin, a relatively inert chemical, shows a very low BI (0.001 to 0.1) in most species and thus is likely to persist for considerable time. Perhaps of greater significance is the Bound Residue Index (ratio of bound ^{14}C to dieldrin concentration in the whole animal), since this may indicate potential covalent bonding of parent or metabolites to tissues, particularly in the absence of other metabolism. As BRI generally exceeded BI by about an order of magnitude, dieldrin may have a potential for being carried over as hazardous residues in the food chain. Such residues are not detected by the usual extraction methods and have become a matter of concern, since carcinogenic metabolites of chlorinated hydrocarbons and polynuclear aromatic hydrocarbons require considerable metabolis activation of this same type.

TABLE V: HEOD residues in macroinvertebrates from TMCs treated with ^{14}C -dieldrin by foliar spray.^a

ppm HEOD fresh weight^b

TMC	VIII	VII	V	Mean ^c
<u>Species</u>				
Earthworm	3.6; 1.0	4.4	5.2	3.2[0.62]
Snails,				
adult	25.0(9)	28.5(9)	23.7(12)	26.9[0.35]
juveniles	21.3	15.3	45.8(15); 29.0	
128		102	84.6	104.8[0.21]
<u>Tenebrio,</u>				
adult	5.1	5.7	37.3	18.4[1.15]
larvae	0.71	1.6	4.3	2.2[0.85]
Crickets,				
live	4.8(9); 3.6	17.7	2.1	7.1[1.02] ^d
dead	---	5.5	2.8	6.4[0.91]
Pillbugs	21.7	33.9	24.5	27.0[0.23]

^aGiles and Gillett, 1977.

^bNumbers in parentheses indicate samples taken other than at termination which was day 12 for VIII, day 20 for VII, and day 27 for V, after treatment with ^{14}C -dieldrin.

^cNumbers in brackets are coefficients of variance (s.e./ $\bar{x}$).

^dMean for combined live and dead crickets.

TABLE VI: Residues of HEOD and Metabolites in Voles^a
(ppm fresh wt.)

Tissue	Percent body wt.	HEOD	Metabolites ^b	Bound Residues
Brain	1.03(4)	17.67 [0.14]	0.45 [0.60]	0.19 [1.71]
Liver	7.11(4)	35.57 [0.29]	0.93 [0.34]	0.98 [1.19]
Kidney	1.69(3)	27.93 [0.26]	0.89 [0.36]	0.44 [1.12]
Reproductive organs ^c	2.19(2)	77.06 [0.79]	nd --	1.43 [1.41]
Heart and lung	2.04(3)	14.09 [0.20]	1.13 [0.52]	0.39 [1.10]
Stomach and g.i. tract ^d	22.46(4)	22.19 [0.52]	1.46 [0.56]	0.93 [0.86]
Carcass ^e	64.40(4)	28.81 [0.48]	1.31 [0.88]	0.24 [1.10]
Whole body ^f	(6)	26.16 [0.40]	1.28 [0.52]	0.34 [0.94]

^a Coefficient of variation in brackets, numbers of organs analyzed in parentheses (Gile and Gillett, 1977).

^b Includes both polar (origin) and non-polar materials detected by TLC (ether:hexane::1:1).

^c Includes uterus and ovaries

^d Includes contents of g.i. tract, pancreas, spleen, and mesentary.

^e Includes skin, hair, skeleton, and musculature.

^f Does not include pups or fetuses, for which HEOD = 7.09 (12) [0.22], metabolites = 0.39 (11) [0.38], and bound residues = 0.13 (12) [0.77].

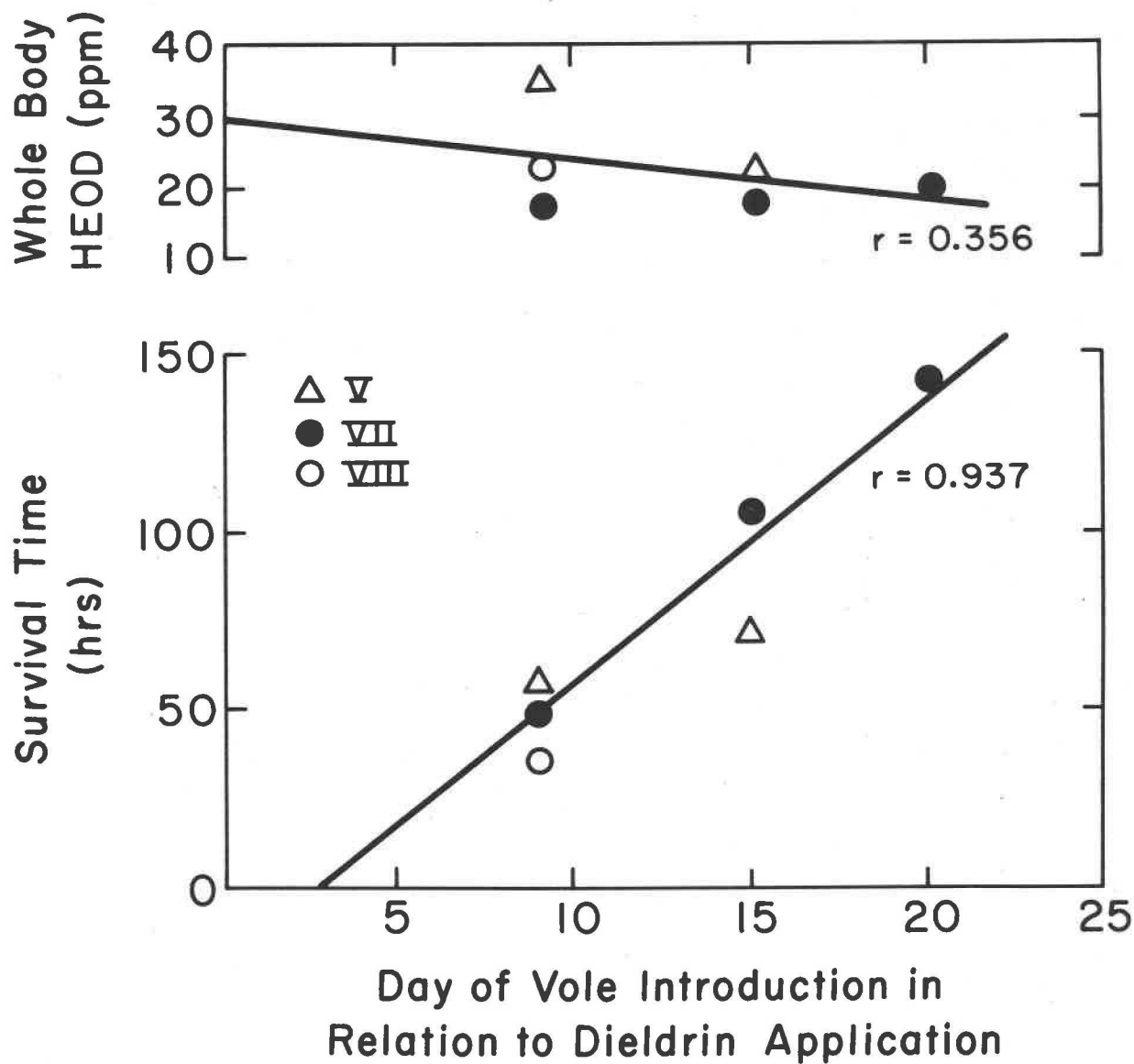


Figure 10: Vole survival and residues in relation to time of introduction after dieldrin treatment of TMC. (Solid lines are L.M.S. estimates of correlation. (Gile and Gillett, 1977).)

TABLE VII: Ecological Magnification Index^a

Species	VIII	VII	V	Mean ^b
Vole female a	37.8	103.6	56.6	59.5 [0.38]
b		51.8	50.5	
c			56.4	
+ pups a	32.9	78.9		53.8 [0.28]
b		47.7		
pups/dam a	0.27	0.15		0.20 [0.31]
b		0.17		
Snails, juvenile	182.9	226.7	228.6	212.7 [0.12]
adult	35.7 (9)	63.3 (9)	64.1 (9)	61.4 [0.54]
	30.4	34.0	123.8 (15)	
<u>Tenebrio</u> , larvae	1.01 ^c	3.56	11.6	
adult	7.27	12.7	100.8	40.3 [1.3]
Pillbugs	31.0	75.3	68.9	58.4 [0.41]
Earthworms	5.14, 1.49	9.78	14.1	7.1 [0.89]
Crickets, alive	6.86 (9)	39.3	5.67	11.9 [1.03]
dead	5.14	12.2, 6.6	7.57	

^a(HEOD) whole animal/(HEOD) soil at termination; number in parentheses indicates day post-treatment at which ratio was determined. Soil residues and day terminated were: VIII-0.700 ppm, day 12; VII-0.450 ppm, day 20; V-0.370 ppm, day 27. (Gile and Gillett, 1977).

^bCoefficient of variation (s.e./x) shown in brackets.

^cAcetone extract only (remainder lost).

To sum up this experiment, the mass balance was satisfactory, and subsequent efforts to improve this accountability have reached better than 99% (Gile and Gillett, unpublished data). The residues in the soil and biota compare generally with those reported by Korschgen (1970). The ratio of residues in dam to fetus for voles agrees with those reported for rabbits (Hathaway, et al., 1977), and the observed interference with reproduction agrees with Harr, et al. (1970). The comparisons of biodegradability between the various microcosm tests is excellent, but EM varies considerably, depending largely on the exact mode of application. Thus, terrestrial microcosm systems are demonstrably capable of providing reasonably accurate reflections of chemical fate in the environment while indicating potential hazardous effects.

THE RELATIONSHIP OF TERRESTRIAL MICROCOSM RESEARCH AND WATER RESEARCH

The Workshop on Terrestrial Microcosms (Gillett and Witt, in press) made four major recommendations for emphasis in microcosm technology research, particularly in relation to the development of a protocol applicable to toxic substance screening:

1. We need to determine how accurately microcosms of various kinds reveal the transport, transformation and bioaccumulation of chemicals and their consequent effects.
2. We need to determine the validity of each system in inter-laboratory tests on the same chemicals, comparing the results between investigators and between systems.
3. We need to specify the criteria for design and operation of systems that will assure validity and accuracy in all users' hands.
4. We need to develop mathematical models of microcosms that will test hypotheses derived from laboratory data on chemical and biological properties and project those models into the field for verification.

These critical needs reflect the relative newness of terrestrial microcosm research. While much is expected of this approach, only a thorough analysis and well researched basis can justify substitution of microcosm technology for more widely used systems involving single species tests. The NRC/NAS panel on Effects of Ambient Environmental Quality (National Academy of Sciences, 1977) recommended, "Techniques based on laboratory microcosms should be refined and applied, but the limited utility of such systems for predicting ecosystem effects must be recognized."

Research is now ongoing to improve validity and establish accuracy, to develop the design criteria and to provide mathematical models. Although some static aquatic/terrestrial systems have been developed (Metcalf, et al., 1971; Cole and Metcalf, 1977; Lichtenstein, 1977), only one flow-through terrestrial/aquatic test has been reported (Isensee, et al., 1976). Generally, aquatic systems have not controlled air flows or assessed input/output at the water/air interface. Similarly, the several stream microcosms have not involved

terrestrial inputs. Because of both physical limitations and our inability to put together the extremely complex set of experiments necessary to replicate all water inputs/outputs, future research is likely to continue the segregated study of fate and effects in aquatic and terrestrial systems. That may be adequate for screening and developing a sound understanding of the particular processes. Field studies and model development on pesticide inputs into water and air from terrestrial sources will probably be the pilot studies for all toxic substance research. Thus, it is likely that we may be making TMC connections with model laboratory streams, such as those of Warren and Davis (1971). To that end, the TMC system has been redesigned in a manner which will permit the atmospheric portion to be attached to terrestrial systems, estuarine wetlands system (with subsurface and surface water changes), and static or flow-through aquatic systems. This would permit tracking of the atmospheric losses or inputs into aquatic systems, not just of the toxic chemical and its transformation products, but also of significant biologic materials such as CO_2 and NH_3 .

CONCLUSION

Terrestrial microcosm research has come a long way but has far to go to gain a full measure of acceptance by not just the scientific community at-large, but even its advocates. Yet the potential for improving the speed and accuracy of decisions on hazard/safety demands that these avenues be explored carefully. We are faced with about 1000 new chemicals annually and need to evaluate about 30,000 potential toxic substances and 600 pesticides already on the market. The capacity for evaluating terrestrial inputs into aquatic systems has been demonstrated in the microcosm systems, but specific research is needed for improvement. Then, this emerging technology must be carefully melded with an integrated health and ecological effects assessment. Much of this integration will be provided by validated mathematical models employing structure/function relationships, laboratory benchmark data, and microcosm technology.

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Toxic Materials in Forest Streams

The toxic materials to be covered in this paper are those chemicals which man intentionally applies to the forest to attain specific management objectives. These management tools are commonly called "forest chemicals", a general term referring to a variety of chemicals including pesticides, fertilizers, and fire retardants.

Pesticides are chemical or biological agents used to control, mitigate, or modify pests, but this definition ignores the fact that pesticides are employed as a management tool to help achieve a specific end. In forestry, the end goal is to protect or enhance forest values. Fertilizers play the same role in forestry as they do in agriculture, that is to improve site productivity. Although not often considered as chemical agents, fire retardants are largely composed of ammonium phosphate or ammonium sulfate and smaller amounts of several other chemicals, such as dyes, wetting agents, thickeners, corrosion inhibitors, and bactericides.

Chemicals play an important role in modern American agriculture and forestry, but the magnitude, intensity, and pattern of each use is vastly different. In intensive agriculture, for example, one or more chemicals may be applied more than once during a crop cycle. Crop cycles in agriculture are short; therefore, regular and repeated applications are common. In forestry, lands that are treated seldom receive more than a single application in 1 year or more than one to three applications in a 20 to 100 year crop cycle. Most land will not be treated with chemicals at any time during a crop cycle.

MAGNITUDE OF CHEMICAL USE

Pesticides

A large number of chemical compounds are registered for use in agriculture, but in forestry the principal pesticides utilized number less than 15.

TABLE 1--Pesticide use in forests, July 1, 1975 to September 30, 1976^{1/}.

Use	ha Treated	Percent	kg Used ^{2/}	Percent
Herbicide	95,327	38	255,611	62
Insecticide	131,991	53	87,171 ^{3/}	21
Fungicide	13,804	5	65,060	16
Rodenticide	9,146	4	2,746	1
Piscicide	195	0	378	0
Bird Repellent	289	0	131	0

^{1/} Reporting period is 15 months, FY 1976 and Transition Quarter (Forest Service, 1977).

^{2/} Reported as kg of active ingredients.

^{3/} Data presented do not include 1,417,239 ha treated with 1,208,031 kg of insecticide chemicals to control defoliation caused by the eastern spruce budworm. These data were omitted in order to provide a closer approximation of the annual pesticide use pattern.

Forestry accounts for only slightly more than 1% of the total pesticide use in the United States (Forest Service, 1977). Data on pesticides used by the Forest Service or on projects involving Federal assistance provided by the Forest Service are presented in Table 1. In general, these figures underestimate the total use in forestry because they omit pesticides applied by other Federal land management agencies and by various State and private groups. The pesticide use data have been modified by deducting the area treated and the amount of insecticide used in a single unusually large project conducted to control defoliation by the eastern spruce budworm. This insect control project alone accounted for 85% of the total land area treated and 75% of the total pesticide chemicals applied during the 15-month period covered in Table 1. These figures indicate that approximately 0.2% of the commercial forest land in the United States is treated with pesticides in any given year (0.8% of the eastern spruce budworm program is included).

Fertilizers

Fertilizers are applied annually to only a small portion of commercial forest land. Several industrial corporations and State agencies, however, have been employing forest fertilization as a standard management practice for over 10 years. These operations are primarily in the Pacific Northwest, where nitrogen deficiencies occur, and in the Southeast, where phosphorus deficiencies may limit tree growth and reduce the survival of young stands. Between 1965 and 1975, approximately 300,000 ha of Douglas fir were fertilized in western Oregon and Washington (Moore, 1975). The extent of fertilizer operations in the Southeast has not reached that of the Northwest. By 1971 approximately 45,000 ha had received chemical fertilizer amendments. Assuming a moderate, steady increase in the practice, Groman (1972) estimated 141,000 ha would be fertilized in the Southeast by 1976.

Fire Retardants

Chemical fire retardants have proven to be a valuable tool in forest fire control. This is reflected in the steady growth of their use since they were introduced in the 1930's. The use of aerially applied fire retardants in the United States increased from 87,000 liters in 1955, to more than 28.4 million liters in 1961. During 1970, 64.4 million liters of fire retardant were applied aerially to forest and rangeland fires (George, 1971).

RELATIONSHIP OF THE FOREST TO THE AQUATIC ENVIRONMENT

Water is the home of a wide diversity of biological communities and it is a critical commodity to downstream water users for domestic, industrial, agricultural and recreational purposes. Forests are watersheds, and the quality of the water they yield reflects the activity of both man and nature on this land. Forest lands comprise only a third of the total area of the United States, but they receive more than half the total precipitation and yield more than three-fourths of the total streamflow. Forested watersheds in the United States annually receive more than 114 cm of precipitation (more than twice the amount that falls on other lands). They yield more than 51 cm of runoff annually (more than 7 times the amount from other lands). Thus, the possibility that chemical use in forest management may impact on water quality needs careful consideration (Storey, 1965).

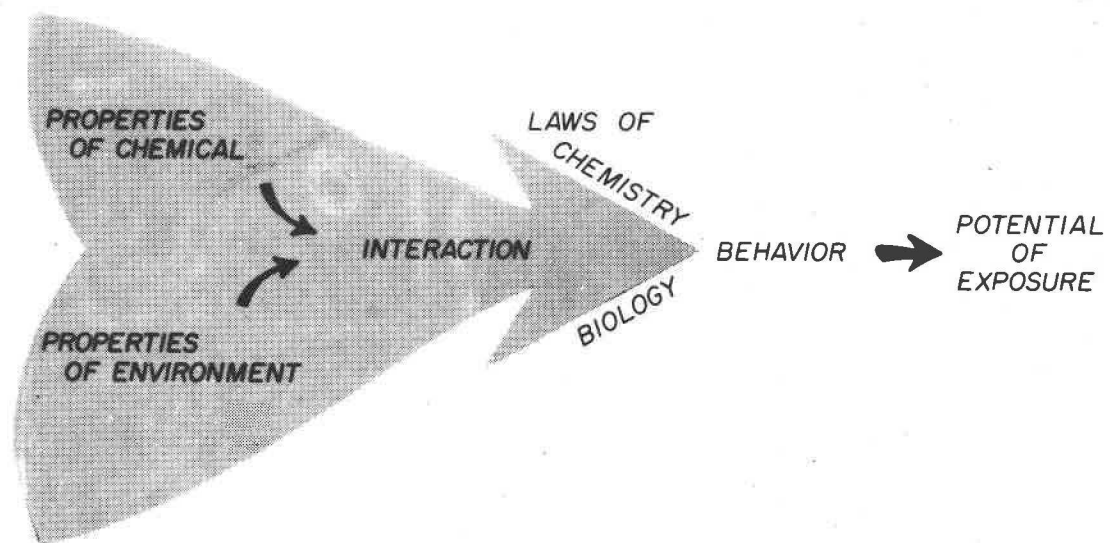
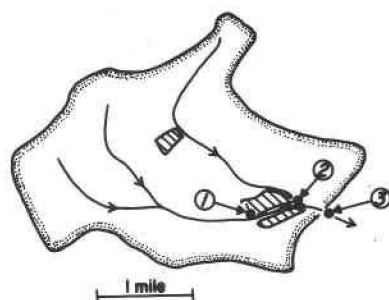
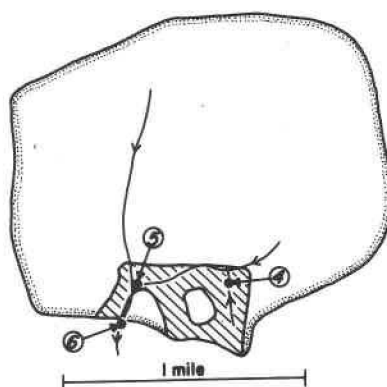


Figure 1. The interaction of chemicals with the environment.



A. Cascade Creek Watershed



B. Eddyville Watershed

- ① → Sampling Point
- Stream
- Watershed Boundary

Figure 2. The Cascade Creek and Eddyville Watershed Treatment areas. (1 mile - 1.6 km).

ASSESSING TOXIC HAZARD

The hazard of using chemicals in the forest is the risk of adverse effects on non-target organisms. The two factors which determine the degree of hazard are (1) the toxicity of the chemical and (2) the likelihood that non-target organisms will be exposed to toxic doses. Toxicity alone does not make a chemical hazardous; exposure to a toxic dose must also occur. Therefore, an adequate assessment of the hazards from the use of any chemical requires equal consideration of both the likelihood of exposure and the toxicity of the chemical (Norris, 1971a).

There are two kinds of toxicity: acute and chronic. Acute toxicity is the fairly rapid response of organisms to a few, relatively large doses of chemical administered over a short period of time. Chronic toxicity is the slow or delayed response of organisms to many, relatively small doses of chemical administered over a long period of time. The kind of response (acute or chronic) observed in an organism, therefore, depends on the nature of the exposure received. The nature of the exposure is described by the magnitude of the dose and the duration of exposure.

The exposure of non-target organisms results from the behavior of the chemical in the environment. The behavior of a chemical is defined as its initial distribution in the environment and its subsequent movement, persistence, and fate. The behavior of the chemical determines how much residue is in what part of the environment, in what form, and for what period of time. These characteristics define the duration and magnitude of exposure of non-target organisms to a particular chemical (Fig. 1).

EXPOSURE IN THE AQUATIC ENVIRONMENT

The magnitude and duration of exposure of organisms in forest waters is largely determined by the route of entry and subsequent behavior of the chemical in the stream. Chemicals can enter the aquatic environment by one or more of the following routes: (1) direct application to surface waters, (2) drift from nearby spray areas, (3) mobilization in ephemeral stream channels, (4) over-land flow, and (5) leaching.

Direct Application to Surface Waters

This is the route most likely to introduce significant quantities of chemicals into surface waters. It has the potential to produce the highest concentrations and, therefore, cause the most pronounced acute toxic effects. The duration of entry and therefore the duration of exposure, however, will be brief (Norris and Moore, 1971). The concentration which results depends on the rate of application and ratio of stream surface area to its volume. The persistence of chemical in the application zone depends on the length of the stream treated, the velocity of streamflow, and the hydrologic characteristics of the water course. The concentration of introduced chemicals normally decreases rapidly with downstream movement due to dilution and interaction between the chemical and various physical and biological components of the stream system.

Drift From Near Nearby Spray Areas

Drift from nearby spray areas is similar to direct application except that peak concentrations will be lower and impacts on stream organisms will be reduced. The accidental drift of chemical from nearby spray areas to stream surfaces is a likely means of chemical entry to surface waters, but one that can be minimized.

Mobilization in Ephemeral Stream Channels

Ephemeral stream channels are difficult to see from the air and may be sprayed along with the rest of the area during aerial application. With subsequent precipitation, residues in these ephemeral stream channels which have not been subjected to volatilization, decomposition, adsorption, or leaching are available for mobilization by the expanding stream system described by Hewlett and Hibbert (1967). This process probably accounts for the immediate flush of chemical observed with the first significant storms after application of some chemicals (Norris, et al., 1976).

Overland Flow

Overland flow occurs infrequently on most forest lands because the infiltration capacity of the forest floor and soil is usually far greater than rates of precipitation (Rothacher and Lopushinsky, 1974). Bare and compacted soil may yield surface runoff, but these areas are not widespread and would seldom be treated with forest chemicals. Pesticides adsorbed on soil particles frequently enter the aquatic environment from agricultural areas (Barnett, et al., 1967). Erosion is common in managed forests, but the principal sources of sediment are road construction, road failure, landslides, and streambank erosion (Rice, et al., 1972). Chemicals are seldom applied in such a temporal and spatial relationship with these events.

Leaching

Leaching of chemicals through the soil profile is the process most feared by the general public, but is the least likely to occur. Chemicals used in forestry are relatively immobile in soil. Intense leaching may move chemicals a few centimeters to 1 meter in depth, but these distances are short in comparison to distances between treated areas and streams (Norris, 1976b). Most forest chemicals do not persist long enough for significant leaching to occur.

The nature of the exposure aquatic organisms may receive from the various routes of chemical entry into streams is quite different. Direct application and drift are likely to result in the highest concentrations of chemicals in water, but persistence is brief. Mobilization in ephemeral stream channels and overland flow are associated with periods of significant precipitation; therefore, the concentrations in the water will be substantially less than those resulting from direct application, although the duration of exposure may be slightly longer. Leaching (if it occurs) can introduce only small amounts of chemical into the stream although the process could be prolonged.

CHEMICALS IN OREGON FOREST STREAMS

A number of studies have been conducted to determine the concentrations and persistence of chemicals in Oregon forest streams. The following examples illustrate some of the concepts of entry of chemicals into forest streams discussed in the previous section of this paper. These studies also provide actual data on the magnitude and duration of exposure aquatic organisms may receive.

Cascade Creek Watershed - 2,4,5-T

About 26 ha of the 400-ha Cascade Creek watershed (western Oregon) were sprayed with low volatile esters of 2,4,5-T, at 2.24 kg/ha in March by helicopter (Fig. 2). A small stream, sampled at Point 1, flows from a 2-ha watershed which was completely sprayed. Streams, sampled at Points 2 and 3, do enter but run adjacent to the treated area (Table 2). The drainage basin at Point 1 had a slump and marshy area which indicated a high water table. The highest concentrations occurred shortly after application started, but low concentrations were found up to 16 weeks later.

At Points 2 and 3, only low levels of herbicide were found, and these persisted for less than 1 day. The residues detected in samples from Point 1 reflect direct application of chemical to the stream surface and the subsequent outflow from the marshy area. Residues in samples from Points 2 and 3 reflect the drift of spray materials to the stream surface. Failure to detect residues from Points 2 and 3 between 5 hours and 10 months after spraying indicate mobilization in ephemeral stream channels, overland flow, and leaching did not contribute significant residues to these streams (Norris, 1967).

Eddyville Watershed - 2,4-D

The Eddyville Watershed in western Oregon was treated with low volatile esters of 2,4-D at the same time as the Cascade Creek Watershed (Fig. 2). Several streams were included in the 28 ha unit. Higher concentrations of herbicide were found in the Eddyville streams than in the Cascade Creek Watershed streams (Table 3). This is attributed to the fact that all of the sampled streams flowed from, or through, the treated area. The highest concentrations of herbicide were found shortly after application. Residue levels declined rapidly with time. The residues in the Eddyville study streams are a result of direct application of chemical to the stream surface. No residues were detected between 50 hours and 10 months after application indicating mobilization in ephemeral stream channels, overland flow, and leaching did not occur to a measurable degree (Norris, 1967).

Farmer Creek - Dicamba

The Farmer Creek Watershed was treated by helicopter with 1.12 kg/ha dicamba in June (Fig. 3). Water samples were collected at three points on streams which drained the treated area. Fig. 4 shows the rainfall patterns and sampling dates. Sampling was concentrated around the time of application in June, and again in the fall and early winter during periods of intense precipitation. Additional samples were collected in the early summer approximately a year after application.

TABLE 2--Concentration of 2,4,5-T in Cascade Creek^{1/}

Sample Point 1		Sample Point 2		Sample Point 3	
Hours after spraying	2,4,5-T (ppb)	Hours after spraying	2,4,5-T (ppb)	Hours after spraying	2,4,5-T (ppb)
0.05	0	0.2	1	0.3	Lost
.6	16	1.3	2	1.4	3
1.3	7	2.2	1	2.0	3
2.0	4	3.9	1	3.9 ³	0
4.0	4	5.4 ³	0		
5.2	4				
9.8	4				
24.7	2				
48.2	1				
74.8 ²	1				

1/ Rate of application - 2.24 kg/ha (Norris, 1967)

2/ Herbicide residues were detected at point 1 up to 16 weeks after spraying

3/ No further residues were detected although sampling continued for 10 months.

TABLE 3--Concentration of 2,4-D in Streams Near Eddyville^{1/}

Sample Point 4		Sample Point 5		Sample Point 6	
Hours after 2,4,5-T spraying	(ppb)	Hours after 2,4,5-T spraying	(ppb)	Hours after 2,4,5-T spraying	(ppb)
0.8	33	1.3	62	1.4	30
1.8	13	2.3	71	2.3	44
2.8	13	3.3	58	3.3	25
53.5 ²	9	4.3	44	4.3	23
		53.6 ²	25	53.6 ²	11

^{1/} Rate of application - 2.5 to 3.36 kg/ha (Norris, 1967).

^{2/} No further residues were detected although sampling continued for 10 months.

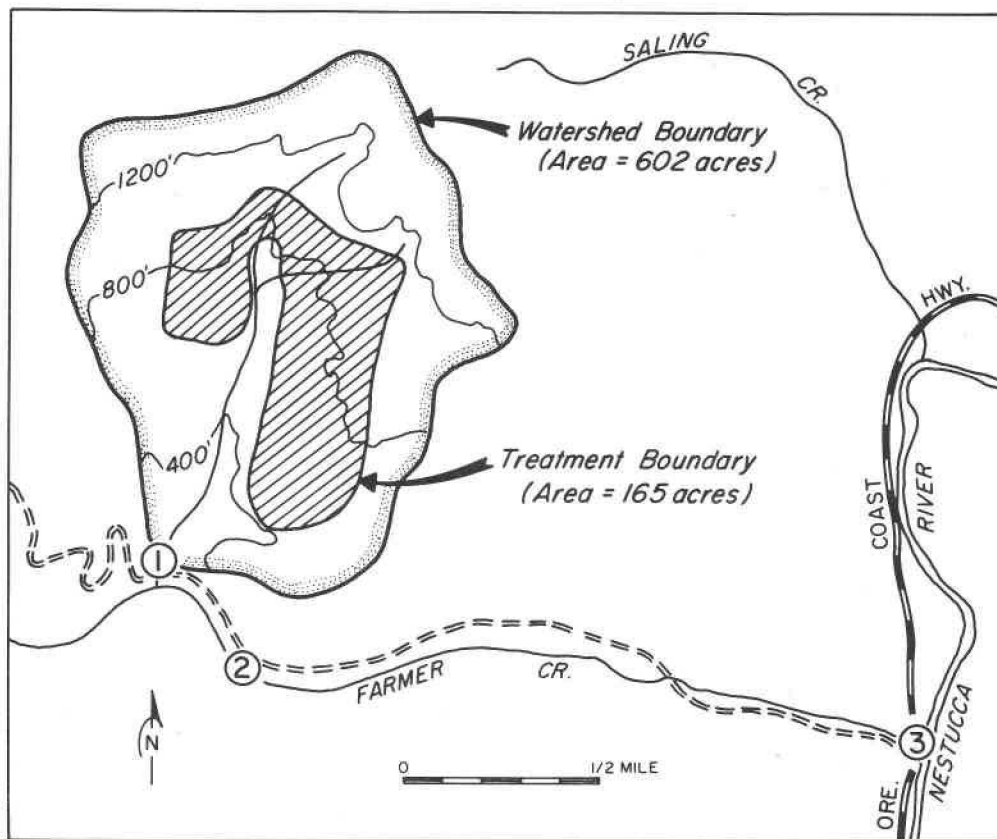
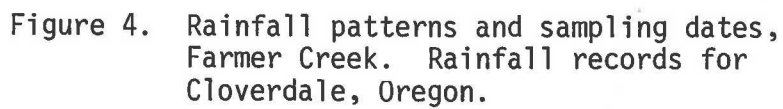


Figure 3. Farmer Creek tributary watershed, treatment area, and sampling points one, two, and three.



Dicamba residues at sampling Point 1 rose sharply to a maximum of 37 ppb in 5.2 hours after spraying and then declined slowly to background levels by 37.5 hours (Fig. 5). These residues probably resulted from a combination of drift and direct application of herbicide to exposed surface waters. Small additional amounts of dicamba were found in the stream between June 10 and 18 during periods of precipitation. These residues may represent mobilization of dicamba in ephemeral stream channels. Samples of water from Point 1 were collected periodically for 14 months after application, but no dicamba residues were found more than 11 days after application. These data indicate that neither overland flow nor leaching were important mechanisms in moving this persistent, relatively mobile herbicide from the treatment areas into the aquatic environment.

The concentration and the total amount of dicamba in stream water was markedly reduced with downstream movement. Integration of the curves of dicamba concentration revealed that 58, 35, and 26 grams of dicamba passed sampling Points 1, 2, and 3, respectively, the first 37.5 hours after application. The mechanism responsible for loss of dicamba between sampling points is not known, but may represent a combination of dilution, degradation, adsorption, and absorption (Norris and Montgomery, 1975).

Beacon Rock Study Area - Picloram and 2,4-D

The Beacon Rock study area is located on a powerline right-of-way where substantial soil compaction and disturbance has occurred. It was treated with 2,4-D and picloram at 4.48 and 1.12 kg/ha on August 19. Fig. 6 shows the pattern of precipitation and herbicide residue levels found in water samples from a small depression which collected runoff water from this area.

The highest concentrations of both herbicides occurred in connection with the first significant fall storms (Fig. 6). No residues were detected after October 27 despite periods of heavy precipitation over the next several months. The residues detected in water in the Beacon Rock study area are believed to represent a combination of mobilization in ephemeral stream channels and overland flow from areas of severe compaction (Norris, 1969).

Hill-Pasture Study Area, Roseburg - Picloram and 2,4-D

Norris, et al., (1976) studied the discharge of picloram and 2,4-D from a 7-ha watershed in southwest Oregon. The study area supported a mixture of native and introduced grasses and a dense stand of poison oak. It was treated with 2,4-D and picloram at 4.6 and 2.3 kg/ha by helicopter in June. The stream channel was dry between the time of application and the first significant rainfall in mid-September (Fig. 7). The first rain resulted in small puddles in the dry stream channel, but no runoff into the catchment basin behind the dam which was a part of the stream gaging station.

A water sample collected in a small puddle about 5 meters upstream from the dam contained 110 ppb picloram, but no 2,4-D. Rain on October 7-9 filled the catchment basin, and the first actual discharge of water from the watershed occurred on October 8 (Fig. 7). Relatively little outflow of water occurred between October 8 and October 27 when an intense storm took place. No samples were collected during the late October storm. The last water sample collected which contained a detectable residue of herbicide was taken from the catchment basin on January 1.

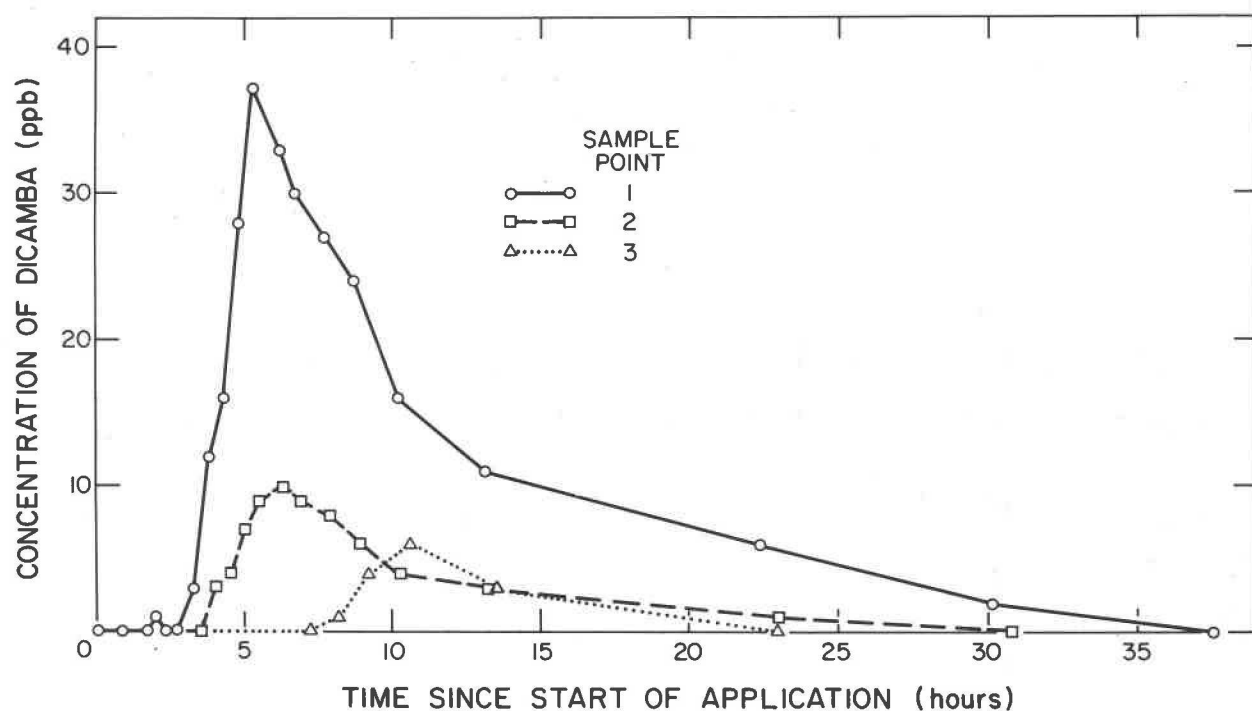


Figure 5. Concentration of dicamba in Farmer Creek after aerial application of 1.12 kg dicamba per ha to 67 ha of a 244-ha watershed.

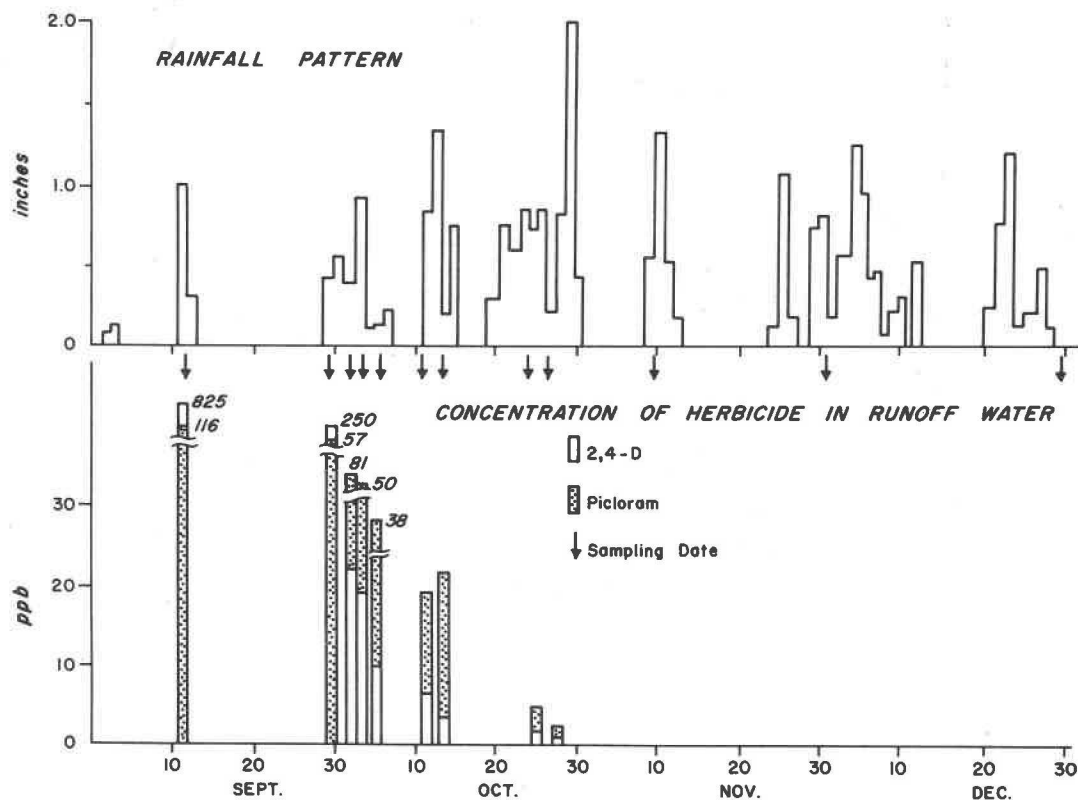


Figure 6. Rainfall patterns, sampling dates and concentration of 2,4-D and picloram, Beacon Rock study area.

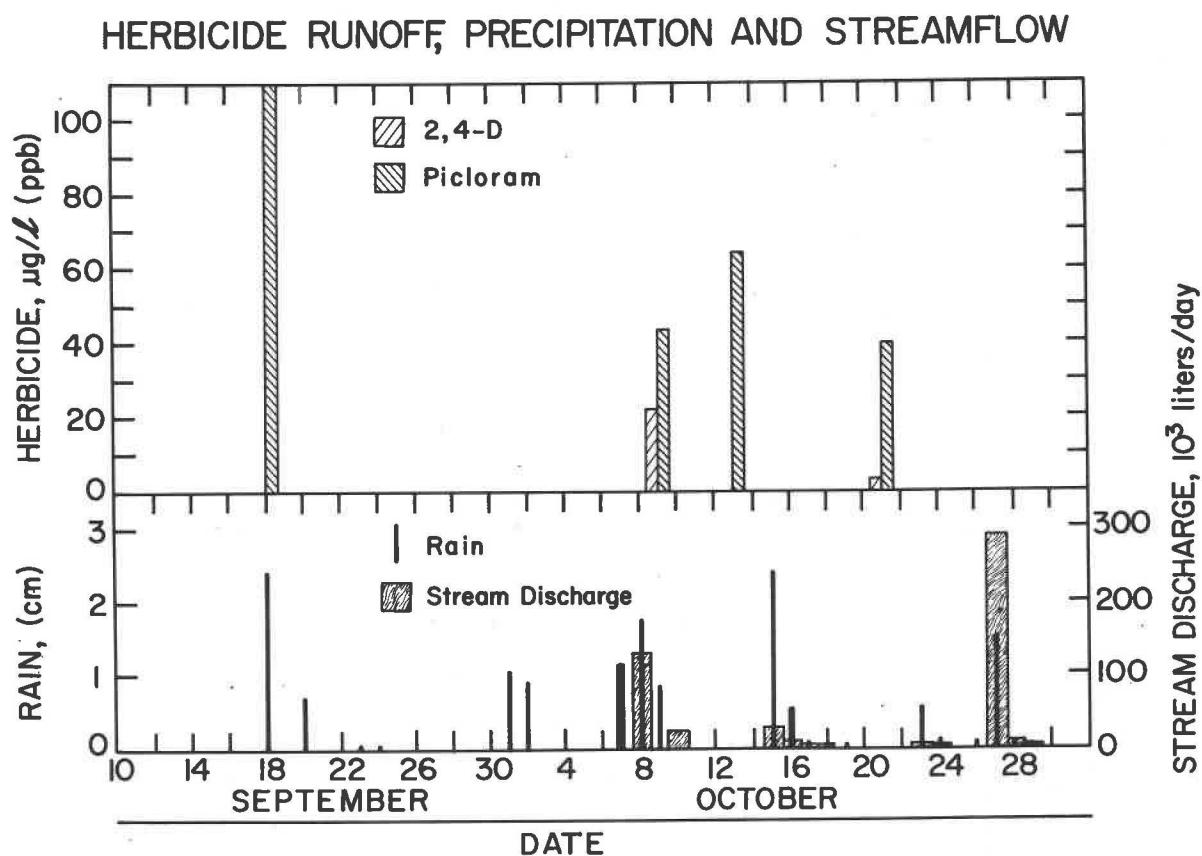


Figure 7. Daily rainfall record, stream discharge, and concentration of herbicide in water in catchment basin behind dam, Boyer Ranch.

The discharge of herbicide from the watershed is shown in Figure.8. The question mark shown for the period December 21-31 represents an equipment malfunction and loss of any measure of stream discharge. During the period through November 11, approximately 0.02% of the 2,4-D and 0.29% of the picloram applied to the watershed were discharged in streamwater. Measurements of the length and width of the dry stream channel indicate the stream represented 0.2% of the watershed. We infer from these data that most of the herbicide discharged from the watershed represents material which was applied directly to the dry stream channel and adjacent streambanks and was mobilized during periods of heavy precipitation. No herbicide residues were detected in water from this site in 3 subsequent years of sampling. This indicates leaching of picloram (a relatively persistent and mobile herbicide in soil) from this site did not contribute measurable residues to the aquatic environment.

FOREST FERTILIZERS

Several forest fertilization projects have been monitored in the Pacific Northwest. Moore (1970, 1971) measured the amounts and forms of nitrogen entering streams during and following aerial application of 224 kg/ha of urea nitrogen to an experimental watershed in southwestern Oregon in March (Fig. 9). Losses of applied nitrogen during the first 9 weeks after application are in Table 4. These losses were measured first as an increase in urea nitrogen and then as a small increase in ammonia nitrogen. The latter is a result of hydrolysis of urea applied to open water. Nitrate nitrogen entering the stream shortly after application is probably leached from the soil immediately adjacent to the stream channel. Approximately half of the applied nitrogen lost during the first 9 weeks after application was due to direct application, and half entered the stream as nitrate nitrogen. All of the applied nitrogen lost during this 9-week period, however, amounted to only 7% of the total loss which occurred over the first year.

A second peak in $\text{NO}_3\text{-N}$ concentration was observed during the winter storm period. This peak coupled with high streamflow over an extended period accounted for 92% of the total loss (Fig. 10). Total loss of applied nitrogen from the fertilized watershed during the first year amounted to 25.88 kg or 0.38 kg/ha (Table 5). Over the same period, the total amount of inorganic and soluble organic nitrogen lost from a 49 ha control watershed was 2.15 kg. or 0.04 kg/ha. Total applied nitrogen loss during the first year after application was less than 0.2% of the nitrogen applied. Monitoring of streamwater from the treated and control watersheds continued through the second and third years following fertilization, and there was no further loss of applied nitrogen (Fredriksen, et al., 1974).

Similar data have been obtained in each of the monitoring studies conducted throughout the Douglas fir region (Fig. 11) (Moore, 1975). Peak concentrations of urea, ammonia, and nitrate nitrogen found in each stream during the monitoring period following fertilization are in Table 6. The monitoring period varied from a few weeks to 6 or 7 months after treatment and, in a few studies, continued at least a full year. Most sampling continued until the forms of nitrogen being measured had decreased to near pretreatment levels.

HERBICIDE DISCHARGE

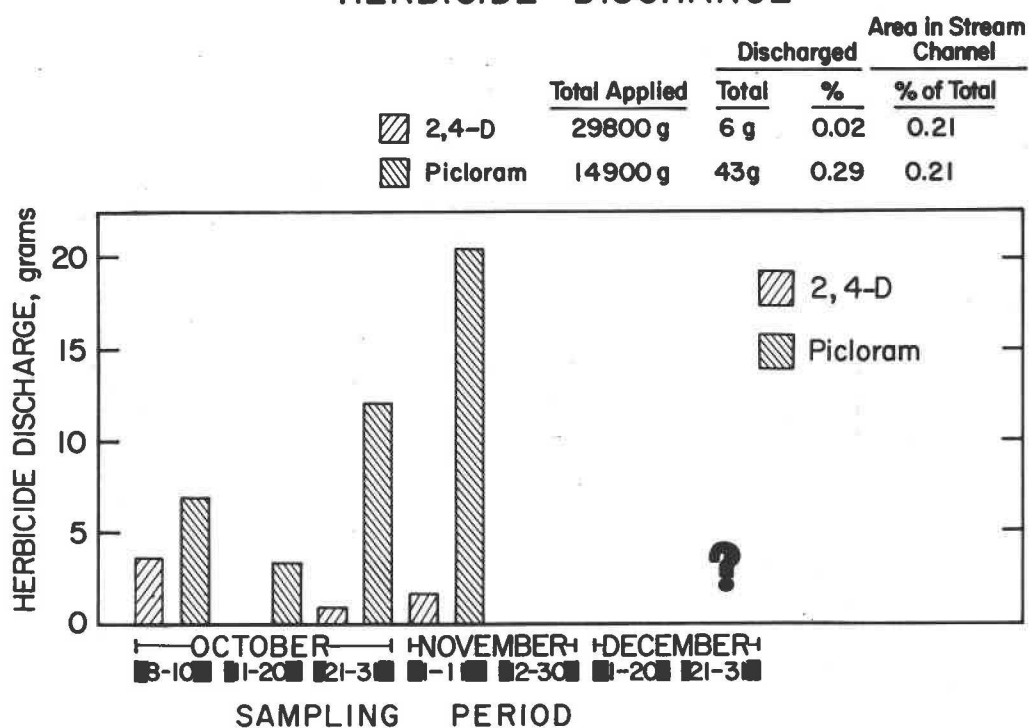


Figure 8. Discharge of herbicide for period represented by water sample, Boyer Ranch.

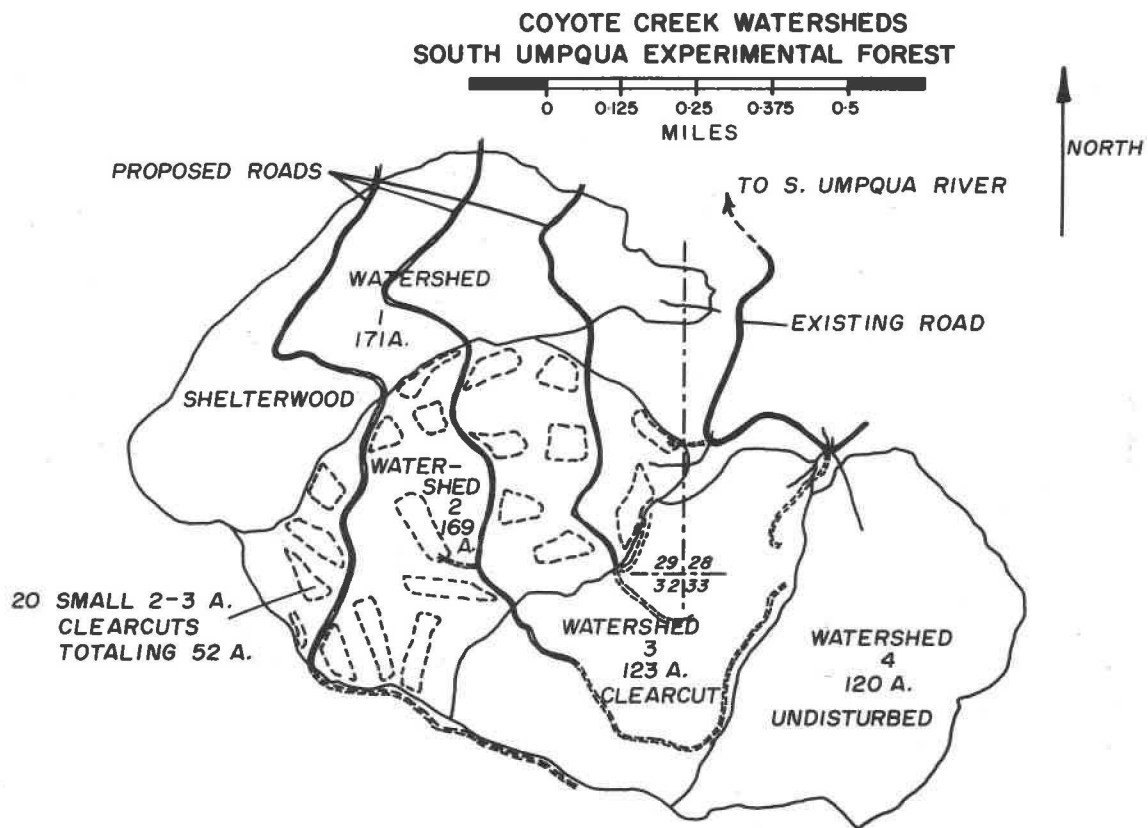


Figure 9. Coyote Creek Watersheds, South Umpqua National Forest, Oregon.

TABLE 4--Nitrogen lost from treated Watershed 2 and untreated Watershed 4,
South Umpqua Experimental Forest, during the first 9 weeks after
application of 224 kilograms urea-N per hectare.^{1/}

Unit	Urea-N	NH ₃ -N	NO ₃ -N	Total
-----Kilograms N-----				
Watershed 2	0.65	0.28	1.01	1.94
Watershed 4	0.02	0.06	0.05	0.13
Net loss	0.63	0.22	0.96	1.81
Percent of total loss	34.75	12.25	53.00	100.00

TABLE 5--Nitrogen lost from treated Watershed 2 and untreated Watershed 4,
South Umpqua Experimental Forest, during the first year after
application of 224 kilograms urea-N per hectare.^{1/}

Unit	Urea-N	NH ₃ -N	NO ₃ -N	Total
-----Kilograms N-----				
Watershed 2	0.65	0.28	27.09	28.03
Watershed 4	0.02	0.06	2.07	2.15
Net loss	0.63	0.22	25.02	25.88
Percent of total loss	2.44	0.86	96.70	100.00

^{1/} From Moore (1971).

TABLE 6. Peak concentrations of nitrogen in stream samples following forest fertilization with urea in Alaska, Idaho, Oregon, and Washington.^{1/}

Study Site	Rate of	Date of	Treated			
	Application	Application	Area	Urea-N	NH ₃ -N ^{2/}	NO ₃ -N
	Kg N/ha		Hectares		ppm	
Burns Creek	56 ^{3/}	Oct. 1970	562	0	0	0.068
Canyon Creek	224	Oct. 1969	1346	15.20	n.d. ^{4/}	0.80
Coyote Creek	224	Mar. 1970	68	1.39	0.048	0.177
Crabtree Creek	224	May 1969	230	24.00	0.080	0.25
Dollar Creek	224	Apr. 1971	34	44.40	0.490	0.13
Elochoman River	224	Nov. 1969	297	19.00	n.d.	4.00
Fairchilds Creek	224	Apr. 1972	192	23.40	0.280	0.828
Falls Creek	213	May 1970	263	n.d.	1.28	1.67
Jackson Creek	168	May 1969	95	0.09	0.044	0.116
Jimmycomelately Creek	224	Apr. 1970	49	0.71	0.040	0.042
McCree Creek	56	Oct. 1970	513	0.62	0	0.210
Mica Creek	224	Sept. 1972	47	0.30	0	0.28
Mill Creek	224	Dec. 1969	228	0.68	0.12	1.32
Nelson Creek	224	Apr. 1970	38	8.60	0.32	2.10
Newaukum River	168	Sept. 1971	2463	0.26	0.008	0.438
Pat Creek	224	Apr. 1972	243	3.26	0.079	0.388
Quartz Creek	224	May 1972	51	1.75	trace	0.70
Roaring Creek	224	Mar. 1972	267	0.76	0.040	0.210
Row River	168	Oct. 1972	2630	0.13	0.022	0.044
Skookumchuck River	168	Sept. 1969	191	2.63	0.026	0.085
Spencer Creek	224	Nov. 1972	3108	0.37	0.123	0.005 ^{5/}
Tahuya River	224	Oct. 1972	1620	27.20	1.40	1.83
Thrash Creek	224 ^{6/}	May 1974	121	-	0.06	1.88
Three Lakes	213	May 1970	69	n.d.	0.13	2.36
Trapper Creek	224	Apr. 1970	64	0.70	0.010	0.121
Trout Creek	224	Mar. 1968	648	14.00	0.700	0.160
Turner Creek	224	Mar. 1972	352	4.36	0.046	0.243
Waddell Creek	224	Dec. 1969	600	2.48	0.340	0.99
Wishbone Creek	224	May 1972	46	0.30	0	0.28

1/ Data included in the table have been provided by the following companies and State and Federal agencies: Crown Zellerbach Corporation, Camas, Washington; Weyerhaeuser Company, Centralia, Washington; Willamette Industries, Inc. Albany, Oregon; Forest, Wildlife and Range Experiment Station, University of Idaho, Moscow, Idaho; Washington Department of Natural Resources, Olympia, Washington; Bureau of Land Management, Portland, Oregon; Pacific Northwest Water Laboratory, Environmental Protection Agency, Corvallis, Oregon; and Pacific Northwest Forest and Range Experiment Station, Juneau, Alaska; Corvallis, Oregon; and Wenatchee, Washington. See figure 10 for site locations in Oregon and Washington (Moore, 1974).

2/ Includes both ionized (NH₄⁺) and un-ionized (NH₃) ammonia-nitrogen.

3/ Applied as ammonium sulfate.

4/ n.d. = no data available.

5/ In this study there was no increase in NO₃-N. Concentration given is background level.

6/ Applied as ammonium nitrate.

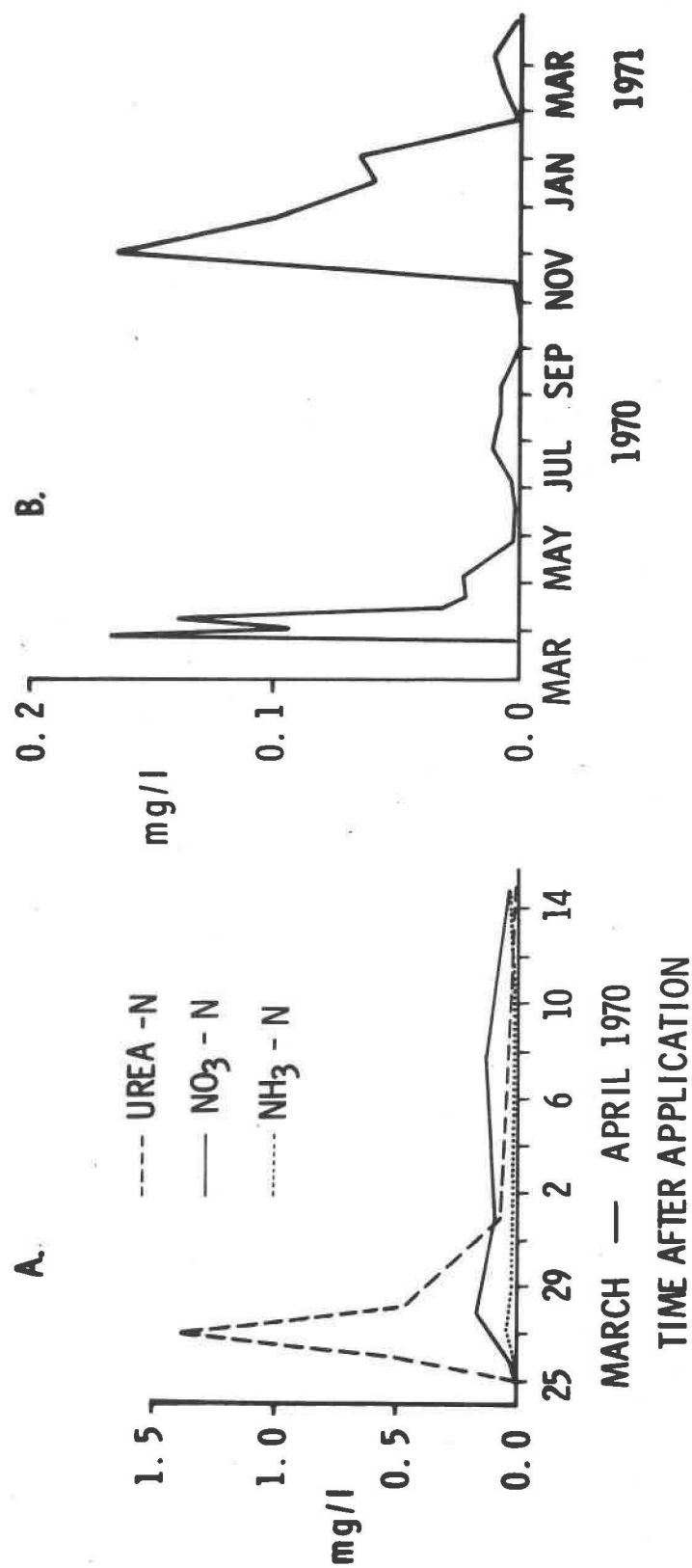


Figure 10. Fertilization of a 68-hectare watershed with 224 kilograms urea-nitrogen per hectare in March 1970. A. Immediate effect on water quality. B. Effect on nitrate-nitrogen concentration in streamflow for 1 year following fertilization (Fredriksen, et al., 1974).

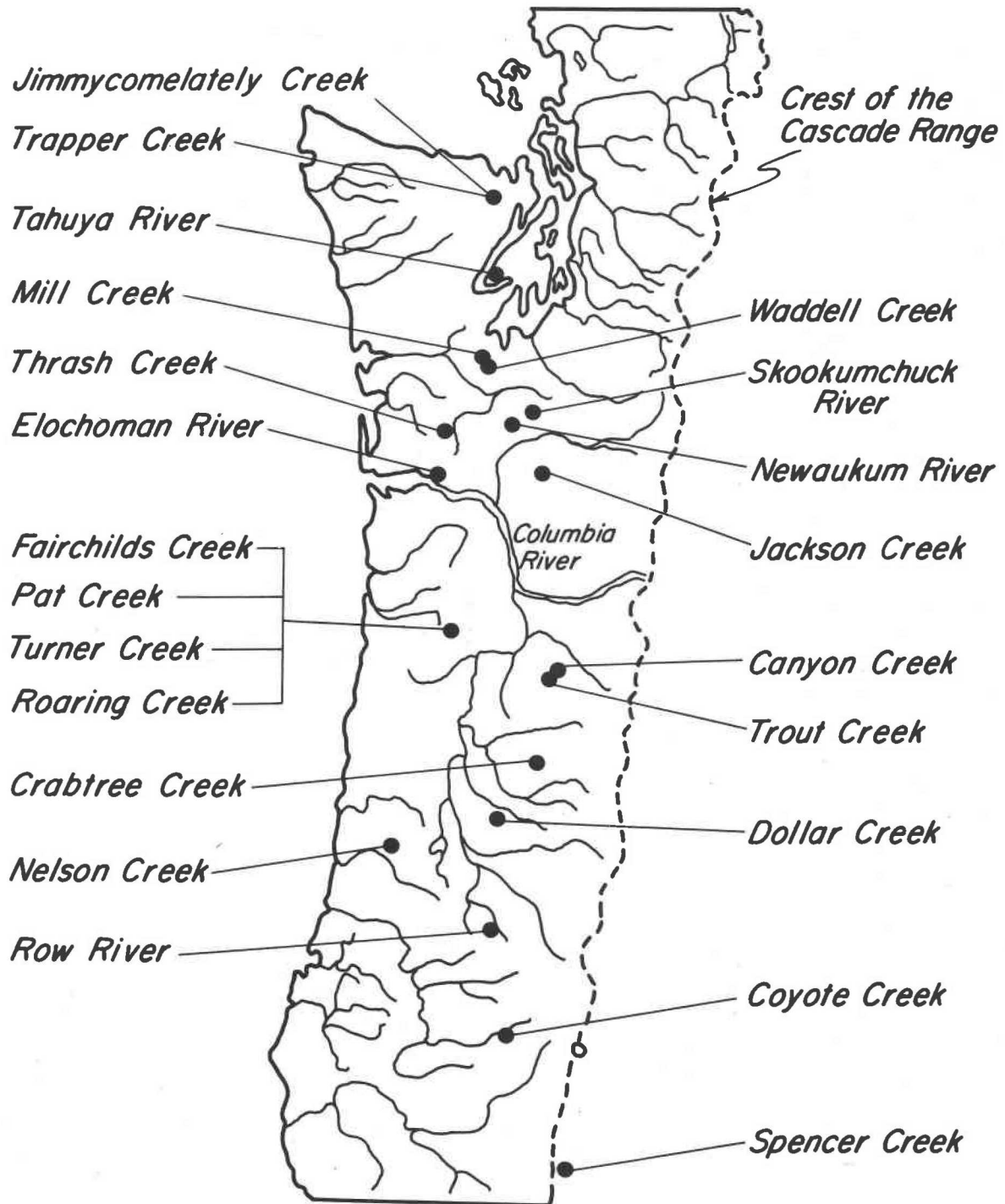


Figure 11. Location of forest fertilization-water quality monitoring studies in western Oregon and Washington.

Fire Retardants

In 1973, a study was initiated to determine the entry and effects of fire retardant materials in forest streams at three sites in Oregon, one in Idaho, and another in California. The purpose of the study was to measure the concentrations of the various forms of nitrogen in the stream after application of fire retardant to the stream and adjacent land area in a pattern which simulated aerial application (Fig. 12). Studies included intensive streamwater sampling at five sites between 50 and 1600 meters downstream from the point of application. Although sampling continued for more than a year, the principal introduction of fire retardant to the stream occurred because of direct application to the stream surface (Table 7). The concentration of total ammonia peaked 50 meters downstream shortly after the application and then declined rapidly until approximate pretreatment levels were established within 10 days of application. Peak concentrations were lower and occurred later with increasing distance downstream.

MINIMIZING THE IMPACT OF FOREST CHEMICALS ON THE AQUATIC ENVIRONMENT

All chemicals have some degree of toxicity, and it is possible through improper practices to cause serious impact on stream organisms. There is little a forest manager can do to influence toxicity because it is an inherent property of the particular chemical. The risk or danger associated with use of that chemical, however, is derived not only from its toxicity but also from the magnitude and duration of organism exposure. Although the forest manager cannot influence toxicity, the magnitude and duration of exposure are directly associated with the pattern of use.

Reconsideration of the processes involved in chemical entry into the streams shows that direct application to the stream surface and accidental drift of spray materials from nearby treatments are the principal processes involved. These processes are not a function of the chemical, but rather planning and the techniques of application.

Special efforts are necessary to avoid direct application to surface waters. Norris (1971) admonishes "if you don't want it in the water, then don't put it there". Pre-project planning to locate and mark live streams to be sure they are excluded from the spray area is necessary. Pre-spray briefing and orientation for the applicator is also necessary to ensure streams are not sprayed. Avoiding drift is more difficult but can be accomplished. Careful attention to atmospheric conditions, formulation, and operation of spray equipment will help minimize the formation and movement of small particles of spray material (Maksymiuk, 1971a, 1971b; Witt, 1971).

CONCLUSIONS

Chemicals are important tools for accomplishing a variety of management objectives involving the protection and enhancement of forest values. The toxic hazards associated with use of forest chemicals are determined by the tox-

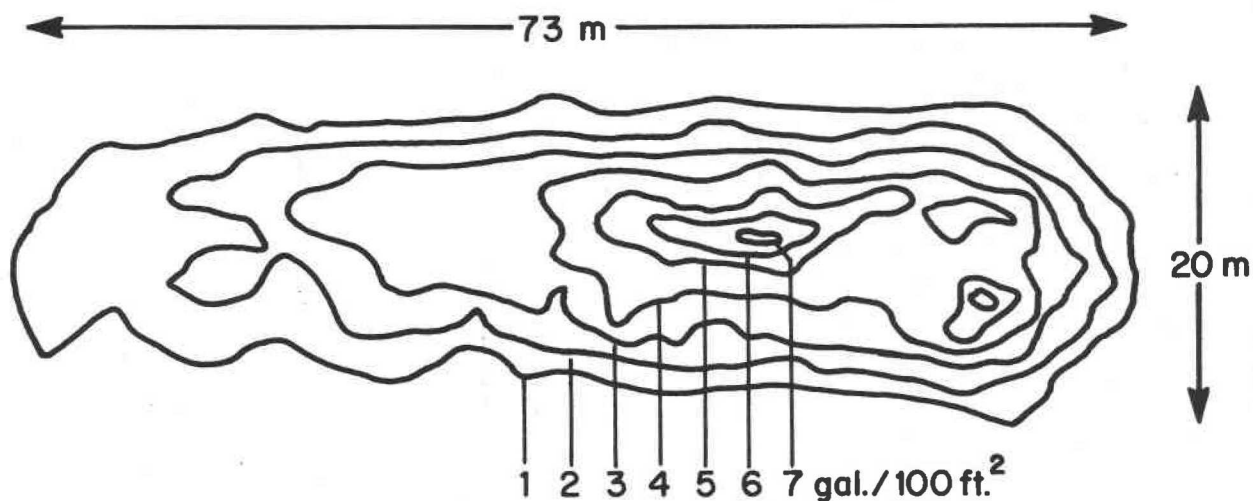


Figure 12. A typical dispersal pattern. The diagram depicts results characteristic of the release of 2270 ✓ of retardant material from an altitude of 30 to 90 m (1 gal./100 ft² = 3.785 L/9.3 m²).

TABLE 7-- Ammonia in Quartz Creek after application of Phos-Chek
to the Quartz Creek study area.

Ammonia in stream water (ppm-N)					
Time after application	Sampling Site				
	Approx. distance downstream from treatment area (meters)				
	50	100	400	800	1600
1 min	0.04	0.06	0.02	0.04	0.17
2	0.02				
3	0.21				
4	1.65				
5	10.25	0.02			
7	15.81	0.02			
9	10.88				
12	5.75				
18	3.56	0.06	0.02		
23	1.11	0.55			
28	0.46	0.17	0.02	0.04	0.06
33	0.39	0.17			
45	0.27	0.16	0.78		
60	0.24	0.34	0.65	0.35	0.17
90	0.16	0.14	0.20	0.40	0.19
2 hrs	0.11	0.14	0.10	0.46	0.15
6 hrs		0.27	0.04	0.22	0.11
12 hrs		0.09	0.04	0.17	0.18
1 day		0.04	0.02	0.14	
3 days					
5 days	0.05			0.04	0.09
10 days					

icity of the chemical and the magnitude and duration of exposure that aquatic organisms receive. Toxicity is an inherent chemical property which cannot be altered. Magnitude and duration of exposure, however, are largely determined by the pattern of chemical use. Chemical entry into streams is principally through direct application to stream surfaces or through drift from nearby treatment units. Managers can minimize the entry and, therefore, the impact of chemicals on stream organisms, by careful attention to formulation and carrier, and to atmospheric and operating conditions which will minimize drift. Pre-project planning and applicator orientation will help prevent direct application to stream surfaces.

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Toxicological Considerations of Heavy Metals in the Aquatic Environment

The periodic table includes 92 elements from hydrogen to uranium, and all but 20 can be classified as metals. As many as 59 of the 72 metals may be considered heavy metals. Obviously, the subject of heavy metal toxicity embraces a majority of the elements in the periodic table.

However, only 17 of the heavy metals are considered to be both very toxic and relatively accessible (Wood et al., 1975). Of these 17 heavy metals (Table 1), nine are being mobilized into the environment by man at rates greatly exceeding those of natural geological processes (Ketchum, 1972). These nine metals should, and do, command a relatively high degree of attention from those interested in the effects of metals on the environment.

Most likely each of these nine metals occurs naturally in water to some extent, and all organisms are naturally exposed to some level, however minute, in all environments. In addition to their ubiquity, some metals, including Cd, Cu and Zn, have known requisite biochemical roles in metallo-enzymes, and others may be required as trace elements by the cell (Wood et al., 1975).

Since any heavy metal may have a positive biological role, it follows that the total absence of a metal may be detrimental, that some concentration may be optimal, and that some concentration will be toxic. One can presume that these concentrations will be different for different species of organisms.

Since we are generally concerned with additions of materials to the aquatic environment, the critical concentration to be determined is that minimum level which will cause significant environmental damage. The determination of this level requires at least two separate scales of judgment. One is essentially a concentration-effect relationship (like a dose-response curve), and the other is a complex evaluation based on ecological, economic, sociological and political factors. I intend to focus on the former in my presentation today.

TABLE I. Heavy metals of particular environmental concern because of toxicity, accessibility, and rates of mobilization (from Wood, 1975 and Ketchum, 1972).

<u>Very toxic and readily accessible</u>	<u>Man-induced mobilization higher than natural rate</u>
Co, Bi	Ag*
Ni, Cu	Cd
Zn, Sn*	Cu
Se*, Te*	Hg*
Pd*, Ag*	Ni
Cd, Pt*	Pb*
Au*, Hg*	Sb
Tl*, Pb*	Sn*
Sb	Zn

*Metal alkyls stable in aqueous systems and reported to be biomethylated.

One of the first considerations in determining the potential environmental impact of the nine heavy metals previously mentioned is that of their relative toxicity. These metals vary in their toxicity to some aquatic organisms by 10,000 to 100,000 fold. A very general ranking of their acute toxicity in water is given in Table 2.

TABLE 2. General ranking of toxicity of heavy metals in the aquatic environment.

Metal	Ag, Cd, Hg	>	Cu	>	Ni, Pb, Zn	>	Sb	>	Sn
Toxic Level	10^{-8} M		10^{-7} M		10^{-6} M		10^{-5} M		10^{-4} M

The frequency of detection of metals in river water was highest for zinc and copper (Kopp and Kroner, no date). Toxic levels of the heavy metals may be closest to environmental levels for Cd, Cu, Hg and Zn. It is not surprising that it is these four metals that have commanded the greatest amount of attention from aquatic toxicologists.

However, it is at the point of comparison of known toxic levels and measured environmental levels that the chief complication arises in the aquatic toxicity of metals. This complication is the many different physical and chemical states in which metals can occur in water.

Analysis of a sample of rock may indicate very high levels of certain metals, but immersion of the rock into water will not, of course, suddenly render the water toxic, even though the "concentration" of the metal in the water may vastly exceed a lethal amount. Similarly, many minute rocks will not suddenly produce toxicity where their total metal content is equally high. The ultimate minute unit of a heavy metal is the free cation, and this form is generally considered to be toxic. Between the two extremes represented by the ion and the rock there are a multitude of physical and chemical forms of metals which can produce different levels of toxic responses in fish and other aquatic organisms.

With the exception of smothering by precipitated forms, the toxicity of metals is due to chemical interactions between the metal and certain chemical moieties of the organism. This chemical action presumably requires that the metal be in soluble form. Moreover, some soluble forms may not take part in these chemical interactions because they are not taken up by the organism or are not properly reactive.

It is the composition of the physical- and chemical-form matrix which ultimately determines the toxic level in the given water. This matrix may vary widely among waters, so that one water may be biologically acceptable at a metal concentration considerably greater than that which would be toxic in another water.

A simple diagram of potential metal forms and interactions is shown in Figure 1. The amount of each of the forms depends on the sediment load, pH and organic and inorganic composition of the water. High metal levels are often associated with high particulate levels during periods of heavy surface run-off, indicating that most of the metal is found adsorbed on, or present in,

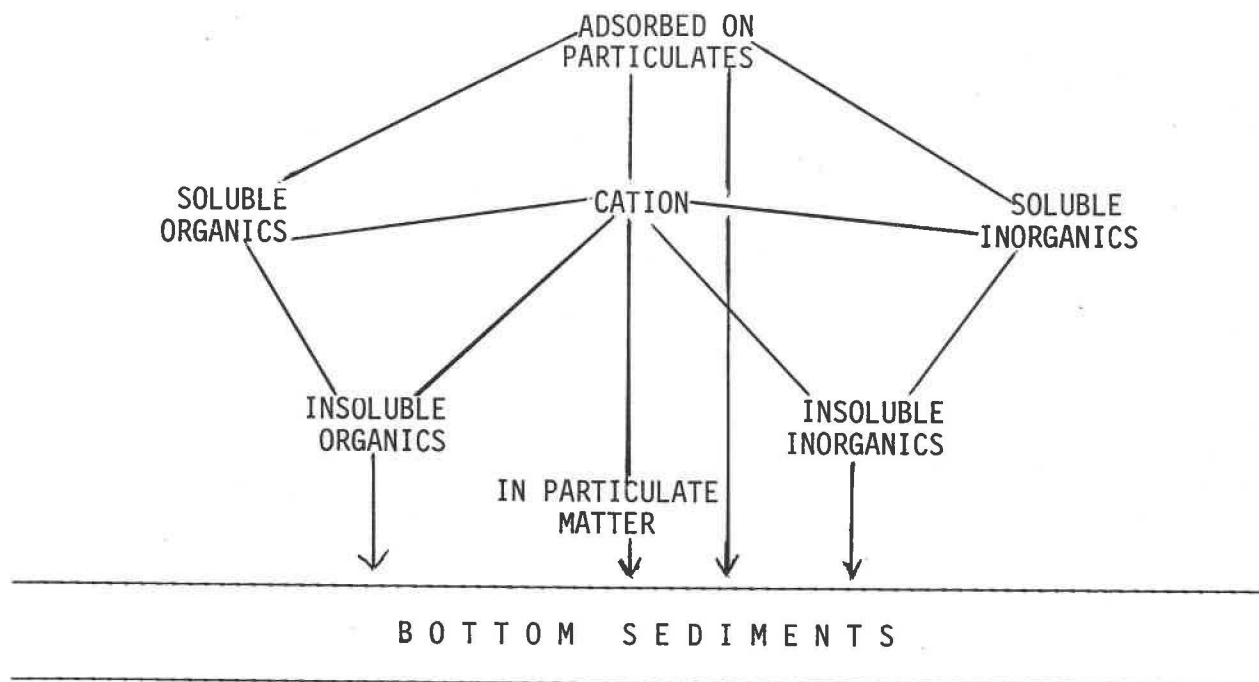


Figure 1. Various physical and chemical forms in which heavy metals can occur in natural waters.

particulate material. Similarly, in forested watersheds the heavy metal content of run-off can increase stream metal concentrations through the complexing of metals by soluble organic acids (Bolter et al., 1975).

Measurement and toxicity of metal forms are being actively investigated at the present time. The proceedings of two meetings held in October, 1975, clearly indicate the research activity regarding metal forms and would be particularly instructive for those interested in metal toxicity (International Conference on Heavy Metals in the Environment, 1975; Toxicity to Biota of Metal Forms in Natural Waters, Andrew et al., 1976).

The chemical aspects of the problem of metal forms are being investigated using electrochemical tools such as anodic stripping voltametry and specific-ion electrodes as well as computer modeling techniques. Biological aspects are being researched using routine acute toxicity testing techniques with waters of specific and known chemical composition.

Additional biological research is being conducted to determine the relative sensitivity of various aquatic species, their life stages and biological functions to poisoning by heavy metals. The scope of the problem of variable sensitivity to pollution among species is overwhelming. The multitude of species of aquatic biota precludes the investigation of all species. In the freshwaters of North America alone there are 660 species of fish, over 5,000 species of aquatic insects, about 1,800 genera of other invertebrates, as well as numerous aquatic algae and macrophytes. Indeed, the numbers involved preclude the testing of all genera or even all families. Regardless of the species involved, there are always reasons advanced for its protection from pollution---ranging from endangered species status, or gene-pool protection, to economics. However, species routinely used in aquatic toxicity research can probably be counted on the fingers of both hands.

For obvious reasons, toxicity tests have been largely limited to organisms which are of a convenient size, easy to collect and hold and whose responses are relatively easy to observe and measure. These considerations have tended to limit studies using microscopic species, rare species, very large species and species sensitive to handling or crowding. Field investigations are probably the best method for establishing a general data base to fill this large void in our knowledge of relative species tolerance.

SOME MORE TOLERANT

Experience has shown that certain species tend to be more pollution tolerant than others, a situation which has led to development of the pollution indicator organism concept. For example, carp are tolerant---trout are sensitive, or tubificid worms are tolerant---mayflies are sensitive. However, reliance on such generalizations may be misleading.

For instance, research at our laboratory has shown rainbow trout (*Salmo gairdneri*) to be very sensitive to copper, with a 96-hr LC50 (the concentration lethal to 50 percent of the test organisms in 96 hours) of about 18 µg/liter. Additional research with an uncommon research species, the northern squawfish (*Ptychocheilus oregonensis*) also yielded a 96-hr LC50 of 18 µg/liter, indicating that the two species were of similar sensitivity (Garton and Andros, personal communication). However, investigations regarding the toxicity of

cadmium yielded a 96-hr LC50 for rainbow trout of 1.0 $\mu\text{g/liter}$ and a 96-hr LC50 for squawfish of 1,104 $\mu\text{g/liter}$. While the two species were equally sensitive to copper, squawfish were over 1,000 times more tolerant of cadmium than were rainbow trout.

A similar circumstance was seen with a species of caddisfly with which we have been working. From life cycle tests with this insect we ascertained that copper altered normal adult emergence and subsequent first instar survival at copper concentrations as low as 18 $\mu\text{g/liter}$ (Nebeker, personal communication). This concentration is about twice the toxicity-threshold for rainbow trout in five-month duration embryo-larval tests. We are conducting similar tests with zinc, and have found no effect on the caddisflies at concentrations up to 5,000 $\mu\text{g/liter}$, while the no-effect level for rainbow was about 280 $\mu\text{g/liter}$.

These examples illustrate the great variability which can exist among organisms and metals with respect to relative tolerance. Interestingly, in both cases it was copper which produced about equal toxicity between species.

A similar result was observed when we compared the toxicities of Cd, Cu and Zn to various life stages of salmon and trout. The toxicity of Cd varies over 25-fold between life stages ranging from newly-hatched alevins to adults, with the youngest alevins being very resistant and the several-weeks older fry being most sensitive (Chapman, 1978).

The studies with zinc and copper showed the same ranking of tolerance among the life stages. However, the toxicity of zinc covered a seven-fold range in toxicity among life stages, and the toxicity of copper showed only a three-fold range. In this illustration, just as in that for relative species tolerance, copper showed the least variability, with zinc and cadmium having greater variability in toxicity.

EARLY STAGES ARE SUSCEPTIBLE

Generally, the early life stages of fish have been found to be the most susceptible to heavy metals, and to pollutants in general. An analysis of embryo-larval tests (tests lasting from egg fertilization until the newly-hatched fish have been feeding for about a month) has shown that these studies yielded an effect level as low as or lower than full life cycle exposures in 46 out of the 56 tests surveyed (McKim, 1977). Where the embryo-larval test was not the most sensitive toxicity test with fish, it never overestimated the ultimate lowest effect concentration by more than a factor of two.

Acute toxicity tests with juvenile chinook salmon (*Onchorhynchus tshawytscha*) at the Western Fish Toxicology Station (WFTS) have shown effects (200-hr LC10) at concentrations as low as 1.2 $\mu\text{g Cd/liter}$, 14 $\mu\text{g Cu/liter}$ and 68 $\mu\text{g Zn/liter}$. Five-month duration embryo-larval tests produced the following no-effect and effect levels: 1.3 and 1.9 $\mu\text{g Cd/liter}$; 1.2 and 7.4 $\mu\text{g Cu/liter}$; and 280 and 511 $\mu\text{g Zn/liter}$ (Chapman, 1975). Thus, with Cd and Zn, the no-effect concentrations in the embryo-larval tests were higher than acutely lethal levels in acute toxicity tests. Only copper produced a chronic effect at concentrations below the 200-hr LC10, but only growth was affected. (Twenty percent mortality occurred in the chronic test at 11.7 $\mu\text{g Cu/liter}$.) It was apparent that the fish became acclimated to the metals during the embryo-larval tests.

We investigated the magnitude of the acclimation by subjecting acclimated and non-acclimated chinook salmon fry to static acute toxicity tests following the five-month embryo-larval exposure. The results of the acute toxicity tests showed that both the copper and zinc acclimated salmon, but surprisingly not the cadmium acclimated salmon, survived at levels of the metals which were lethal to non-acclimated salmon. The resistance to copper and zinc was dose dependent, with a higher degree of tolerance obtained from higher acclimation levels. There was apparently an optimal concentration for copper acclimation (9-16 µg/liter) above which the degree of tolerance diminished.

In order to determine if acclimation could readily be lost, we transferred one-half of a group of acclimated fish to clean water for three weeks and then conducted a comparative toxicity test. Loss of acclimation after three weeks in clean water was considerable, but not complete.

The development of heavy metal tolerance in salmonids may be facilitated by the relatively long period of embryonic and larval development. These stages appear to be rather resistant to heavy metal toxicity, perhaps through a combination of low metal uptake rate and lack of functioning target systems. The embryo also may be protected through the binding of metals by components of the perivitelline fluid within the egg (Wedemeyer, 1968).

Several weeks after hatching, the larval salmonid develops into the swim-up stage which is considerably more susceptible to heavy metals and other pollutants (Chapman, 1978; Nebeker et al., 1978; Larson et al., 1977). Acclimation during the earlier, more resistant stages can act to protect the later, more sensitive stages.

SWIM-UP STAGE TESTING

Since embryo-larval tests are conducted to estimate chronic effect levels, and since acclimation during the initial portions of such tests can be a significant factor, we conducted an experiment to determine the result of copper exposure at various stages within the embryo-larval period. Exposure of steelhead trout (anadromous Salmo gairdneri) was started at four different times during the experiment: fertilization; eye-pigmentation; hatch; and swim-up.

Cumulative mortality during the course of the 110-day test showed considerable variation depending upon the stage at initial exposure. The greatest acclimation (lowest cumulative mortality) occurred when copper exposure was started at eye-pigmentation or at hatch. Beginning the exposure at swim-up produced the greatest mortality.

It appears that an acute toxicity test with swim-up stage salmonids can be a more sensitive test of potential effect levels than embryo-larval tests, at least in waters of low metal complexing capacity such as the WFTS well water. Determinations of acute toxicity thresholds for swim-up stage salmonids in such waters may be a quick method for estimating chronic toxicity thresholds for heavy metals.

Avoidance of heavy metals by salmon has been shown both in the laboratory and in nature (Sprague, 1964; Sprague et al., 1965). As we were interested

in the effects of acclimation on avoidance, we conducted a series of copper avoidance tests at 10, 20, 40, 60 and 80 $\mu\text{g/liter}$ using control fish and fish acclimated to 9 $\mu\text{g/liter}$ from a steelhead embryo-larval test with copper. Using a basic end-inlets, center-drain avoidance chamber, we observed the behavior of 10 control and 10 acclimated fish.

Individual fish were introduced into the chamber and allowed to adjust for 10 minutes prior to the first 20 minute avoidance test (at 10 $\mu\text{g/liter}$). Following the first test period, the copper concentration was increased and the control and copper receiving ends switched. Ten minutes later, the next 20 minute test was conducted, and the sequence repeated until the fish had avoided the copper for >70% of the 20 minute test or until the test at 80 $\mu\text{g/liter}$ was completed.

Eighty percent of the control fish avoided the copper at 10 or 20 $\mu\text{g/liter}$, but none of the acclimated fish avoided any tested concentration of copper despite the fact that 32 $\mu\text{g/liter}$ was lethal to 100 percent of the acclimated fish in 48 hours. Thus, the development of acclimation may be a mixed blessing to aquatic organisms, allowing existence in a marginal environment, but interfering with a behavioral defense mechanism.

Anadromous fish such as the salmon undergo significant physiological changes at the time they migrate to the ocean. Salmonids at this stage, known as smolts, can readily tolerate high salinity and evince an active downstream migratory urge. Heavy metals and other pollutants may upset the normal development of the smolt stage.

FIELD STUDIES

The smolting of coho salmon was used as the index of pollutant effect by Lorz and McPherson (1977) who found that tolerance of seawater, gill (Na, K-simulated) ATPase, serum chloride and downstream migration were all adversely affected by sublethal exposure to copper. Downstream migration was the most sensitive effect measured, being partially inhibited by exposure to copper levels as low as 5 $\mu\text{g/liter}$.

Several other metals (Cd, Cr, Hg, Ni and Zn) had less influence on smolting, although Cd and Zn acted synergistically with copper to inhibit downstream migration (Lorz et al., 1978). The migration studies were performed in the field following exposure to metals in the laboratory.

Such field studies are considerably more holistic than laboratory studies, but are usually greatly complicated by uncontrolled variables. A significant field study of the effect of copper was conducted as a relatively controlled experiment in an Ohio stream, Shayler Run (Geckler et al., 1976). The purpose of the study was to test the applicability of laboratory-derived toxicity data to a natural stream.

Following a two-year control period, the stream was dosed with copper at an essentially constant level for three years. Behavioral effects appeared to be the most significant feature of fish response to the added copper. Fish deaths were observed only during the first week of dosing, although fish were present in the test section throughout the course of the study. Avoidance of

copper by fish was an important effect only during the first year of the study (this may be related to the effect of acclimation on avoidance previously described for trout). Fish tended not to spawn in the copper-treated section of Shayler Run so that fry abundance was decreased seven-fold in the exposure area. Fish would, however, spawn successfully in aquaria receiving Shayler Run water at the same concentration of copper as that shunned in the stream.

The populations of macroinvertebrates in Shayler Run were generally reduced in the area of copper exposure, with several common forms virtually eliminated. Interestingly, no effects of the reduction of macroinvertebrate populations were seen in the fish population.

Thus, the toxic effect of heavy metals is highly dependent upon both the physical-chemical behavior of the metals and the biological behavior of the organisms which are exposed to the metal. The former tends to decrease the toxicity of a given concentration of metal in natural waters as compared to laboratory studies because laboratory water supplies generally are not as metal-complexing as natural waters. However, organism behavioral effects such as avoidance, rejection of spawning areas and failure of smolt migration tend to occur at metal concentrations which may not be obviously harmful in routine laboratory toxicity tests.

Regardless of such problems, use of laboratory toxicity data to predict field effects is necessary to limit environmental damage from pollution.

I hope this discussion has provided a cursory understanding of the factors influencing heavy metal toxicity to aquatic organisms and also an appreciation that one must be skeptical of the simple extrapolation of aquatic toxicity data from one situation to another.

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Chemicals in Our Water

ABSTRACT*

This paper provides a layman's overview of the very complex, nationwide problem--chemical contamination of our water--and discusses EPA's multifaceted approach to its solution. It touches on the general sources, types, and quantities of water contaminants and how they end up in our Nation's surface and ground waters. It highlights several pieces of EPA regulated legislation; noting the intent, mechanisms, milestones, and goals of each. The paper attempts to reveal the intertwining of the rules and regulations generated pursuant to these laws in an integrated attempt to regain our Nation's clean water.

* This paper has been approved for general availability. The contents of this paper reflect the views of the author, who is responsible for the facts and accuracy of the data presented herein, and do not necessarily reflect the official views or policy of EPA. This paper does not constitute a standard, specification, or regulation.

HISTORICAL DEVELOPMENT

In 1607, the first permanent English village was established in Virginia along the James River. The lands that were later to become the United States would never be quite the same again. America, land of bountiful food, water, natural resources, and land, entered an era of environmental deterioration that would last for several hundred years.

One of our country's strongest selling points to the overcrowded European settlers was the "land of plenty" concept. America was touted as a land of endless resources. By the middle of this century, it was apparent that the air, water, and land could not indefinitely assimilate the wastes of modern man.

Until the early 1900's, both industries and municipalities disposed of their untreated wastes by discharging into the Nation's waterways. This inherent "right to pollute" was based on the assumed infinite dilution provided by waters. In 1899 the Rivers and Harbors Act was passed by Congress. Section 13 of the Act required dischargers to apply for a permit to discharge to the Nation's navigable waters. This permit without limitations reinforced the earlier precept that we had a right to pollute.

With the abundant availability of raw materials, there was little interest in recovering usable materials from the waste streams. The Puritan ethic of "waste not, want not" was rapidly eroded and eventually evolved to "use it once and throw it away". Recycling, though possibly used in some cases, was not the rule of the day. Similarly, there were minimal environmental or health concerns. Most emphasis was placed on the control and treatment of communicable diseases, such as smallpox, bubonic plague, cholera, and typhoid. With the introduction and widespread use of chlorine disinfection in the early 1900's, the incidence of waterborne diseases dropped dramatically. The environment was viewed as an adversary in most instances, and little thought was given to the long-term adverse effects of "civilization".

As American industries and municipalities grew, so did their waste discharges. The quantity and complexity of the wastes continued to increase. As new products emerged, so did new pollutants. Civilization, with its paved streets and sidewalks, brought urban runoff. Agricultural yields were increased with the use of insecticides, herbicides, and fertilizers which migrated or washed into the streams. The result was an appalling state of degradation of the Nation's waters.

THE "CONTRIBUTORS"

In 1974, industry used about 15 trillion gallons of water, of which only about 5 trillion gallons received any sort of treatment before being discharged. The total biochemical oxygen demand (BOD) generated by industry was roughly equivalent to that generated by a population of 360 million people.

Besides BOD, industry made major contributions of other common pollutants such as materials with high chemical oxygen demand (COD); total organic carbon (TOC); acid and bases (measured by pH), and total suspended solids (TSS). Large quantities of metals, such as iron, chromium, mercury, and copper, were

discharged along with salts of sodium, calcium, and magnesium. Large quantities of acids, mostly sulfuric and hydrochloric, were dumped as contaminated process by-products. Petroleum refinery wastes and brines with components like phenols, cyanides, ammonia, and toluene were also discharged in large quantities. A rogues' gallery of other culprits, like blast furnace wastes, oils and greases, dissolved solids, and miscellaneous toxic chemicals, including radio-nuclei, were pumped into the waters.

On the other hand, municipalities with their almost 5 trillion gallons of discharge per year were running a close second. In 1974, cities and towns generated about 57.2 million pounds a day of BOD of which about 12 million pounds a day found its way to the waters.

In addition to BOD, municipal wastes contain total suspended solids, high pH's, and oils and greases. Metals, such as iron, chromium, cadmium, mercury, lead, copper, and zinc, were discharged in sizable quantities. The salts of sodium, calcium, and magnesium combined with the basic (i.e., high pH) nature of municipal wastes played havoc with the water chemistry of the streams. Bacteriological and viral contaminants entered the streams, in many cases without even the pretense of disinfection.

Using a single pollutant parameter, BOD, we can make rough comparisons between municipal and industrial waste generation as follows:

Assuming one million people generate 200,000 pounds per day of BOD, then the following industries generated these approximate BOD waste loads:

Meat Processing = 30,000,000 lbs/day or equal to
150 million people

Fruits & Vegetables = 2,000,000 lbs/day or equal to
10 million people

Beet Sugar = 6,700,000 lbs/day or equal to
33.5 million people

Organic Chemicals = 50,000,000 lbs/day or equal to
250 million people

Leather = 1,600,000 lbs/day or equal to
8 million people

Pulp and Paper = 2,143,000 lbs/day or equal to
10.7 million people

Unfortunately, the list of contributors does not end with industries and municipalities. Hundreds of Federal facilities, ranging from military installations to Indian reservations, discharged both industrial and domestic type wastes. Agricultural and silvicultural runoffs added silts and man-made chemicals by the hundreds of tons. Last, but not least, Mother Nature herself helped contribute to the problem with landslides, floods, and erosion.

In the late 1960's, a flood of technological advancements gave us marked improvements in analytical instrumentation and techniques. Before these improvements, our analytical limits of detection prevented our confirmation of many compounds we knew (and many we suspected) were present in the water. This knowledge was based on simple mass balances. To our dismay, these new analytical tools confirmed many environmentalists' worst fears. The Nation's waters were laden with hundreds (and possibly thousands) of man-made chemicals in trace amounts. Many of these substances have since been deemed toxic (e.g., PCB's, PBB's and DDT). This information coincided with reports from academia and other government agencies of adverse health effects from long-term, low-dose exposure to various chemical substances. Public interest soared as more information trickled out on the new threat of chemicals in our water.

Now comes the coup de grace; not only are our Nation's surface waters contaminated, but our groundwater in some areas may also be fouled! Extremely heavy demands, direct contamination of aquifers entering from thousands of abandoned wells and drill holes, and sanitary landfill, dump and lagoon leachates, are all contributors to this sad state of affairs.

So there's the problem...chemical contamination of our water, both surface and ground, resulting from decade upon decade of pollution by municipal, industrial, Federal, agricultural, silvicultural, and natural sources.

THE SOLUTION

As the interest and concern of the citizenry heightened, an awareness of the nature and extent of the problem began to grow at the Federal government level. Our elected officials began to respond with legislative measures aimed at eliminating perpetuation of the problem and correction of some of the damage already done. It was acknowledged that two hundred years of abuse to our Nation's waters could not be corrected overnight. Many Federal agencies pooled resources, knowledge, and purpose in an attempt to provide a coordinated attack on the problem.

Today, EPA works with numerous agencies: the Food & Drug Administration (FDA); Army Corps of Engineers; Consumer Product Safety Commission (CPSC); U.S. Geological Survey (USGS); National Oceanographic and Atmospheric Administration (NOAA); National Institute of Occupational Safety and Health (NIOSH); Forest Service; Occupational Safety and Health; and the Department of Transportation (DOT) to name a few. The combined and coordinated efforts of these and other agencies have initiated the long, costly process of restoring the Nation's water quality under the auspices of the EPA.

The actual authority to perform these tasks of restoring the Nation's waters and protecting the public from toxic substances is spelled out in several pieces of EPA mandated legislation.

THE FEDERAL WATER POLLUTION CONTROL ACT (FWPCA)

The most significant of these laws is the Federal Water Pollution Control Act Amendments of 1972 (or Public Law 92-500). The intent of this law can be expressed in five phrases as:

1. To restore the physical, chemical, and bacteriological integrity of the Nation's water.
2. To return the water to a fishable, swimmable, drinkable condition.
3. To address the problems of hazardous waste management.
4. To encourage the research and development of all aspects of water pollution and to study its health effects.
5. To encourage citizen involvement during the rulemaking process and to provide citizens with legal recourse to take action against polluters.

In attempting to carry out this Congressional intent, EPA has focused on three major implementation mechanisms. The first of these is known as the National Pollutant Discharge Elimination System (NPDES) permit program. This program requires municipal, industrial, and Federal facilities to apply for a discharge permit. This permit differs from the old Refuse Act permits in that the discharger must comply with stringent effluent limits set by EPA. These limits are based upon the best technology that can be used and not on the quality of the receiving stream. This oftentimes results in discharges which are actually of better water quality than the receiving water. As the lakes and streams begin to show improvements, this apparent difference between effluent quality and water quality will slowly diminish, and hopefully disappear, or reverse itself in the future.

Because the permit limitations require municipalities, large and small, to treat their wastes prior to discharge, some financial aid had to be established. The construction grant program, EPA's second implementation means, provides just such assistance. Businesses, unlike cities, can generally absorb pollution control costs as production necessities. Tax write-offs, accelerated depreciation, or reduced annual dividends are examples of how industry can absorb treatment costs. Congress has authorized about \$22.5 billion dollars to help municipalities build or improve their treatment facilities. EPA can fund 75% (and up to 85% in some cases) of the costs of compliance for publicly owned treatment plants.

The last major mechanism of the Act is the planning requirements. EPA requires areawide or drainage basin plans to establish overall water availability and use. EPA also requires local water use and water quality planning to be compatible with the overall planned uses. By planning and coordinating activities, the best value for the taxpayer's money is found. For example, if two adjacent communities must both build a sewage treatment facility, it is often less expensive and more efficient to build one regional facility.

So where are we now? We have just passed the first milestone date of July 1, 1977. This is the date that all direct dischargers must be treating their wastes to levels achievable through the use of the Best Practicable Control Technology Currently Available (BPCTCA). For municipal systems, this means a minimum of secondary biological treatment of their wastes. Over \$18 billion dollars have been granted to cities and towns throughout the country to help them build the plants that are needed. Most of the required areawide and basin plans have been completed and submitted to EPA for approval. Lastly, EPA has

designated 271 substances as hazardous and established penalties and liabilities for spills and accidents involving these chemicals.

Where are we headed from here? The second level of required treatment, Best Available Technology Economically Achievable (BATEA), becomes effective on July 1, 1984 for those industries with toxic pollutants in their waste discharges. This will require those facilities which discharge directly to the waterways to increase their degree of treatment.

For some industries, "no discharge of pollutants" will be their new limits! Industrial dischargers with only conventional pollutants (like BOD, TSS, pH, etc.) must upgrade to Best Conventional Pollutant Control Technology (BCPCT) by July 1, 1984. Municipal treatment facilities must increase their level of treatment to Best Practicable Waste Treatment Technology (BPWTT) by July 1, 1983. Those dischargers without toxic or conventional pollutants (i.e., non-conventional pollutants) must achieve the more stringent BATEA level of treatment technology by July 1, 1987, at the very latest. The question of how to satisfactorily address the problem of non-point sources (e.g., urban and agricultural runoff) must still be answered. EPA will continue to fund the municipal construction grant program. It is estimated that this grant program will continue for the next ten years at a "guesstimated" level of about \$5 billion a year.

The bottom line of all these programs is work towards the overall goal of the Act. This goal has been stated as follows: "The National goal (sic: of the Act) is to eliminate all discharges of pollutants into receiving water by 1985 and to achieve an interim goal that provides for protection of aquatic life and wildlife and for recreation in and on the water by 1983."

THE SAFE DRINKING WATER ACT (SDWA)

In 1974, Congress enacted the Safe Drinking Water Act (Public Law 93-523). The intent of this law is twofold. First, it is intended to establish minimum, uniform standards of potability for public water supplies. Secondly, the Act requires continued research into the health effects of drinking water contaminants.

EPA again uses three main mechanisms in implementing the requirements of this law. Firstly, EPA has been given the authority to establish standards for drinking water quality. This job was previously performed by the Public Health Service. These standards cover the microbiological, chemical, physical, and aesthetic aspects of the drinking water. The basic thought behind these standards is that a citizen should be able to draw a glass of water from the tap of any public water system in the country and be reasonably sure of its potability. It should look, taste, and smell like water. It should contain a minimum of harmful chemical substances and be relatively free from microbiological contamination.

The second implementation mechanism involves EPA's designating certain treatment processes to remove specific contaminants. If, based on publicly available information, it is found that only a specific treatment process can remove one or more compounds that have been found to be harmful to humans, then EPA will require that such treatment technology be used. This mechanism must be carefully used. The necessity of treatment must be balanced

against such factors as economics, environmental impact, and what-to-do with the waste from the treatment process itself.

The third and last major means of implementation requires public notification by the water suppliers of any regulation violation. In case of severe violation, like bacteriological contamination, the water purveyor must notify the media (i.e., radio, T.V., and the newspapers) immediately. More routine violations of the regulations require the publication in the public notice section of the local newspapers. In all cases, the customers must be notified in writing of the violation, duration, risk to their health, and any steps taken to rectify the situation.

Since this law became effective only last June 24 (1977), EPA has just gotten into gear. The first set of standards, known as the National Interim Primary Drinking Water Regulations (NIPDWR's), has been established. These regulations set maximum contaminant levels (MCL's for microbiological contaminants; turbidity, 10 inorganic chemicals, 6 organic chemicals (4 insecticides and 2 herbicides), and radionuclides. The secondary regulations have been proposed, but have not been finalized yet. These regulations address the aesthetics of drinking water by placing limits on hardness, taste, odor, color, pH, and total organic carbon (TOC). In Oregon, EPA is enforcing the primary regulations since the State declined the opportunity to assume the primary enforcement responsibility. To date, only about 40% to 60% of the community water supplies are complying by regularly reporting their sampling results. Fortunately, these systems represent about 95% of the population. The non-reporters are mostly small mobile home parks and camps.

What's left to go under the SDWA? The NIPDWR's (interim primary regulations) must be revised and promulgated as final regulations. Similarly, the secondary regulations must be revised and finalized taking into consideration all comments received on the proposed regulations. All non-community systems (restaurants, cafes, motels, etc.) must begin reporting by June of 1979. Treatment technologies for removing specific harmful substances must be evaluated. The first technology delineation has been proposed. It would require granular activated carbon for the treatment and removal of a class of substances called trihalomethanes.

And where is all of this taking us?

Hopefully, towards the goal of the Act, which is the elimination of chemical contaminants (e.g., teratogens, carcinogens, mutagens, toxics, etc.) and waterborne pathogens from our drinking waters.

THE TOXIC SUBSTANCES CONTROL ACT (TSCA)

This is one of the most recent pieces of Federal environmental legislation. The intent of the Toxic Substances Control Act of 1976 (Public Law 94-469) is to determine which of the 30,000 to 40,000 chemical substances that Americans regularly contact are toxic. In addition, the law intends to ban the manufacture of polychlorinated biphenyls (PCB's); regulate their disposal; and require pre-market notification and evaluation before new chemical substances are introduced to the public. The law specifically excludes EPA's regulation of any substance controlled by other Federal agencies. These substances include

pesticides (Dept. of Agriculture), nuclear wastes and fuels (Nuclear Regulatory Commission), tobacco, liquor, and weapons (Alcohol, Tobacco & Firearms - Treasury) and cosmetics, food additives, and pharmaceutical products (Food & Drug Administration).

EPA plans to implement this law by:

1. Preventing or limiting the use of a chemical substance;
2. Banning the manufacture of PCB's by 1981 using a two year, phase-out program; and
3. Allowing citizen suit against non-compliers with provisions for reimbursement of their expenses.

Where we are now is that we have passed the first milestone date of May 1 (1977). This was the date that manufacturers were to submit data to EPA for its inventory of chemical substances. This data was to include the sites of manufacture; the quantities manufactured; kinds of chemicals produced; and any imported chemicals received and used in products on the American marketplace. The PCB disposal regulations have been finalized. These regulations require that PCB containers be disposed at approved sites and the liquid PCB's be incinerated at certain facilities. Regulations banning the manufacture, processing, distribution, and use of PCB's are about to be proposed. An inter-agency effort between EPA, FDA, and the Consumer Product Safety Commission (CPSC) has resulted in a banning of chlorofluorocarbons for non-essential uses. A second regulation controlling the use of chlorofluorocarbons as refrigerants and for industrial uses is being prepared.

What's left to go? The inventory must be published and expanded to cover those chemicals that the public is exposed to either directly or as a part of a manufactured good. The chemical substances on the inventory must be evaluated for toxic effects, including carcinogenicity, mutagenicity, and teratogenicity. The chlorofluorocarbon regulations concerning industrial uses must be completed. Criteria for testing chemical substances prior to marketing must be developed.

All the efforts expended under TSCA are aiming towards a goal of eliminating toxic substances from our environment through limiting their use, production, importation, and disposal.

This brings us to the last law aimed at solving the problem of chemicals in our water.

THE RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)

In 1976, Congress passed the Resource Conservation and Recovery Act (Public Law 94-580) with the immediate intent of:

1. Regulating the handling and disposal of hazardous wastes;
2. Identifying those wastes that are hazardous, and;

3. Eliminating open dumps by 1983. In addition, the law intends to further the Government's interest in recovery technology and incorporating recycled goods into the Federal supply system.

EPA will attempt to carry out this mandate by setting standards for hazardous waste disposal sites; establishing civil and criminal penalties for improper waste disposal, and providing a means for citizens to bring suit against violators of the law.

What EPA has done to date is to initiate a nationwide inventory of dumps, due by 1980. The criteria for determining what is an approvable hazardous waste disposal site has been proposed. A facility in Arlington, Oregon, looks like it will be the first approved hazardous waste disposal site in the country.

What's left to do? A "cradle-to-grave" manifest system is being developed to track the origination, use, and ultimate disposal of hazardous wastes. The landfill and hazardous waste disposal site criteria must be finalized. The Agency plans to continue and even expand its research and development efforts into recovery technologies. Finally, EPA will implement a comprehensive, government-wide conservation program. The first steps in this direction have already been taken. EPA now requires Federal facilities to sell carbonated beverages in returnable containers with deposits. They have started office paper recycling programs in their own offices and have encouraged them in other agencies.

All of this effort is being expended towards the RCRA goal of significantly reducing the Nation's demands for raw materials by conservation and recovery while providing for adequate disposal of the remaining solid wastes.

A summary of each of the Acts discussed to this point can be found as Attachments 1 through 4.

Other Contributors to the Solution

So as not to convey the impression that EPA is singlehandedly combating the problem of chemicals in our water, I should give due credit to our allies.

Firstly, there is the environmental awareness and consciousness of the American public. Without this, EPA might not have come into existence back in 1970. Laws are generally the result of direct public pressure and environmental laws are no exception.

Next are the conservationists, wilderness preservationists, and environmentalists. These concerned organizations have lent their expertise, ideas, and in some cases, even the influence of their lobbyists to the cause of clean water. Often they have had to assume an adversary role to bring a particular point to the Agency's attention.

Then there is industry itself. Virtually all of EPA's programs rely on voluntary compliance and self-monitoring. Incredible sums of money have been invested and reinvested by industry into pollution abatement equipment.

Process changes have occurred to alleviate or eliminate waste discharge problems. Without the cooperation of industry and related trade associations, most environmental regulation would be continually tied up in law suits and appeals.

Lastly, there are the other Federal agencies and laws. The Federal Insecticide, Fungicide, & Rodenticide Act controls the use of all sorts of pesticides. The FDA, CPSC, Department of Interior, Corps of Engineers, Forest Service, and many others have all made significant contributions to eliminating chemicals from the Nation's waters.

CONCLUSIONS

To assure compliance with the existing laws, EPA must continue to receive adequate authorizations for personnel and money from Congress. As loopholes and oversights are discovered, EPA will need new legislation and amendments from Congress.

During these inflationary, economically depressed times, cost is an unavoidable consideration. EPA must continue to listen to both the industrial and the environmental/public health sides of all issues. The three factors used by EPA to resolve issues are environmental acceptability, technical feasibility, and economic impact. By weighing the cost versus the benefit, EPA can set its priorities in generating new regulations and enforcing existing ones.

Care must be taken to prevent our regulatory viewpoint from becoming too narrow. We must continue to sit back and try to look at the entire picture. For example, clean water can be a goal achievable by implementing and enforcing water pollution regulations requiring treatment. This might result in a clean discharge, but what about the resultant sludge problem? Myopic viewpoints can sometimes have you end up in a position worse than where you started.

I have talked enough about Federal legislation and bureaucratic implementation. What are your roles as new scientists and engineers? I feel the answer can be summed up by a 1960's activist quotation: "If you're not part of the solution, you're part of the problem." By this, I mean that if you do not choose to join the government--local, State, or Federal--then you have a responsibility to challenge it. Remember, bureaucrats are not infallible. They are humans with emotions and weaknesses, and are often susceptible to political influence. By challenging government, you will help to keep the system honest, responsive, and accurate.

Attachment 1

FEDERAL WATER POLLUTION CONTROL ACT AMENDMENTS OF 1972 (P.L. 92-500)

Intent of the Act	Major Implementation Mechanisms	Where Are We Now?	What's Left To Go?	Goal
...Restore the physical, chemical, and bacteriological integrity of our Nation's waters... ...Fishable....drinkable ...swimmable waters ...Address the problems of hazardous wastes managements. ...Encourage research of all aspects of water pollution and its health effects. ...Provide a legal mechanism for citizens to take action against polluters and allow public input into the regulation development process.	1. National Pollutant Elimination Discharge System (NPDES) permits for municipal, industrial, and Federal facilities with point source discharges. 2. Construction grants to municipalities (\$22.5 billion authorized to date). 3. Areawide and local water use and water quality planning.	1. Have just passed the July 1, 1977 date where direct dischargers are limited to levels achievable through the use of Best Practicable Control Technology currently available 2. More than \$18 billion in grants (75% of costs) given to municipalities primarily for secondary biological treatment plants and storm sewer separation. 3. Most areawide and basin plans completed. 4. Designated 271 substances as hazardous and established penalties and liabilities for spills & accidents.	1. The second step in limiting direct discharges by requiring compliance with the more stringent limits achievable by application of Best Available Technology economically achievable by July 1, 1984. 2. Satisfactorily address the problem of non-point source water pollution (e.g. urban and agricultural runoff) 3. Continuation of the municipal construction grant program.	The National goal is to eliminate all discharges of pollutants into receiving waters by 1985 and achieve an interim goal that provides for protection of aquatic life and wildlife and for recreation in and on the water by 1983.

Attachment 2

SAFE DRINKING WATER ACT OF 1974 (P.L. 93-523)

Intent of the Act	Major Implementation Mechanisms	Where Are We Now?	What's Left To Go?	Goal
...Establish minimum uniform standards of potability for public water supplies... ...Continue research into the health effects of contaminants...	1. Establishment of primary and secondary drinking water quality standards. 2. Require specific treatment processes for the removal of certain pollution. 3. Require public notification and customer notification of violations by water suppliers.	1. National Interim Primary Drinking Water Regulations have been promulgated. Microbiological turbidity; 10 inorganic chemicals; and radionuclide contaminants are now limited. 2. Secondary regulations addressing hardness; taste; odor; color; pH; and total organic carbon have been proposed. 3. The State Govts. are enforcing the law in most states. EPA has primacy in Oregon. 4. 40% to 60% of the community systems affecting about 95% of the population are now reporting in Oregon. 5. Granular activated carbon has been proposed as the treatment for total trihalomethane removal.	1. Revise the Interim Primary Regs. to Final Primary Regs. 2. Promulgate the secondary regulations. 3. Begin tracking non-community public water supplies by 1979 4. Finalize treatment technology determinations for the removal of trihalomethanes.	"Provide the public with safe drinking water by the elimination of chemical, radiological, & microbiological substances that may have an adverse health effect."

Attachment 3

TOXIC SUBSTANCES CONTROL ACT OF 1976 (P.L. 94-469)

Intent of the Act	Major Implementation Mechanisms	Where Are We Now?	What's Left to Go?	Goal
...To determine which of the 30,000 to 40,000 chemical substances in the consumer marketplace are toxic... ...To ban the manufacture of PCB's and regulate the disposal of existing PCB's... ...Require pre-market notification of new chemical substances... ...Prepare an inventory of chemical substances manufactured in U.S.	1. Prevent or limit the use of toxic chemicals in the American marketplace. 2. Ban PCB manufacture by 1981 through the use of a two-year phase-out program. 3. Allow for citizen's suit against violators with provision for reimbursement of expenses.	1. Have passed the cut-off date for inventory submittal of information for the final inventory now under preparation. 2. Finalized PCB disposal regulations and proposed manufacture ban. 3. As a joint effort with FDA & CPSC, banned non-essential use of chlorofluorocarbons.	1. Publish and expand the inventory. 2. Evaluate inventoried chemicals for toxic effects. 3. Address industrial - refrigerant uses of chlorofluorocarbons. 4. Establish testing criteria for pre-market notification.	"...the elimination of toxic substances from our environment through limiting their use, production, importation, and disposal."

Attachment 4

RESOURCE CONSERVATION AND RECOVERY ACT OF 1976 (P.L. 94-580)

Intent of the Act	Major Implementation Mechanisms	Where Are We Now?	What's Left to Go?	Goal
...To regulate the handling and disposal of hazardous wastes. ...Identify hazardous wastes. ...Eliminate open dumps by 1983.	1. Set standards for hazardous waste disposal sites. 2. Establish civil and criminal penalties for improper disposal. 3. Provide legal recourse for citizens against violators	1. The inventory of all dump sites has been initiated. 2. Proposed criteria for approvable hazardous waste disposal sites. 3. Initiated Federal facilities beverage containers and office paper recycling programs.	1. Complete the dump inventory 2. Establish a cradle-to-grave manifest system. 3. Finalize sanitary landfill and hazardous waste disposal site criteria. 4. Continue & expand R&D into recovery processes. 5. Implement comprehensive conservation programs.	"The goal of RCRA is to significantly reduce the Nation's demands for raw materials by conservation & recovery and to provide adequate disposal of remaining solid wastes."

Petroleum in the Marine Environment

The current interest in the problem of petroleum in the marine environment can probably be traced largely to the spill of Saudi Arabian crude oil from the Torrey Canyon shipwreck in 1967, and the blowout in 1968 of an offshore oil well in the Santa Barbara channel. A continuing series of such catastrophic spill incidents, coupled with the realization that worldwide oil consumption, offshore oil production, and oceanic trans-shipment of oil by ever larger supertankers is increasing annually, has raised public concern and stimulated research efforts to examine the harmful effects of petroleum pollution.

In this paper an overview of the problem of petroleum in the marine environment will be presented. No attempt will be made to provide an exhaustive review of the extensive literature in the field. For such information the reader is referred to several recent comprehensive volumes which contain excellent reviews (Malins, 1977a, 1977b; Wolfe, 1977; McIntyre and Whittle, 1977). We will consider the characteristics of petroleum and sources of its input to the marine environment, the fate of spilled petroleum in the marine environment, and finally, the biological effects of spilled petroleum on marine biota will be examined and evaluated in terms of the overall seriousness of the marine petroleum pollution threat.

CHARACTERISTICS OF PETROLEUM AND MARINE INPUTS

Physical and Chemical Characteristics of Petroleum

One of the most perplexing, and at the same time most interesting, features of petroleum with respect to the study of environmental effects is its extreme complexity and variability. Crude petroleum contains hundreds, perhaps thousands, of chemical compounds. Crudes from various worldwide sources differ dramatically in both physical and chemical characteristics. Furthermore, the properties of crude oils taken from a single well may differ substantially during the life span of the well.

Important physical characteristics of crude oil are specific gravity, viscosity, pour point, and fractional distillation temperatures. The values of these physical characteristics are related to the kinds and amounts of chemicals in an oil and their molecular interactions. The specific gravities of crude oils typically range from 0.79 to 1.00. Crude oils may have a very low viscosity, comparable to gasolines or kerosines, or they may be very viscous, even tarlike. The pour point is defined as the lowest temperature at which an oil can be poured. This is determined under empirical but standardized conditions. The pour points of world crude oils may range from -43°C to 43°C (Clark and Brown, 1977). The fractional distillation temperatures are temperatures at which the various components in petroleum evaporate. These may range from below 20°C to well above 540°C at one atmospheric pressure. The percentages of the total crude petroleum evaporating within any range of temperatures relates to the chemical composition of the crude petroleum; short chain and low molecular weight components generally volatilizing at the lower temperatures.

The major classes of chemical components found in crude petroleum are listed in Table 1. Of these, the hydrocarbons constitute the major group, contributing about 60 to 98% of the total chemical composition of crude oil, usually in the higher ranges. Hydrocarbons can be divided into three major subclasses: 1) the paraffins, open chain compounds which may be further divided into straight chain or n-alkanes and branched alkanes; 2) the cycloalkanes, consisting of at least one ring structure and usually containing five or six carbon atoms; and 3) the aromatics, compounds containing at least one benzene ring in their structure. The aromatics are typically characterized as mononuclear (benzene and various substituted benzenes), dinuclear (naphthalenes and substituted naphthalenes), and polynuclear (compounds having three or more benzene rings).

A second major group of chemicals, referred to as non-hydrocarbons or NSO compounds, are compounds containing nitrogen, sulfur or oxygen. Typical nitrogen containing compounds, which as a class may constitute from 0-1% of the total chemical composition of crude petroleum, are pyridine, quinoline and indole. Higher levels of sulfur containing compounds are often found; from 0-10% of the total crude petroleum. The classes of sulfur compounds include thiols, disulfides and thiophenes; the latter two predominate in the higher boiling fractions of petroleum. Oxygen containing compounds may constitute from 0-5% of the total crude petroleum and include such compounds as fatty acids, phenols, carboxylic acids and ketones.

Asphaltenes are very large (average molecular weights between 1000 and 10,000) materials containing nitrogen, sulfur, oxygen and metals and consist of many aromatic and heterocyclic structures with aliphatic and naphthenic side chains. The basic asphaltine units may further polymerize, yielding much higher molecular weight materials. Asphaltenes may constitute from 0-20% of crude petroleum; usually at the lower end of the range.

Metals, largely vanadium and nickel, frequently occur in crude petroleum. These are often found as metal porphyrins. The concentrations of porphyrins range from 0-3.5% (Posthuma, 1977).

A typical crude oil and various refined petroleum products may have the compositions shown in Table 2.

Table 1. Major classes of petroleum compounds

HYDROCARBONS

Paraffins

n-alkanes

branched alkanes

Cycloalkanes

Aromatics

mononuclear

dinuclear

polynuclear

NON-HYDROCARBONS (NSO's)

Nitrogen compounds

Sulfur compounds

Oxygen compounds

ASPHALTINES

METALS AND ORGANOMETALLIC COMPOUNDS

Table 2. The hydrocarbon class composition of a typical crude oil and refined products

Petroleum Type	Major classes of compounds (%)			
	Paraffins	Cycloalkanes	Aromatics	NSO's
Crude oil	30 (C ₁ -C ₆₀₊) ¹	50	15	5
Bunker C (No. 6 Fuel oil)	15 (C ₃₀₊)	45	25	15
Diesel (No. 2 Fuel oil)	30 (C ₁₂ -C ₂₅)	45	25	0
Kerosene	35 (C ₁₀ -C ₁₂)	50	15	0
Gasoline	50 (C ₅ -C ₁₀)	40	10	0

¹Figures in parentheses refer to the numbers of carbon atoms per molecule

Table 3. Annual worldwide inputs of petroleum hydrocarbons to the marine environment by source¹

Source	Estimated annual input (metric tons)	
	1973	1980
Land-based discharges		
Refineries	200,000	20,000
Waste oils, runoff, sewage	2,500,000	2,400,000
Marine operations		
Tankers, using LOT	310,000	200,000
Tankers, not using LOT	770,000	--
Drydocking	250,000	300,000
Bilge discharges	500,000	--
Marine Accidents	300,000	150,000
Offshore Production	80,000	200,000
Natural Oil Seeps	600,000	600,000
Atmospheric Fallout	600,000	600,000
TOTAL	6,100,000	4,470,000

¹Estimated by National Academy of Sciences, (1975)

Sources of Petroleum Hydrocarbon Pollution

According to Blumer et al., (1972), total world production of petroleum in 1970 was 2,200 million metric tons, of which 1,500 million metric tons were transported by tanker. By 1980, these values were estimated at 4,000 and 2,000 million metric tons, respectively. In contrast, the annual estimated petroleum hydrocarbon input to the marine environment for 1973 was 6.1 million metric tons (National Academy of Sciences, 1975), less than 0.3% of the 1970 world production figure.

An estimate of the amounts of petroleum hydrocarbons contributed to the marine environment by various sources is given in Table 3. Major inputs are from urban storm water runoff and sewage effluents, and from normal marine shipping operations. According to a report from the Washington State Department of Ecology (1973), waste automotive oils probably contributed more than half of the urban oil runoff from that state in 1971. In 1973, normal marine shipping operations contributed about 1.8 million metric tons of petroleum to the marine environment. Such operations are primarily associated with the cleaning of waste oils from cargo tanks and bilges and are expected to contribute much less oil contamination by 1980 due to elimination of tankers not using load-on-top (LOT) tank cleaning methods and to increasing adoption of land based bilge discharging.

Accidental oil spillage from ships amounted in 1973 to 300,000 metric tons, about 18% of that from normal ship operations, and about 5% of all petroleum hydrocarbons entering the oceans. The highly localized nature of such spills, however, may result in serious local pollution problems. Furthermore, such accidents most frequently occur within a short distance of shipping ports.

Petroleum contamination from offshore oil production facilities includes minor spills and discharge of oil field brines (about 20,000 metric tons) and major spills associated with well blowouts and pipeline ruptures (about 60,000 metric tons).

Natural oil seeps and atmospheric fallout represent the final two major contamination sources, each contributing about 10% of the total world petroleum hydrocarbon input to the marine environment.

FATE OF PETROLEUM IN THE MARINE ENVIRONMENT

As with any pollutant introduced to the marine environment, the ultimate biological and ecological effects of petroleum depend upon its fate in the system. The fate of spilled petroleum in the marine environment is dependent upon a variety of physical, chemical and biological processes. Although it may be possible to quantitate each of these processes to some extent, prediction of the fate of spilled petroleum is nevertheless extremely difficult because the relative effects of each of these processes differs from one oil to another and under different environmental conditions.

Physical Processes

Important physical processes include the spreading of petroleum in a surface slick, dissolution of the more soluble components of oil into the

water column, evaporation or aerosol injection of low boiling components into the atmosphere, emulsification of oil with water, agglomeration and sinking of oil, and the formation of tarballs.

Because of the lower specific gravity of oil compared with seawater, spilled oil usually accumulates at the air/water interface and quickly spreads over the surface of the water. The spreading of oil may initially be very rapid and depends largely on the forces of gravity and inertia and on viscosity (Fay, 1969). During later stages of spreading the balance between surface tension and viscosity becomes the controlling factor. Spreading usually stops well before the achievement of a monomolecular film. During the spreading process, rapid evaporation and dissolution of low molecular weight components of the oil tends to substantially increase the viscosity of the residual oil, thus impeding its further flow.

During the initial period of contact with water, oil slicks may be rapidly modified by dissolution of the more water soluble components into the seawater beneath the slick. Table 4 lists the reported water solubilities of a variety of the lower molecular weight petroleum hydrocarbons found in crude and refined oils. Several important relationships are: 1) solubility rapidly diminishes as carbon number and molecular weight increase, 2) solubility increases in the order straight and branched chain alkanes < cycloalkanes < aromatics, 3) branched chain compounds are more soluble than straight chain compounds of equal carbon number, 4) chain substitution on aromatic nuclei decreases water solubility, and 5) water solubility dramatically decreases in the sequence mononuclear > dinuclear > polynuclear aromatics. From these relationships it is obvious that one fate of spilled oil would be the relatively rapid elimination of simple aromatic compounds and to a lesser extent short chain n-alkanes and simple cycloalkanes into the water phase.

In general, the same compounds are also lost by evaporation and aerosol injection into the atmosphere. The rates of these processes are directly related to wind velocities, water temperatures and wave energies. Most hydrocarbons smaller than C_{15} will evaporate within 10 days, the lightest compounds within hours. Some evaporation of compounds in the C_{15} to C_{25} range will also occur, but larger hydrocarbons will remain in the slick (Smith and MacIntyre, 1971). About 30-50% of the hydrocarbons of a typical crude, 10% of a Bunker C, 70% of No. 2 fuel oil and 100% of gasoline and kerosine will ultimately evaporate from a slick (National Academy of Sciences, 1975).

Depending on the physical energy available for mixing, the specific gravity and viscosity of the oil, the presence of surfactant molecules (either in the oil itself or in the water) and other factors, the formation of oil/water emulsions may occur. These may be of two types: oil-in-water or water-in-oil emulsions. The former are far more common, are unstable and may be expected to increase the rate of dissolution and microbial degradation of the oil. Water-in-oil emulsions can be very stable and may significantly retard dispersion of the oil.

Oil may absorb in or adsorb to particulate matter in seawater. Particularly where adsorption is to sand or other dense material, the effect may be to transfer the oil rapidly to the sediments where it may be stabilized and retained for years (Vandermeulen and Gordon, 1976).

Table 4. Solubility of Petroleum Hydrocarbons in Water (adapted from Clark and MacLeod, 1977)¹

Compound	Carbon Number	Solubility (ppm)	Compound	Carbon Number	Solubility (ppm)
ALKANES			CYCLOALKANES		
Methane	1	24	Cyclopentane	5	156
Ethane	2	60	Cyclohexane	6	55
Propane	3	62	Cycloheptane	7	30
n-Butane	4	61	Cyclooctane	8	7.9
n-Pentane	5	39	AROMATICS		
n-Hexane	6	9.5	Benzene	6	1,780
2-Methylpentane	6	13.8	Toluene	7	515
3-Methylpentane	6	12.8	o-Xylene	8	175
2,2-Dimethylbutane	6	18.4	Ethylbenzene	8	152
n-Heptane	7	2.9	1,2,4-Trimethylbenzene	9	57
n-Octane	8	0.66	Naphthalene	10	31.3
n-Nonane	9	0.220	1-Methylnaphthalene	11	25.8
n-Decane	10	0.052	2-Ethyl naphthalene	12	8.00
n-Dodecane	12	0.0037	2,3-Dimethylnaphthalene	12	1.99
n-Tetradecane	14	0.0022	Biphenyl	12	7.45
n-Hexadecane	16	0.0009	Phenanthrene	14	1.07
			Anthracene	14	0.075
			Chrysene	18	0.002

¹Original data from: Eganhouse and Calder, (1976), McAuliffe, (1966, 1969), National Academy of Sciences, (1975) and Sutton and Calder, (1974).

Chemical Processes

Photochemical oxidation of petroleum hydrocarbons can be considerable and very rapid. Fregard and Hatchett, (1970) estimated that a slick 2.5 μm thick could be completely degraded in 100 hrs. of exposure to sunlight. Thus, photochemical decomposition alone might completely destroy a slick within a week, and working in concert with other factors such as evaporation, dissolution and microbial degradation, the disappearance of the slick could be much faster. Metals in the parent oil may act as catalysts to speed photochemical oxidation rates and sulfur compounds tend to serve as inhibitors (Parker et al, 1971). The formation of excess free radicals during the absorption of light tends to make the process autocatalytic.

Biodegradation

Biodegradation may result from microbial activity or from the action of macroorganisms. Microbial degradation is probably far more important in a quantitative sense. Microbial processes are predominantly aerobic and the rates depend on numerous environmental factors such as oxygen availability, temperature and oil/water surface area. Specific taxa of microorganisms tend to specialize on certain chemical components of petroleum (Walker et al, 1975; ZoBell, 1973). Degradation of alkanes, cycloalkanes and aromatic compounds all occur, but long chain alkanes, polynuclear aromatics and asphaltines are resistant to microbial degradation (Cundell and Traxler, 1973).

Biodegradation of petroleum hydrocarbons by macroorganisms may be significant to an individual organism as a way to speed elimination of the chemical from the body tissues, but it probably is of minor consequence in the degradation of or fate of spilled oil. Conover, (1971) however, reported that zooplankton may have processed up to 20% of the oil droplets resulting from the Bunker C fuel oil spill at Chedabucto, Nova Scotia. The ingested oil was eliminated in feces with a density greater than seawater and probably settled to the bottom sediments. Processing of significant quantities of emulsified oil by plankton has been suggested by others also (Parker et al, 1971).

Petroleum Hydrocarbon Levels in the Marine Environment

Clark and MacLeod, (1977) have recently published an extensive compilation of reported petroleum hydrocarbon levels in the marine environment. Extreme ranges are reported for hydrocarbons in water, sediments, and organisms. Generally, however, seawater from uncontaminated regions contains only a few parts per billion (ppb) hydrocarbons, or less, while in polluted areas the concentrations may be 100 times those values. Unpolluted sediments contain from a few parts per million (ppm) in the deep ocean up to 70 ppm in coastal areas. Polluted sediments may contain hydrocarbons in the range of 100 to 12,000 ppm. Hydrocarbons from organisms collected in unpolluted areas may contain 0.1 to 10 ppm while organisms from polluted regions may contain 10-100 times these levels.

BIOLOGICAL EFFECTS

The biological effects of petroleum can be broadly characterized as being due to gross physical effects (e.g., smothering of organisms), or toxicity due to the absorption by organisms of certain chemical components of oil. The direct physical effects are most commonly associated with major oil spills, resulting from tanker accidents, or oil well blowouts. Organisms massively coated with oil are frequently unable to carry out normal respiratory functions, feeding processes, or locomotion. Of course, organisms so exposed undoubtedly also absorb large quantities of hydrocarbons which may have direct toxic effects. The usual effect of such direct exposure to oil is widespread mortality of the impacted organisms.

The more subtle, and perhaps more widespread, effects of oil are those involving chronic exposure to petroleum hydrocarbons by organisms living in the vicinity of oil terminals, municipal outfalls, shipping lanes, and other areas of continual oil inputs to marine waters. In such areas, lethal and sublethal effects follow the absorption of toxic doses of the dissolved chemical components from oil.

Bioaccumulation and Biotransformation of Petroleum Hydrocarbons

Numerous studies have been carried out under laboratory conditions aimed at characterizing the rates of uptake and depuration of petroleum hydrocarbons by a variety of marine organisms (Varanasi and Malins, 1977). Comparisons between studies are often difficult due to the variety of exposure conditions used by different investigators. As a general conclusion, however, the rates of uptake of hydrocarbons from seawater, and also their rates of depuration, are fairly rapid in most forms studied. An experiment by Neff et al, (1976a) utilizing the oyster, *Crassostrea virginica*, clearly illustrates this result (Table 5).

The concentration of total petroleum hydrocarbons in oysters exposed for only 8 hrs to dispersed No. 2 fuel oil increased from a background level of only 2.4 $\mu\text{g/g}$ to 312 $\mu\text{g/g}$. Depuration was extremely rapid during the first few hours following transfer to clean seawater, and by the end of the first 24 hours, total hydrocarbon levels had been reduced to only 67 $\mu\text{g/g}$. Further depuration was relatively slow. Neff's experiment also illustrates another frequent observation, namely that the aromatic hydrocarbons tend to be more tenaciously retained by organisms than the n-alkanes.

In agreement with the relatively rapid exchange rates of absorbed hydrocarbons, bioaccumulation factors are also relatively low; usually no more than two orders of magnitude. For individual compounds the bioconcentration factors tend also to be directly related to the lipid solubility of the compound (Neff et al, 1976a).

Our understanding of the abilities of marine organisms to metabolize ingested or absorbed hydrocarbons is rapidly increasing. The generally accepted view is that metabolism involves the activity of the microsomal mixed function oxidases and various conjugating enzyme systems (Varanasi and Malins, 1977). The polar metabolites thus formed may be more readily excreted by the organisms than the parent compounds. Although metabolism of hydrocarbons may be considered as potentially beneficial, since elimination of these pollutants may

Table 5. Uptake and depuration of hydrocarbons from No. 2 fuel oil by the oyster, *Crassostrea virginica* (adapted from Neff et al, 1976a).

Time (hr)	Tissue hydrocarbon concentration ($\mu\text{g/g}$, wet weight)						
	n-p	N	1-MN	2-MN	DMN	TMN	Total
Exposure							
0	-	0.2	0.1	0.3	1.0	0.8	2.4
8	235	14.7	8.7	15.0	21.8	9.1	312
Depuration							
3	156	12.0	8.4	12.0	22.7	10.8	228
6	68	7.3	5.1	7.3	13.2	5.7	109
24	18	6.5	5.7	7.6	14.8	9.5	67
120	10	8.2	4.7	6.8	13.4	4.9	54
672	-	-	-	0.1	0.5	0.9	1.5

Abbreviations used: n-p, n-paraffins; N, naphthalene; 1-MN, 1-methylnaphthalene; 2-MN, 2-methylnaphthalene; DMN, dimethylnaphthalene; TMN, trimethylnaphthalene.

then be enhanced, there is also concern that the oxygenated products of some of these reactions may be more toxic than the parent compounds and potential carcinogens.

Studies by Payne, (1977) and others (Burns, 1976a; Lee et al, 1972a) show that marine fishes generally possess the capability to transform hydrocarbons. In the Crustacea, some species possess hydrocarbon metabolizing abilities, while others do not (Burns, 1976b; Corner et al, 1973; Payne, 1977). Most molluscs studied appear to lack mixed function oxidase activity (Lee et al, 1972b; Payne, 1977) as do macroalgae (Payne, 1977). The mixed function oxidases may be induced by hydrocarbon exposure (Payne and Penrose, 1975) and this may lead to synergism with other pollutants.

Acute Toxicity

Acute toxicity studies with petroleum hydrocarbons have been valuable in several regards. They have provided for comparisons of the toxicities of different crude and refined oils and of various components in oils. Other studies have provided useful comparisons of the relative sensitivities of species and phyla, and life stages of individual species.

Toxicity studies with oil are fraught with technical difficulties compared with studies with other toxic chemicals. The difficulties stem largely from the water insolubility of most of the components in crude and refined oils, and also from the chemical dissimilarities of different oils. Early studies of the toxicities of oils are largely useless since the exposure conditions were not rigorously defined. Data were often reported as the concentration of oil added to seawater. Most of the added oil remained at the surface and no attempt was made to measure the soluble components to which the organisms were directly exposed.

Recent studies have generally employed two kinds of exposures. In one, oil is vigorously mixed with water and then allowed to separate for periods of one to several hours. The aqueous phase, which contains considerable oil in the form of very fine droplets, is then removed from beneath the oil surface for toxicity testing. Such a system is referred to as an oil-in-water dispersion (OWD). Another approach involves the careful layering of a small amount of oil, usually 1 to 10% by volume, on the water surface followed by a standardized period (often approximately 20 hours) of very gentle stirring. During this period the most soluble components of oil pass into solution in the seawater. Following the stirring period, the mixture is allowed to stand for several more hours and the aqueous phase is then siphoned or drawn from the bottom. This preparation is referred to as a water soluble fraction (WSF).

Comparisons of the toxicities of WSF's and OWD's using a variety of species and oils (Anderson et al, 1974a; Rice et al, 1976) have led to the conclusion that most of the toxicity in the OWD's is attributable to the dissolved components rather than the larger amount of oil still in emulsion or particulate form (Rice et al, 1977a).

The WSF's prepared from different oils also differ in toxicity (Anderson et al, 1974a). WSF's of No. 2 fuel oil are usually more toxic than WSF's of crudes which in turn are more toxic than WSF's prepared from Bunker C fuel oil. Table 6 compares the reported chemical composition of water soluble

Table 6. Hydrocarbon content of water-soluble fractions of four test oils
(adapted from Anderson et al, 1974a).

Compound	Hydrocarbon content of water-soluble fraction (ppm)			
	S. Louisiana crude oil	Kuwait crude oil	No. 2 fuel oil	Bunker C residual oil
Alkanes				
Ethane	0.54	0.23	-	-
Propane	3.01	3.30	-	-
Butane	2.36	3.66	-	-
Isobutane	1.69	0.90	0.39	0.05
Pentane	0.49	1.31	-	-
Isopentane	0.70	0.98	-	-
Cyclopentane + 2-methylpentane	0.38	0.59	0.02	0.005
Methylcyclopentane	0.23	0.19	0.019	0.004
Hexane	0.09	0.29	0.014	0.004
Methylcyclohexane	0.22	0.08	0.03	0.002
Heptane	0.06	0.09	0.02	0.004
C ₁₆ n-Paraffin	0.012	0.0006	0.008	0.0012
C ₁₇ n-Paraffin	0.009	0.0008	0.006	0.0019
Total C ₁₂ -C ₂₄ n-paraffins	0.089	0.004	0.047	0.012
Aromatics				
Benzene	6.75	3.36	0.55	0.04
Toluene	4.13	3.62	1.04	0.08
Ethylbenzene + m-, p-xylenes	1.56	1.58	0.95	0.09
o-Xylene	0.40	0.67	0.32	0.03
Trimethylbenzenes	0.76	0.73	0.97	0.11
Naphthalene	0.12	0.02	0.84	0.21
1-Methylnaphthalene	0.06	0.02	0.34	0.19
2-Methylnaphthalene	0.05	0.008	0.48	0.20
Dimethylnaphthalenes	0.06	0.02	0.24	0.20
Trimethylnaphthalenes	0.008	0.003	0.03	0.10
Biphenyl	0.001	0.001	0.011	0.001
Methylbiphenyls	0.001	0.001	0.014	0.001
Dimethylbiphenyls	0.001	0.001	0.003	0.001
Fluorene	0.001	0.001	0.009	0.005
Methylfluorenes	0.001	0.001	0.009	0.004
Dimethylfluorenes	0.001	0.001	0.002	0.002
Dibenzothiophene	0.001	0.001	0.004	0.001
Phenanthrene	0.001	0.001	0.010	0.009
Methylphenanthrenes	0.002	0.001	0.007	0.011
Dimethylphenanthrenes	0.001	0.001	0.003	0.003
Total saturates	9.86	11.62	0.54	0.081
Total aromatics	13.90	10.03	5.74	1.28
Total dissolved hydrocarbons measured	23.76	21.65	6.28	1.36

fractions prepared from four such oils; two crudes, No. 2 fuel oil and Bunker C fuel oil. It is clear that the differences in toxicity reflect the differing compositions of the WSF's which depend, in turn, upon the original composition of the parent oils. The high toxicity of No. 2 fuel oil WSF's is presumably due to the high concentrations of dicyclic and polycyclic aromatic compounds in those preparations, since they contain lower levels of total dissolved hydrocarbons and total dissolved aromatics. In studies with the polychaete, *Neanthes arenaceodentata*, Rossi et al, (1976) reported that worms exposed to WSF's of No. 2 fuel oil accumulated about twice the concentration of total aromatics in their tissues as did worms exposed to Southern Louisiana crude oil. The hydrocarbons in the No. 2 fuel oil exposed worms were largely in the form of the methyl-substituted naphthalenes whereas worms exposed to the crude oil WSF had lower levels of these components and a higher level of methylated benzenes.

Several recent studies have compared the relative toxicity of the individual aromatic components found in WSF's. Table 7 adapted from Rice et al, (1977a), summarizes these results. Two relationships are clear: 1) toxicity increases in proportion to the number of benzene rings; and 2) toxicity (in both benzene and naphthalene families of aromatics) increases as a function of degree of alkyl substitution of the aromatic nuclei. The high toxicities of naphthalene and methyl-substituted naphthalenes clearly account for the higher toxicities of No. 2 fuel oil WSF's which have elevated levels of these components relative to the monoaromatics. However, WSF's of crude oils typically have higher concentrations of monoaromatics than diaromatics and as a result of the inverse relationship between concentration and toxicity, Caldwell et al, (1977) estimated that all of these components contributed about equally to the toxicity of a Cook Inlet crude oil WSF.

Where similar oil WSF' have been employed in toxicity tests, comparisons between large numbers of species representing several phyla have probably been most notable for the lack of differences observed in the sensitivity of the organisms (Rice et al, 1977a; Anderson, 1977). Toxic concentrations of total hydrocarbons in acute, partial chronic and chronic studies all fall within the range of about 0.1 to 20 ppm and predominantly in the 0.8 to 5 ppm range. In addition, the differences in toxicity that have been noted in comparisons of different life stages of single species have also been modest. As is found for other kinds of toxic chemicals, the sensitivity of larval and juvenile stages is usually greater than that of adults, and eggs tend to be the most resistant. In at least one instance (Rossi and Anderson, 1976), juveniles of *Neanthes arenaceodentata* were slightly less sensitive to oil WSF' than were the adults.

Chronic Toxicity and Sublethal Effects

Organisms surviving a single short term exposure to dissolved hydrocarbons in water are likely to recover quickly due to the rapidity with which depuration occurs, and this response is often seen in laboratory experiments. However, there are a number of natural circumstances in which oil exposure may be very prolonged. For example, chronic oil contamination may occur in the vicinity of municipal ocean outfalls, near oil refineries or in heavily used shipping lanes---not to mention that due to natural oil seeps. Also massive oil spills often result in the trapping of large quantities of oil in benthic sediments. Such oil often retains an unweathered character and gradually and continually seeps into the overlying water (Vandermeulen and Gordon, 1976).

Table 7. Comparative toxicity of different aromatic hydrocarbons, expressed as 96-hr LC50's with concentrations in ppm (Tabulated by Rice *et al*, 1977a).

AROMATIC HYDROCARBONS	96-hr LC50's in ppm				
	POLYCHAETE ¹	SHRIMP ²	CRAB LARVAE ³	SHRIMP ⁴	BASS ⁵
Benzene	--	27	108	20	5.8-10.9
Toluene	--	9.5	28	4.3	7.3
Ethyl benzene	--	--	13	0.5	4.3
Tri-methyl benzene	--	5.4	5.1	--	--
Xylene	--	7.4	--	--	--
m-	--	--	12	3.7	9.2
o-	--	--	6	1.3	11.0
p-	--	--	--	2.0	2.0
Naphthalene	3.8	2.4	> 2		
Methyl naphthalene	--	1.1	1.6		
Di-methyl naphthalene	2.6	0.7	0.60		
Tri-methyl naphthalene	2	--	--		
Phenanthrene	0.6	--	--		
Methyl phenanthrene	0.3	--	--		
Fluorene	1	--	--		
Fluoranthrene	0.5	--	--		

¹Neff *et al*, (1976b). *Neanthes arenaceodentata*

²Neff *et al*, (1976b). *Palaemonetes pugio*

³Caldwell *et al*, (1977). *Cancer magister*, Stage 1 larvae

⁴Benville and Korn, (1977). *Crago franciscorum*

⁵Benville and Korn, (1977). *Morone saxatilis*

Information about the sublethal effects of petroleum hydrocarbons during long-term or repetitive exposures is required to completely understand and predict the biological effects in such areas.

Delayed lethality is one effect that may occur as a result of long-term exposure to concentrations of petroleum which are acutely sublethal. There are a number of reasons for such a response. Normal physiological, homeostatic mechanisms may be functioning at low efficiency in chronically exposed organisms, and what would usually be considered a sublethal environmental stress, e.g., a temperature or salinity fluctuation, may not be tolerated. Also, compounds with very high bioaccumulation potential may continue to accumulate from an acute sublethal water concentration over a long period of time until the lethal body burden is eventually exceeded. This latter possibility is not likely to be a significant problem for the petroleum hydrocarbons found in seawater, however, as these compounds do not greatly bioaccumulate and tissue equalibria are usually rapidly achieved (Neff et al, 1976a).

Delayed lethality may also occur if certain discontinuous developmental processes are especially sensitive. Caldwell et al, (1977) found that many first stage zoeae of the crab, *Cancer magister*, survived approximately 1 mg/l of dissolved benzene until the 10th day of culture and then deaths of most of the remaining larvae occurred within 1-3 days. This period coincided with the time of molting in control cultures and it was assumed that the molting process was in some way affected.

As a general rule, where mortalities during long-term exposures to petroleum hydrocarbons have been studied, delayed lethality occurs only if the hydrocarbon concentrations are within approximately one order of magnitude of acutely toxic concentrations. Such a response is expected for toxic compounds with low bioaccumulation potential.

Numerous workers have studied the effects of petroleum exposure on respiration (Anderson, 1977). Alteration of respiration rates usually occurs only when the oil exposures are at least one-tenth of the acutely toxic levels (Anderson et al, 1974a; Rice et al, 1977b). The exact response is usually not predictable. In some instances stimulation occurs; in others, respiratory depression is seen. Respiratory depression is, however, the response usually observed at higher toxicant concentrations.

Osmotic and ionic regulation in oil exposed organisms has received only limited study (Anderson et al, 1974b), but the available evidence suggests that this physiological response is not very sensitive to petroleum hydrocarbon exposure.

Very little has been done to investigate biochemical perturbations due to oil exposure. Caldwell et al, (1978) have postulated that toxic chemicals, including petroleum, which are known to induce the mixed function oxidases (MFO) may also modify other biochemical functions of the microsomes where an interaction between these functions and the MFO system exists. One such interaction may involve the microsomal fatty acid desaturases, but experimental evidence is still required.

Algal photosynthetic rates have been shown to be affected by petroleum hydrocarbon concentrations as low as 5 ppb (Parker, 1974). This concentration

is well below levels that normally impede growth and division of algae and phytoplankton (Anderson et al, 1974b; Mironov, 1970).

Behavioral effects of petroleum hydrocarbon exposure may be among the most significant. These may include altered patterns of locomotion, reproduction, habitat selection, and feeding activities. Johnson, (1977) has pointed out that the most sensitive behavioral effects are usually those in which the behavior is initiated by an organism's recognition of exogenous chemical cues. Hydrocarbon concentrations in the range of 1-10 ppb blocked normal chemoreceptive feeding behaviors in crab and snails (Jacobson and Boylan, 1973; Takashi and Kittredge, 1973). Benzene inhibits chemotaxis in marine bacteria at 100 ppb (Walsh and Mitchell, 1973). The available evidence indicates that fish behavior may be substantially less sensitive to hydrocarbon exposures than that of invertebrates and microbes (Patten, 1977).

There is still little available information on the effects of petroleum on growth, development and reproduction of marine organisms, perhaps reflecting the great technical difficulty of conducting chronic studies with these materials. Cox and Anderson, (1973) reported no effects on molting frequency or growth of young brown shrimp (*Penaeus aztecus*) during 6 weeks exposure to 0.97 ppm of the WSF of No. 2 fuel oil. Caldwell et al, (1977) found that stage duration (time between molts) and size of larvae of *C. magister* were not especially affected even at near lethal concentrations of benzene (1.1 to 1.2 ppm) during long-term exposures. However, naphthalene (0.13 ppm) and Cook Inlet crude oil WSF (0.22 ppm as total dissolved aromatics) resulted in an increased duration of larval stages.

Various reproductive functions of amphipods may be affected by low levels of petroleum hydrocarbons. Linden (1976a, 1976b) showed that precopulatory behavior, fecundity and larval growth rates were all affected at sublethal levels---unfortunately the hydrocarbon concentrations of the water fraction (OWD) were usually not reported. The oil concentration (measured by infrared spectrophotometry) affecting fecundity was reported to be 0.3-0.4 ppm.

One of the lowest concentrations affecting reproduction is that reported by Steele, (1977) for the complete inhibition of fertilization of eggs of the macroalga, *Fucus edentatus*. Inhibition occurred at only 0.2 ppb of no. 2 fuel oil.

Clearly a substantial amount of additional work is required on the sublethal and chronic effects of petroleum on marine organisms. However, it is possible to make the following generalizations: 1) that many sublethal effects occur at concentrations about one order of magnitude below acutely lethal levels; and 2) that some effects, particularly those involving larval and early developmental stages or chemosensory response, may occur at concentrations as low as 3 orders of magnitude below acutely toxic levels (i.e. in the ppb range). Future research should focus on these latter areas.

Effects on Populations, Communities and Ecosystems

Our ultimate concern about oil pollution pertains to its possible effects on biological populations and communities. The deaths of a few organisms, more or less, is of little consequence, but a substantial decline in the population of several species, could have severe effects on the composition and functioning of whole communities.

Our knowledge of these effects and our ability to accurately predict them is still very limited. It is based largely on community studies following a spill event, but unfortunately adequate knowledge of the "normal" situation before the spill is usually lacking. Furthermore, the complexity of possible effects is enormous. For example, the fate of an oil spilled in a tropical area would be considerably different than if it were spilled in cold, temperate, or arctic regions. The degrading organisms differ, the physical and chemical factors of the environment which influence fate differ, the organisms that would be affected, and their ecological relationships to one another, differ, and so on. Even at one geographic location numerous variables could be anticipated: season and weather conditions, including direction of prevailing winds; microhabitats impacted, whether marsh, sand beach or rocky intertidal; type and quantity of oil spilled, etc.

To date, there has been no strong evidence of major damage to plankton communities resulting from an oil spill. Such an event is unlikely because: 1) plankton populations typically cover large areas and are characterized by rapid regeneration rates; and 2) the soluble components of oil which enter the water column disperse or evaporate readily, and do not long remain at toxic concentrations.

Effects on the benthos may be severe and, in some cases, persistent following spill incidents. The problems differ for different microhabitat or microgeographic areas. Massive mortalities of the intertidal biota have been documented in the Tampico Maru (North et al, 1965) and West Falmouth (Blumer et al, 1971) incidents. In both instances, a highly toxic light fuel oil was involved. Depending on the degree of exposure to waves and wind, the contaminating oil may be fairly rapidly dispersed or weathered to non-toxic residues. Often, however, the community is slow to recover, passing through distinct successional stages involving; 1) algal blooms prior to herbivore recovery, and 2) herbivore overabundance due to high food availability and absence of normal predator populations. The latter organisms may require many years to approach their normal population densities and age structures.

Marshes and subtidal regions may be severely affected for many years. These are often low energy areas favoring persistence of the spilled oil even in warmer climates. It is now well known that oil has frequently accumulated in subtidal sediments following spills (Blumer et al, 1971; Vandermeulen and Gordon, 1976) and evidence is accumulating that these areas may often experience long-term damage (Michael, 1977). Some important observations from such areas are: 1) that sediment trapped oil may retain its original chemical characteristics for long periods, and may gradually seep toxic chemicals back into the surface sediments and water column; and 2) that such regions are to be characterized by altered community components due to replacement of normal dominant fauna by opportunistic species, such as the polychaete *Capitella capitata* (Grassle and Grassle, 1974; Michael et al, 1975).

The evidence for major damage to economic species from oil spill is generally lacking and indeed these species, especially finfish which may have widely dispersed populations, may not usually be affected. However, the potential for damage exists as demonstrated recently by Dow and Hurst, (1976). These workers documented population declines of the softshell clam, *Mya arenaria*, following a fuel oil spill in Maine. Mortality was highest immediately following the spill, but continued to occur for three years with the initial population

size being reduced by 86% during that period. Since another 5 to 6 years would be required for young clams to achieve marketable size, the economic impact of such an incident could be substantial.

CONCLUSIONS

Petroleum hydrocarbons represent significant marine pollutants whether derived from massive spills or from low level chronic inputs. Although advancing technologies and more stringent environmental controls should check the growth of this problem, the continuing dependence of society on petroleum and petroleum products will ensure that it will remain with us in its present form for many more decades.

Assessments of the fate and biological impacts of petroleum in the marine environment are complicated by the chemical complexities of oils and refined products and the sometimes considerable differences between them. However, two general conclusions may be drawn. One of these is that petroleum hydrocarbons, unlike certain synthetic organic compounds such as the chlorinated hydrocarbons, are usually readily degraded by chemical and biological processes, and, therefore, are not readily concentrated in the marine environment or in biological compartments. The second is that petroleum hydrocarbons tend to be only moderately toxic and, as a result, the effects on organisms will usually be restricted to the locations of major spills or moderately high level chronic inputs. Future research concerned with the biological effects of petroleum in the marine environment should focus on areas that represent exceptions to the above generalities. One of these concerns the fate of oil stranded in marine sediments. Current information suggests that such oil is largely protected from the normal chemical and biological degradation mechanisms and provides a continuing source of toxic petroleum hydrocarbons to communities of benthic organisms.

Another problem requiring further study pertains to the possible high sensitivity of certain physiological processes to petroleum hydrocarbons. In particular, chemosensory processes may be impaired by concentrations of hydrocarbons in the parts per billion range. Chemoreception is extremely important to aquatic organisms in a variety of ways which involve the orientation of organisms to various components of their physical and biological environment. Finally, there is a continuing need to integrate our knowledge of physical and chemical processes and the effects on individual organisms to achieve a more complete understanding of the impact of oil contamination on the structure and dynamics of marine biological communities.

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Federal Legislation for the Control of Hazardous/Toxic Substances

INTRODUCTION

In previous seminars given in this series, many of the speakers alluded to Federal Legislative Acts for the control of hazardous/toxic substances. It is the goal of this seminar to present a summary of the various Federal Legislative Acts that impact on controlling hazardous/toxic substances through either policy, planning or regulatory actions.

The various Legislative Acts of which there are 28 general actions have been divided into six medias as presented in the Tabulation following the next section of this report.

In the food media, there are numerous acts relating to FDA and FSQS of the Department of Agriculture. These various Acts are grouped into those relating to FDA and to FSQS. In addition, in the multi-media category the IRLG via the Economy Act and Federal Common Law of Nuisance are not Federal Legislative Acts per se but are included in this report because of the significance of these two modes of possible regulation.

For this seminar series hazardous/toxic substances do not include the items such as alcohol, fire arms, automobiles, etc. The summary is limited primarily to those substances that are primarily man-made and are introduced into the environment.

SYNOPSIS PRESENTATION

For each of the Acts, the following data are presented:

Act
Official Title and Date
Purpose of Act(s)
Primary Responsible Federal Organization(s)
Media(s) Covered
Pertinent Sections of Act(s) Related to
Hazardous/Toxic Substances

For some of the acts additional information is also included in the summary.

TABULATION OF FEDERAL LEGISLATIVE ACTS BY ENVIRONMENTAL MEDIA FOR
CONTROLLING TOXIC/HAZARDOUS SUBSTANCE(S)

I. Multi-Media

- A. National Environmental Policy Act
- B. Toxic Substance Control Act
- C. Occupational Safety and Health Act
- D. IRLG via Economy Act
- E. Consumer Product Safety Commission
- F. Atomic Energy
- G. Federal Common Law of Nuisance

II. Air

- A. Clean Air
- B. Energy Supply and Environmental Coordination

III. Water

- A. Clean Water
- B. Fishery Conservation and Management
- C. Safe Drinking Water
- D. Water Resources Development
- E. Ocean Dumping
- F. Ports and Waterways Safety
- G. Deepwater Port
- H. Outer Continental Shelf Lands
- I. River and Harbor and Flood Control

IV. Land

- A. Resource Conservation and Recovery
- B. Federal Environmental Pesticide Control
- C. Hazardous Materials Transportation
- D. Surface Mining Control and Reclamation
- E. Soil and Water Resources Conservation

V. Noise

- A. Noise
- B. Federal Aviation Act
- C. Airport and Airways Development

VI. Food

- A. Food, Drug and Cosmetic
- B. Acts Relating to FSQS

ACT

NATIONAL ENVIRONMENTAL POLICY

OFFICIAL TITLE
AND DATE

National Environmental Policy Act of 1969
Public Law 91-190
January, 1970

As Amended by
Public Law 94-83
August 1975

PURPOSE OF ACT

To establish a national policy for the environment, to provide for the establishment of a Council on Environmental Quality, and for other purposes.

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION

Council on Environmental Quality

MEDIA(S) COVERED

Man and his environment

PERTINENT SECTIONS
OF ACT RELATED TO
HAZARDOUS/TOXIC
POLLUTANTS
(All sections are
related with the major
sections indicated)

Section 101
 ° Declaration of National Environmental
 Policy

Section 102 (s)
 ° Environmental Impact Statements

Section 201, 202, 203, 204, 206, and 207
 ° Council on Environmental Quality

ACT

TOXIC SUBSTANCE CONTROL

OFFICIAL TITLE
AND DATE

Toxic Substance Control Act
Public Law 94-469
October 1976

PURPOSE OF ACT

To regulate commerce and protect human health and the environment by requiring testing and necessary use restrictions of certain chemical substances, and other purposes.

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

U. S. Environmental Protection Agency

MEDIA(S) COVERED

Regulations may prohibit or limit the manufacture, processing, distribution in commerce, commercial use and/or disposal of a chemical substance or mixture.

Chemical substance means any organic or inorganic substance of a particular molecular identity.

Mixture means a combination of chemical substances that is not a result of a chemical reaction.

Excluded are pesticides, food, drugs, cosmetics, tobacco, liquor, and several other compounds regulated by other federal laws.

PERTINENT SECTIONS
OF ACT RELATED TO
HAZARDOUS/TOXIC
SUBSTANCES
(All sections are
related with the major
section as indicated)

Section 3
 ° Definitions

Section 4
 ° Testing of Chemical Substance and Mixtures

Section 5
 ° Manufacturing and Processing Notices

Section 6
 ° Regulation of Hazardous Chemical Substances and Mixtures

Section 7

- ° Imminent Hazards

Section 8

- ° Reporting and Retention of Information

ACT

OCCUPATIONAL SAFETY AND HEALTH ACT

OFFICIAL TITLE
AND DATE

Occupational Safety and Health Act of 1970
Public Law 91-596
December 1970

PURPOSE OF
ACT

To assure safe and healthful conditions for
working men and women - - -.

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATIONS(S)

Occupational Safety and Health Administration
Department of Labor

National Institute for Occupational Safety
and Health
Department of Health, Education and Welfare

MEDIA(S) COVERED

Standards which requires conditions or the
adoption or use of one or more practices,
means, methods, operations, or processes,
reasonably necessary or appropriate to pro-
vide safe or healthful employment and places
of employment.

PERTINENT SECTIONS
OF ACT RELATED TO
HAZARDOUS/TOXIC
SUBSTANCES

Section 6

- ° Occupational Safety and Health
Standard Subsection (a) (5)
Toxic Materials

Section 8

- ° Inspections, Investigations, and
Record-keeping

Section 13

- ° Procedures to Counteract Imminent
Danger

Section 20

- ° Research and Related Activities
Subsection (a) (5)
Toxic substance records
Subsection (a) (6)
Toxic substance publications
Subsection (a) (&
Annual chronic studies

Section 22

- ° National Institute for Occupational
Safety and Health

ACT/AGREEMENT

IRLG VIA ECONOMY ACT

OFFICIAL TITLE
AND DATE

Interagency Agreement on Regulation of
Toxic and Hazardous Substances

October 11, 1977

PURPOSE OF
ACT/AGREEMENT

"To make most efficient use of resources,
achieve consistent regulatory policy, and
improve the protection of public health
and environment."

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

U. S. Environmental Protection Agency

Occupational Safety and Health Administration
Department of Labor
Consumer Product Safety Commission
Food and Drug Administration
Department of Health, Education and Welfare

MEDIA(S) COVERED

Those activities related to regulation of
toxic and hazardous substances by the four
agencies.

PERTINENT SECTIONS OF THE
AGREEMENT RELATED TO
HAZARDOUS/TOXIC SUBSTANCE(S)

1. Testing protocols, criteria for interpretations, quality assurance procedures, and other policies relating to the testing of toxic and hazardous substances;
2. Epidemiological practices and procedures;
3. Approaches to the assessment of risk presented by a toxic or hazardous substance and to the estimation of benefits associated with a substance;
4. Methods of obtaining, analyzing, storing, and exchanging information which might be of mutual interest;
5. Research and development policies, possibly including methods of sharing costs and facilities;
6. Regulations and regulatory development activities where a hazard can be most effectively controlled by joint participation or by use of the statutory

authorities of more than one agency,
e.g., joint public hearings or rule-
making actions;

7. Compliance and enforcement procedures
and policies.
8. Public communication and education pro-
grams and informational services to in-
dustry;
9. Other activities as may be applicable.

ACT

CONSUMER PRODUCT SAFETY COMMISSION

OFFICIAL TITLE
AND DATE

Consumer Product Safety Commission
Improvement Act of 1976
Public Law 94-284
May 1976

Amending:

Poison Prevention Packing Act of 1970

Consumer Product Safety Act

Federal Hazardous Substance Act

Flammable Fabrics Act

PURPOSE OF
ACT

To protect consumers against unreasonable injury from hazardous products, and for other purposes.

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION

Consumer Product Safety Commission

MEDIA(S) COVERED

"Consumer product" means any article, or component part thereof produced or distributed (i.e.-for sale to a consumer for use in or around a permanent or temporary household or residence, a school, in recreation, or otherwise, or (i.e.) for presumed use, consumption, or enjoyment of a consumer in or around a permanent or temporary household or residence, a school, in recreation, or otherwise

Excludes:

- ° Tobacco and tobacco products
- ° Food, drugs, devices, and cosmetics regulated by FDA
- ° Pesticides regulated by EPA
- ° Motor vehicles
- ° Aircraft
- ° Boats

PERTINENT SECTIONS
OF ACT RELATED TO
HAZARDOUS/TOXIC
SUBSTANCES

Section 7

- ° Consumer Product Safety Standards

Section 8

- ° Banned Hazardous Products

Section 12

- ° Imminent Hazards
- ° Substantial Product Hazard

Section 13

- ° New Products

Section 14

- ° Product Certification and Labeling

CONSUMER PRODUCT COMMISSION AGREES ON CANCER
POLICY:

The Consumer Product Safety Commission, on April 27, 1978, has tentatively agreed to a cancer policy covering carcinogens to which the public may be exposed in various products.

The CPSC policy would focus on four categories of substances:

- ° Category A: "potential carcinogens," including substances for which there are positive replicated long-term animal studies or one unreplicated long-term test, plus two different types of short-term tests. In this category would fall the most hazardous substances and the Commission's actions could result in either bans or lowest possible levels of exposure.
- ° Category B: "suspect carcinogens," including those with one positive short-term test or one unreplicated animal test. They would be subjected to further testing and possible labeling or recordkeeping rules.
- ° Category C: "questionable substances," including those in a class of substances which include many known carcinogens but which may not reach the public. They would

be subject to further testing, requests for more information.

- ° Category D: substances with negative test results, but which would require possible monitoring and data collection.

If carcinogens are capable of getting into the human system, CPSC will require that the use of such carcinogens be phased out in favor of "reasonable substitutes: where they exist, under the policy.

- ° TRIS

The CPSC took action April 1077 to ban TRIS (2,3-dibromoprophyl phosphate) as a flame retardant in children's clothing.

ACT

ATOMIC ENERGY

OFFICIAL TITLE
AND DATE

Atomic Energy Act of 1954
Public Law 83-703
1954

As Amended by
Energy Reorganization Act of 1974
Public Law 93-438
October, 1974

PURPOSE OF ACT

Related to Standards for Protection Against
Radiation

"Make every reasonable effort to maintain
radiation exposures, and releases of radio-
active materials in effluents to unrestricted
areas, as low as is reasonably achievable."

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

Nuclear Regulatory Commission
Department of Energy
U. S. Environmental Protection Agency
Department of Transportation

MEDIA(S) COVERED

Regulations apply to all persons who receive,
possess, use, or transfer material including
persons licensed to operate a production or
utilization facility.

PERTINENT SECTIONS
OF ACT RELATED
TO HAZARDOUS/TOXIC
SUBSTANCE

Reference is made to

- ° Title 10 - Chapter 2
Code of Federal Regulation
for
Rules and Regulations
of the
United States Regulatory Commission
- ° Part 20
Standards for Protection Against
Radiation

Maximum Permissible Concentrations (MPC)

- ° International Commission on Radiation
Protection has established MPC's for
the United Nations.

- ° National Committee for Radiation Protection and Measurements has established MPC's for the USA.
- ° MPC's in the human body and in air and water are listed in "National Bureau of Standards Handbook No. 52" (1953)
- ° MPC's concerning allowable internal exposure for radiation workers and general population are listed in "National Bureau of Standards Handbook, No. 59" (1957)
- ° MPC's concentrations in air and water above natural background
CRC, Title 10, Revised Jan. 1, 1977.
 - ° Permissible quantities of radioactive material, CRC, Title 10, Revised Jan. 1, 1977.
 - ° In June 1975, EPA issued proposed environmental radiation exposures limits that were generally twenty times more restrictive than previous standards.

Emission Controls

- ° Control of disposal of radioactive material is a responsibility of the NRC.
- ° EPA also has authority under:
 - (1) Section 120 of the Clean Air Act
 - (2) Section 101 of the Ocean Dumping Act
- ° A 1972 international agreement to which the U. S. is a signatory prohibits the dumping of high-level waste at sea.

Other radioactive waste require a permit.

- ° Since 1967, eight European countries have dumped solidified low-level radioactive waste packaged in 55 gallon drums into a deep trench in the Northeast Atlantic. The dumping is supervised by the Nuclear Energy Agency of the Organization for Economic Cooperation and Development.
- ° NRC is considering ocean burial of waste in the central North Pacific in testimony presented at Congressional Hearing May 16, 1978.

ACT/LAW

FEDERAL COMMON LAW OF NUISANCE

OFFICIAL TITLE
AND DATE

Traditional, non-statutory Federal Common
Law of Nuisance

PURPOSES OF LAW

Relief for those claiming injury

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

U. S. Courts

MEDIA(S) COVERED

Intrastate Nuisances

ADDITIONAL DATA

Milwaukee Water Pollution Case

- ° Judge John F. Grady ruled on July 29, 1977 in U. S. District Court, Northern District of Illinois in favor of the plaintiffs (People of the State of Illinois, etc. et al) vs. (City of Milwaukee, etc., et al)

- ° Because of the "health hazards" wastewater treatment standards higher than those required by the State of Wisconsin and EPA were specified by the Judge.

BOD	5 mg/l
S. Solids	5 mg/l
T. Phosphorus	1 mg/l

In addition certain treatment trains were specified.

- ° Government Files Brief in Milwaukee Water Pollution Case:

Illinois based its legal claims on the traditional, non-statutory common law of nuisance. A Federal District Court in 1973 found first that the Federal statute on water pollution did not pre-empt common law. After further proceedings, the court concluded in 1977 that the Milwaukee discharges did in fact create a health

hazard to the people of Illinois and ordered Milwaukee to meet stringent pollution control requirements as indicated above.

In its "friend of the court" brief, the Federal Government took no position regarding the facts of the case. It explained the structure of the Clean Water Act, including the rights and remedies under the Act which Illinois could have used to gain the remedy it sought instead under Federal common law.

The brief concluded that the Clean Water Act did not pre-empt the Federal common law. This conclusion was based on the language and legislative history of the Clean Water Act, upon the same parties and issues, and upon the legal principle that unless a statute explicitly pre-empts common law, the common law will remain in effect to allow another form of relief for those claiming injury.

ACT

CLEAN AIR

OFFICIAL TITLE
AND DATE

Clean Air Act Amendments of 1977
Public Law 95-95
August 1977

Amending the Clean Air Act of 1974

PURPOSE OF ACT

"To protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population----."

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATIONS(S)

U. S. Environmental Protection Agency
Nuclear Regulatory Commission

MEDIA(S) COVERED

The regulation of ambient air emissions of air pollutants from stationary, fugitive and mobile sources.

Radioactive emission into the ambient air are included in conjunction with the Nuclear Regulatory Commission

PERTINENT SECTIONS OF
ACT RELATED TO
HAZARDOUS/TOXIC
SUBSTANCES

Section 103
 ° Air Quality Control Regions

Section 104
 ° Criteria and Control Techniques

Section 105
 ° Transportation Planning and Guidelines

Section 106
 ° Air Quality Criteria

Section 107
 ° Energy or Economic Energy Authority

Section 108
 ° Implementation Plans

- Section 109
 - ° New Source Performance Standards
- Section 110
 - ° Standards for Hazardous Air Pollutants
- Section 111
 - ° Enforcement Provisions
- Section 112
 - ° Compliance Order (including coal conversion)
- Section 117
 - ° Primary Non-ferrous Smelter Orders
- Section 120
 - ° Unregulated Pollutants
- Section 126
 - ° Ozone Protection
- Section 127
 - ° Prevention of Significant Deterioration
- Section 129
 - ° Nonattainment Areas
- Section 102
 - ° Light-duty Motor Vehicle Emissions
- Section 215
 - ° Fill Pipe Standards
- Section 216
 - ° Onboard Hydrocarbon Technology
- Section 222
 - ° Testing of Fuels and Fuel Additives
- Section 223
 - ° Small Refineries
- Section 224
 - ° Emission Standards for Heavy Duty Vehicles or Engines or Certain Other Vehicles or Engines

Section 225

- ° Aircraft Emissions

Section 306

- ° Sewage Treatment Grants

Section 401

- ° Basis of Administrative Standard

ACT	ENERGY SUPPLY AND ENVIRONMENTAL COORDINATION
OFFICIAL TITLE AND DATE	Energy Supply and Environmental Coordination Act of 1974 Public Law 93-319 June 1974
PURPOSE OF ACT	To provide means of dealing with energy shortages by requiring reports with respect to energy resources, by providing temporary suspension of certain air pollution require- ments, by providing for coal conservation, and for other purposes.
PRIMARY RESPONSIBLE FEDERAL ORGANIZATION(S)	Federal Energy Administrator U. S. Environmental Protection Agency
MEDIA(S) COVERED	(1) Coal Conversion - any major fuel burning installation (2) Air Quality Emission Limitations
PERTINENT SECTIONS RELATED TO HAZARDOUS/TOXIC SUBSTANCES	Section 2 ° Coal conversion and allocation Section 3 ° Suspension authority Section 7 ° Protection of public health and the environment
ADDITIONAL DATA	Major Impact ° Major impact will probably be in the health effects of sulfur oxides

ACT

CLEAN WATER

OFFICIAL TITLE
AND DATE

Federal Water Pollution Control Act, as
Amended
Public Law 95-217
December 1977

Amending
Federal Water Pollution Control Act of 1972
Public Law 92-500

PURPOSE OF ACT

"To restore and maintain the chemical,
physical and biological integrity of the
Nation's water..."

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

U. S. Environmental Protection Agency
Corps of Engineers
Department of the Army

MEDIA(S) COVERED

- (1) The regulations of ambient waste-
water discharges of water pollutants
water discharges of water pollutants
from point and non-point sources to
rivers, streams, coastal water,
estuaries, bays, lakes, and the lands
drained thereby.
- (2) Liability of oil and hazardous sub-
stances spills into waterways

PERTINENT SECTIONS
OF ACT RELATED
TO HAZARDOUS/TOXIC
SUBSTANCES

- Section 101 (a) (c)
- ° It is the national policy that the
discharge of toxic pollutants in
toxic amounts be prohibited.
- Section 107
- ° Mine Water Pollution Control
Demonstration
- Section 108
- ° Pollution Control in Great Lakes
- Section 115
- ° In-place Toxic Pollutants
- Section 208
- ° Areawide Waste Treatment Management

- Section 301
 - ° Effluent Limitations
- Section 302
 - ° Water Quality Related Effluent Limitations
- Section 303
 - ° Water Quality Standards and Implementation Plans
- Section 304
 - ° Effluent Guidelines
- Section 306
 - ° National Standards of Performance
- Section 307
 - ° Toxic and Pretreatment Effluent Standards
- Section 311
 - ° Oil and Hazardous Substances Liability
- Section 312
 - ° Marine Sanitation Devices
- Section 316
 - ° Thermal Discharges
- Section 318
 - ° Aquaculture
- Section 402
 - ° National Pollutant Discharge Elimination System
- Section 403
 - ° Ocean Discharge Criteria
- Section 404
 - ° Permits for Dredged or Fill Material
- Section 405
 - ° Disposal of Sewage Sludges
- Section 504
 - ° Emerging Power

ACT

FISHERY CONSERVATION AND MANAGEMENT

OFFICIAL TITLE
AND DATE

Fishery Conservation and Management Act
of 1976
Public Law 94-265
April 1976

PURPOSE OF
ACT

To provide for the conservation and management of the fisheries, and for other purposes.

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

Secretary of State
Coast Guard
Department of Transportation
U. S. Environmental Protection Agency

MEDIA(S) COVERED

Conserve and manage the fishery resources found off the coasts of the United States and the anadromous species and Continental Shelf resources.

PERTINENT SECTIONS OF
ACT RELATED TO HAZARDOUS/
TOXIC SUBSTANCES

Sections 301 to 312
° National Fishery Management Program

ADDITIONAL DATA

Related to Section 311 (Oil and Hazardous Substance Liability) of Clean Water Act

ACT

SAFE DRINKING WATER

OFFICIAL TITLE
AND DATE

Safe Drinking Water Act
Public Law 93-523
December 1974

Amended
Public Law 95-190
November 1977

PURPOSE OF ACT

To assure that the public is provided with
safe drinking water, and for other purposes.

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

U. S. Environmental Protection Agency

MEDIA(S) COVERED

Primary (health-related) drinking water
Secondary (welfare-related) drinking water
Regulation of underground injections

PERTINENT SECTIONS
OF ACT RELATED
TO HAZARDOUS/TOXIC
SUBSTANCES

Section 1412
° National Drinking Water Regulations
- Primary
- Secondary

Section 1413, 1414, 1415, and 1416
° Protection of Underground Sources
of Drinking Water

Section 1431
° Emergency Powers

Section 1445
° Records and Inspections

ACT	WATER RESOURCES DEVELOPMENT
OFFICIAL TITLE AND DATE	Water Resources Development Act of 1974 Title I River Basin Monetary Authorization Act of 1974 Title II Public Law 93-251 March 1974
PURPOSE OF ACT(S)	Authorizing the construction, repair and preservation of certain public works on rivers and harbors for navigation, flood control, and for other purposes.
PRIMARY RESPONSIBLE FEDERAL ORGANIZATION(S)	Water Resources Council Bureau of Reclamation Department of Interior Corps of Engineers Department of Army Soil Conservation Service Department of Agriculture U. S. Environmental Protection Agency Tennessee Valley Authority
MEDIA(S) COVERED	Multi-purpose water resources development projects including: ° flood control ° hurricane-flood protection ° navigation ° beach erosion ° water supply ° shore line erosion ° water quality ° channel maintenance (debris) ° recreation ° wildlife enhancement
PERTINENT SECTIONS OF ACT(S) RELATED TO HAZARDOUS/ TOXIC SUBSTANCES	Most of the 108 sections deal mainly with flood control and navigation

Section 65

- ° Benefits of stream flow regulation for water quality purposes

Section 80

- ° Review of principles and standards for planning and evaluating water and related resources projects.

ACT

OCEAN DUMPING

OFFICIAL TITLE
AND DATE

Marine Protection, Research, and Sanctuaries
Act of 1972
Public Law 92-532
October 1972

PURPOSE OF ACT

To regulate the transportation for dumping,
and the dumping of materials into ocean
waters and for other purposes.

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

U. S. Environmental Protection Agency
CORPS of Engineers
Department of Army

Coast Guard
Department of Transportation

MEDIA(S) COVERED

Materials includes dredged material, solid
waste, incinerator residue, garbage, sewage,
sewage sludge, munitions, radiological,
chemical, and biological and laboratory waste,
wrecked or discarded equipment, rock, sand,
excavation debris, and industrial, municipal
and agriculture and other waste.

Does not include oil of Section 111 of Clean
Water Act or discharge from marine sanitation
devices of Section 112.

Ocean waters means those waters of the open
sea lying seaward of the base line from which
the territorial sea is measured.

PERTINENT SECTIONS
OF ACT RELATED TO
HAZARDOUS/TOXIC
SUBSTANCES

Section 101
° Prohibited Acts

Section 102
° Environmental Protection Agency
Permits

Section 103
° Corps of Engineers Permits

Section 104
° Permit conditions

Section 105
° Penalties

ACT

PORTS AND WATERWAYS SAFETY

OFFICIAL TITLE
AND DATE

Ports and Waterways Safety Act of 1972
Public Law 92-340
July 1972

PURPOSE OF
ACT

To promote the safety of ports, harbors,
water-front areas, and navigable waters of
the United States

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

Coast Guard
Department of Transportation

U. S. Environmental Protection Agency

MEDIA(S) COVERED

The protection of navigable waters and the
resources therein from environmental harm
resulting from vessel or structural damage,
destruction or loss.

PERTINENT SECTIONS
OF ACT RELATED TO
HAZARDOUS/TOXIC

Title I

- ° Ports and waterway safety and
environmental quality

Title II

- ° Vessels carrying certain cargoes in
bulk

ADDITIONAL DATA

Coast Guard

- ° Establishes rules and regulations
for the prevention or mitigation of
damage to the marine environment
(as part of this act).

U. S. Environmental Protection Agency

- ° Designates hazardous polluting
substances under Section 311 of the
Clean Water Act.

Regulations

- ° Set forth comprehensive minimum
standards of design, construction,
alteration, repair, maintenance
and operation of such vessels.

ACT

DEEPWATER PORT

OFFICIAL TITLE
AND DATE

Deepwater Port Act of 1974
Public Law 93-627
January 1975

PURPOSE OF ACT

To regulate commerce, promote efficiency in transportation, and protect the environment, by establishing procedures for the location, construction and operation of deepwater ports off the coast of the United States and for other purposes.

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

Department of Transportation
Environmental Protection Agency

Corps of Engineers,
Dept. of the Army

National Oceanic and Atmospheric Administra-
tion
Dept. of Commerce

MEDIA(S) COVERED

Construction and operation of deepwater
ports

PERTINENT SECTIONS OF
ACT RELATED TO
HAZARDOUS/TOXIC
SUBSTANCES

Section 4
° License for ownership, construction
and operation of a deepwater port.

Section 5
° Procedure

Section 6
° Environmental Review Criteria

Section 10
° Marine Environmental Protection and
Navigational Safety

Section 18
° Liability

ACT

OUTER CONTINENTAL SHELF LANDS

OFFICIAL TITLE
AND DATE

Outer Continental Shelf Lands Act
Public Law 212, 1953

Amending statutes not included in this report
having major application and operations re-
lating to OCS

Fish and Wildlife Act of 1956

Geneva Convention of 1958

National Gas Pipeline Safety Act of 1968

National Environmental Policy Act of 1969

Deep Water Port Act of 1974

Coastal Management Act of 1972

(as amended in 1976)

Clean Water Act of 1977

PURPOSE OF ACT

"Establish very general guidelines and
directives in managing the resources of the
outer continental shelf in leasing tanks for
oil and gas, and other mineral exploration.

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

Bureau of Land Management
U. S. Geological Survey
Fish and Wildlife Service
Department of Interior

NOAA

Department of Commerce

U. S. Environmental Protection Agency

Coast Guard

Department of Transportation

Department of Defense

MEDIA(S) COVERED

Managing the oil and gas resources in the
outer continental shelf and possible conflicts
of other uses of the marine environment.

PERTINENT SECTIONS OF ACT
RELATING TO HAZARDOUS/TOXIC
SUBSTANCES

Leasing Process Steps

1. Leasing planning schedule
2. Request for tract nomination
3. Selection of general areas for inclusion in a lease schedule.
4. Draft environmental impact statement
5. Public hearing
6. Final statement
7. Decision by the Secretary of Interior
8. Notice of Sale
9. Lease sale
10. Oil and gas lease contract
11. Exploratory drilling plan
12. Development plan
13. Permitting of development
14. Commercial production

Oil Spill Liability

- ° Under Section 58 of the Clean Water Act of 1977 amending Section 311 of PL 92-500, the oil spill liability effort of EPA is to be conducted in connection with the activities of the OCS Act

Outer Continental Shelf (and Act Amendment of 1977) (House of Representatives Report 95-590)

- ° Ad Hoc select committee report gives detail information on OCS.

ACT

RIVER AND HARBOR AND FLOOD CONTROL

OFFICIAL TITLE
AND DATE

River and Harbor Act of 1970
Title I
Flood Control Act of 1970
Title II
Public Law 91-611
December 1970

PURPOSE OF ACT(S)

Authorizing construction, repair, and presentation of certain public works in rivers and harbors for navigation, flood control and other purposes.

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

Corps of Engineers
Department of the Army

MEDIA(S) COVERED

Control of destructive flood waters
Comprehensive studies of water and related resources

PERTINENT SECTIONS OF ACT
RELATED TO HAZARD/TOXIC
SUBSTANCES

Section 101
 ° Navigation

Section 122
 ° Adverse environmental effects

Section 123
 ° Contained spoil disposal

Section 201
 ° Flood control

Section 238
 ° Comprehensive water and related
 resources studies

ACT

RESOURCE CONSERVATION AND RECOVERY

OFFICIAL TITLE
AND DATE

Resource Conservation and Recovery
Act of 1976
Public Law 94-580
October 1976

PURPOSE OF ACT

To provide technical and financial assistance for the development of management plans and facilities for the recovery of energy and other resources from discarded material and for the safe disposal of discarded materials, and to regulate the management of hazardous waste.

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

U. S. Environmental Protection Agency
Department of Commerce
Department of Transportation

MEDIA(S) COVERED

- (1) Control of hazardous waste from cradle to grave (non-nuclear)
- (2) the elimination of improper land disposal practices, and (non-wastewater)
- (3) development of long-term program in resource recovery

PERTINENT SECTIONS
OF ACT RELATED TO
HAZARDOUS/TOXIC
SUBSTANCES

- Section 3001
- ° Identification and Listing of Hazardous Waste
- Section 3002
- ° Standards Applicable to Generators of Hazardous Waste
- Section 3003
- ° Standards applicable to Transporters of Hazardous Waste
- Section 3004
- ° Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities

Section 3005

- ° Permits for Treatment, Storage or Disposal of Hazardous Waste

Section 3006

- ° Authorized State Hazardous Waste Programs

Section 3007

- ° Inspections

Section 3010

- ° Effective Dates

Section 3011

- ° Assistance to States

Section 5001, 5002, and 5003

- ° Duties of Department of Commerce

Section 7003

- ° Imminent Hazard

ACT	FEDERAL ENVIRONMENTAL PESTICIDE CONTROL
OFFICIAL TITLE AND DATE	The Federal Insecticide, Fungicide, and Rotenticide Act Public Law 92-516 October 1972 as amended by Public Law 94-140 November 1975
PURPOSE OF ACT	To control the entry of pesticides into the environment
PRIMARY RESPONSIBLE FEDERAL ORGANIZATION(S)	U.S. Environmental Protection Agency Department of Transportation Department of Agriculture Department of Treasury Department of Interior
MEDIA(S) COVERED	Environment includes water, air (and all plants and man and other animals living therein and interrelationships which exist among these Pesticide means (1) any substance or mixture of substance intended for preventing, destroying, repelling, or mitigating any pest, and (2) any substance or mixture of sub- stances intended for use as a plant regulator, defoliant or desiccant.
PERTINENT SECTIONS OF ACT RELATED TO HAZARDOUS/TOXIC SUBSTANCES (All sections of Act are related with the major sections as indicated)	Section 3 ° Registration of Pesticides Section 4 ° Restricted Use of Pesticides Certified Applicators Section 5 ° Experimental Use Permits Section 6 ° Administration Review; Suspension Section 11 ° Standards Applicable to Pesticide Applicators Section 12 ° Unlawful Acts

Section 13

° Stop Sale, Use, Removal and Seizure

Section 17

° Imports and Exports

Section 19

° Disposal and Transportation

ACT

HAZARDOUS MATERIALS TRANSPORTATION

OFFICIAL TITLE
AND DATE

Hazardous Materials Transportation Act
Amendments of 1976
Public Law 94-474
October 1976

Amending
Public Law 93-633
January 1975

PURPOSE OF ACT

To regulate commerce by improving the protections afforded the public against risks connected with the transportation of hazardous material, and for other purposes.

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

Department of Transportation
U. S. Environmental Protection Agency
Interstate Commerce Commission
Nuclear Regulatory Commission

MEDIA(S) COVERED

Transport of a particular quantity and form of material in commerce may pose an unreasonable risk to health and safety or property.

May include explosives, radioactive materials, etiologic agents, flammable liquids or solids, combustible liquid or solids, poisons, oxidizing or corrosive materials, and compressed gases

PERTINENT SECTIONS
OF ACT RELATED TO
HAZARDOUS/TOXIC
SUBSTANCE

Section 105
° Regulations Governing Transportation
of Hazardous Materials

Section 106
° Handling of Hazardous Materials

Section 107
° Exemptions

Section 108
° Transportation of Radioactive
Materials on Passenger-Carrying
Aircraft

Section 111
° Specific Relief and Imminent Hazards

ACT

SURFACE MINING CONTROL AND RECLAMATION

OFFICIAL TITLE
AND DATE

Surface Mining Control and Reclamation
Act of 1977
Public Law 95-87
August 1977

PURPOSE OF
ACT

"Establish a nationwide program to protect
society and the environment from adverse
effects of surface coal mining operations
---"

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

Department of Interior
U. S. Environmental Protection Agency

MEDIA(S) COVERED

Regulation of surface coal mining opera-
tions, and the acquisition and reclamation
of abandoned mines

PERTINENT SECTIONS
OF ACT RELATING TO
HAZARDOUS/TOXIC
SUBSTANCES

Section 501
 ° Environmental Standards

Section 502
 ° Initial Regulatory Procedures

Section 506
 ° Permits

ADDITIONAL DATA

Air and Water Quality Standards
 ° Regulations promulgated with
 respect to Section 501 relating
 to air and water quality standards
 must have written concurrence
 from EPA.

ACT

SOIL AND WATER RESOURCES CONSERVATION

OFFICIAL TITLE
AND DATE

Soil and Water Resources Conservation
Act of 1977

Public Law 95-192
November 1977

PURPOSE OF
ACT

To provide for furthering the conserva-
tion, protection, and enhancement of
the Nation's soil, water and related
resources for sustained use.

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

Soil Conservation Service
Department of Agriculture

MEDIA(S) COVERED

"Soil, water, and related resources",
means those resources which come within
the scope of the programs administered
and participated by the Soil Conservation
Service.

PERTINENT SECTIONS
OF ACT RELATED TO
HAZARDOUS/TOXIC
SUBSTANCES

Section 4
° Declaration of Policy and
Purpose:
Promotion thereof

Section 5
° Appraisal

Section 6
° Soil and Water Conservation
Program

ADDITIONAL DATA

Use of waste products in Section 6 (a) (5)
° Includes industrial organic
waste and municipal sludges to
improve soil health and
fertility

ACT

NOISE

OFFICIAL TITLE
AND DATE

Noise Control Act of 1972
Public Law 92-574
October 1972

PURPOSE OF ACT

To control the emission of noise detrimental to the human environment and for other purposes.

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

U. S. Environmental Protection Agency
Federal Aviation Administration
Department of Transportation

MEDIA(S) COVERED

Establishment of Federal noise emission standards for products distributed in commerce...except:

- ° aircraft
- ° military weapons
- ° NASA activities

PERTINENT SECTIONS OF
ACT RELATING TO
HAZARDOUS/TOXIC SUBSTANCES
(All Sections are related
with major sections
indicated)

Section 5

- ° Identification of major noise criteria, and control technology.

Section 6

- ° Noise emission standards for products distributed in commerce.

Section 7

- ° Aircraft noise standards
- ° Control and abatement of aircraft noise and sonic boom.

Section 11

- ° Enforcement

Section 17

- ° Railroad noise emission standards

Section 18

- ° Motor carrier noise emission standards

ACT

FEDERAL AVIATION ACT

OFFICIAL TITLE
AND DATE

Federal Aviation Act of 1958
49 USC 1431 (1970)
Amended by Public 92-574
October 1972

PURPOSE OF ACT

"To afford present and future relief and protection to the public health and welfare from aircraft noise and sonic boom..."

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

Federal Aviation Administration
U. S. Environmental Protection Agency
Department of Transportation

MEDIA(S) COVERED

Prescribe and amend standards for the control and abatement of aircraft noise and sonic boom.

PERTINENT SECTIONS OF ACT
RELATED TO HAZARDOUS/TOXIC
SUBSTANCES

Section 7 (PL 92-574)
° Aircraft Noise Standards
° Control and Abatement of Aircraft
Noise and Sonic Boom

ADDITIONAL DATA

Section 7 Regulations
° FAA regulates after consultation
with EPA and DOT

ACT

AIRPORT AND AIRWAYS DEVELOPMENT

OFFICIAL TITLE
AND DATE

Airport and Airways Development Act Amendments
of 1976
Public Law 94-353
July 1976

Amending the Airport and Airway Development
Act of 1970

PURPOSE OF ACT

To provide for the expansion and improvement
of the Nation's airport and airways system...

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

Federal Aviation Administration
U. S. Environmental Protection Agency
Department of Transportation

MEDIA(S) COVERED

Reduction of noise in the "impact zones
adjacent to airports."

PERTINENT SECTIONS OF
ACT RELATED TO
HAZARDOUS/TOXIC SUBSTANCES

Section 3
° Definitions--diminishing the effect
of aircraft noise...

Section 26
° Special Studies...soundproofing
schools, hospitals and public
facilities located near airports

ADDITIONAL DATA

Report to Congress
° Under Section 26, a report was
submitted to Congress on July 1977.

° FAA is considering actions to
implement recommendations.

ACT

FOOD, DRUG AND COSMETIC

OFFICIAL TITLE
AND DATE

Food and Drug Act
46 Statue 392
May 1930

As Amended by
Federal Food, Drug, and Cosmetic Act
Fair Packaging and Labeling Act
Federal Caustic Poison Act
Radiation Control for Health and Safety
Public Health Service Act (Provisions re-
lating to biologics, mild and food
service, and shellfish)
Federal Meat Inspection Act
Poultry Products Inspection Act
Egg Products Inspection Act

PURPOSE OF
ACT

To protect the health of the Nation against
impure and unsafe foods, drugs and cosmetics,
and other potential hazards.

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

Food and Drug Administration
Department of Health, Education and Welfare

MEDIA(S) COVERED

The specific medias are presented in the
"Code of Federal Regulations, 21, Foods and
Drug General medias are:

- Food standards, food additive, color
additives
- Drugs
- Cosmetics
- Biological products (serums)
- Animal feeds, drugs and related pro-
ducts
- Controlled substances (narcotics, etc.)
- Radiation (ionizing and nonionizing)
- Poisons (household)
- Communicable diseases vectors

PERTINENT SECTIONS
OF ACT RELATED TO
HAZARDOUS/TOXIC
SUBSTANCES

For detailed information see Title 21 - Food
and Drug Administration, Chapter 1 (Parts 0-
1299), Code of Federal Regulations

A report published by U. S. Government Printing Office on the Federal Food, Drug, and Cosmetic Act, as amended October 1976, documents the various amendments through May 1976.

Classification of Food Additives by Food and Drug Administration

- Intentional
Substances purposely and directly added to food
- Indirect
Have no planned function in food but become (or have a reasonable possibility of becoming) part of it during some phase of processing, packaging, or storing.
- Generally Recognized as Safe (GRAS)
Generally recognized by experts as having been "adequately shown" to be safe for its intended use in food.
- Prior Sanctioned Substances
Legal destination created by the 1958 amendment--substances that had received some form of official permission as additives under Acts before the 1958 amendments.
- Color Additives
Different legal treatment from food additives.
- Pesticides
Chemical applied in the production storage of raw agriculture commodities.

Scientific Review Screening of Generally Recognized as Safe (GRAS) Additives.

- Affirmed as generally regarded as safe and maintained on GRAS list
- Placed on GRAS List, but with restrictions.
- Converted to regulated food additive status with strict control over its use.
- Banned from use in food.

Removal from Case

- FDA cannot ban a food product after it has given final approval for marketing just because a question has been raised about its safety.
- Scientific bases required
- FDA cannot ban a product during the scientific debate (this was the case for nitrites; USDA restricted its use, not FDA).

Delaney Clause (1958 Act)

- Prohibits the use as a food additive of any chemical found to induce cancer in man or animal.

Guidelines on Use of Human Sludges on Soils Use in Human Food Production

FDA has issued guidelines on the use of human sludge on soils used in human food production.

ACT

ACTS RELATING TO FSQS

OFFICIAL TITLE
AND DATE

Egg Products Inspection Act of 1970
Agriculture Marketing Act of 1946
Federal Meat Inspection Act of 1907
Poultry Products Inspection Act

PURPOSE OF ACT(S)

"Standardization, inspection, and grading
of agriculture products..."

PRIMARY RESPONSIBLE
FEDERAL ORGANIZATION(S)

Food Safety and Quality Service
Department of Agriculture

MEDIA(S) COVERED

Standardization, inspection and grading of

- ° meat and meat products
- ° poultry and poultry products
- ° eggs and egg products
- ° rabbits
- ° dairy and dairy products
- ° fresh and processed fruits and vegetables

PERTINENT SECTIONS OF ACT
RELATED TO HAZARDOUS/TOXIC
SUBSTANCES

Reader is referred to Title 7 of the CFR

ADDITIONAL DATA

- ° Nitrite Restriction
The May 1978 restrictions on the amount of nitrites in bacon was ordered by the Department of Agriculture.
- ° FSQS requires that water used in food processing must be potable and defined by EPA.

SUMMARY

Initially, in putting together the synopsis of the Legislative Acts pertaining to the control of hazardous/toxic substances, only a few Federal Agencies such as EPA, OSHA, and FDA were involved. However, as can be seen for the 28 major acts, the distribution of regulatory responsibility is spread over numerous Federal Agencies. For example, in the water area, there are nine major pieces of legislation involving over ten Federal Agencies.

In summary, at the Federal level the Legislative Acts appear to cover all possible modes of entry of hazardous/toxic substances to man and his environment. In the next three to five years the development of specific regulations will be a very challenging effort to the various Federal Agencies. In this respect, the continuing awareness of the regulations proposed by these Federal Agencies in the Federal Register will be a monumental task for those of us who are concerned with the control of hazardous/toxic substances at the Federal, State and local level.

Postscript:

For this report there is a limited amount of additional information. As part of a more comprehensive effort, the additional information section is being expanded and will be issued as a report from the Industrial Environmental Research Laboratory, Research Triangle Park.