Manual of Acute Toxicity: Interpretation and Data Base for 410 Chemicals and 66 Species of Freshwater Animals

By

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Abstract

All acute toxicity data developed by the Columbia National Fisheries Research Laboratory, U.S. Fish and Wildlife Service, since 1965 were evaluated for quality, and a data base was established for 4,901 tests with 410 chemicals (mainly pesticides) and 66 species of aquatic animals. The data were also analyzed by various statistical approaches to make taxonomic comparisons, and to assess the degree to which various factors affect toxicity. Insects were the most sensitive group, followed by crustaceans, fishes, and amphibians. Among the four most commonly tested forms, daphnids were the most sensitive 58% of the time, followed by rainbow trout, *Salmo gairdneri* (35%), bluegills, *Lepomis macrochirus* (5%), and fathead minnows, *Pimephales promelas* (2%). In comparisons with other species tested with the same chemical, two observations were evident: (1) the lowest of the two LC50's for daphnids and rainbow trout was ≤15 × that of the most sensitive species 95% of the time, and ≤25 × 100% of the time; and (2) testing of three species (*Daphnia*, *Gammarus*, and rainbow trout) provided the lowest toxicity value 88% of the time, and could not be improved more than 2.5% by adding any other single species. Interspecies correlation models can be used to predict acute toxicity values, but the confidence limits were smallest when extrapolations were within families. Flow-through toxicity values can be obtained by multiplying static values by 0.51, but the error is likely to be large because ratios of static to flow-through tests differed by 1.8 orders of magnitude. Toxicity of aged test solutions increased by a factor of 2 or more only 11% of the time and never increased by more than a factor of 4; toxicity decreased in 22% of the tests and remained unchanged in 69%. Although pH affected the toxicity of only 20% of the chemicals tested, it caused a greater average

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change in toxicity than did any other factor examined. Temperature affected the toxicity of 40% of the chemicals tested, toxicity generally increasing with increases in temperature—although the toxicity of a few chemicals (DDT, dimethrin, and methoxychlor) decreased. The effect of temperature on toxicity conformed to the Q_{10} concept and was predictable. Temperature increased the toxicity of most chemicals by a factor of 3.1 per 10°C rise in temperature, but the factor for organophosphate insecticides was higher (5.1)—possibly due to the simultaneous increase in acetylcholinesterase (AChE) activity and rate of AChE inhibition. Regression slopes were consistent among species within a chemical for both pH and temperature, indicating chemical rather than biological differences in toxicity. Water hardness had little if any effect on the toxicity of organic chemicals; any effects observed were probably due to pH differences in solutions of differing hardness. Formulations of pesticides increased the toxicity of technical material 32% of the time, and decreased it 11% of the time. The effect of formulation on toxicity was within a factor of 0.2 to 5× 85% of the time, but was as high as 318×. The diet fed to fish before they were tested altered toxicity by as much as 5.7×, but factors of 1.1 to 3.8× would be anticipated within available commercial diets. Source of rainbow trout contributed to variation in toxicity data, differences ranging from 1.8 to 4.7× 88% of the time. Sensitivity of invertebrates and fish decreased as development of the animals progressed and size increased. Differences in toxicity among different life stages of fish were 5× or less 83% of the time. The change in toxicity was usually small within the sizes normally tested.

Of the factors affecting toxicity, the differences were within 5× or less 80% or more of the time, and this generalization included pH and temperature, evaluated on the basis of a 1.0 unit or 10°C change. Generalizations and predictions can be made for comparative toxicity and factors affecting toxicity $\geq$80% of the time. However, due to inherent variation and frequent exceptions in acute toxicity data, it remains best to test the chemical and species of concern under environmental conditions of interest when precise information is required.

The Federal Insecticide, Fungicide, and Rodenticide Act (PL 80-104), as amended by the Federal Environmental Pesticide Control Act of 1972 and others (7 U.S.C. 136-136y), requires that all formulators and producers of pesticides register their products and establishments with the U.S. Environmental Protection Agency (EPA) on the basis of safety data regarding health and environment. Furthermore, the Toxic Substances Control Act of 1976 (PL 94-469) and the Federal Insecticide, Fungicide, and Rodenticide Act authorize EPA to obtain data from industry on the health and environmental effects of chemical substances and mixtures. Acute toxicity testing plays a major role in the testing requirements involved in both laws, for good reason. In terms of utility for the assessment of hazard to aquatic environments, acute toxicity tests were rated highest of 15 tests evaluated by Brungs and Mount (1978) and Macek et al. (1978). Six criteria were used in the evaluations: ecological significance of effects, scientific and legal defensibility, availability of acceptable methodology, utility of test results in predicting effects in aquatic environments, general applicability to all classes of chemicals, and simplicity and cost of the test.

Toxicologists are well aware of the merits and limitations of the acute toxicity test; yet, there are probably few measurements for evaluating hazard or safety of a chemical to aquatic life that have been as grossly misunderstood. Users of acute toxicity data must bear in mind that the LC50 generally measures only one biological response—a lethal one. Its main value lies in its provision of a relative starting point for hazard assessment, along with the expected environmental concentration, and other measurements (e.g., water solubility, partition coefficient, and degradation rate) of the chemical in question. In addition, the acute toxicity test provides a rapid, cost-efficient way to measure relative toxicity of different forms and formulations of a chemical, toxicity in different types of water, and toxicity to organisms representing different trophic levels (Buikema et al. 1982; Sprague 1970).

One of the greatest needs in acute toxicity testing today is an evaluation of the data already available for its utility and applicability in the assessment of chemical hazard. At present, there is a tendency to dwell on the selection of species for toxicity tests and the biological, chemical, and physical factors affecting acute toxicity, without fully defining the variation in species sensitivity, the extent to which various physicochemical and biological factors affect toxicity, and the probabilities associated with such variation. Assessments of the probability that adverse ecological effects will result from environmental releases of a given contaminant are of primary importance in hazard evaluation. Probabilities should be derived that will reasonably represent acute toxicity to most species—especially the more sensitive ones. However, the probabilities that can be developed today are, for the most part, based on species easily and economically tested, and therefore may or may not include a reasonable portion of the very sensitive species. Furthermore, a hazard assessment is not a one-time estimate. Additional evaluations must be made as the data base and knowledge expand; and at the present state of the art, no scheme or procedure can eliminate the need for sound scientific judgment.

The large acute toxicity data base (Appendix Table A5) used in the analyses presented here is unique in that the research was conducted within one laboratory system and by methods that, for the most part, are the consensus methods in use today (American Society for Testing and Materials 1980; Committee on Methods for Toxicity Tests with Aquatic Organisms 1975). The objectives were as follows:

1. Make available the data base, especially unpublished data.
2. Develop the general statistical relation of relative sensitivities within species, families, and classes.
3. Determine the frequency with which EC50's or LC50's determined with commonly tested species (daphnids; rainbow trout, *Salmo gairdneri*; fathead minnows, *Pimephales promelas*; or bluegills, *Lepomis macrochirus*) are lower than the EC50's or LC50's for all other species tested.
4. Determine if there is a group of three or four test species that would yield the lowest EC50 or LC50 at least 95% of the time.
5. Develop the statistical relation between static and flow-through LC50's.
6. Determine how often the toxicity of an aged test solution is less than that of a fresh solution.
7. Assess the effects of physical, chemical, and biological factors on acute toxicity.

We hope that these data will contribute to the many assumptions, comparisons, and extrapolations required in an ecotoxicology testing scheme for hazard assessment and for other purposes.

Materials and Methods

General

The data base used to prepare this report (Appendix Table A5) was compiled from the results of tests conducted at the Columbia National Fisheries Research Laboratory and its field laboratories in 1965–1984, and judged acceptable according to good laboratory practices. It consists of data from 4,901 tests performed with 66 species of aquatic organisms and 410 chemicals. Not all of the species were tested with every chemical. The species of invertebrates, fishes, and amphibians tested are listed in phylogenetic order (Appendix Tables A1 and A2), and chemicals are arranged alphabetically by common name or trade name where common names do not exist (Appendix Table A4). Toxicity values are expressed as ng/L, µg/L, mg/L, or ml/L. Duration of the toxicity tests was either 48 h (fairy shrimp, *Streptocephalus seali*; daphnids, *Daphnia magna*, *D. pulex*, and *Simocephalus serrulatus*; seed shrimp, *Cypridopsis vidua*; and larval midges, *Chironomus plumosus*) or 96 h (all other species). The chemicals represent all major pesticides, as well as several industrial and inorganic chemicals. Most of the data are on organic chemicals and fishes. Data for invertebrates were often lacking, and are therefore discussed only when adequate data exist.

Portions of the data base (static acute tests on 271 chemicals, 58 species, and 1,587 tests) were previously published by Johnson and Finley (1980). The present data base includes data from tests on 139 additional chemicals. In many of the tests, the following factors were assessed: test type (static or flow-through), aging of test solutions, temperature, pH, hardness, formulation, diet, fish source, and size and life stage. Where the few discrepancies occur between our data and those of Johnson and Finley (1980), the present data should be used. Because we used original data records to prepare this report, the absence of data that were previously published does not necessarily mean that the data were unacceptable: they may have been lost or were unavailable. Furthermore, although some data on certain chemicals did not appear to conform with other test results, the tests were included in the data base because they could not be eliminated on the basis of good laboratory practice.

Static toxicity test procedures with invertebrates and fishes were previously described by Johnson and Finley (1980). Static and flow-through test techniques were generally those of the American Society for Testing and Materials (1980) and the Committee on Methods for Toxicity Tests with Aquatic Organisms (1975). Test procedures for amphibians (tadpoles) were those described by Sanders (1970). The level of statistical significance in all tests was $P \leqslant 0.05$.

Statistical Analyses

Comparative Toxicity

Taxonomic comparisons. The data set analyzed included most of the data in Appendix Table A5, but did not include data from tests on eggs, flow-through tests, or aged test solutions, or tests yielding "less-than" or "more-than" values. The data were analyzed by one-way analyses of variance (Snedecor and Cochran 1967) that included the effect of category (species, family, or class) for each chemical. Log_{10} transformation of toxicity data was used to meet the assumptions for normally distributed data in analysis of variance. The first step in statistical analyses of the data set was to determine the number of repeated measurements (48-h EC50's and 96-h LC50's) within a category for each chemical. This step was necessary to enable derivation of an error term for testing differences among species, families, or classes. The design was not balanced because the numbers of observations in each category were unequal. To determine mean differences among EC50's or LC50's, we used Fisher's least significance difference (LSD), and sum of ranks/*n* analyses, based on the log of the values or means that were used for comparisons of sensitivity. Frequency analysis by inspection—determination of how often the EC50 or LC50 of one taxonomic group was greater or less than that of others—was also used.

Interspecies comparisons and correlations. Interspecies comparisons were made by summing ranks/*n* and frequency analysis by inspection—determining how often the EC50 or LC50 for one species was greater or less than that for others. The values used for comparisons were log values; their derivation is described in the materials and methods for taxonomic comparisons.

We conducted interspecies correlations, using Model II least squares methodology (Snedecor and Cochran 1980), on daphnids (*Daphnia magna* or *D. pulex*, or both), rainbow trout, fathead minnows, and bluegills with other species. A standardized data set was established from Appendix Table A5 for these analyses, to reduce variation. The data set was based mainly on technical materials, and water temperature, pH, and hardness conformed to the requirements of American Society for Testing and Materials (1980) and the Committee on Methods for Toxicity Tests with Aquatic Organisms (1975); data were not included from tests on eggs, flow-through tests, or aged test solutions, or tests having "less-than" or "more-than" values. Acceptable fish weights were 0.2 to 1.5 g. The coefficient of variation for a species with three or more tests on a chemical (all fishes) averaged 37% (range, 3–115%) for toxicity values in the standardized data set, whereas the data used in the comparative toxicity section on species averaged 65% (range, 13–215%). Slopes and intercepts were derived from the equation $\log Y = a+b(\log X)$, where X equaled toxicity values for one of the four species previously mentioned and Y equaled toxicity values for other species. Paired tests on five or more chemicals were the minimum requirement for inclusion in the analyses. When either one of the paired values included more than one EC50 or LC50 value, the logs of the individual values were averaged.

Frequency distribution of toxicity. Estimates of frequency distributions of toxicity of all chemicals for the categories of species, class, and all taxa combined were performed with the standardized data set. Each chemical was classified by the following 48-h EC50 or 96-h LC50 concentrations (μg/L): <0.01, 0.01 < 0.1, 0.1 < 1.0, 1.0 < 10, 10 < 100, 100 < 1,000, 1,000 < 10,000, 10,000 < 100,000, or ⩾100,000. Frequency distributions of the toxicity classification were then made for each species and class, and for all taxa tested. Only results for 14 of the individual species are presented graphically, but 75% of the tests were conducted with those species.

Static and flow-through tests and aged test solutions. Formulation and categorization of the ratios were used in analyzing data on static and flow-through tests and aged test solutions. Ratios of static to flow-through tests (96-h LC50's) were calculated for 123 paired tests that included 41 chemicals and 19 species. The geometric mean was used when two or more toxicity values existed under similar conditions. The percent incidence of the ratios occurring in three categories was determined: at <0.5, the chemical was more toxic under static than under flow-through conditions; at 0.5–1.5, there was no difference in toxicity between the two types of tests; and at >1.5, the chemical was more toxic under flow-through than under static conditions.

Aged test solutions were compared with fresh test solutions (46 paired tests), under static conditions, for 22 pesticides and 12 species. Solutions were aged for 4 to 28 days, and 96-h LC50's determined on both fresh and aged test solutions. Most comparisons were made at 7 days, for consistency. Deactivation indices (Marking and Dawson 1972) were obtained by dividing the 96-h LC50 of an aged test solution by the 96-h LC50 of the paired fresh solution. Further details about the deactivation index were described by Marking (1972). The percent incidence of the indices was determined for three categories: at <0.5, the chemical was more toxic after aging; at 0.5–1.5, aged and fresh solutions were equally toxic; and at >1.5, aged solutions were the less toxic.

No differences were considered to exist at ratios of 0.5 to 1.5 in comparisons between static and flow-through tests, and between aged and fresh test solutions. Although this ratio range is not statistically exact, it appears to encompass most of the range observed within normal experimental variation. This approach was also used in comparing the toxicity of technical materials with that of formulated pesticides.

Factors Affecting Toxicity

Temperature, pH, and hardness of test solution, and size of test animal. We conducted regression analyses, using Model II least squares methodology, to determine relations between 48-h EC50's or 96-h LC50's and pH, temperature (°C), and hardness (mg/L as $CaCO_3$) of the test water, or size (weight, g) of the test animals. Slopes and intercepts were derived from the equation $\log Y = a + bX$, where Y = the toxicity value and X = pH, temperature, hardness, or size. Only tests containing three or more data points (EC50's or LC50's) for a specific species and chemical combination were used. Analyses of covariance were computed to determine differences between linear slopes for treatment. Also, we tested the hypothesis that the individual linear slopes were equal to zero by using individual regression analyses, as well as by calculating a pooled estimate of the standard error in the analysis of covariance (Snedecor and Cochran 1980). If the slopes had been analyzed individually, they might have differed significantly from zero, but not necessarily with analysis of covariance. Only tests having slopes that differed significantly from zero are presented in tabular form.

Formulation, diet, source, and life stage. Ratios of technical to formulated pesticides (static 48-h EC50's or 96-h LC50's), based on active ingredients, were calculated for 161 paired tests that included 48 chemicals and 16 species. The percent incidence of the ratios occurring in three categories was determined: at <0.5, the formulated pesticide was less toxic than the technical form; at 0.5–1.5, technical and formulated pesticides were equally toxic; and at >1.5, the formulated pesticide was the more toxic.

Differences among 96-h LC50's attributable to diet were determined by comparing means within 95% confidence intervals (Mehrle et al. 1977). Frequency analysis by inspection—how often the 96-h LC50 of one category was greater or less than that of another category—was used for comparisons of fish source and life stage, owing to the small sample sizes and characteristics of the data.

Results and Discussion

Comparative Toxicity

Taxonomic Comparisons

Species. Acute static toxicity data were highly variable among the 63 species tested against 174 chemicals. Some species appeared to be very sensitive or very insensitive overall, but there were also frequent exceptions for the same species. The largest number of species (14 to 25) consistently tested in the total data base were tested with 14 insecticides (2 carbamates, 6 organochlorines, and 6 organophosphates). Data from these tests were compared by sum of ranks/n to provide a general sensitivity ranking. In descending order of sensitivity (not necessarily statistically significant), the species ranked as follows: stoneflies (*Claassenia sabulosa*, *Pteronarcys californica*, *Pteronarcella badia*), glass shrimp (*Palaemonetes kadiakensis*), amphipods (*Gammarus fasciatus*), daphnids (*Daphnia pulex*, *D. magna*, *Simocephalus serrulatus*), brown trout (*Salmo trutta*), rainbow trout (*S. gairdneri*), seed shrimp (*Cypridopsis vidua*), largemouth bass (*Micropterus salmoides*), cutthroat trout (*S. clarki*), bluegills (*Lepomis macrochirus*), sow bugs (*Asellus brevicaudus*), coho salmon (*Oncorhynchus kisutch*), yellow perch (*Perca flavescens*), channel catfish (*Ictalurus punctatus*), common carp (*Cyprinus carpio*), black bullheads (*I. melas*), green sunfish (*L. cyanellus*), fathead minnows (*Pimephales promelas*), goldfish (*Carassius auratus*), western chorus frog

(*Pseudacris triseriata*), and Fowler's toad (*Bufo woodhousei fowleri*). Analysis of the standardized data provided a slightly different ranking: stoneflies, glass shrimp, daphnids (*Daphnia magna, D. pulex*), amphipods, daphnids (*Simocephalus serrulatus*), rainbow trout, sow bugs, bluegills, largemouth bass, seed shrimp, coho salmon, cutthroat trout, yellow perch, brown trout, channel catfish, common carp, green sunfish, fathead minnows, goldfish, black bullheads, western chorus frog, and Fowler's toad. The rankings should be viewed only as general trends, since not all species were tested with all chemicals, and all the chemicals tested were insecticides. The overall trends for species sensitivity were, however, consistent with those found for family and class groupings.

Among 82 chemicals tested with 6 or more (up to 42) species, the highest toxicity values within a chemical averaged 256 × the lowest, and ranged from 2.6 to 166,000 ×. Average differences were largest for insecticides (868 ×; range, 5.0 to 166,000 ×), followed by herbicides, fungicides, and other pesticides ($\bar{x}$, 33 ×; range, 2.6 to 438 ×); the few industrials were lowest ($\bar{x}$, 8.8 ×; range, 3.6 to 127 ×).

The four forms most commonly tested (*Daphnia magna* or *D. pulex*, rainbow trout, fathead minnows, and bluegills) were compared with each other in tests of 40 chemicals in which all four were tested together. *Daphnia* was the most sensitive 58% of the time, followed by rainbow trout (35%), bluegills (5%), and fathead minnows (2%). Sensitivity was greatly increased in combinations of *Daphnia* and rainbow trout only in that one of the two species was the most sensitive 93% of the time; in the remaining 7%, fathead minnows and bluegills were the most sensitive. However, the rainbow trout was always the next most sensitive species, and the LC50's were never significantly different from those of fathead minnows and bluegills.

Kenaga (1978) reported that no aquatic species was always the least or most sensitive for the 42 compounds he evaluated with rainbow trout, fathead minnows, and bluegills. Blanck et al. (1984), who tested 18 chemicals and an industrial wastewater with 13 green algae, showed that differences in sensitivity among species within a chemical may be as high as a factor of 2,000. Blanck (1982) concluded that no algal species of the 13 tested was generally sensitive or generally insensitive to all chemicals, and that even within a group of organisms such as algae, it is impossible to select a test species with a sensitivity representative of that group. Mount (1982) basically agreed with this assessment when, on the subject of surrogate species, he wrote:

> The point is that we have ample data to prove that a species can only represent itself consistently and not a group.
>
> However, species can be viewed as indicators of sensitivity in quite a different way. We can see that species sensitivity (LC50 or LD50) distributes itself in a rather consistent way for most chemicals. The distribution resembles a log normal one. We can then take the approach of sampling this distribution in order to predict the range about the mean. This is in reality our objective. Thus, each species we test is not representing any other species but is one estimate of general species sensitivity. With several such estimates, the overall range of sensitivity for all species can be determined. Our problem is to know how many species and what type of species to test to adequately represent the whole range.

Birge and Black (1982) also agreed with this concept, and further stated that with as few as three or no more than five aquatic species, it should be possible to establish a "biological response range." Blanck et al. (1984) reported that toxicity values for 3 algal species (randomly selected from the 13 studied) would be within two orders of magnitude of the most sensitive algae tested for 95% of the chemicals, and that a 5-species group would increase predictiveness to 99% of the chemicals. Although Mount (1982) maintained that species must be randomly chosen, he found that for most chemicals, the five most commonly tested species (*Daphnia magna, Gammarus*, rainbow trout, fathead minnows, and bluegills) represented a large part of the range of sensitivity of all species tested.

The many chemicals requiring hazard assessment and the lack of testing capabilities to quickly screen such an array of chemicals may require an effective toxicity screening process within a short time, as opposed to the "Surrogate Species Cluster Concept." This assessment is further complicated by the many new chemicals marketed each year (Maki et al. 1979). Kenaga (1978) proposed methods for early assessment of acute toxicity of chemicals to aquatic organisms, which were further expanded by Doherty (1983). Kimerle et al. (1983) analyzed an approach used by the Organization for Economic Cooperation and Development and the U.S. Environmental Protection Agency that includes only two or three species—a daphnid, a fish, and possibly an alga. This latter approach is discussed first, based on our data.

Kimerle et al. (1983) compared the lowest LC50 of the four most commonly tested species to the LC50 of other species tested within 82 chemicals by orders of magnitude. Daphnids (*Daphia magna* or *D. pulex*, or both), rainbow trout, fathead minnows, or bluegills were within an order of magnitude of the most sensitive species 76, 74, 47, and 52% of the time, and within two orders of magnitude 93, 91, 74, and 70% of the time, respectively. Combinations of the three fish species did not improve the percent of chemicals included within one and two orders of magnitude. However, daphnids in combination with one of the three fish species (69 to 81 chemicals) greatly improved the frequency: 90% of the chemicals were within one order of magnitude of the lowest LC50 value and up to 98% were within two orders of magnitude.

The four main species were tested together with 40 chemicals (6 to 42 species per chemical) in our data, and the LC50 comparisons generally agreed with those of Kimerle et al. (1983). Daphnids (*Daphnia magna* or *D. pulex*), rainbow trout, fathead minnows, and bluegills were within an order of magnitude of the most sensitive species 75, 35, 28, and 38% of the time and within two orders of magnitude 90, 65, 58, and 72% of the time, respectively. The testing of daphnids in combination with one of the three fishes increased the frequency to 85% within one order of magnitude and 98 to 100% within two orders of magnitude. More specifically, the exact orders of magnitude to include the most sensitive species tested 100% of the time within the 40 chemicals we examined were 1.40 (25×) for daphnid-rainbow trout combinations, 2.05 (112×) for daphnid-fathead minnows, and 1.87 (74×) for daphnid-bluegills. In other words, one could divide the lowest of the two LC50's for daphnids and rainbow trout by 25 to obtain an estimate of an LC50 that would include the "most sensitive" species, based on the 6 to 42 species examined. The value for daphnid-fathead minnows was 112 and that for daphnid-bluegills was 74. The values that included the most sensitive species 95% of the time for the three combinations of species were 15 for daphnid-rainbow trout, 46 for daphnid-fathead minnows, and 28 for daphnid-bluegills.

As attractive as it may seem, the use of specific factors can lead to overestimation of the toxicity for the most sensitive species with some chemicals. The daphnid-rainbow trout combinations were examined thoroughly within the 40 chemicals, since in the few tests where LC50's for fathead minnows or bluegills were below those for daphnids or rainbow trout, the differences were not statistically significant. Other species were more sensitive than daphnids or rainbow trout to 27 of the 40 chemicals tested—only 0.5 order of magnitude difference in toxicity values included 59% of the 27 chemicals, and one order of magnitude included 85%. However, LC50's of the most sensitive species were significantly less than those of daphnids or rainbow trout in 11 of the 27 chemicals. No particular chemical type was represented by the 11 compounds (aldrin, benomyl, DDD, fenitrothion, fenvalerate, fluridone, heptachlor, lindane, permethrin, Pydraul 50E, and terbufos) except that eight were insecticides. The species having values (*n*) significantly less than those of *Daphnia* or rainbow trout were *Gammarus* (5), *Orconectes nais* (1), *Pteronarcys californica* (2), *Chironomus plumosus* (1), coho salmon (1), and channel catfish (1). If an amphipod (*Gammarus*) was included in the comparisons as a test species, as suggested by Mount (1982), the number of chemicals having a species LC50 significantly less than that for daphnids, amphipods, or rainbow trout was five (12%). The most sensitive species for those five chemicals (Aldrin, benomyl, fluridone, heptachlor, and Pydraul 50E) represented no one particular taxonomic group; they were *Orconectes nais*, *Pteronarcys californica*, *Chironomus plumosus*, coho salmon, and channel catfish.

An approach by Doherty (1983) and Kenaga (1978) was to correlate the LC50's of one species against another for all chemicals tested with those two species, by regression analyses. They each used four species of freshwater organisms (*Daphnia magna* or *D. pulex*, rainbow trout, fathead minnows, and bluegills) in their correlations. The correlations were good in Doherty's study ($r = 0.89$ to 0.97), indicating that the LC50 of one species can be estimated by the substitution of the LC50 of another species in appropriate regression equations. Kenaga found that correlations within the three fish species were also good ($r = 0.85$ to 0.99), but the correlation with *Daphnia* and rainbow trout was poor ($r = 0.56$) with 95% confidence limits of 2.2 to 3.3 orders of magnitude. We also found that the toxicity values for *D. magna* did not correlate well with those for other species (Table 1). This observation with daphnids confirms those by Kenaga (1978) and LeBlanc (1984)—all three data sets consisted of all or mostly

Table 1. *Interspecies correlations*[a] *for acute static LC50's (ng/L) with* Daphnia magna.

Species	*n*	Intercept (*a*)	Slope (*b*)	$\bar{Y}$ ± 95% CL	Correlation coefficient (*r*)
Daphnia pulex	8	3.031	0.156	3.566 ± 0.497	0.21
Simocephalus serrulatus	9	2.346	0.395[b]	3.690 ± 0.322	0.70
Asellus brevicaudus	5	12.035	-1.963	4.581 ± 1.231	0.83
Gammarus fasciatus	14	1.876	0.611[b]	4.289 ± 0.457	0.82
Gammarus pseudolimnaeus	18	-0.462	1.010[b]	4.912 ± 0.271	0.95
Claassenia sabulosa	5	6.949	-0.999	3.147 ± 0.761	0.78
Pteronarcella badia	7	2.597	0.220	3.497 ± 0.491	0.35
Pteronarcys californica	10	1.475	0.667[b]	4.151 ± 0.938	0.65
Chironomus plumosus	25	0.802	0.846[b]	5.527 ± 0.300	0.86
Coho salmon	8	7.056	-0.531	4.969 ± 1.511	0.36
Cutthroat trout	7	4.943	0.265	6.061 ± 1.159	0.43
Rainbow trout	31	3.208	0.428[b]	5.338 ± 0.387	0.54
Goldfish	6	9.212	-0.941	5.981 ± 1.578	0.48
Common carp	5	10.494	-1.480	5.590 ± 2.032	0.67
Fathead minnow	26	4.743	0.236	5.890 ± 0.478	0.32
Black bullhead	5	10.367	-1.402	5.723 ± 2.529	0.56
Channel catfish	31	5.306	0.095	5.776 ± 0.434	0.12
Green sunfish	6	7.652	-0.591	5.624 ± 1.689	0.31
Bluegill	31	3.140	0.488[b]	5.480 ± 0.432	0.60
Largemouth bass	6	9.548	-1.326	5.013 ± 1.625	0.60
Fowler's toad	5	7.092	-0.438	5.405 ± 0.495	0.65
Western chorus frog	5	7.165	-0.414	5.724 ± 0.606	0.73

[a] $\log Y = a + b(\log X)$; Y = LC50 for other species, X = LC50 for *Daphnia magna*.

[b] Significantly different from zero ($P \leqslant 0.05$).

pesticides. The data of Doherty (1983) covered a broader range of chemical types.

For our data, correlations of toxicity values for rainbow trout, fathead minnows, or bluegills were good with those of some invertebrate species, better with those of other fish species, but best with those of other species within the same family (Tables 2 through 4). This general trend was also observed by LeBlanc (1984) and Suter and Vaughn (1985), who concluded that the more distant the relationship between two species, the more different their responses to chemical toxicity. Although toxicity of a chemical for one species can be predicted from the known toxicity of another, it must be remembered that correlation is not necessarily the same as causation in regression analyses, and that the error of estimation in correlation can therefore be large.

In initial hazard assessment testing tiers, Doherty (1983) concluded that *D. magna* should be the species of choice; Kenaga (1978) recommended a daphnid and a fish species; and Kimerle et al. (1983) recommended an alga, a daphnid, and a fish. Considering these studies and the present data, *Daphnia* and rainbow trout appear to be the first two taxa of choice for estimating freshwater animal sensitivity to chemicals in a first tier of testing. Other fish species could be used, but rainbow trout appeared to be the most sensitive overall. When a small margin of safety exists (less than one order of magnitude) between the expected or measured environmental concentration of a chemical and its acute toxicity, a more extensive data base is justified. As judged by our data, the inclusion of tests with amphipods and possibly stoneflies is indicated, to better approximate the toxicity for the most sensitive animal species.

On the basis of the work of Kimerle et al. (1983) and Blanck et al. (1984), algae should be further investigated as a third possible species for first tier testing. Additionally, interspecies correlations and other statistical and mathematical approaches must be expanded to include freshwater and marine species, and both the common and uncommon test species for which data exist.

Table 2. *Interspecies correlations*[a] *for acute sta*[illegible]*LC50's (ng/L) with rainbow trout.*

Species	n	Intercept (a)	Slope (b)	$\bar{Y} \pm 95\%$ CL	Correlation coefficient (r)
Daphnia magna	31	1.299	0.687[b]	4.961±0.493	0.54
Daphnia pulex	34	2.368	0.408[b]	4.502±0.492	0.35
Simocephalus serrulatus	35	2.979	0.298	4.555±0.502	0.25
Cypridopsis vidua	9	1.165	0.703[b]	4.390±0.311	0.85
Asellus brevicaudus	15	0.858	0.841[b]	4.854±0.398	0.80
Gammarus fasciatus	45	2.635	0.424[b]	4.855±0.397	0.36
Gammarus lacustris	19	2.219	0.357	4.121±0.489	0.44
Gammarus pseudolimnaeus	22	−0.968	1.067[b]	5.245±0.443	0.83
Claassenia sabulosa	10	1.296	0.434[b]	3.222±0.346	0.74
Pteronarcella badia	12	0.760	0.560[b]	3.729±0.329	0.90
Pteronarcys californica	42	0.990	0.632[b]	4.266±0.363	0.55
Chironomus plumosus	24	−0.135	0.960[b]	5.442±0.411	0.74
Coho salmon	24	0.022	0.985[b]	5.441±0.248	0.95
Chinook salmon	7	0.212	0.962[b]	6.047±0.284	0.98
Cutthroat trout	18	0.726	0.894[b]	5.803±0.178	0.96
Atlantic salmon	11	−0.163	1.026[b]	5.667±0.337	0.95
Brown trout	14	−0.023	1.019[b]	5.478±0.165	0.98
Brook trout	11	−0.804	1.130[b]	5.697±0.186	0.98
Lake trout	8	0.654	0.872[b]	5.627±0.184	0.99
Goldfish	15	1.258	0.878[b]	5.508±0.463	0.86
Common carp	8	1.511	0.832[b]	5.734±0.824	0.78
Fathead minnow	61	0.796	0.928[b]	5.961±0.134	0.94
Black bullhead	8	2.203	0.708[b]	5.553±0.972	0.79
Channel catfish	78	1.391	0.802[b]	5.906±0.160	0.82
Green sunfish	13	1.137	0.849[b]	5.408±0.255	0.96
Bluegill	101	0.135	1.005[b]	5.800±0.084	0.96
Largemouth bass	15	0.258	0.983[b]	5.611±0.339	0.96
Yellow perch	11	1.236	0.834[b]	5.391±0.366	0.94
Fowler's toad	12	3.563	0.456[b]	5.537±0.337	0.70
Western chorus frog	10	3.796	0.448[b]	5.904±0.300	0.85

[a] Log $Y = a + b(\log X)$; Y = LC50 for other species, X = LC50 for rainbow trout.
[b] Significantly different from zero ($P \leqslant 0.05$).

Families. The relative sensitivity of 34 families of aquatic organisms tested with 203 chemicals varied greatly. The maximum number of families (15) was tested with DDT, endrin, and malathion; they are listed here in descending order of sensitivity: Perlidae, Pteronarcidae, Gammaridae, Daphnidae, Centrarchidae, Palaemonidae, Salmonidae, Astacidae, Cypridae, Asellidae, Ictaluridae, Cyprinidae, Rhagionidae, Bufonidae, and Hylidae. However, some of the families were represented by only one species and others by many. A more complete representation might change the ranking. Although additional comparisons with smaller numbers of families and greater numbers of chemicals altered the ranking to some degree, the overall trend was maintained (e.g., insects were the most sensitive, followed by crustaceans, fishes, and amphibians).

Sensitivity of crustaceans was evaluated with six families and five insecticides, and four families and nine chemicals (eight insecticides and one herbicide). Gammaridae were the most sensitive to the five insecticides (carbaryl, DDT, endrin, malathion, and methoxychlor), followed by the Palaemonidae, Daphnidae, Astacidae, Cypridae, and Asellidae. Sanders (1970) found a different order of sensitivity with herbicides, reporting that Daphnidae were the most sensitive, followed in descending order by Cypridae, Palaemonidae, Asellidae, Gammaridae, and

Table 3. *Interspecies correlations*[a] *for acute static LC50's (ng/L) with fathead minnows.*

Species	n	Intercept (a)	Slope (b)	$\bar{Y}$ ± 95% CL	Correlation coefficient (r)
Daphnia magna	26	2.241	0.442	4.841 ± 0.636	0.33
Daphnia pulex	22	5.741	-0.311	3.996 ± 0.537	0.34
Simocephalus serrulatus	22	5.969	-0.336[b]	4.054 ± 0.455	0.43
Cypridopsis vidua	8	2.649	0.314[b]	4.253 ± 0.381	0.73
Asellus brevicaudus	11	1.446	0.567[b]	4.511 ± 0.404	0.82
Gammarus fasciatus	24	4.744	-0.086	4.270 ± 0.512	0.10
Gammarus lacustris	14	3.107	0.167	4.052 ± 0.457	0.34
Gammarus pseudolimnaeus	14	-1.911	1.123[b]	5.060 ± 0.690	0.80
Claassenia sabulosa	9	1.692	0.303[b]	3.274 ± 0.407	0.71
Pteronarcella badia	11	1.859	0.286[b]	3.434 ± 0.180	0.87
Pteronarcys californica	27	2.012	0.326[b]	3.887 ± 0.413	0.42
Chironomus plumosus	18	-0.888	1.082[b]	5.651 ± 0.551	0.73
Coho salmon	17	-0.856	1.038[b]	5.249 ± 0.308	0.96
Cutthroat trout	13	-0.559	1.001[b]	5.731 ± 0.471	0.86
Rainbow trout	61	-0.090	0.947[b]	5.555 ± 0.126	0.95
Atlantic salmon	10	-1.772	1.198[b]	5.736 ± 0.322	0.96
Brown trout	9	-2.225	1.259[b]	5.656 ± 0.571	0.88
Brook trout	11	-1.329	1.134[b]	5.697 ± 0.421	0.92
Goldfish	19	0.572	0.924[b]	5.732 ± 0.189	0.97
Common carp	8	-0.040	0.988[b]	5.734 ± 0.365	0.96
Black bullhead	8	1.411	0.767[b]	5.553 ± 0.664	0.91
Channel catfish	48	0.954	0.832[b]	5.865 ± 0.185	0.88
Green sunfish	12	0.695	0.842[b]	5.472 ± 0.333	0.95
Bluegill	62	0.018	0.954[b]	5.675 ± 0.148	0.93
Largemouth bass	15	-0.433	0.972[b]	5.370 ± 0.423	0.93
Yellow perch	7	-0.110	0.967[b]	5.229 ± 0.322	0.99
Fowler's toad	12	5.075	0.087	5.492 ± 0.399	0.16
Western chorus frog	9	4.776	0.192	5.733 ± 0.391	0.50

[a] $\log Y = a + b(\log X)$; Y = LC50 for other species, X = LC50 for fathead minnows.
[b] Significantly different from zero ($P \leqslant 0.05$).

Astacidae. The nine-chemical comparison resulted in a similar trend of decreasing sensitivity, in the following order: Gammaridae, Daphnidae, Cypridae, and Asellidae. The Cypridae and Asellidae were significantly more sensitive than Daphnidae only to lindane. The Streptocephalidae were tested only with phosmet; the LC50 was higher than that for the other invertebrates tested, but below the range of LC50's for fishes.

Among families, insects were generally the most sensitive, due to the high sensitivity of stoneflies (Perlidae, Perlodidae, and Pteronarcidae) and one family of mayflies (Baetidae). The LC50's for species in other families of insects (Ephemeridae, Coenagrionidae, Gomphidae, Hydropsychidae, Limnephilidae, Culicidae, Rhagionidae, Tendipedidae, and Tipulidae) were within the range of (or generally not statistically significant from) the invertebrate and vertebrate families more commonly tested. However, the LC50's for Tendipedidae were significantly less than those of other families tested within a chemical for fluoridone, metolachlor, oxamyl, piperonyl butoxide, and Santicizer 148.

Macek and McAllister (1970) reported on the sensitivity of fishes to nine insecticides: the Cyprinidae and Ictaluridae were the least sensitive, the Centrarchidae were intermediate, and the Salmonidae were the most sensitive; the Percidae ranked between the Centrarchidae and Salmonidae. In the present study, in tests with the four main fish

Table 4. *Interspecies correlations*[a] *for acute st LC50's (ng/L) with bluegills.*

Species	n	Intercept (a)	Slope (b)	$\bar{Y}$ ± 95% CL	Correlation coefficient (r)
Daphnia magna	31	0.649	0.745[b]	4.785 ± 0.529	0.61
Daphnia pulex	25	3.081	0.242	4.339 ± 0.640	0.19
Simocephalus serrulatus	27	3.422	0.186	4.414 ± 0.612	0.16
Cypridopsis vidua	7	1.767	0.593[b]	4.285 ± 0.541	0.76
Asellus brevicaudus	13	0.607	0.887[b]	5.053 ± 0.472	0.86
Gammarus fasciatus	47	1.863	0.546[b]	4.774 ± 0.361	0.49
Gammarus lacustris	19	2.436	0.306	3.992 ± 0.511	0.40
Gammarus pseudolimnaeus	22	−1.117	1.040[b]	5.220 ± 0.386	0.87
Procambarus sp.	5	1.465	0.701	5.589 ± 1.497	0.70
Claassenia sabulosa	10	1.580	0.368[b]	3.222 ± 0.330	0.77
Pteronarcella badia	12	1.724	0.392	3.680 ± 0.546	0.57
Pteronarcys californica	40	0.514	0.732[b]	4.430 ± 0.398	0.63
Chironomus plumosus	25	0.649	0.811[b]	5.458 ± 0.430	0.72
Coho salmon	24	0.222	0.933[b]	5.155 ± 0.233	0.95
Chinook salmon	5	−0.511	1.083[b]	5.788 ± 0.285	0.99
Cutthroat trout	22	0.692	0.876[b]	5.696 ± 0.229	0.90
Rainbow trout	101	0.440	0.898[b]	5.635 ± 0.079	0.96
Atlantic salmon	13	−0.229	1.028[b]	5.426 ± 0.214	0.98
Brown trout	14	−0.691	1.141[b]	5.323 ± 0.251	0.94
Brook trout	11	−0.886	1.139[b]	5.728 ± 0.337	0.95
Lake trout	11	0.237	0.903[b]	5.004 ± 0.197	0.98
Goldfish	17	1.295	0.846[b]	5.644 ± 0.460	0.84
Common carp	8	1.951	0.746[b]	5.734 ± 0.787	0.80
Fathead minnow	62	0.947	0.883[b]	5.931 ± 0.152	0.92
Black bullhead	8	1.696	0.798[b]	5.553 ± 0.883	0.85
Channel catfish	75	1.918	0.713[b]	5.870 ± 0.171	0.78
Green sunfish	15	0.999	0.881[b]	5.486 ± 0.195	0.97
Largemouth bass	15	0.051	1.003[b]	5.408 ± 0.233	0.98
Yellow perch	12	0.078	1.029[b]	5.167 ± 0.432	0.91
Fowler's toad	11	3.996	0.375	5.523 ± 0.400	0.44
Western chorus frog	9	4.412	0.297	5.733 ± 0.339	0.66

[a] $\log Y = a + b(\log X)$; Y = LC50 for other species, X = LC50 for bluegills.
[b] Significantly different from zero ($P \leqslant 0.05$).

families and 65 chemicals, Salmonidae were the most sensitive, followed by the Centrarchidae, Ictaluridae, and Cyprinidae—a ranking that confirms the observations of Macek and McAllister (1970). However, Percidae ranked between Centrarchidae and Ictaluridae when tests of all five families with 18 chemicals were compared. Five of the six LC50's for Esocidae were below those of five other families (Centrarchidae, Cyprinidae, Ictaluridae, Percidae, and Salmonidae), but the difference was significant only for azinphos methyl. In the few tests conducted with fish of other families, the LC50's for Poeciliidae were within the range for the other families tested and those for the Cichlidae were generally greater, but not significantly so. Only 38% of the fish tests with 65 chemicals showed significant differences among families, and 76% of those differences were between cyprinids and salmonids.

When test data from seven major families tested with 20 insecticides and 1 herbicide were compared, invertebrates were the most sensitive 95% of the time. The Pteronarcidae were the most sensitive, followed by Daphnidae, Gammaridae, Salmonidae, Centrarchidae, Ictaluridae, and Cyprinidae.

Classes. No one class was always the most sensitive or always the least sensitive. Overall, sensitivity to 163 chemicals decreased in the following order: Insecta, Crustacea, Osteichthyes, and Amphibia. These four classes occurred together in tests of 16 chemicals; Insecta were the most sensitive 50% of the time, followed by Crustacea (31%), Osteichthyes (19%), and Amphibia (0%). The comparisons were not balanced, since the Crustacea were represented by 12 species, Insecta by 21, Osteichthyes by 30, and Amphibia by 2. In other studies (Birge et al. 1980; Black et al. 1982), amphibians (pickerel frog, *Rana palustris*; African clawed frog, *Xenopus laevis*; Fowler's toad) were as tolerant as cyprinids, whereas the leopard frog (*R. pipiens*) and European common frog (*R. temporaria*) were as sensitive as salmonids. However, we believe that the overall trend would not be greatly changed by the addition of more species. In comparisons of Crustacea, Insecta, and Osteichthyes tested with 85 chemicals, the Insecta were the most sensitive 49% of the time, followed by Crustacea (27%) and Osteichthyes (24%). Crustacea were the second most sensitive 51% of the time, and Osteichthyes the least sensitive 55% of the time. Analysis of variance indicated that toxicity was not significantly different among classes for 32 of the 85 chemicals examined: 2 fungicides, 9 herbicides, 7 industrials, 12 insecticides, 1 molluscicide, and 1 surfactant.

Frequency Distribution of Chemical Toxicity

Frequency distributions of EC50's and LC50's tended to be bimodal for many species—the toxicities of insecticides were mainly in the <100 μg/L categories, and those of herbicides, fungicides, industrials, and other chemicals were in the >1,000 μg/L categories (Fig. 1*A*–1*D*). The lower mode contained almost all of the insecticides tested with invertebrates, whereas among fishes, insecticides were spread over more of the toxicity range. Insecticides occurring in the lower modes of fishes were mainly botanicals and organochlorines plus some carbamates and organophosphates. The distribution of chemical toxicities in larval frogs and toads was similar to that for fishes, within the confines of the few chemicals tested against amphibians. For all invertebrates and fishes, the higher mode consisted mainly of herbicides and industrials. The trends were the same as those found by Kenaga (1978); insecticides are generally more toxic to animals than are herbicides.

Frequency distributions of EC50's and LC50's among species (352 chemicals, 61 species) ranged over nine orders of magnitude, and 90% fell within five orders of magnitude (Fig. 1*E*). For all the compounds tested within a class, the ranges of EC50 or LC50 values were eight orders of magnitude for Crustacea, seven for Insecta, nine for Osteichthyes, and four for Amphibia (Fig. 1*E*). The frequency distributions for classes were similar to those for species, in that they were bimodal rather than normally distributed for Crustacea, Insecta, and Osteichthyes. The frequency was highest in the low mode (1.0–10 μg/L) for Insecta and in the high mode (1,000–10,000 μg/L) for fish; for Crustacea, frequencies in the two modes (10–100 and 1,000–10,000 μg/L) were about equal. The chemical distribution was similar to that for species, in that insecticides were mainly in the first mode and herbicides, industrials, and others in the second mode. However, insecticides were spread more evenly over the entire range of chemical toxicities for Insecta and Osteichthyes.

If large variations in species response to a variety of chemicals is desirable for differentiating between toxicities of compounds (Kenaga 1978), we can make recommendations for test species. Various chemical toxicities ranged over seven orders of magnitude for *Daphnia magna*, *D. pulex*, *Gammarus fasciatus*, and *G. pseudolimnaeus*; for all other invertebrates this range was six orders of magnitude or less. The range was nine orders of magnitude for rainbow trout and eight orders of magnitude for coho salmon, fathead minnows, and bluegills. The orders of magnitude for all other fish and amphibians ranged from three to seven. However, the data may be somewhat misleading, since not all species were tested with all chemicals. Also, an upper limit of testing (100–1,000 mg/L), though appropriate, may have reduced the full range of toxicities for the generally less sensitive species.

Static and Flow-through Tests

The data set consisted of 123 paired static and flow-through tests with 41 chemicals. Ratios of static to flow-through tests (96-h LC50's) used for analyses ranged from 0.12 to 8.5 (mean, 2.0). The ratios varied considerably among chemicals, but the variation was generally as great among species within a chemical. Static LC50's were more than 1.5× those of flow-through tests 53% of the time, and no differences (ratios of 0.5–1.5) were observed in 37%

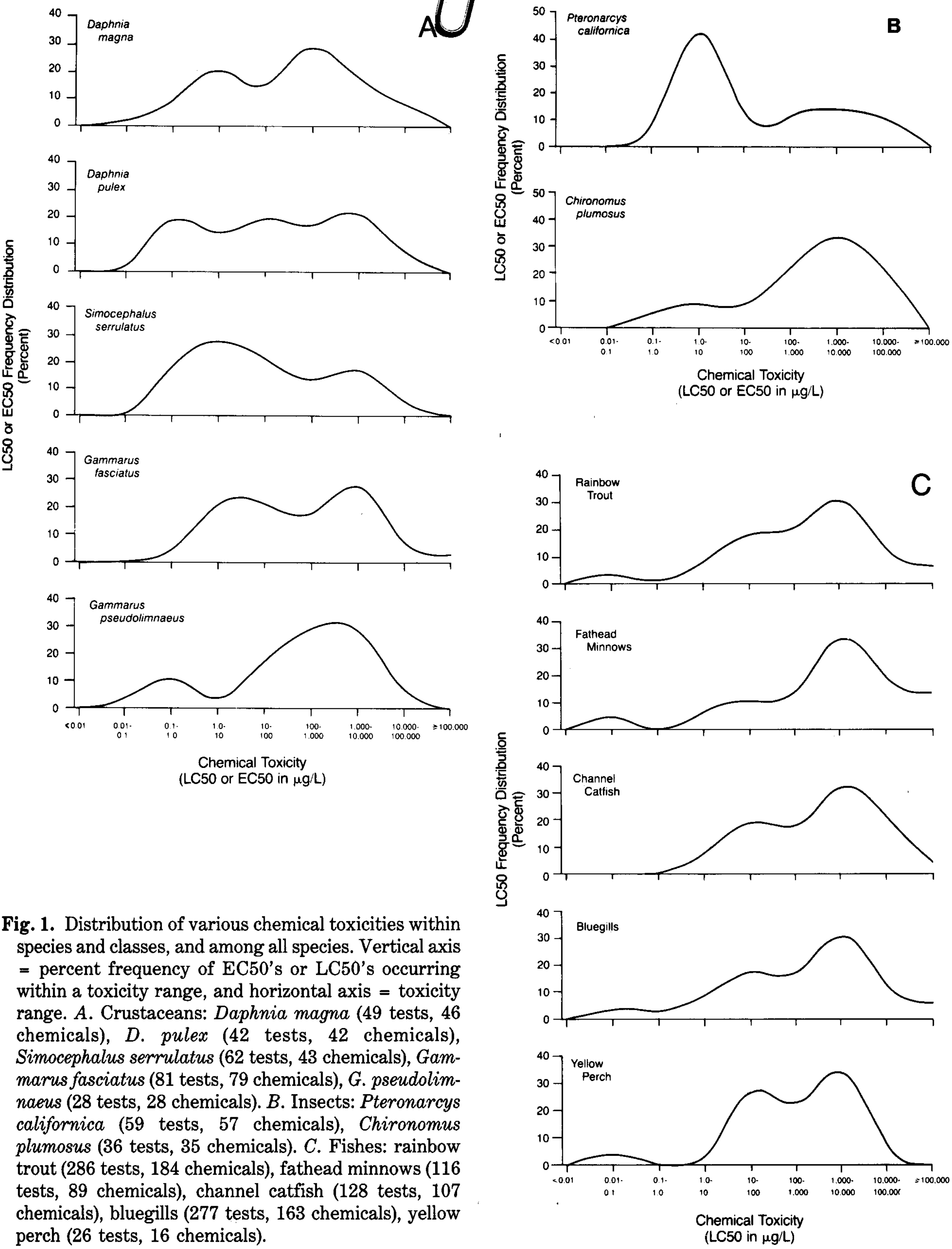

Fig. 1. Distribution of various chemical toxicities within species and classes, and among all species. Vertical axis = percent frequency of EC50's or LC50's occurring within a toxicity range, and horizontal axis = toxicity range. *A*. Crustaceans: *Daphnia magna* (49 tests, 46 chemicals), *D. pulex* (42 tests, 42 chemicals), *Simocephalus serrulatus* (62 tests, 43 chemicals), *Gammarus fasciatus* (81 tests, 79 chemicals), *G. pseudolimnaeus* (28 tests, 28 chemicals). *B*. Insects: *Pteronarcys californica* (59 tests, 57 chemicals), *Chironomus plumosus* (36 tests, 35 chemicals). *C*. Fishes: rainbow trout (286 tests, 184 chemicals), fathead minnows (116 tests, 89 chemicals), channel catfish (128 tests, 107 chemicals), bluegills (277 tests, 163 chemicals), yellow perch (26 tests, 16 chemicals).

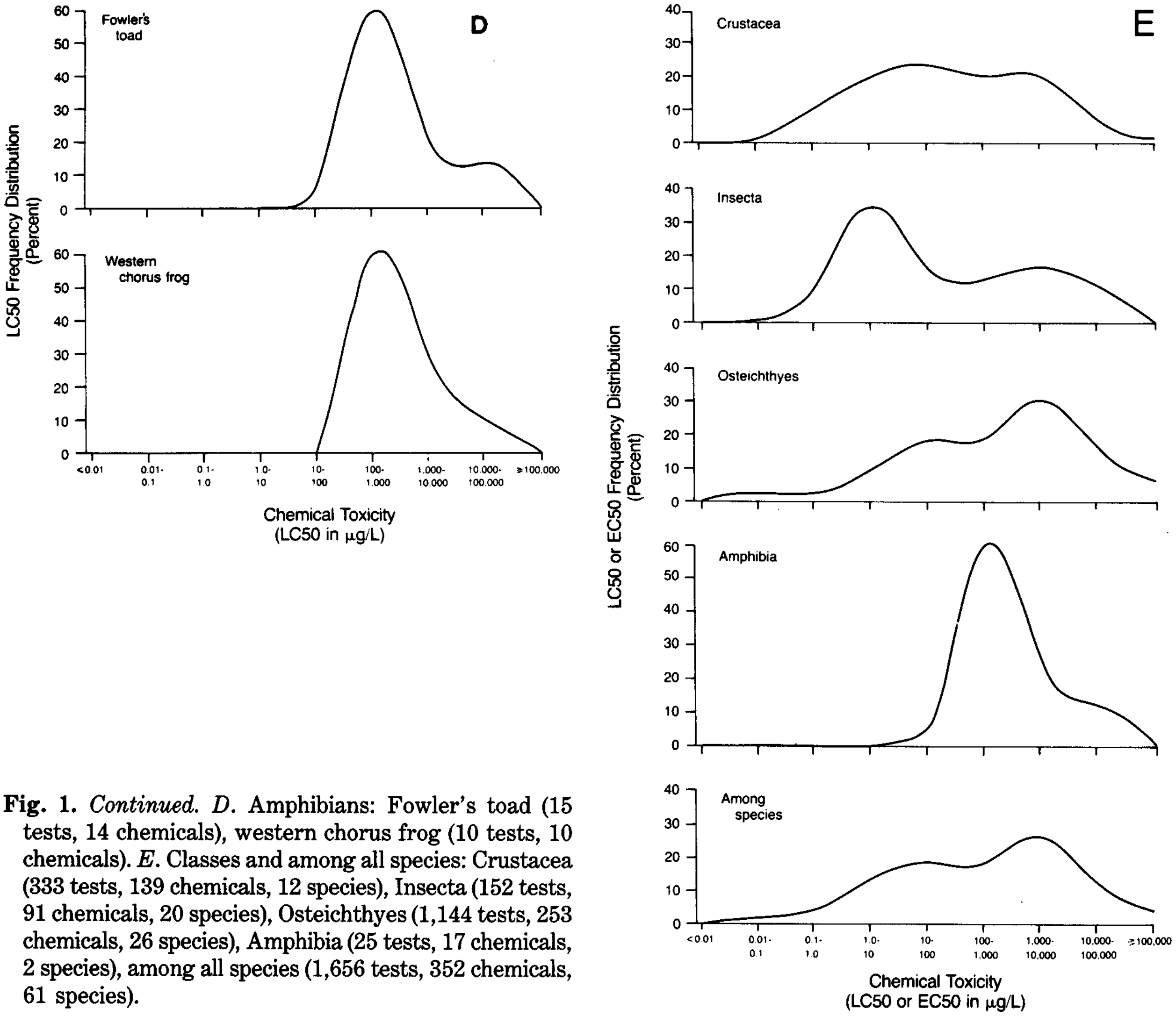

Fig. 1. *Continued. D.* Amphibians: Fowler's toad (15 tests, 14 chemicals), western chorus frog (10 tests, 10 chemicals). *E.* Classes and among all species: Crustacea (333 tests, 139 chemicals, 12 species), Insecta (152 tests, 91 chemicals, 20 species), Osteichthyes (1,144 tests, 253 chemicals, 26 species), Amphibia (25 tests, 17 chemicals, 2 species), among all species (1,656 tests, 352 chemicals, 61 species).

of the tests. The observation that 10% of the ratios were <0.5 could indicate that degradation or hydrolysis products more toxic than the parent compounds were being tested under static conditions.

The eight organochlorine insecticides had one of the highest average ratios (2.5; range, 0.66–6.4) as expected, but the six pyrethrins and pyrethroids had the same average ratio (2.5; range, 0.51–8.5)—which was not expected. However, since the toxicity of pyrethrins and pyrethroids did not decrease with aging (Tables 5 and 6), these chemicals may be somewhat persistent, having a higher static to flow-through ratio, as organochlorine insecticides do. The ratios for four carbamate insecticides (1.8; range, 0.12–3.8) and nine organophosphate insecticides (1.9; range, 0.27–7.5) were similar to those of the two fungicides (2.1; range, 0.75–3.6); the ratios for nine herbicides (1.4; range, 0.32–3.3) and three industrial compounds (1.4; range, 0.83–2.4) tested were not different from each other.

It was previously reported that static toxicity values can be multiplied by 0.71 to estimate values for flow-through tests (U.S. Environmental Protection Agency 1979). The factor of 0.71 was based on the geometric mean of values for 24 pairs of tests on 12 chemicals. Our data for 123 paired tests and 41 chemicals indicate an average factor of 0.51, which varies with chemical type. The use of the factor of 0.51 would only be a crude estimate, however, since the ratios of static to flow-through 96-h LC50's varied by 1.8 orders of magnitude.

Aged Test Solutions

The biological activity of a toxicant, which is responsible for the killing power, decreases as the toxicant is deactivated biologically and chemically over time (Marking 1972). In the absence of adequate analytical methods to measure the half-life of some chemicals in water, Marking (1972) outlined an appropriate bioassay method. His method does not differentiate between chemical degradation, physical removal, and biological inactivation, but does estimate the total activity of a chemical and its degradation products, except as the chemical is removed. The deactivation index, derived by Marking and Dawson (1972) is obtained by dividing the LC50 of an aged test solution by the LC50 of a fresh test solution, and determines both decreases and increases in biological activity.

To determine how often the toxicity of an aged test solution differed from that of a fresh solution, we established a data set with 46 tests on 22 chemicals. Data for dinoseb, glyphosate, mexacarbate, picloram, pyrethrins, and pyrethroids (Table 5) were previously published by Folmar et al. (1979), Mauck et al. (1976, 1977), and Woodward (1976).

Although toxicity increased in some fish species and decreased in others within the same chemical (e.g., aminocarb, fenitrothion, and glyphosate), it appears that deactivation indices between about 0.5

Table 5. *Toxicity (96-h LC50, mg/L) of pesticides in fresh and aged solutions to aquatic organisms in soft water (40–44 mg/L $CaCO_3$) under static conditions.*

Chemical and species	pH	Toxicity of solution: Fresh	Toxicity of solution: Aged 7 days	Deactivation index[a]
Aminocarb				
Rainbow trout	7.2	0.14	0.12	0.86
Atlantic salmon	7.5	2.4	3.5	1.46
Brown trout	7.5	17	8.6	0.51
Bluegill	7.2	0.24	0.24	1.00
Carbaryl				
Isogenus sp.[b]	7.5	0.004	0.007	1.75
Cutthroat trout	7.3	6.8	4.0	0.59
2,4-D butyl ester				
Cutthroat trout	7.4	0.67	0.98	1.46
Lake trout	7.4	0.72	1.3	1.81
2,4-D dimethylamine salt				
Fathead minnow	7.4	760	760	1.00
2,4-D dodecyl/tetradodecyl amine salt				
Fathead minnow	7.4	9.1	2.2	0.24
2,4-D propylene glycol butyl ether ester				
Cutthroat trout	7.4	0.49	1.4	2.86
Lake trout	7.4	1.1	1.4	1.27
Dimethrin				
Bluegill	6.5	0.024	0.028	1.17
	7.5	0.030	0.028	0.93
	9.5	0.029	0.034	1.17
Dinoseb				
Cutthroat trout	7.4	0.071	0.16	2.25

Table 5. *Continued.*

Chemical and species	pH	Toxicity of solution: Fresh	Toxicity of solution: Aged 7 days	Deactivation index[a]
Diuron				
Cutthroat trout	7.0	1.5	12	8.00
Rainbow trout	7.5	3.5	4.2	1.20
Lake trout	7.0	2.7	3.2	1.18
d-trans allethrin				
Bluegill	6.5	0.056	0.040	0.71
	7.5	0.056	0.034	0.61
	9.5	0.060	0.074	1.23
EPTC				
Cutthroat trout	7.1	16	16	1.00
Fenitrothion				
Atlantic salmon	7.5	0.33	0.64[c]	1.94
Brown trout	7.5	2.4	1.7	0.71
Brook trout	7.5	1.9	1.7	0.89
Bluegill	7.2	4.3	4.4	1.02
Glyphosate				
Rainbow trout	7.4	9.0	7.6	0.84
Bluegill	7.4	4.0	5.6	1.40
Leptophos				
Rainbow trout	7.4	0.013	0.038	2.92
Methomyl				
Gammarus pseudolimnaeus[b]	7.2	1.0	0.34	0.34
Rainbow trout	7.2	1.4	1.5	1.07
Mexacarbate				
Coho salmon	7.5	23	15	0.65
Bluegill	6.5	23	18	0.78
	8.5	4.0	1.0	0.25
	9.5	1.0	0.92	0.92
Phosmet				
Chironomus plumosus[b]	7.4	3.3	>10[d]	> 3.03
Bluegill	7.2	0.39	>10[d]	>25.64
Phoxim				
Bluegill	7.5	1.0	1.0	1.00
Picloram				
Cutthroat trout	7.4	5.8	4.8	0.83
Pyrethrum				
Bluegill	6.5	0.041	0.066	1.61
	7.4	0.053	0.056	1.06
	9.5	0.087	0.090	1.03
s-Bioallethrin				
Bluegill	6.5	0.039	0.034	0.87
	7.5	0.033	0.044	1.33
Trichlorfon				
Cutthroat trout	7.5	1.7	0.47	0.28

[a] Deactivation index $= \dfrac{\text{LC50 aged solution}}{\text{LC50 fresh solution.}}$

[b] 48-h LC50.

[c] Solutions aged 14 days.

[d] Solutions aged 4 days.

Table 6. *Distribution of toxicity change of pesticides in test solutions aged for 7 days under acute static conditions.*

Pesticide type	Pesticides (*n*)	Tests (*n*)	Toxicity change distribution (%)[a]		
			None	Decrease	Increase
All chemicals	22	46	69	22	9
All chemicals (pH effects removed)	22	37	68	24	8
Herbicides	9	14	64	29	7
Insecticides	13	23	69	22	9
Carbamates	4	10	80	10	10
Organophosphates	5	9	44	44	11
Pyrethrins and pyrethroids	4	4	100	0	0

[a] Change in toxicity due to aging was determined by the ratio of aged to fresh solutions, and the ratios were categorized by change: none, 0.5–1.5; increase, <0.5; decrease, >1.5.

and 1.5 are probably within the range of normal experimental variation. If this assumption is true, aging did not affect chemical toxicity in 69% of the tests, decreased it in 22%, and increased it in 9% (Table 6). Stability of the chemicals was indicated where no change occurred. The toxicity of aged solutions decreased most in herbicides and increased most in carbamate insecticides.

Toxicities of dinoseb, EPTC, glyphosate, and picloram solutions aged for 7 days remained essentially unchanged. Although the toxicity of dinoseb appeared to decrease slightly and that of picloram to increase, continued aging and testing beyond 7 days showed no real change in toxicity. After 4 weeks of aging, deactivation indices for dinoseb, EPTC, and picloram were 1.22, 1.06, and 1.02, respectively. Conversely, diuron and the 2,4-D group of herbicides continued to decrease in toxicity after 3 to 4 weeks of aging. The one exception was the dodecyl/tetradodecylamine salt of 2,4-D, which increased in toxicity after 7 days of aging.

Essentially no changes occurred in deactivation studies with the carbamate insecticides aminocarb and methomyl. However, tests on *Gammarus pseudolimnaeus* with methomyl indicated some increase in toxicity. Exposure of fish to carbaryl and mexacarbate tended to show that the toxicity of aged solutions exceeded that of fresh solutions. Mauck et al. (1977) reported that mexacarbate hydrolyzes to chemicals that are more toxic than the parent compound before further hydrolyzing to less toxic chemicals. This phenomenon may have been the same for cutthroat trout exposed to carbaryl, since carbaryl hydrolyzes at pH 7.0 and above in aqueous solutions (Aly and El-Dib 1971). However, if hydrolysis products were formed, their toxicity to the stonefly *Isogenus* decreased after carbaryl was aged.

Studies on pyrethrum deactivation demonstrated no change in toxicity with aging at pH 7.5 and 9.5, but deactivation occurred at pH 6.5. Toxicity of dimethrin, s-bioallethrin, and *d*-trans allethrin was unchanged.

The biological activity of the organophosphate insecticides leptophos (phosphonothioate) and phosmet (phosphorodithioate) decreased considerably, whereas that of trichlorfon (phosphonate) increased. The responses of fishes to aged phosphorothioates (fenitrothion and phoxim) varied, but tended toward no change in toxicity. However, Eisler (1970) reported that 4 days of aging increased the toxicity of another phosphorothioate (methyl parathion) by 6.6×.

Deactivation studies are useful for determining biological activity of aged solutions of chemicals to aquatic organisms, but toxicity changes should not be of great concern in acute static tests. Chemical toxicity increased (by a factor of 2 or more) only 11% of the time and decreased 13% of the time. Toxicity never increased by more than a factor of 4; however, it decreased by as much as a factor of 25 in one test with phosmet, and the solutions were aged for 4 days—the same duration as that for acute static toxicity tests.

Factors Affecting Toxicity

Temperature

The effect of temperature on toxicity of chemicals to aquatic organisms was reviewed by Cairns et al. (1975*a*,*b*), Johnson (1968), Sprague (1970), and Tucker and Leitzke (1979). Temperature and toxicity are positively correlated for most chemicals: toxicity increases as temperature increases (positive temperature coefficient). Conversely, toxicity of DDD, DDT, and methoxychlor are negatively correlated with temperature and thus have negative temperature coefficients (Tucker and Leitzke 1979). Mauck et al. (1976) demonstrated a negative temperature coefficient in fishes for pyrethrins and several of the pyrethroids as well.

Differences in toxicity due to temperature have been attributed to differences in respiration rate (Weiss and Botts 1957), chemical absorption (Wuhrmann 1952), and excretion and detoxification of chemicals (Sprague 1970). Gammon et al. (1981) reported that the neurophysiological effects of *d*-trans allethrin on the cockroach (*Periplaneta americana*) are excitatory at both high and low temperatures, the temperature-dependent differences being in the types of nerves directly affected. Both peripheral and central nervous systems are affected at 32°C, but only the peripheral system at 15°C. Gammon et al. (1981) concluded that the negative temperature coefficient of allethrin toxicity could be a result of increases in sensitivity of peripheral nerves at low temperatures.

To determine if temperature affects acute toxicity in this data base, we conducted covariance analysis on 48 chemicals and 90 temperature tests for fishes (Table 7). Slopes in 26 tests with 19 chemicals differed significantly from zero. The ratio of the highest to lowest LC50 within a temperature test averaged 9.8 (ratio range, 3.1 to 51) among the 19 chemicals affected. Temperature coefficients were negative for DDT, dimethrin, and methoxychlor. There were also negative temperature coefficients (though not significantly different from zero) for pyrethrins and pyrethroids (fenvalerate, permethrin, and pyrethrum); however, the coefficient was positive for *d*-trans allethrin.

The negative slopes (positive temperature coefficient) were variable, ranging from −0.0218 for diuron to −0.1002 for chlorpyrifos, but were much more consistent among species within a chemical and within chemical groupings. When the slopes were compared with each other (Table 7), they were never significantly different among species within a chemical. Thus, differences were chemically rather than biologically specific. The slopes for the carbamates (aminocarb, carbaryl, and methomyl) were statistically similar, as were those for the organochlorines chlordecone and endrin. Among slopes for the herbicides, only those for diuron and trifluralin differed significantly. The slopes for the organophosphate insecticides varied to some degree, but the variation was reduced by further categorization. Among the slopes for phosphorothioates or phosphorodithioates, only two (phosphorodithioate) differed; the slope for azinphos-methyl and yellow perch was significantly different from that for malathion and bluegills. The slopes for malathion and parathion (phosphorothioate) differed significantly from most tests with trichlorfon, a phosphonate. The slope for the one organophosphate herbicide, merphos (phosphorotrithioate), was not significantly different from the slopes of any of the organophosphate insecticides. The slopes of the three chemicals (DDT, dimethrin, and methoxychlor) having negative temperature coefficients were also not significantly different from each other.

The temperature coefficient (Q_{10}) of respiration generally ranges from 2 to 4, indicating that a 10°C rise in temperature increases the rate of the reaction twofold to fourfold in cold-blooded animals (Giese 1968). Although Cairns et al. (1975*a*,*b*) included this well-known generalization in their review, they did not relate Q_{10} to the effects of temperature on chemical toxicity to aquatic organisms. The application of the Q_{10} concept is appropriate and useful for biologic effects, but was originally applied only to rate constants for nonbiotic reactions and processes. Thus it should apply to rates of reaction of factors that affect bioavailability under static test conditions (e.g., hydrolysis, microbial degradation, photolysis, solubility, sorption–desorption, and vaporization). If test concentrations are not measured, as in the present data, bioavailability could contribute significantly to temperature effects. In regard to the test organisms, the Q_{10} concept may apply not only to the rate of reaction of the toxicant at the site(s) of action, but also to residue dynamics within the organism (e.g., uptake, metabolism, and depuration). We analyzed the slopes (Table 7) to determine if the effects of temperature on toxicity were predictable within chemicals having positive or negative temperature coefficients, and whether the effects were related to the Q_{10} concept.

Table 7. *Effect of temperature on acute static toxicity (96-h LC50) of organic chemicals to fishes.*[a]

Chemical and species	Temperature range (°C)	LC50's (n)	LC50 range (µg/L)	Intercept (a)	Slope[b] (b)	r^2 (%)
Aminocarb						
Brook trout	7–17	3	2,600–9,400	4.3611	−0.0558	100
Yellow perch	7–22	4	1,700–11,700	4.4306	−0.0518	94
Azinphos-methyl						
Yellow perch	7–22	3	2.4–40	2.1678	−0.0820	100
Carbaryl						
Brook trout	7–17	3	680–2,100	3.9842	−0.0645	92
Yellow perch	7–22	4	1,200–13,900	4.6053	−0.0678	98
Chlordecone						
Redear sunfish	7–29	5	29–140	2.3558	−0.0304	100
Chlorpyrifos						
Rainbow trout	2–18	4	1.0–51	1.9361	−0.1002	96
DDT						
Bluegill	7–29	5	1.6–5.8	0.0282	0.0278	89
Dimethrin						
Bluegill	12–22	3	21–85	0.6517	0.0601	94
Diuron						
Bluegill	7–29	5	2,800–9,500	4.2199	−0.0218	74
Endothall, Aquathol K						
Bluegill	7–22	4	343–1,740[c]	6.6683	−0.0467	86
Endrin						
Bluegill	7–29	5	0.19–0.73	0.1008	−0.0258	90
Malathion						
Bluegill	7–29	5	20–87	2.2149	−0.0285	92
Merphos						
Bluegill	12–22	3	8,000–32,000	5.1043	−0.0546	100
Methomyl						
Bluegill	12–27	9	430–2,000	3.6418	−0.0394	75
Methoxychlor						
Brook trout	7–17	12	7.0–30	0.7625	0.0282	42
Parathion						
Bluegill	7–29	5	18–400	2.7551	−0.0421	37
Phosmet						
Bluegill	10–25	8	60–560	3.3188	−0.0664	92
Phoxim						
Coho salmon	7–17	3	215–1,160	3.5472	−0.0732	98
Bluegill	12–22	3	82–432	3.5074	−0.0722	100
Trichlorfon						
Rainbow trout[d]	7–17	21	190–11,400	3.7995	−0.0696	41
Atlantic salmon	7–17	3	580–4,100	4.0731	−0.0849	77
Brook trout	7–17	3	1,100–9,400	4.5889	−0.0932	98
Bluegill[d]	7–17	9	1,720–50,000	4.8566	−0.0867	50
Trifluralin						
Rainbow trout	2–18	7	14–330	2.6653	−0.0777	93
Bluegill	7–29	8	8.4–400	3.2144	−0.0635	70

[a] Log 96-h LC50 in µg/L = $a+b$ (temperature in °C).

[b] Significantly different from zero ($P \leqslant 0.05$).

[c] mg/L.

[d] Combined temperature effects at four pH's (6.5, 7.5, 8.5, and 9.0).

The antilog of the slope in the equation log LC50 = $a+b$ (temperature in °C) is, in essence, a factor of change in 96-h LC50 per 1°C. The slopes (Table 7) were multiplied by 10 to derive the log change per 10°C. The average for the 23 chemicals having positive temperature coefficients was 0.6082 (95% confidence limits [CL], 0.5140–0.7024). Thus, the log 96-h LC50 at a 10°C higher temperature can be predicted by subtracting 0.6082 from the log 96-h LC50 of an acute test previously conducted, or 0.6082 would be added for a 10°C decrease in temperature. This is equal to the LC50 increasing by a factor of 4.06 per 10°C decrease in temperature, or decreasing by a factor of 0.25 per 10°C increase. Similar factors for chemicals having negative temperature coefficients could be derived if adequate data were available.

The factor 4.06 (95% CL, 3.26–5.04) tends to be above the coefficients of 2 to 4 mentioned for the Q_{10} concept. Cairns et al. (1975*a*) stated that temperature interactions with organophosphates may be very complex due to the change in acetylcholinesterase (AChE) activity from temperature alone. The results of Hogan (1970) confirmed the increase in AChE activity with increased temperature for bluegills (log AChE = 2.4539 + 0.0165 [°C] or a factor of 1.46 increase per 10°C), and the slopes for the organophosphates tended to be greater than those for other chamicals (Table 7). The average slope was 0.7113 (95% CL, 0.5836–0.8390) for organophosphates alone, and 0.4956 (95% CL, 0.3775–0.6137) for the remaining chemicals.

Increased temperature, by accelerating AChE activity, may simultaneously increase the rate of AChE inhibition by organophosphates. By inspection, the interaction appears to be slightly more than additive, but further research is required to better delineate that interaction. The carbamates did not seem to be affected as much as the organophosphates, on the average, and this decreased effect may be due to differences in modes of action between carbamates and organophosphates in AChE inhibition (O'Brien 1967).

Most reports addressing temperature effects showed that most chemicals, including inorganics, were within or approximated a 2× to 4× increase or decrease in LC50 per 10°C change (Cairns et al. 1975*a*,*b*; DeGraeve et al. 1980; Hashimoto and Nishiuchi 1981; Macek et al. 1969; Mauck et al. 1976; Sanders 1969; Sanders et al. 1983; Schoettger 1970; Schoettger and Mauck 1978; Smith and Heath 1979; Sullivan 1977; Woodward 1976). This observation implies that the effect of temperature on 96-h LC50's for fish generally conforms to the Q_{10} concept.

Although the interactions between temperature and toxicity are not completely understood, interim approaches can be used to estimate effects. When a 96-h LC50 for a chemical has been determined for a fish species (96-h $LC50_1$), the following equations can be used for estimating the effect of a ±10°C change on the 96-h LC50's of chemicals having positive temperature coefficients:

Organophosphates:

$$\log 96\text{-h } LC50_2 = \log 96\text{-h } LC50_1 \pm 0.7113$$

Other chemicals:

$$\log 96\text{-h } LC50_2 = \log 96\text{-h } LC50_1 \pm 0.4956$$

Temperature effects on chemicals with negative temperature coefficients can also be estimated if the temperature coefficient is known. Additional research on temperature and toxicity of chemicals to invertebrates and structure–activity relations of chemicals with temperature is strongly indicated.

Hydrogen Ion Concentration (pH)

Depending on the chemical, the 96-h LC50 either increases or decreases with changes in pH (Johnson 1968; Sprague 1970; Tucker and Leitzke 1979). The toxicity of ionizable organic chemicals (weak acids and bases) is greatly affected by pH—increases in pH decrease the toxicity of acids but increase that of bases (Crandall and Goodnight 1959; Folmar et al. 1979; Goodnight 1942; Holcombe et al. 1980; Kaila and Saarikoski 1977; Kobayashi and Kishino 1980; Konemann and Musch 1981; Levy and Gucinski 1964; Marking 1975; Marking and Olson 1975; McLeay et al. 1979; Saarikoski and Vilukela 1981; Schoettger and Julin 1969; Sills and Allen 1971; Woodward 1976; Zanella 1983). The toxicities differ because un-ionized forms diffuse more readily across fish gills (Maren et al. 1968). Ionic pesticides such as diquat and paraquat might also be influenced by pH (Weber 1972).

It has been generally believed that carbamates and organophosphates undergo rapid hydrolysis under alkaline conditions; therefore, toxicity decreases due to the presence of less toxic hydroxylated products of the parent compounds. O'Brien (1967) reported that organophosphate hydrolysis products are generally poor inhibitors of acetylcholinesterase (AChE); however, inhibitory potency is not reduced in some hydrolysis products, and may even be increased (O'Brien 1967; Schoettger and Mauck 1978; Tucker and Leitzke 1979; Woodward and Mauck

Table 8. *Effect of pH on acute static toxicity (96-h LC50) of organic chemicals to aquatic organisms.*[a]

Chemical and species	pH range	LC50's (*n*)	LC50 range (µg/L)	Intercept (*a*)	Slope[b] (*b*)	r^2 (%)
Aminocarb						
Rainbow trout	7.5–9.5	3	5,000–21,000	6.8928	−0.3116	84
Bluegill	6.5–9.5	4	1,000–10,500	6.4465	−0.3272	84
Yellow perch	6.5–9.0	4	425–7,000	7.5024	−0.5023	69
Benomyl						
Rainbow trout	6.5–8.5	3	160–880	−0.4856	0.3702	82
Bluegill	6.5–8.5	3	1,200–6,400	0.5642	0.3461	71
Carbaryl						
Cutthroat trout	6.5–8.5	3	970–7,100	6.3612	−0.3561	
Yellow perch	6.5–9.0	4	350–4,200	7.5810	−0.5416	80
2,4-D dodecyl/tetradodecyl amine salt						
Fathead minnow	6.5–8.5	6	1,900–8,400	5.9166	−0.2930	86
Dinoseb						
Cutthroat trout	6.5–8.5	3	41–1,350	−3.7844	0.7588	96
Lake trout	6.5–8.5	3	32–1,440	−4.4295	0.8266	91
Diquat						
Bluegill	6.5–9.5	4	115,000–498,000	7.3810	−0.2312	92
Glyphosate						
Rainbow trout	6.5–9.5	4	1,400–7,600	5.2671	−0.2262	66
Mexacarbate						
Coho salmon	6.5–9.0	3	4,000–23,000	7.0636	−0.3702	73
Cutthroat trout	6.0–9.0	3	630–15,800	6.2523	−0.3364	46
Bluegill	6.5–9.5	5	600–22,900	8.5980	−0.5746	86
Phosmet						
Rainbow trout	6.5–9.5	5	105–4,700	−2.1843	0.5711	85
Bluegill	6.5–8.5	3	22–640	−3.7051	0.7319	97
Trichlorfon						
Pteronarcella badia	6.5–8.5	3	5.3–100	6.3414	−0.6379	90
Cutthroat trout	6.5–8.5	3	375–4,750	7.5694	−0.5513	99
Rainbow trout[c]	6.5–9.0	12	210–11,400	6.6397	−0.4337	49
Atlantic salmon	6.5–8.5	4	300–4,400	7.5368	−0.5832	81
Brook trout	6.5–9.0	7	240–9,200	8.6374	−0.6532	85
Bluegill[c]	6.5–9.0	12	1,720–50,000	8.0379	−0.4904	56

[a] Log 96-h LC50 in µg/L = $a + b$(pH).
[b] Significantly different from zero ($P \leqslant 0.05$).
[c] Combined pH effects at three temperatures (7, 12, and 17°C).

1980). Many of the hydroxylated products of carbamates have pronounced AChE inhibitory activity (O'Brien 1967; Mauck et al. 1977; Schoettger and Mauck 1978; Woodward and Mauck 1980).

Covariance analysis was conducted on 49 chemicals and 100 pH tests (pH range, 6.0–9.5) with fishes and a few aquatic invertebrates. Slopes significantly different from zero were observed in 23 of the tests on 10 chemicals (Table 8). Although pH significantly affected the toxicity of only 20% of the chemicals, it caused greater average changes in 96-h LC50's than did any other factor examined. The ratio of the highest to lowest LC50 within a pH test averaged 16 (range, 4.2 to 45) among the 10 chemicals affected. The slopes were relatively consistent among species within a chemical, indicating chemical rather than biological differences. No significant effects of pH on acute toxicity were found for the nine industrials, two organochlorine insecticides, or five pyrethrin and pyrethroid insecticides tested, although five of the industrials were organophosphate compounds.

The toxicities of only 2 of the 11 organophosphate insecticides—phosmet and trichlorfon—were significantly affected by pH. The toxicity of phosmet decreased and that of trichlorfon increased within a change of 2 to 3 pH units. O'Brien (1967) reported that phosphates hydrolyze more readily than their corresponding phosphorothionates under alkaline conditions; our data agree, in that eight of the nine organophosphates not affected by pH were thionates of one form or another. The only exception was the phosphate dichlorvos, which is structurally similar to trichlorfon. The 96-h LC50's of dichlorvos for cutthroat trout were the same (170 μg/L) from pH 6.0 to 9.0, and Eisler (1970) found that dichlorvos aged for 4 days was slightly less toxic than fresh material to mummichogs (*Fundulus heteroclitus*). Either dichlorvos is hydrolyzed more slowly than trichlorfon, or the toxicity of the dichlorvos hydrolysis products differs little from that of the parent compound. Trichlorfon rapidly hydrolyzes to dichlorvos under alkaline conditions (O'Brien 1967), and dichlorvos was 2.6 to 350× more toxic than trichlorfon to aquatic organisms. Phosmet, the only thionate significantly affected by pH, differs from the other thionates in being a phthalimide. It is rapidly metabolized by animals to phthalamic acid by amidase cleavage and subsequent hydrolysis (O'Brien 1967).

Carbamate toxicity increased with pH, indicating the formation of toxic hydrolysis products under alkaline conditions (Table 8). Effects of pH were significant with three methyl carbamate insecticides, but not with methomyl (thioacetimidate). However, the toxicity of benomyl, a carbamate fungicide with a chemical structure (benzimidazole) totally different from that of the insecticides, decreased significantly with increasing pH.

The effects of pH on carbamate and organophosphate insecticides corresponded to the age of the test solutions. Toxicity decreased or increased with solution age (Tables 5 and 6) and with increased pH. Thus the impact of pH on toxicity of these chemicals appears to be primarily a hydrolytic phenomenon, although aging does not necessarily involve only hydrolysis.

Many of the herbicides tested were dissociable organic chemicals, but only 4 of 17 were significantly affected by pH (Table 8). Of these four, diquat is cationic and 2,4-D, dinoseb, and glyphosate are dissociable. The toxicity of dinoseb decreased, as would be expected, but the toxicities of dodecyl/tetradodecyl amine salt of 2,4-D and glyphosate increased. When dissolved in water, organic amines convert partly to ions (O'Brien 1967; Sills and Allen 1971), and the increased accumulation of the un-ionized form of dodecyl/tetradodecyl amine at higher pH's could oppose the expected effects of pH on 2,4-D. The glyphosate tested was formulated, and the increased toxicity was due to the surfactant (MON 0818) in the formulation (Folmar et al. 1979). The acidic technical glyphosate was more toxic at pH 6.5 than at pH 9.5. The toxicity of most of the acidic herbicides decreased with increasing pH, as would be expected—though the decreases were not statistically significant.

Predicting the effects of pH on acute toxicity of organic chemicals is difficult because the impact of the effects is varied. We agree with Saarikoski and Viluksela (1981), who reported that pH effects have been poorly analyzed for predicting the toxicity and accumulation of ionizable organic chemicals or the toxicity of those that hydrolyze. Before the effects of pH on bioavailability and toxicity can be adequately predicted, more research relating pH to structure–activity interactions is needed, in which properly designed replications of toxicity tests and appropriate statistical and mathematical analyses are used.

Hardness

Water hardness is known to affect chemical toxicity. Inglis and Davis (1972) and Sprague (1970) reviewed the effects of hardness on chemical toxicity to aquatic organisms. Although the results varied, the toxicity of most inorganic and some organic chemicals was affected by water hardness. We agree with the intimations of Inglis and Davis (1972) and Pickering and Henderson (1964), who found that hardness had little effect on toxicity of organic chemicals, and that any changes were probably due to differences in pH.

Analysis of covariance on 39 tests with 25 organic chemicals (herbicides, insecticides, and solvents) and fishes indicated that the slopes of only two chemicals, dimethylamine and dodecyl/tetradodecyl amine salts of 2,4-D, differed significantly from zero. The increase in hardness (from 12 to 250–300 mg/L as $CaCO_3$) caused a 2.8× increase in the LC50 of the dimethylamine salt (96-h LC50 range, 285 to 800 mg/L) and a 2.1× increase in that of the dodecyl/tetradodecyl amine salt (96-h LC50 range, 1.9 to 4.0 mg/L). The increase in LC50 values was probably due to the increase in pH (1.5 units) between the very soft and very hard test waters. Because 2,4-D is a weak acid (pK_a = 2.80; Weber

Table 9. *Distribution of toxicity change of technical pesticides of various formulations under acute static conditions.*

Formulation	Pesticides (*n*)	Tests (*n*)	Toxicity change distribution (%)[a] None	Decrease	Increase
All Formulations	48	161	57	11	32
Emulsifiable concentrate	23	62	65	11	24
Granular	4	10	50	10	40
Liquid	10	35	66	3	31
Wettable powder	16	39	56	13	31
Other	3	15	13	20	67
Oil disperson	1	3	0	100	0
Oil soluble concentrate	1	11	9	0	91
Spray concentrate	1	1	100	0	0

[a] Change in toxicity due to formulation was determined by the ratio of technical to formulated material, and the ratios were categorized by change: none, 0.5–1.5; decrease, <0.5, increase, >1.5.

1972), its toxicity should decrease in alkaline water. However, toxicity of the dodecyl/tetradodecyl amine salt was the only one of five 2,4-D compounds that increased (rather than decreased) with increasing pH (Table 8), and was the only one of four 2,4-D compounds that increased in toxicity with aging (Table 5). The dodecyl/tetradodecyl amine group may be the main factor in toxicity differences, and may mask the effect of 2,4-D.

Hardness-related toxicity changes of carbamate and organophosphate insecticides have been indicated by others (Schoettger and Mauck 1978; Woodward and Mauck 1980). In these types of chemicals, toxicity changes could be caused by the hydrolysis products, which are formed more rapidly under alkaline pH, as previously discussed.

Formulation

The effects of formulation were determined for 48 pesticides (Table 9). Ratios of 48-h EC50's or 96-h LC50's of technical grade pesticides to those of formulated materials were compared ($n = 161$). A ratio greater than 1.0 indicated increased toxicity of the formulated material and a ratio less than 1.0 indicated decreased toxicity. However, ratios between 0.5 and 1.5 are probably within the range of normal experimental variation, since this range frequently occurred among groups of species (invertebrates or fishes) within a chemical. Overall, toxicity was not affected 57% of the time, decreased 11% of the time, and increased 32% of the time. The average ratios (ranges in parentheses) were as follows: emulsifiable concentrate, 2.5 (0.10 to 24); granular, 1.7 (0.34 to 5.0); liquid, 3.6 (0.08 to 33); oil dispersion, 0.30 (0.14 to 0.47); oil soluble concentrate, 69 (1.2 to 318); spray concentrate, 0.59 (one test); and wettable powder, 1.4 (0.06 to 5.1).

Among the formulations in which toxicity increased, toxicity doubled 61% of the time and increased within a factor of five 80% of the time. The ratios exceeded one order of magnitude in 10% of the tests involving aminocarb, cyprazine, glyphosate, and temephos; liquid formulated aminocarb increased in toxicity as much as 318×. The toxicities of wettable powder and oil dispersion formulations were frequently less than the toxicity of technical material—the wettable powder probably due to chemical adsorption to talc in the formulation, and the oil dispersion formulation due to an altered octanol–water partition coefficient in the presence of petroleum hydrocarbons (Stecher 1983). Hashimoto and Nishiuchi (1981) reported that, in general, emulsifiable concentrates were the most toxic, followed by technical materials, wettable powders, dust, and granules. Pickering et al. (1962) also found emulsifiable concentrates to be slightly more toxic than technical materials. In our study, formulations ranked in order of most toxic to least toxic were oil soluble concentrate, liquid, emulsifiable concentrate, granular, wettable powder, spray concentrate, and oil dispersion.

Materials added to technical chemicals in the preparation of formulations should not be regarded, as they often are, as "inert" ingredients with little or no biological activity. Although the effects of "inerts" on acute toxicity of technical chemicals are

Table 10. *Diet effects on the acute static toxicity of organic chemicals to rainbow trout.*^{a}

Chemical and diet	Weight^b (g)	96-h LC50 (μg/L)	
		LC50	95% Confidence limits
Antimycin A			
Glencoe	1.10	0.032	(0.027–0.038)
Ewos	0.80	0.016	(0.012–0.021)
High protein (45%)	1.10	0.052	(0.044–0.062)
Fish protein concentrate	0.75	0.024	(0.020–0.029)
Carbaryl			
Glencoe	1.10	1,900	(1,590–2,260)
Ewos	0.80	2,080	(1.580–2,730)
High protein (45%)	1.10	2,300	(1,500–3,500)
Fish protein concentrate	0.80	1,360	(900–1,860)
Chlordane			
Oregon Moist	1.00	8.2	(6.1–11)
Glencoe	1.10	9.1	(4.8–17)
Silver Cup	1.00	20	(14–28)
Ewos	1.10	31	(22–43)
Low protein (23%)	1.00	28	(20–41)
High protein (45%)	1.50	47	(38–58)

[a] Handling and feeding (3% body weight/day) were consistent with all three chemicals and the fish source was the same. The chlordane study was conducted at a different time than that with Antimycin A and carbaryl, and initial fish weights differed (0.4 and 0.2 g, respectively). Conditions of the toxicity tests were as follows: chlordane—temperature 12°C, pH 7.1, hardness 44 mg/L; Antimycin A and carbaryl—temperature 10°C, pH 7.4, hardness 40–44 mg/L.

[b] Weight at time of testing.

generally less than 0.5 order of magnitude, they may be as high as 2.5 orders of magnitude. In view of the widespread use of various formulations for pesticides and some industrial chemicals and the alteration in toxicity of the technical chemicals involved, it is evident that further investigation of the toxicology of those formulations is needed.

Diet

Diet affects body composition, physiological and biochemical functions, and nutritional status of the subject, and thereby influences toxicity (Doull 1980). The 96-h LC50 values for rainbow trout exposed to Antimycin A, carbaryl, and chlordane were affected by the type of diet fed 42 days before exposure (Table 10). Proximate analyses of the various diets were reported by Mehrle et al. (1974). The LC50 for trout fed a high protein diet before exposure to Antimycin A was significantly higher than that for trout fed other diets. The LC50's for all dietary groups differed significantly from each other. No significant effects were observed with carbaryl, although it was the least toxic in the group fed the high protein diet.

Significant differences occurred in chlordane toxicity among rainbow trout fed commercial or synthetic diets (Mehrle et al. 1974; Table 10). Differences existed between the group fed the Ewos diet and the other three commercial diets, and between the group fed Silver Cup and the groups fed Glenco and Oregon Moist diets. The difference in LC50's between the fish fed the Oregon Moist and Glenco diets was not statistically significant. The LC50 for the group receiving the high protein diet differed from the LC50's of all other groups, but the groups fed the low protein and Ewos diets were not significantly different. Differences in size of fish fed the various diets may have contributed to the differences in LC50's.

Feeding of protein-deficient diets has resulted in decreased tolerances to organochlorine, organophosphate, and carbamate pesticides in rats (Boyd and Boulanger 1968; Boyd and DeCastro 1968; Boyd and Tanikella 1969). This response was observed for acute toxicities of Antimycin A, carbaryl, and chlordane to rainbow trout, where a decrease in protein in the diet increased pesticide toxicity. However, protein may be only one of the many dietary factors affecting toxicity. Fish fed fish protein concentrate ranged from most susceptible to intermediate when tested against Antimycin A or carbaryl; fish fed

Table 11. *Acute toxicity (LC50, µg/L) of pesticides to rainbow trout from various sources and steelhead under static conditions.*[a]

Chemical and duration of test (hours)	Source of rainbow trout							
	Donaldson	Iowa	Missouri	Mt. Whitney	New Hampshire	Soap Lake	Wytheville	Steelhead
Antimycin A								
24	>0.087	0.049	0.10	>0.087	0.085	>0.075	0.10	
96	0.013	<0.008	0.019	0.031	0.009	0.007	0.008	
Carbaryl								
24	6,200	2,800	3,900		4,600	4,600	6,100	
96	<750	<320	1,000		<420	1,500	<320	
Carbofuran								
24							680	1,000
96							380	600
Chlordane								
24			44		78	62		13
96			27		20	13		2.9
d-trans Allethrin								
24							14	19
96							14	18
Malathion								
24			160			39		
96			94			4.1		
Trichlorfon								
24							>12,000	>7,000
96							1,800	1,400

[a] Temperature, 12°C; pH, 7.1–7.5; hardness, 40–40 mg/L.

Ewos (58% protein) were the most sensitive to Antimycin A; and the LC50's among the groups of fish fed the commercial diets were not always directly related to dietary protein concentrations. The primary sources of protein in fish food were fish meal, soybean meal, cottonseed meal, and wheat germ meal in the Glenco, Oregon Moist, and Silver Cup diets; fish protein concentrate in the Ewos diet; and casein in the low and high protein diets. Miranda and Webb (1972) reported that the oral toxicity of heptachlor was less for rats fed a low quality protein (gluten) than for rats fed casein; thus both qualitative and quantitative alterations in dietary proteins may affect acute toxicity.

Dietary constituents other than protein may also affect chronic toxicity of chemicals to fish. Mehrle et al. (1977) reported that a diet high in the amino acid methionine increased the toxicity of DDT to rainbow trout, and Mayer et al. (1978) found that increased levels of dietary vitamin C decreased toxaphene toxicity to channel catfish.

The reason for differences in susceptibility to chemicals due to diet is not completely understood. Differences in commercial diets alone altered the 96-h LC50 by an average of 2.3× (range, 1.1 to 3.8×) or 3.6× (range, 1.7 to 5.7×), if synthetic diets were included. However, the type of diet fed before chemical exposure is important, and the standardization of diets fed to aquatic organisms used in toxicological research would help reduce the variation in toxicity data.

Source of Fish

Rainbow trout from seven sources (several strains) and steelhead were tested with seven chemicals in 25 static tests. The ratios of the highest to lowest LC50's (24 h and 96 h) within a chemical ranged from 1.3 to 23 and averaged 4.8 (Table 11). The highest LC50 was 1.3 to 4.7× that of the lowest LC50 77% of the time, but exceptions occurred with chlordane and malathion. When the effects of steelhead were excluded, the highest LC50 was 1.8 to 4.7× the lowest 88% of the time. The sensitivity of steelhead (anadromous rainbow trout) to chlordane far exceeded that of any other trout. Because the weight of steelhead fry was only 12 to 23% of that

Table 12. *Acute static 96-h LC50 values (mg/L) of organic chemicals for various life stages of fishes.*

	Life stage			
Chemical and species	Eyed egg	Yolk-sac fry	Swim-up fry	Advanced fry[a]
Aminocarb				
Rainbow trout	>32	0.036	0.048	0.14
Benomyl				
Rainbow trout		0.28	0.16	0.23
Channel catfish		0.006	0.012	0.029
2,4-D dimethylamine salt				
Fathead minnow	1,450	630	425	320
2,4-D dodecyl/tetradodecyl amine salt				
Rainbow trout	47	7.6	1.4	3.2
Dowell M38N				
Cutthroat trout	1.6	0.28		0.46
Fenitrothion				
Rainbow trout	16	4.3	2.4	2.4
Channel catfish		3.8	1.4	4.8
Fire-Trol 100				
Coho salmon		90	920	>1,500
Rainbow trout		150	780	>1,000
Fire-Trol 931				
Coho salmon		580	930	1,000
Rainbow trout		700	790	940
MBC				
Rainbow trout		0.14	0.32	0.65
Channel catfish		0.007	0.012	0.016
Methomyl				
Rainbow trout		3.2	1.3	2.0
Channel catfish		1.8	<0.56	0.76
Methoxychlor				
Brook trout	>50	0.017	0.015	0.019
Mexacarbate				
Brown trout		16		20
Phos-Chek 202				
Coho salmon		145	200	320
Rainbow trout		105	110	230
Phos-Chek 259				
Coho salmon		145	170	250
Rainbow trout		115	94	160
Phosmet				
Rainbow trout	>10	>10	0.28	0.48
Picloram				
Rainbow trout		8.0	8.0	11
Channel catfish		5.8	6.8	16
Pydraul 50E				
Lake trout		2.8	2.9	1.5
Toxaphene				
Channel catfish		0.008	0.001	0.004
Tretolite JW-8226				
Cutthroat trout	0.048	2.9		2.2
Trifluralin				
Rainbow trout		1.6	0.083	0.086
Channel catfish		0.66	0.33	2.2

[a] Weight = 0.2 to 1.2 g.

of the other strains tested, size may have accounted for some of the difference in sensitivity, but most probably represented physiological differences. Due to incompleteness of data and the small size of the data base, no rainbow trout from a particular source or of a particular strain could be identified as being the most sensitive. However, differences in LC50's among rainbow trout from different sources within the chemicals tested were similar to the mean interlaboratory differences reported by Lemke (1981) in a round-robin study where different laboratories obtained fish from different sources.

Life Stage and Size

Many investigators have reported the effects of life stage and size of invertebrates and fishes on susceptibility to toxicants. Susceptibility of invertebrates generally decreases with maturity (Sanders and Cope 1968; Sanders 1972). The sensitivity of tadpoles of Fowler's toad to DDT increases as the animals mature (Sanders 1970), whereas that of tadpoles of the southern leopard frog (*Rana sphenocephala*) to toxaphene decreases with age (Hall and Swinford 1980). Similarly, decreases in sensitivity have been observed with increased size in fishes (Anderson and Weber 1975; King 1962; Marking 1966; Mount 1962; Pickering et al. 1962; Surber 1948), although responses varied considerably among the early life stages (Akiyama 1970; Bills and Marking 1976; Dean et al. 1977; Iatomi et al. 1958; Klaverkamp et al. 1977; Mauck et al. 1977; Olson and Marking 1973; Piavis and Howell 1975; Pickering and Vigor 1965; Spotila and Paladino 1979).

Life stage. Analysis of 96-h LC50's for yolk-sac and swim-up fry exposed to 20 chemicals indicated that each was the most sensitive 50% of the time (Table 12). Advanced fry were generally less sensitive than yolk-sac and swim-up fry, but yolk-sac and swim-up fry were less sensitive than advanced fry 3% and 7% of the time, respectively. The ratios of the highest to lowest 96-h LC50 among yolk-sac fry, swim-up fry, and advanced fry averaged 4.5 (range, 1.2 to 36), and were 5.0 or less 83% of the time.

The eyed-egg stage was the least sensitive stage tested, except that it was the most sensitive stage when exposure was to Tretolite JW-8226. Although eggs are generally the least susceptible stage, several exceptions are known. For example, Akiyama (1970) found eggs to be more resistant than fry to two mercurials, but not to a third mercurial. And Mauck et al. (1977) reported that brown trout eggs were significantly more sensitive than yolk-sac fry and fingerlings to mexacarbate. In contrast, TFM was most toxic to green eggs of coho salmon and rainbow trout, followed by swim-up fry and yolk-sac fry; eyed-eggs were the least sensitive (Bills and Marking 1976; Olson and Marking 1973).

Toxicity decreased with increasing maturity in other species that were exposed to different chemicals (shown in parentheses): apple snail, *Pomacea paludosa* (Cutrine-plus); crayfish, *Orconectes nais* (DDT, endrin, malathion, and parathion); and stoneflies, *Pteronarcys californica* (lindane). The 96-h LC50's increased by 1.3× for apple snails (from 1–2 days to 2–4 weeks), 56 to 375× for crayfish (3–5 weeks to maturity), and 4.5× for stonefly naiads (first and second year classes). Although toxicity decreased with age, the change may be small within the stages normally tested. The 96-h LC50's for crayfish exposed to DDT were consistent up to 5 weeks of age (LC50's, µg/L: 1 day, 0.30; 1 week, 0.18; 2 weeks, 0.20; 3 weeks, 0.24; and 5 weeks, 0.90), but increased markedly thereafter (8 weeks, 28; mature, 100).

Fish size. Analysis of covariance was conducted on 27 chemicals used in 51 tests for fish of different weights (Table 13). Toxicity decreased as weight increased, but in only 10 of the equations (six chemicals) were the slopes significantly different from zero. The six regressions with a large range in fish size (antimycin and chlordane) varied in slopes among species, the average being 0.0370 (95% CL, ±0.0213). Ratios of the highest to the lowest LC50 averaged 13 (range, 5.3 to 54) within differences in weight of one to two orders of magnitude.

Most acute toxicity tests are conducted with fish weighing 0.2 to 1.5 g, but of 38 regressions within that size range, only 4 slopes (glyphosate, merphos, toxaphene, and trichlorfon) differed significantly from zero. Ratios of the highest to the lowest LC50 value ranged from 4.9 to 6.2 and averaged 5.6. The slopes for these four chemicals were significantly greater than those for chlordane. However, the four tests with glyphosate, merphos, toxaphene, and trichlorfon represented only 10% of the 38 tests (24 chemicals) in which fish weighing 0.2 to 1.5 g were analyzed; thus size effects would not usually be of great concern in standardized acute toxicity testing, as judged by the range of weights represented here.

Table 13. *Effect of weight on acute static toxicity (96-h LC50) of organic chemicals to fishes.*[a]

Chemical and species	Weight (g)	LC50's (*n*)	LC50 range (μg/L)	Intercept (*a*)	Slope[b] (*b*)	r^2 (%)
Antimycin A						
Coho salmon	0.9–19	5	0.009–0.06	−1.8883	0.0273	51
Rainbow trout	0.7–107	16	0.009–0.12	−1.7712	0.0167	38
Bluegill	1.2–20	4	0.038–0.20	−1.3390	0.0369	77
Chlordane						
Coho salmon	0.6–19	5	14–80	1.1177	0.0461	87
Rainbow trout	1.2–46	5	10–135	1.3601	0.0187	65
Channel catfish	1.9–18	4	6.7–230	1.1896	0.0764	61
Glyphosate						
Rainbow trout	0.4–1.0	4	1,300–8,300	2.6078	1.4158	77
Merphos						
Bluegill	0.5–0.8	3	1,300–8,000	2.0045	2.3758	75
Toxaphene						
Channel catfish	0.02–0.3	4	0.82–4.2	−0.0429	2.1283	75
Trichlorfon						
Atlantic salmon	0.2–0.6	4	610–2,970	2.4416	1.6326	93

[a] Log 96-h LC50 in μg/L = $a + b$(weight in grams).
[b] Significantly different from zero ($P \leqslant 0.05$).

Conclusions

1. No one species, family, or class was the most sensitive to all chemicals all of the time.
2. By rank-order comparison, stoneflies (*Claassenia sabulosa, Pteronarcys californica, Pteronarcella badia*) were the most sensitive aquatic animals tested, followed by glass shrimp (*Palaemonetes kadiakensis*), amphipods (*Gammarus fasciatus*), daphnids (*Daphnia pulex, D. magna, Simocephalus serrulatus*), brown trout, rainbow trout, seed shrimp (*Cypridopsis vidua*), largemouth bass, cutthroat trout, bluegills, sow bugs (*Asellus brevicaudus*), coho salmon, yellow perch, channel catfish, common carp, black bullheads, green sunfish, fathead minnows, goldfish, western chorus frog, and Fowler's toad. The ranking was slightly altered by standardizing test media characteristics and organism size.
3. Of the four most commonly tested forms compared together, daphnids (*Daphnia magna* or *D. pulex*) were the most sensitive 58% of the time followed by rainbow trout (35%), bluegills (5%), and fathead minnows (2%). However, the sensitivity of daphnids or rainbow trout either equaled or exceeded that of the other two species, as determined by analysis of variance and multiple mean comparisons.
4. When daphnids and rainbow trout were compared with 4 to 40 other species tested with the same chemicals, (a) the lowest of the two LC50's for daphnids and rainbow trout never exceeded 15 × the LC50 of the most sensitive species tested 95% of the time, or never exceeded 25 × the LC50 of the most sensitive species 100% of the time; and (b) testing of three forms (*Daphnia, Gammarus,* and rainbow trout) provided the lowest toxicity value 88% of the time, and could not be improved more than 2.5% by adding any other single species.
5. Interspecies correlation models could be used to predict acute toxicity values, but the confidence limits were smallest when extrapolation was within families.
6. Of the seven major families tested, the Pteronarcidae were the most sensitive, followed by the Daphnidae, Gammaridae, Salmonidae, Centrarchidae, Ictaluridae, and Cyprinidae. The sensitivities of Daphnidae and Gammaridae may be more realistic here than in the species comparisons, since all three daphnid and amphipod species are represented in the family comparisons. Invertebrates were the most sensitive 95% of the time.
7. The class Insecta was the most sensitive 50% of the time, followed by Crustacea (31%), Osteichthyes (19%), and Amphibia (0%).
8. Frequency distributions of chemical toxicity (EC50's or LC50's) were generally bimodal; insecticides were mainly in the <100 μg/L mode, and herbicides, fungicides, industrials, and other chemicals in the >1,000 μg/L mode.

9. Flow-through toxicity values may be estimated by multiplying static values by 0.51, but the error can be large: ratios of static to flow-through tests varied by 1.8 orders of magnitude.

10. Toxicity of aged test solutions increased by a factor of 2 or more only 11% of the time and never increased by a factor of more than 4. Toxicity decreased 22% of the time, and no change occurred in 69% of the tests.

11. Temperature affected the toxicity of 40% of the chemicals tested, generally increasing it. However, the toxicity of a few chemicals (DDT, dimethrin, and methoxychlor) decreased with increasing temperature.

12. The effect of temperature on toxicity conforms to the Q_{10} concept and can be predicted. Temperature increased the toxicity of most chemicals by a factor of 3.1 per 10°C rise in temperature; the factor for organophosphate insecticides was higher (5.1)—possibly due to the simultaneous increase in acetylcholinesterase (AChE) activity and rate of AChE inhibition.

13. Although pH affected the toxicity of only 20% of the chemicals tested, it caused a greater average change in toxicity (16×; range, 4.2 to 45) than did any other factor examined.

14. Regression slopes were consistent among species within a chemical for both pH and temperature, indicating chemical rather than biological differences in toxicity.

15. Hardness had little if any effect on the toxicity of organic chemicals; the negligible effects we observed were probably due to pH differences in solutions of differing hardness.

16. Formulations of pesticides increased the toxicity of the technical material used in preparing them 32% of the time, and decreased it 11% of the time. The effect of formulation on toxicity was within a factor of 0.2 to 5× 85% of the time, but was as high as 318×. Formulations ranked in order of most toxic to least toxic were as follows: oil soluble concentrate, liquid, emulsifiable concentrate, granular, wettable powder, spray concentrate, and oil dispersion. Tests on both formulated and technical pesticides are strongly indicated.

17. Differences in the diet fed to fish before they were tested altered toxicity by as much as 5.7×, but factors of 1.1 to 3.8× would be anticipated within available commercial diets. Standardized diets would help reduce variation in acute toxicity data.

18. Source of rainbow trout contributed to variation in toxicity data; the differences ranged from 1.8 to 4.7× about 8[illegible]% of the time.

19. Sensitivity of invertebrates and fish decreased with development and increased size. Differences in toxicity among the life stages of fish were 5× or less 83% of the time. The change in toxicity was usually small within the sizes normally tested, and thus size should be of no great concern in standardized acute toxicity testing. However, life stage could be of considerable importance in the natural environment.

20. Of the factors affecting toxicity (except for pesticide formulation), the ratios of the highest to lowest LC50's for a chemical were 5.0 or less 80% or more of the time; this generalization includes pH and temperature, when evaluated on the basis of changes of 1.0 pH unit and 10°C.

21. Generalizations and predictions are accurate for comparative toxicity and factors affecting toxicity 80% of the time. The utility of predictive techniques should be realized, but no single approach correctly predicts acute toxicity under all situations. Factors affecting acute toxicity of a chemical (except pesticide formulations) appear to vary within 5× under standard laboratory conditions. Also, these factors often alter bioavailability of the chemical in the field. Studies involving a range of field conditions, therefore, are strongly indicated to determine the interactions of such factors on both bioavailability and acute toxicity. Species sensitivity varied more than factors affecting toxicity, since toxicity differences between the least to the most sensitive species tested within a chemical averaged two orders of magnitude and were as high as five orders of magnitude. Due to inherent variation and exceptions in acute toxicity data, it is best to test the chemical and species of concern under environmental conditions of interest only when exact information is required.

The acute toxicity test provides a rapid, cost-efficient way of measuring relative toxicity to organisms representing different trophic levels, toxicity in different types of water, and toxicity of different forms and formulations of a chemical. Its main value lies in its use as a relative starting point for determining effects in hazard assessment, along with the expected or measured environmental concentration. Toxicity studies are too often conducted to develop data, without subsequent comprehensive interpretation. We hope that this manual will serve as a guide for future research and bring into focus the pertinent aspects of laboratory studies on acute toxicity, thereby providing a foundation for predictive correlations and hazard assessments.

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Appendix

Table A2. *Scientific and common names of vertebrates used for acute toxicity testing.*

Class, order, family, genus, and species	Common name
Osteichthyes	
Acipenseriformes	
Polyodontidae	
Polyodon spathula	Paddlefish
Salmoniformes	
Salmonidae	
Oncorhynchus kisutch	Coho salmon
Oncorhynchus tshawytscha	Chinook salmon
Salmo clarki	Cutthroat trout
Salmo gairdneri	Rainbow trout
Salmo salar	Atlantic salmon
Salmo trutta	Brown trout
Salvelinus fontinalis	Brook trout
Salvelinus namaycush	Lake trout
Esocidae	
Esox lucius	Northern pike
Cypriniformes	
Cyprinidae	
Carassius auratus	Goldfish
Cyprinus carpio	Common carp
Notropis blennius	River shiner
Pimephales promelas	Fathead minnow
Catostomidae	
Catostomus catostomus	Longnose sucker
Catostomus commersoni	White sucker
Siluriformes	
Ictaluridae	
Ictalurus melas	Black bullhead
Ictalurus punctatus	Channel catfish
Clariidae	
Clarias batrachus	Walking catfish
Atheriniformes	
Poeciliidae	
Gambusia affinis	Mosquitofish
Perciformes	
Centrarchidae	
Lepomis cyanellus	Green sunfish
Lepomis macrochirus	Bluegill
Lepomis microlophus	Redear sunfish
Micropterus dolomieui	Smallmouth bass
Micropterus salmoides	Largemouth bass
Pomoxis annularis	White crappie
Pomoxis nigromaculatus	Black crappie
Percidae	
Perca flavescens	Yellow perch
Stizostedion vitreum vitreum	Walleye
Cichlidae	
Tilapia mossambica	Tilapia
Amphibia	
Anura	
Bufonidae	
Bufo woodhousei fowleri	Fowler's toad
Hylidae	
Pseudacris triseriata	Western chorus frog

Table A3. *Species list with chemicals tested.*

STREPTOCEPHALUS SEALI — 1 TESTS

1	PHOSMET

DAPHNIA MAGNA — 110 TESTS

2	ALACHLOR
1	AMDRO
3	AMINOCARB
1	ANTIMYCIN A
1	AZINPHOS-ETHYL
1	BARBAN
1	BENOMYL
1	BENZOTHIAZOLE 2-METHYL MERCAPTO
1	CARBARYL
1	CCA TYPE III
1	CHLORDECONE
1	CHLORFENETHOL
1	CLONITRALIDE
1	CYHEXATIN
1	CYTROL AMITROLE-T
4	DCPA
2	DDD
1	DDT
1	DEF
1	DICAMBA
1	DICHLOROPROPENE
2	DIFLUBENZURON
1	DIOXATHION
1	DIPHENAMIDE
3	ENDRIN
1	ETHION
3	FENITROTHION
1	FENVALERATE
2	FLUCHLORALIN
2	FLUOMETURON
1	FLUORENE
4	FLURIDONE
1	FOSAMINE AMMONIUM
1	FYRQUEL GT
1	GLYPHOSATE
1	HOUGHTO-SAFE 520
1	KRONITEX 200
2	LINURON
1	MALATHION
2	METHOMYL
2	METHYL PARATHION
2	METOLACHLOR
1	METRIBUZIN
1	MIREX
1	MON 0818
1	NITRALIN
2	OXAMYL
1	PARATHION
2	PENTACHLOROPHENOL
1	PENTACHLOROPHENOL (DOWICIDE EC-7)
2	PENTACHLOROPHENOL COPPER SALT
1	PERMETHRIN
1	PHOSFLEX 31P
2	PHOSMET
1	PICLORAM
2	PROFENOFOS
2	PROPACHLOR
1	PYDRAUL 50E
1	SANTICIZER 148
1	SANTICIZER 154
2	SIMAZINE
2	SODIUM SELENITE
1	SRCII SYNFUEL
1	TERBUFOS
1	THANITE
1	TOXAPHENE
2	TRIALLATE
1	TRIFLURALIN
1	WATER GLYCOLS 894-44A
1	WATER GLYCOLS 894-44B
1	WATER GLYCOLS 894-44C
1	XYLENOL DIMETHYLAMINO
1	2,3,4,6-TETRACHLOROPHENOL
3	2,4-D BUTOXYETHANOL ESTER
2	2,4-D DIMETHYLAMINE SALT
1	2,4-D PROPYLENE GLYCOL BUTYL ETHER ESTER
1	6-CHLORO-2-PICOLINIC ACID

DAPHNIA PULEX — 45 TESTS

1	ALDRIN
1	ALLETHRIN
1	ARAMITE
1	AZIDE POTASSIUM
1	AZIDE SODIUM
1	AZINPHOS-ETHYL
1	BENZENE HEXACHLORIDE
1	CARBARYL
1	CHLORDANE
1	CHLOROBENZILATE
1	CRYOLITE
1	DALAPON
1	DDD
1	DDT
1	DEAD-X
1	DEMETON
1	DIAZINON
1	DICHLOBENIL
1	DICHLORVOS
1	DIELDRIN
1	DIURON
1	DNOC
1	ENDRIN
1	ETHION
1	FENAC
1	FENTHION
1	HEPTACHLOR
1	LIME SULFUR
1	LINDANE
1	MALATHION
1	METHOXYCHLOR
1	MEVINPHOS
1	MEXACARBATE
1	MIREX
1	NALED
1	PARAQUAT
1	PARATHION
1	PHOSPHAMIDON
1	PROPHAM
1	ROTENONE
1	SILVEX PROPYLENE GLYCOL BUTYL ETHER ESTE
1	SODIUM ARSENITE
1	TOXAPHENE
1	TRICHLORFON
1	TRIFLURALIN

Table A3. *Continued.*

SIMOCEPHALUS SERRULATUS 67 TESTS

2	ALDRIN
1	ALLETHRIN
1	ARAMITE
1	AZIDE POTASSIUM
1	AZIDE SODIUM
1	AZINPHOS-ETHYL
3	CARBARYL
2	CHLORDANE
1	CHLOROBENZILATE
1	COUMAPHOS
1	CRYOLITE
1	DALAPON
2	DDD
2	DDT
1	DEAD-X
2	DIAZINON
1	DICHLOBENIL
2	DICHLORVOS
1	DICROTOPHOS
2	DIELDRIN
1	DIURON
2	ENDRIN
1	ETHION
1	FENAC
1	FENTHION
2	HEPTACHLOR
1	LIME SULFUR
2	LINDANE
3	MALATHION
2	METHOXYCHLOR
1	METHYL PARATHION
2	MEVINPHOS
1	MEXACARBATE
1	MIREX
2	NALED
1	PARAQUAT
2	PARATHION
2	PHOSPHAMIDON
1	PROPHAM
1	ROTENONE
1	SILVEX PROPYLENE GLYCOL BUTYL ETHER ESTER
1	SODIUM ARSENITE
2	TOXAPHENE
2	TRICHLORFON
1	TRIFLURALIN
1	2,4-D PROPYLENE GLYCOL BUTYL ETHER ESTER

CYPRIDOPSIS VIDUA 22 TESTS

1	ALDRIN
1	CARBARYL
1	CLONITRALIDE
1	DDD
1	DDT
1	DICHLONE
1	DIPHENAMIDE
1	ENDRIN
1	FENTHION
1	LINDANE
1	MALATHION
1	METAM-SODIUM
1	METHOXYCHLOR
1	MOLINATE
1	SILVEX BUTOXYETHANOL ESTER
2	SILVEX PROPYLENE GLYCOL BUTYL ETHER ESTER
1	SIMAZINE
1	VERNOLATE
1	2,4-D BUTOXYETHANOL ESTER
1	2,4-D DIMETHYLAMINE SALT
1	2,4-D PROPYLENE GLYCOL BUTYL ETHER ESTER

ASELLUS BREVICAUDUS 39 TESTS

1	ANTIMYCIN A
1	AZINPHOS-METHYL
1	BINAPACRYL
1	CARBARYL
1	CYTROL AMITROLE-T
1	DDD
1	DDT
1	DICAMBA
1	DICHLOBENIL
1	DICHLONE
1	DIELDRIN
1	DIPHENAMIDE
1	DIURON
1	ENDRIN
1	EPTC
1	FENTHION
1	LINDANE
1	MALATHION
1	METHOXYCHLOR
1	MEVINPHOS
1	MEXACARBATE
1	NALED
1	ORYZALIN
1	OXYDEMETON-METHYL
2	PARATHION
2	PHOSMET
1	PIPERONYL BUTOXIDE
1	SILVEX
2	SILVEX BUTOXYETHANOL ESTER
1	SILVEX PROPYLENE GLYCOL BUTYL ETHER ESTER
1	TRIFLURALIN
1	VERNOLATE
1	2,4-D BUTOXYETHANOL ESTER
1	2,4-D PROPYLENE GLYCOL BUTYL ETHER ESTER
1	2,4,5-T BUTOXYETHANOL ESTER
1	6-CHLORO-2-PICOLINIC ACID

GAMMARUS FASCIATUS 149 TESTS

2	ALDRIN
1	ALLETHRIN
1	AMINOCARB
2	AMITROLE
1	ANILAZINE
1	ANTIMYCIN A
1	ARAMITE
1	FENAMINOSULF
1	FENITROTHION
1	FENSULFOTHION
1	FENTHION
1	FOLPET
1	GLYODIN
2	HEPTACHLOR

Table A3. *Continued.*

CUTTHROAT TROUT 305 TESTS

7	ACEPHATE
9	AMINOCARB
7	ANTIMYCIN A
2	BENZENE HEXACHLORIDE
5	BLACK CRUDE OIL
1	CAPTAN
10	CARBARYL
2	CHLORDANE
4	CHLORPYRIFOS
1	COUMAPHOS
1	CROTOXYPHOS
1	D-D SOIL FUMIGANT
2	DDT
1	DEMETON
2	DIAZINON
2	DICHLOFENTHION
5	DICHLORVOS
2	DICOFOL
1	DIELDRIN
7	DIFLUBENZURON
14	DINOSEB
1	DIOXATHION
15	DIURON
1	DOWELL A170
1	DOWELL F75A
1	DOWELL F75N
1	DOWELL L47
6	DOWELL M38N
1	DOWELL W35
1	DOWICIL 75
1	ENDOTHALL HYDROTHOL 191
1	ENDRIN
2	EPN
15	EPTC
2	ETHION
9	FENITROTHION
5	FENTHION
1	FLIT MLO
8	GREEN CRUDE OIL
3	LEPTOPHOS
2	LETHANE 384
5	MALATHION
1	METHOMYL
5	METHOXYCHLOR
2	METHYL PARATHION
1	METHYL TRITHION
3	MEXACARBATE
1	NALED
2	PARATHION
1	PCB AROCLOR 1221
1	PCB AROCLOR 1232
1	PCB AROCLOR 1242
1	PCB AROCLOR 1248
1	PCB AROCLOR 1254
1	PCB AROCLOR 1260
1	PCB AROCLOR 1262
1	PCB AROCLOR 1268
1	PCB AROCLOR 4465
1	PCB AROCLOR 5442
1	PCB AROCLOR 5460
1	PENTACHLOROPHENOL
1	PENTACHLOROPHENOL (DOWICIDE EC-7)
1	PENTACHLOROPHENOL SODIUM SALT
2	PHORATE
1	PHOTO-DIELDRIN
22	PICLORAM
2	RONNEL
2	TEMEPHOS
2	THANITE
1	TRETOLITE J-146
1	TRETOLITE JN-9045
7	TRETOLITE JW-8226
17	TRICHLORFON
6	ZINC SULFATE
12	2,4-D
17	2,4-D BUTYL ESTER
16	2,4-D PROPYLENE GLYCOL BUTYL ETHER ESTER

RAINBOW TROUT 917 TESTS

9	ACEPHATE
1	ACETONE
1	AKTON
2	ALACHLOR
2	ALDICARB
6	ALDRIN
1	ALLETHRIN
1	AMDRO
1	AMETRYN
26	AMINOCARB
1	ANILAZINE
20	ANTIMYCIN A
1	APHOLATE
1	AQUA COP
1	AQUA-VATOR
1	ARAMITE
1	ATRAZINE 4L
1	AZIDE POTASSIUM
1	AZIDE SODIUM
1	AZINPHOS-ETHYL
5	AZINPHOS-METHYL
1	BACILLUS THURINGIENSIS
14	BENOMYL
1	BENSULIDE
2	BENTHIOCARB
1	BENZALKONIUM CHLORIDE
1	BENZENE
4	CHLORPYRIFOS
2	CHLORPYRIFOS-METHYL
1	CLARIFITE
1	CLONITRALIDE
1	COPPER SULFATE
1	COPPER-COUNT-N
1	COPPER-COUNT-NS
2	CORREX
1	COUMAPHOS
1	CROTOXYPHOS
1	CRYOLITE
1	CUMYLPHENYL DIPHENYL PHOSPHATE
1	CYANAZINE
1	CYANO(METHYLMERCURI)GUANIDINE
2	D-D SOIL FUMIGANT
1	D-TRANS ALLETHRIN
2	DDD
1	DDE
7	DDT
1	DEAD-X
11	DEF
2	DEMETON
1	DIAZINON
1	DICAMBA
2	DICHLOBENIL
1	DICHLOFENTHION
1	DICHLONE

Table A3. *Continued.*

(CONT.) GAMMARUS FASCIATUS 149 TESTS

1	AZIDE POTASSIUM
1	AZIDE SODIUM
2	AZINPHOS-METHYL
1	BENEFIN
1	BENSULIDE
1	BENZYL BENZOATE
2	BUFENCARB
1	BUTOXY POLYPROPYLENE GLYCOL
2	BUTYLATE
2	CACODYLIC ACID
1	CARBARYL
1	CARBOPHENOTHION
1	CHLORDANE
1	CHLORFENVINPHOS
1	CLONITRALIDE
2	CRUFOMATE
1	CYANAZINE
1	CYHEXATIN
2	DDD
3	DDT
1	DEAD-X
1	DEET
1	DEF
2	DEMETON
1	DIAZINON
2	DICAMBA
2	DICHLOFENTHION
1	DICHLONE
1	DICROTOPHOS
2	DIELDRIN
1	DINOCAP
2	DIOXATHION
1	DIPHENAMIDE
1	DIQUAT
2	DISULFOTON
1	DIURON
1	DNOC
1	DODINE
1	ENDOSULFAN
1	ENDOTHALL HYDROTHOL 47
1	ENDOTHALL POTASSIUM SALT
2	ENDRIN
1	EPN
1	EPTC
1	ETHION
1	ETHYLENE DICHLORIDE
1	FENAC
2	LETHANE 384
2	LINDANE
3	MALATHION
1	METHOXYCHLOR
2	METHYL PARATHION
1	METHYL TRITHION
3	MEVINPHOS
1	MEXACARBATE
1	MOLINATE
1	MONOCROTOPHOS
1	MSMA
1	NALED
1	NITRALIN
1	NITROFEN
1	NOREA
1	ORYZALIN
2	OXYDEMETON-METHYL
1	PARAQUAT
3	PARATHION
1	PCB AROCLOR 1248
1	PCB AROCLOR 1254
1	PEBULATE
2	PHORATE
2	PHOSMET
3	PHOSPHAMIDON
1	PICLORAM
1	PROPANIL
1	PROPHAM
2	PYRETHRUM
2	RONNEL
1	ROTENONE
1	SILVEX
1	SIMAZINE
1	TEPP
1	TETRADIFON
1	TETRAMINE
2	THANITE
2	TOXAPHENE
1	TRIFLURALIN
1	TRIPHENYLTIN HYDROXIDE
2	VERNOLATE
2	2,4-D BUTOXYETHANOL ESTER
1	2,4-D DIMETHYLAMINE SALT
1	2,4-D ISOOCTYL ESTER
3	2,4-D PROPYLENE GLYCOL BUTYL ETHER ESTER
2	2,4,5-T BUTOXYETHANOL ESTER
1	6-CHLORO-2-PICOLINIC ACID

GAMMARUS LACUSTRIS 28 TESTS

1	BENZENE HEXACHLORIDE
1	CAPTAFOL
1	CARBARYL
1	CARBOPHENOTHION
1	CHLORONITROPROPANE
1	CHLORPYRIFOS
1	COUMAPHOS
1	CROTOXYPHOS
1	DDT
1	DICHLOBENIL
1	DICHLOFENTHION
1	DICHLORVOS
1	DICROTOPHOS
1	DILAN
1	DIMETHOATE
1	ENDOSULFAN
1	ENDOTHALL HYDROTHOL 191
1	ENDRIN
1	FENTHION
1	HEPTACHLOR
1	LINDANE
1	METHOXYCHLOR
1	METHYL DEMETON
1	MEXACARBATE
1	PARATHION
1	PROPOXUR
1	TEMEPHOS
1	TRICHLORFON

GAMMARUS PSEUDOLIMNAEUS 90 TESTS

2	ACEPHATE
9	AMINOCARB
1	MIREX
1	PCB AROCLOR 1242

Table A3. *Continued.*

(CONT.) GAMMARUS PSEUDOLIMNAEUS — 90 TESTS

1	BENOMYL
1	BENZOTHIAZOLE 2-METHYL MERCAPTO
4	CARBARYL
1	CCA TYPE III
1	CHLORDECONE
1	CLONITRALIDE
2	DCPA
1	DEF
2	DIFLUBENZURON
4	FENITROTHION
1	FENVALERATE
1	FIRE-TROL 100
1	FIRE-TROL 931
1	FLUCHLORALIN
4	FLURIDONE
1	FOSAMINE AMMONIUM
1	FYRQUEL GT
1	GLYPHOSATE
1	HOUGHTO-SAFE 1120
1	HOUGHTO-SAFE 520
1	KRONITEX 200
7	METHOMYL
5	METHOXYCHLOR
1	PCB 2,2',4,4',6,6'-HEXACHLOROBIPHENYL
1	PCB 2,2',4,5,5'-PENTACHLOROBIPHENYL
1	PCB 2,3,4'-TRICHLOROBIPHENYL
1	PCB 2,4-DICHLOROBIPHENYL
1	PCB 4,4'-DICHLOROBIPHENYL
1	PERMETHRIN
1	PHOS-CHEK 202
1	PHOS-CHEK 259
1	PHOSFLEX 31P
1	PHTHALATE DI-2-ETHYLHEXYL
1	PHTHALATE DIBUTYL
1	PICLORAM
2	PROFENOFOS
2	PYDRAUL 50E
1	SANTICIZER 148
1	SANTICIZER 154
1	TERBUFOS
2	TFM
9	TRICHLORFON
1	WATER GLYCOLS 894-44A
1	WATER GLYCOLS 894-44B
1	WATER GLYCOLS 894-44C

ORCONECTES NAIS — 30 TESTS

1	BENOMYL
1	CHLORDANE
1	CLONITRALIDE
7	DDT
1	DEF
1	DICROTOPHOS
1	DIELDRIN
2	ENDRIN
2	FENTHION
1	GLYPHOSATE
1	HEPTACHLOR
2	MALATHION
1	METHOXYCHLOR
1	METHYL PARATHION
2	PARATHION
1	PCB AROCLOR 1242
1	PCB AROCLOR 1254
1	PHTHALATE DIBUTYL
1	PYDRAUL 50E
1	TFM

PROCAMBARUS SP. — 13 TESTS

1	AZINPHOS-METHYL
1	BENOMYL
1	CARBARYL
1	LEPTOPHOS
4	MEXACARBATE
1	PARATHION
1	PCB AROCLOR 1254
1	PHOXIM
2	TRICHLORFON

PALAEMONETES KADIAKENSIS — 44 TESTS

1	ALDRIN
1	ANTIMYCIN A
1	AZINPHOS-METHYL
1	BUFENCARB
1	CACODYLIC ACID
1	CARBARYL
1	CARBOPHENOTHION
1	CLONITRALIDE
2	DDD
2	DDT
1	DICAMBA
1	DIPHENAMIDE
1	DISULFOTON
1	ENDOTHALL HYDROTHOL 191
2	ENDRIN
1	EPN
1	ETHANOL
1	ETHION
1	FENTHION
1	HEPTACHLOR
3	MALATHION
1	METHOXYCHLOR
1	MEVINPHOS
2	MEXACARBATE
1	MOLINATE
1	NALED
2	PARATHION
1	PCB AROCLOR 1254
1	SILVEX PROPYLENE GLYCOL BUTYL ETHER ESTER
1	SIMAZINE
1	TRIFLURALIN
1	VERNOLATE
2	2,4-D BUTOXYETHANOL ESTER
1	2,4-D PROPYLENE GLYCOL BUTYL ETHER ESTER
1	2,4,5-T BUTOXYETHANOL ESTER
1	6-CHLORO-2-PICOLINIC ACID

ACRONEURIA SP. — 1 TESTS

1	ENDRIN

Table A3. *Continued.*

CLAASSENIA SABULOSA 10 TESTS

1	CARBARYL	1	HEPTACHLOR
1	CHLORPYRIFOS	1	MALATHION
1	DDT	1	PARATHION
1	DIELDRIN	1	TOXAPHENE
1	ENDRIN	1	TRICHLORFON

ISOGENUS SP. 14 TESTS

2	ACEPHATE	2	METHOMYL
6	CARBARYL	2	TRICHLORFON
2	DIFLUBENZURON		

ISOPERLA SP. 2 TESTS

1	DDT	1	MALATHION

SKWALA SP. 4 TESTS

2	AMINOCARB	2	FENITROTHION

PTERONARCELLA BADIA 41 TESTS

3	ACEPHATE	2	METHOMYL
6	AMINOCARB	2	METHOXYCHLOR
4	CARBARYL	1	PARATHION
1	DDT	1	PCB AROCLOR 1016
1	DIELDRIN	1	TEMEPHOS
1	ENDRIN	1	TOXAPHENE
3	FENITROTHION	1	TRETOLITE J-146
1	FENTHION	4	TRICHLORFON
2	GREEN CRUDE OIL	1	2,4-D BUTYL ESTER
1	HEPTACHLOR	1	2,4-D PROPYLENE GLYCOL BUTYL ETHER ESTE
3	MALATHION		

PTERONARCYS CALIFORNICA 77 TESTS

1	ALDRIN	1	ETHION
1	ALLETHRIN	1	ETHYLENE DICHLORIDE
1	ARAMITE	2	FENAC
1	AZIDE POTASSIUM	1	FENAMINOSULF
1	AZIDE SODIUM	1	FENITROTHION
1	AZINPHOS-ETHYL	1	FENTHION
1	AZINPHOS-METHYL	1	HEPTACHLOR
1	BACILLUS THURINGIENSIS	2	LINDANE
1	BENZENE HEXACHLORIDE	1	MALATHION
1	CAPTAFOL	1	METHIOCARB
1	CARBARYL	1	METHOXYCHLOR
1	CHLORDANE	1	METHYL DEMETON
1	CHLORFENVINPHOS	1	METHYL TRITHION
1	CHLORPYRIFOS	1	MEVINPHOS
1	CLONITRALIDE	1	MEXACARBATE
1	CROTOXYPHOS	3	MOLINATE
1	DALAPON	1	NALED
1	DDD	1	OVEX
1	DDT	1	PARAQUAT
1	DEAD-X	1	PARATHION
1	DEF	1	PHORATE
1	DIAZINON	1	PHOSPHAMIDON
1	DICHLOBENIL	1	PICLORAM
1	DICHLOFENTHION	1	PROPOXUR
1	DICHLORVOS	1	SILVEX PROPYLENE GLYCOL BUTYL ETHER EST
1	DICOFOL	1	SIMAZINE
1	DICROTOPHOS	1	SODIUM ARSENITE
1	DIELDRIN	1	TEMEPHOS
1	DIMETHOATE	1	TERPENE POLYCHLORINATES
1	DISULFOTON	1	TOXAPHENE
1	DIURON	1	TRICHLORFON

Table A3. *Continued.*

(CONT.) PTERONARCYS CALIFORNICA 77 TESTS

1	DNOC	1	TRICHLORONATE
1	ENDOSULFAN	1	TRIFLURALIN
1	ENDOTHALL HYDROTHOL 191	1	2,4-D BUTYL ESTER
1	ENDRIN	2	2,4-D PROPYLENE GLYCOL BUTYL ETHER ESTER
1	EPN	1	2,4-DB

BAETIS SP. 1 TESTS

1	ENDRIN

EPHEMERELLA SP. 1 TESTS

1	DDT

HEXAGENIA BILINEATA 3 TESTS

1	DDT	1	PARATHION
1	ENDRIN		

ISCHNURA VERTICALIS 9 TESTS

1	DDD	1	PARATHION
1	DIELDRIN	1	PCB AROCLOR 1242
2	ENDRIN	1	PCB AROCLOR 1254
1	METHYL PARATHION	1	TFM

LESTES CONGENER 1 TESTS

1	MALATHION

OPHIOGOMPHUS SP. 1 TESTS

1	DDT

MACROMIA SP. 2 TESTS

1	PCB AROCLOR 1242	1	PCB AROCLOR 1254

HYDROPSYCHE SP. 1 TESTS

1	MALATHION

LIMNEPHILUS SP. 1 TESTS

1	MALATHION

CHAOBORUS SP. 1 TESTS

1	DDT

ATHERIX VARIEGATA 4 TESTS

1	DDT	1	MALATHION
1	ENDRIN	1	TOXAPHENE

CHIRONOMUS PLUMOSUS 95 TESTS

6	ACEPHATE	2	OXAMYL
2	ALACHLOR	2	PENTACHLOROPHENOL COPPER SALT
1	AMDRO	1	PERMETHRIN
3	AMINOCARB	1	PHOSFLEX 31P
1	BARBAN	8	PHOSMET
1	BENOMYL	1	PHTHALATE DI-2-ETHYLHEXYL
1	BENZOTHIAZOLE 2-METHYL MERCAPTO	2	PHTHALATE DIBUTYL
1	CHLORDECONE	1	PHTHALATE 2-ETHYLHEXYL
1	CLONITRALIDE	1	PHTHALIC ACID
2	DCPA	2	PROFENOFOS

Table A3. *Continued.*

(CONT.) CHIRONOMUS PLUMOSUS

95 TESTS

1	DEF
1	DIFLUBENZURON
3	FENITROTHION
1	FENVALERATE
2	FLUCHLORALIN
2	FLUOMETURON
1	FLUORENE
4	FLURIDONE
1	FOSAMINE AMMONIUM
1	FYRQUEL GT
3	GLYPHOSATE
1	HOUGHTO-SAFE 520
1	KRONITEX 200
2	LINURON
2	METHOMYL
2	METOLACHLOR
1	MIREX
1	MON 0818
2	PROPACHLOR
1	PYDRAUL 50E
1	SANTICIZER 148
1	SANTICIZER 154
2	SODIUM SELENITE
1	SRCII SYNFUEL
1	TERBUFOS
6	TOXAPHENE
1	TRIALLATE
1	WATER GLYCOLS 894-44A
1	WATER GLYCOLS 894-44B
1	WATER GLYCOLS 894-44C
1	XYLENOL DIMETHYLAMINO
1	2-ETHYLHEXANOL
2	2,4-D BUTOXYETHANOL ESTER
1	2,4-D DIMETHYLAMINE SALT
1	2,4-D DODECYL/TETRADODECYL AMINE SALT

PENTANEURA SP.

1 TESTS

1	DDT

TIPULA SP.

3 TESTS

1	DDT
1	ENDRIN
1	TOXAPHENE

APPLE SNAIL

6 TESTS

1	AQUA-VATOR
3	CUTRINE-PLUS
1	DIQUAT
1	KOMEEN

PADDLEFISH

1 TESTS

1	ANTIMYCIN A

COHO SALMON

105 TESTS

10	ANTIMYCIN A
3	AZINPHOS-METHYL
2	CAPTAN
5	CARBARYL
1	CARBOFURAN
5	CHLORDANE
2	D-TRANS ALLETHRIN
2	DDT
3	DINITRAMINE
1	DIURON
1	ENDOTHALL AQUATHOL K
1	ENDRIN
1	FENAMINOSULF
1	FENITROTHION
1	FENTHION
4	FIRE-TROL 100
4	FIRE-TROL 931
1	FOLPET
1	HEXACHLOROBENZENE
1	HOUGHTO-SAFE 1120
2	LINDANE
2	MALATHION
1	METHYL PARATHION
15	MEXACARBATE
4	PHOS-CHEK 202
4	PHOS-CHEK 259
9	PHOXIM
1	PHTHALATE DI-2-ETHYLHEXYL
1	POTASSIUM NAPHTHALENEACETATE
1	PYDRAUL 50E
2	PYRETHRUM
2	RESMETHRIN
2	RU-11679
1	SD 16898
1	SD 17250
1	SILVEX
4	TEMEPHOS
1	TOXAPHENE
1	TRICHLORFON

CHINOOK SALMON

35 TESTS

1	ALDRIN
1	CAPTAN
1	CARBARYL
1	HEXACHLOROBENZENE
8	MEXACARBATE
3	PENTACHLOROPHENOL
6	PENTACHLOROPHENOL SODIUM SALT
2	PHOSMET
1	PURIFLOC C-3
1	PYDRAUL 50E
1	PYRETHRUM
3	UREABOR
3	2,4-D DIMETHYLAMINE SALT
3	2,4-D DODECYL/TETRADODECYL AMINE SALT

Table A3. *Continued.*

CUTTHROAT TROUT 305 TESTS

7	ACEPHATE
9	AMINOCARB
7	ANTIMYCIN A
2	BENZENE HEXACHLORIDE
5	BLACK CRUDE OIL
1	CAPTAN
10	CARBARYL
2	CHLORDANE
4	CHLORPYRIFOS
1	COUMAPHOS
1	CROTOXYPHOS
1	D-D SOIL FUMIGANT
2	DDT
1	DEMETON
2	DIAZINON
2	DICHLOFENTHION
5	DICHLORVOS
2	DICOFOL
1	DIELDRIN
7	DIFLUBENZURON
14	DINOSEB
1	DIOXATHION
15	DIURON
1	DOWELL A170
1	DOWELL F75A
1	DOWELL F75N
1	DOWELL L47
6	DOWELL M38N
1	DOWELL W35
1	DOWICIL 75
1	ENDOTHALL HYDROTHOL 191
1	ENDRIN
2	EPN
15	EPTC
2	ETHION
9	FENITROTHION
5	FENTHION
1	FLIT MLO
8	GREEN CRUDE OIL
3	LEPTOPHOS
2	LETHANE 384
5	MALATHION
1	METHOMYL
5	METHOXYCHLOR
2	METHYL PARATHION
1	METHYL TRITHION
3	MEXACARBATE
1	NALED
2	PARATHION
1	PCB AROCLOR 1221
1	PCB AROCLOR 1232
1	PCB AROCLOR 1242
1	PCB AROCLOR 1248
1	PCB AROCLOR 1254
1	PCB AROCLOR 1260
1	PCB AROCLOR 1262
1	PCB AROCLOR 1268
1	PCB AROCLOR 4465
1	PCB AROCLOR 5442
1	PCB AROCLOR 5460
1	PENTACHLOROPHENOL
1	PENTACHLOROPHENOL (DOWICIDE EC-7)
1	PENTACHLOROPHENOL SODIUM SALT
2	PHORATE
1	PHOTO-DIELDRIN
22	PICLORAM
2	RONNEL
2	TEMEPHOS
2	THANITE
1	TRETOLITE J-146
1	TRETOLITE JN-9045
7	TRETOLITE JW-8226
17	TRICHLORFON
6	ZINC SULFATE
12	2,4-D
17	2,4-D BUTYL ESTER
16	2,4-D PROPYLENE GLYCOL BUTYL ETHER ESTER

RAINBOW TROUT 917 TESTS

9	ACEPHATE
1	ACETONE
1	AKTON
2	ALACHLOR
2	ALDICARB
6	ALDRIN
1	ALLETHRIN
1	AMDRO
1	AMETRYN
26	AMINOCARB
1	ANILAZINE
20	ANTIMYCIN A
1	APHOLATE
1	AQUA COP
1	AQUA-VATOR
1	ARAMITE
1	ATRAZINE 4L
1	AZIDE POTASSIUM
1	AZIDE SODIUM
1	AZINPHOS-ETHYL
5	AZINPHOS-METHYL
1	BACILLUS THURINGIENSIS
14	BENOMYL
1	BENSULIDE
2	BENTHIOCARB
1	BENZALKONIUM CHLORIDE
1	BENZENE
4	CHLORPYRIFOS
2	CHLORPYRIFOS-METHYL
1	CLARIFITE
1	CLONITRALIDE
1	COPPER SULFATE
1	COPPER-COUNT-N
1	COPPER-COUNT-NS
2	CORREX
1	COUMAPHOS
1	CROTOXYPHOS
1	CRYOLITE
1	CUMYLPHENYL DIPHENYL PHOSPHATE
1	CYANAZINE
1	CYANO(METHYLMERCURI)GUANIDINE
2	D-D SOIL FUMIGANT
1	D-TRANS ALLETHRIN
2	DDD
1	DDE
7	DDT
1	DEAD-X
11	DEF
2	DEMETON
1	DIAZINON
1	DICAMBA
2	DICHLOBENIL
1	DICHLOFENTHION
1	DICHLONE

Table A3. *Continued.*

(CONT.) RAINBOW TROUT 917 TESTS

1	BENZENE HEXACHLORIDE
1	BENZOTHIAZOLE 2-MERCAPTO
1	BENZOTHIAZOLE 2-METHYL MERCAPTO
3	BENZOYLPROP ETHYL
1	BINAPACRYL
2	BOMYL
1	BUTYLATE
2	CAPTAFOL
1	CAPTAN
14	CARBARYL
1	CARBOFURAN
1	CCA TYPE III
1	CHLORAMBEN
1	CHLORBROMURON
19	CHLORDANE
3	CHLORDANE-HCS-3260
2	CHLORDECONE
1	CHLORDIMEFORM
3	CHLORENDATE DIBUTYL
3	CHLORENDATE DIMETHYL
1	CHLORFENVINPHOS
1	CHLORINATED ALPHA OLEFIN 22/44
1	CHLORMEQUAT CHLORIDE
1	CHLOROBENZILATE
1	CHLORONITROPROPANE
1	CHLOROWAX LV
1	CHLOROWAX 40
1	CHLOROWAX 50
6	CHLOROWAX 500C
1	CHLOROWAX 70
1	CHLOROXURON
1	DICHLOROPHENYL METHYLSULFONATE
1	DICHLORVOS
1	DICLOFOP METHYL
1	DICOFOL
1	DICROTOPHOS
6	DIELDRIN
8	DIFLUBENZURON
2	DILAN
2	DIMETHOATE
1	DIMETHYL FORMAMIDE
1	DIMETHYLSULFOXIDE
2	DINITRAMINE
1	DINOBUTON
2	DINOCAP
1	DIOXATHION
1	DIPHENAMIDE
1	DIQUAT
1	DISULFOTON
11	DIURON
1	DNOC
2	EMCOL AD-410
4	ENDOSULFAN
1	ENDOTHALL
2	ENDOTHALL AQUATHOL K
1	ENDOTHALL COPPER SALT
1	ENDOTHALL DES-I-CATE
1	ENDOTHALL HERBICIDE 282
1	ENDOTHALL HYDROTHOL 191
1	ENDOTHALL POTASSIUM SALT
6	ENDRIN
1	EPN
1	ETHANOL
1	ETHION
2	ETHOFUMESATE
1	ETHYLAN
1	ETHYLBENZENE
1	ETHYLENE DICHLORIDE
2	ETHYLENE GLYCOL
2	FENAC
1	FENAMINOSULF
1	FENAZAFLOR
2	FENBUTATIN-OXIDE
21	FENITROTHION
1	FENSON
2	FENTHION
11	FENVALERATE
4	FIRE-TROL 100
4	FIRE-TROL 931
2	FLAMPROP-METHYL
2	FLUCHLORALIN
3	FLUOMETURON
1	FLUORODIFEN
10	FLURIDONE
2	FOLPET
1	FONOFOS
1	FOSAMINE AMMONIUM
2	FOSPIRATE
9	FYRQUEL GT
1	GERANIOL
1	GLENBAR
1	GLYCEROL
18	GLYPHOSATE
6	HEPTACHLOR
1	HEPTACHLOR EPOXIDE
1	HEXACHLOROBUTADIENE
2	HEXAZINONE
3	HOUGHTO-SAFE 1120
4	HOUGHTO-SAFE 520
1	JODFENPHOS
9	KRONITEX 200
2	MIREX
1	MOLINATE
3	MON 0818
1	MONOCROTOPHOS
2	MONOETHANOLAMINE
1	MSMA
5	NALED
2	NEODOL 25-9
1	NITRALIN
4	NITRAPYRIN
1	NONYLPHENYL DIPHENYL PHOSPHATE
2	ORTHO 11775
3	OVEX
2	OXAMYL
2	OXYDEMETON-METHYL
1	OXYTHIOQUINOX
1	PARA-DICHLOROBENZENE
1	PARAQUAT
4	PARATHION
1	PARATHION DITHIOATE ANALOGUE
2	PAROIL 1032
1	PAROIL 1048
1	PAROIL 160
3	PCB AROCLOR 1016
1	PCB AROCLOR 1242
1	PCB AROCLOR 1248
1	PCB AROCLOR 1254
1	PCB AROCLOR 1260
1	PCB 2-CHLOROBIPHENYL
1	PCB 3-CHLOROBIPHENYL
1	PCB 4-CHLOROBIPHENYL
4	PENTACHLOROPHENOL
6	PENTACHLOROPHENOL SODIUM SALT
10	PERMETHRIN
2	PHORATE
1	PHORAZETIM
4	PHOS-CHEK 202
4	PHOS-CHEK 259
1	PHOSALONE

Table A3. *Continued.*

(CONT.) RAINBOW TROUT 917 TESTS

1	LANDRIN
11	LEPTOPHOS
1	LIME SULFUR
5	LINDANE
5	MALATHION
4	MBC
1	MCPB
5	MERPHOS
1	METHANOL
1	METHIDATHION
1	METHIOCARB
23	METHOMYL
2	METHOPRENE
10	METHOXYCHLOR
2	METHYL PARATHION
1	METHYL TRITHION
1	METRIBUZIN
1	MEVINPHOS
10	MEXACARBATE
1	ROTENONE
1	ROWMATE
1	RU-11679
2	RYANIA
1	RYLEX D (2-HYDROXY-4-DODECOXYBENZOPHENONE)
1	RYLEX H (2,4-DIHYDROBENZOPHENONE)
1	RYLEX NBC (NICKEL DIBUTYLDITHIO CARBAMATE)
6	SANTICIZER 148
9	SANTICIZER 154
2	SD 16898
1	SD 17250
1	SD 7438
1	SD 8339
2	SILVEX
1	SILVEX PROPYLENE GLYCOL BUTYL ETHER ESTER
1	SIMAZINE
1	SODIUM ARSENITE
9	TEMEPHOS
1	TEPA
1	TEPP
10	TERBUFOS
1	TERBUTRYN
1	TERPENE POLYCHLORINATES
1	TETRACHLORVINPHOS
2	TETRADIFON
1	TETRAMINE
1	TETRASUL
1	TH 285-N
1	TH 336-N
1	TOLUENE
7	TOXAPHENE
9	PHOSFLEX 31P
18	PHOSMET
1	PHOSPHAMIDON
1	PHOXIM
1	PHTHALATE DI-2-ETHYLHEXYL
4	PHTHALATE DIBUTYL
14	PICLORAM
3	PIPERONYL BUTOXIDE
2	PROFENOFOS
1	PROPANIL
1	PROPHAM
1	PROPOXUR
1	PROPYLENE GLYCOL
2	PURIFLOC C-3
2	PYDRAUL 115E
3	PYDRAUL 50E
1	PYRETHRUM
2	RESMETHRIN
2	RONNEL
1	TRANID
1	TREFMID
2	TRIALLATE
83	TRICHLORFON
1	TRICHLORONATE
1	TRICLOPYR
2	TRICRESYL PHOSPHATE
25	TRIFLURALIN
1	TRIPHENYL PHOSPHATE
1	TRIPHENYLTIN HYDROXIDE
1	UC 10854
4	UREABOR
1	VERNOLATE
4	WATER GLYCOLS 894-44A
4	WATER GLYCOLS 894-44B
4	WATER GLYCOLS 894-44C
4	XYLENE
1	2,3,4,6-TETRACHLOROPHENOL
1	2,4-D
4	2,4-D DIMETHYLAMINE SALT
8	2,4-D DODECYL/TETRADODECYL AMINE SALT
2	2,4-D PROPYLENE GLYCOL BUTYL ETHER ESTER
1	2,4-D/2,4,5-T 24%/28%
1	2,4-D/2,4,5-T 30%/28%
1	2,4-D/2,4,5-T 34%/17%
2	2,4-DB
1	2,4,5-T TRIETHYLAMINE SALT
1	2,6-DICHLOROBENZOIC ACID
1	2,6-DIOCTADECYL-P-CRESOL
1	6-CHLORO-2-PICOLINIC ACID

RAINBOW TROUT DONALDSON 2 TESTS

1	ANTIMYCIN A
1	CARBARYL

RAINBOW TROUT IOWA 2 TESTS

1	ANTIMYCIN A
1	CARBARYL

RAINBOW TROUT MISSOURI 9 TESTS

6	ANTIMYCIN A
1	CARBARYL
1	CHLORDANE
1	MALATHION

RAINBOW TROUT MT. WHITNEY 3 TESTS

3	ANTIMYCIN A

RAINBOW TROUT NEW HAMPSHIRE 3 TESTS

1	ANTIMYCIN A
1	CARBARYL
1	CHLORDANE

Table A3. *Continued.*

RAINBOW TROUT SOAP LAKE 4 TESTS

1	ANTIMYCIN A
1	CARBARYL
1	CHLORDANE
1	MALATHION

RAINBOW TROUT STEELHEAD 13 TESTS

1	CARBOFURAN
1	CHLORDANE
2	D-TRANS ALLETHRIN
1	PHOXIM
3	PYRETHRUM
2	RESMETHRIN
2	RU-11679
1	TRICHLORFON

RAINBOW TROUT WYTHEVILLE 2 TESTS

1	ANTIMYCIN A
1	CARBARYL

ATLANTIC SALMON 131 TESTS

8	ACEPHATE
12	AMINOCARB
17	AZINPHOS-METHYL
15	CARBARYL
1	DDE
1	DDT
1	DIFLUBENZURON
19	FENITROTHION
10	METHOMYL
5	METHOXYCHLOR
3	MEXACARBATE
1	PCB AROCLOR 1016
3	PHOXIM
1	PYRETHRUM
2	RU-11679
21	TEMEPHOS
11	TRICHLORFON

BROWN TROUT 77 TESTS

13	AMINOCARB
6	AZINPHOS-METHYL
2	CAPTAN
2	CARBARYL
2	CARBOFURAN
2	CHLORDANE
1	DDT
2	DINITRAMINE
15	FENITROTHION
1	FENTHION
2	FOLPET
1	GERANIOL
2	HEXACHLOROBENZENE
1	LEPTOPHOS
3	LINDANE
1	MALATHION
1	METHYL PARATHION
6	MEXACARBATE
1	PCB AROCLOR 1016
1	PCB AROCLOR 1260
3	PHOXIM
3	PYDRAUL 50E
2	PYRETHRUM
1	RESMETHRIN
1	RU-11679
1	TOXAPHENE
1	TRICHLORFON

BROOK TROUT 201 TESTS

11	ACEPHATE
16	AMINOCARB
1	AZINPHOS-METHYL
9	CARBARYL
2	CHLORPYRIFOS-METHYL
7	DIFLUBENZURON
23	FENITROTHION
1	HEXACHLOROBENZENE
2	HEXAZINONE
1	HOUGHTO-SAFE 1120
3	METHOMYL
88	METHOXYCHLOR
1	MEXACARBATE
1	PCB AROCLOR 1016
3	PERMETHRIN
3	PHOXIM
1	PYDRAUL 50E
6	TEMEPHOS
1	TFM
3	TOXAPHENE
18	TRICHLORFON

LAKE TROUT 146 TESTS

1	ANTIMYCIN A
3	CAPTAN
5	CARBARYL
1	CARBOFURAN
6	CHLORPYRIFOS
1	COUMAPHOS
2	D-TRANS ALLETHRIN
1	DIAZINON
2	DICHLORVOS
2	MALATHION
2	METHOXYCHLOR
2	METHYL PARATHION
1	MEXACARBATE
1	NALED
2	PARATHION
2	PCB AROCLOR 1016
13	PICLORAM
3	PYDRAUL 50E

Table A3. *Continued.*

(CONT.) LAKE TROUT — 146 TESTS

1	DICOFOL
1	DINITRAMINE
10	DINOSEB
15	DIURON
8	EPTC
3	FENTHION
1	FLIT MLO
2	FOLPET
1	LEPTOPHOS
2	LETHANE 384
2	LINDANE
2	PYRETHRUM
2	RESMETHRIN
2	RONNEL
2	RU-11679
4	TEMEPHOS
2	THANITE
2	TRICHLORFON
6	2,4-D
14	2,4-D BUTYL ESTER
14	2,4-D PROPYLENE GLYCOL BUTYL ETHER ESTER

NORTHERN PIKE — 15 TESTS

1	AZINPHOS-METHYL
1	D-TRANS ALLETHRIN
1	DDT
1	DINITRAMINE
1	EPN
1	FENTHION
1	HEPTACHLOR
1	METHOXYCHLOR
1	METHYL PARATHION
1	PHORATE
2	PHOXIM
1	PYRETHRUM
1	RESMETHRIN
1	RU-11679

GOLDFISH — 45 TESTS

3	ANTIMYCIN A
1	AZINPHOS-METHYL
1	BENEFIN
1	BENZENE HEXACHLORIDE
1	BUFENCARB
2	CAPTAFOL
2	CARBARYL
1	COPPER SULFATE
2	DDT
2	DICHLOBENIL
1	DICHLOROPROPENE
2	DIELDRIN
1	DINOCAP
1	DIPHENAMIDE
1	DIQUAT
1	DITHIANON
1	ENDRIN
1	FENITROTHION
2	FENTHION
2	LINDANE
1	MALATHION
2	METHOXYCHLOR
1	METHYL PARATHION
2	MEXACARBATE
1	MSMA
1	NOREA
2	PARATHION
1	PIPERALIN
1	SILVEX BUTOXYETHANOL ESTER
2	TOXAPHENE
1	TRIFLURALIN
1	TRIPHENYLTIN HYDROXIDE

CARP — 12 TESTS

1	AZINPHOS-METHYL
1	CARBARYL
1	DDT
1	DINITRAMINE
1	ENDRIN
1	FENITROTHION
1	FENTHION
1	LINDANE
1	MALATHION
1	METHYL PARATHION
1	MEXACARBATE
1	TOXAPHENE

RIVER SHINER — 1 TESTS

1	DDT

FATHEAD MINNOW — 280 TESTS

2	ACEPHATE
1	AKTON
1	ALDRIN
1	ALUMINUM NITRATE
1	ALUMINUM SULFATE
1	AMDRO
2	AMINOCARB
1	AMITROLE
9	ANTIMYCIN A
3	AZINPHOS-METHYL
1	BENEFIN
4	BENOMYL
1	BENZENE HEXACHLORIDE
1	FENBUTATIN-OXIDE
5	FENITROTHION
3	FENTHION
2	FENVALERATE
1	FIRE-TROL 100
1	FIRE-TROL 931
2	FLURIDONE
2	FOLPET
1	FOSAMINE AMMONIUM
1	FOSPIRATE
1	FYRQUEL GT
2	GERANIOL
5	GLYPHOSATE

Table A3. *Continued.*

(CONT.) FATHEAD MINNOW 280 TESTS

3	BENZOYLPROP ETHYL
2	CALCIUM HYPOCHLORITE
2	CAPTAN
3	CARBARYL
3	CARBOFURAN
2	CHLORDANE
1	CHLORDANE-HCS-3260
2	CHLORDECONE
1	CHLORENDATE DIBUTYL
2	CHLORENDATE DIMETHYL
2	CHLORFENETHOL
1	CHLORMEQUAT CHLORIDE
1	CHLOROWAX 500C
1	CHLORPYRIFOS-METHYL
1	COPPER SULFATE
1	COPPER-COUNT-N
1	COPPER-COUNT-NS
1	CORREX
1	CROTOXYPHOS
1	CUMYLPHENYL DIPHENYL PHOSPHATE
4	CYANAZINE
2	CYPRAZINE
2	D-TRANS ALLETHRIN
1	DDD
3	DDT
2	DICHLOBENIL
1	DICHLOROPHENYL METHYLSULFONATE
1	DICHLOROPROPENE
1	DICHLORVOS
1	DIELDRIN
1	DIFLUBENZURON
1	DIMETHRIN
2	DINITRAMINE
1	DIPHENAMIDE
1	DISULFOTON
1	DITHIANON
1	ENDOSULFAN
1	ENDOTHALL HYDROTHOL 191
2	ENDRIN
1	ETHION
1	PHTHALATE DI-2-ETHYLHEXYL
2	PHTHALATE DIBUTYL
1	PROPOXUR
2	PURIFLOC C-3
1	PYDRAUL 115E
3	PYDRAUL 50E
2	PYRETHRUM
3	RESMETHRIN
2	RU-11679
2	S-BIOALLETHRIN
1	SANTICIZER 154
2	SILVEX
1	SILVEX BUTOXYETHANOL ESTER
1	SILVEX PROPYLENE GLYCOL BUTYL ETHER ESTER
3	SIMAZINE
1	SODIUM SELENITE
1	TEMEPHOS
1	TEPP
2	TERBUFOS
10	TOXAPHENE
1	TRI-N-BUTYL PHOSPHATE
1	HALOWAX 1099
1	HEPTACHLOR
1	HEXACHLOROBENZENE
2	HOUGHTO-SAFE 1120
1	HOUGHTO-SAFE 520
1	LEPTOPHOS
1	LIME SULFUR
4	LINDANE
2	MALATHION
1	MBC
1	MCPB
3	METHOMYL
2	METHOPRENE
1	METHOXYCHLOR
3	METHYL PARATHION
2	METOLACHLOR
2	MEXACARBATE
1	MIREX
1	MITIN FF
1	MON 0818
1	MONOCROTOPHOS
1	MSMA
1	NALED
2	NEODOL 25-12
1	NEODOL 25-9
2	NITRAPYRIN
1	NONYLPHENYL DIPHENYL PHOSPHATE
1	NOREA
2	ORTHO 11775
2	PARATHION
1	PENTACHLOROPHENOL
1	PENTACHLOROPHENOL SODIUM SALT
2	PERMETHRIN
1	PHOS-CHEK 202
1	PHOS-CHEK 259
1	PHOSALONE
1	PHOSFLEX 31P
2	PHOSMET
1	PHOSPHAMIDON
1	PHOXIM
1	TRICHLORFON
3	TRIFLURALIN
1	TRIPHENYL PHOSPHATE
1	TRIPHENYLTIN HYDROXIDE
1	UREABOR
1	WATER GLYCOLS 894-44A
1	WATER GLYCOLS 894-44B
1	WATER GLYCOLS 894-44C
1	2-HYDROXY-2',4,4'-TRICHLORODIPHENYL ET
1	2-HYDROXY-4,4'-DICHLORODIPHENYL ETHER
1	2,3,4,6-TETRACHLOROPHENOL
1	2,3,5-TRIMETHYL NAPHTHALENE
1	2,3,6-TRICHLOROBENZOIC ACID
1	2,3,6-TRIMETHYL NAPHTHALENE
1	2,4-D
1	2,4-D BUTOXYETHANOL ESTER
24	2,4-D DIMETHYLAMINE SALT
18	2,4-D DODECYL/TETRADODECYL AMINE SALT
1	2,4-DB
1	2,4,5-T TRIETHYLAMINE SALT

LONGNOSE SUCKER 1 TESTS

1	PCB AROCLOR 1016

WHITE SUCKER 8 TESTS

2	CHLORDANE
1	D-TRANS ALLETHRIN
1	PCB AROCLOR 1016
2	RESMETHRIN
2	RU-11679

Table A3. *Continued.*

BLACK BULLHEAD 25 TESTS

1	ALDRIN
2	ANTIMYCIN A
3	AZINPHOS-METHYL
1	CARBARYL
2	DDT
1	DIELDRIN
2	DIQUAT
1	ENDRIN
2	FENTHION
1	HEPTACHLOR
1	LINDANE
2	MALATHION
1	METHYL PARATHION
2	MEXACARBATE
2	TOXAPHENE
1	TRICHLORFON

CHANNEL CATFISH 341 TESTS

2	ACEPHATE
1	AERO XANTHATE 343
1	AEROFROTH 71
1	AKTON
1	ALDRIN
1	AMDRO
5	AMINOCARB
2	AMITROLE
1	ANILAZINE
9	ANTIMYCIN A
1	AQUA COP
1	AQUA-VATOR
1	AZINPHOS-METHYL
6	BENOMYL
2	BENTHIOCARB
1	BENZENE
1	BENZENE HEXACHLORIDE
1	BENZOTHIAZOLE 2-MERCAPTO
1	BENZOTHIAZOLE 2-METHYL MERCAPTO
1	BINAPACRYL
1	CAPTAFOL
1	CAPTAN
3	CARBARYL
1	CARBOFURAN
1	CARBOPHENOTHION
1	CCA TYPE III
1	CHLORBROMURON
5	CHLORDANE
1	CHLORDANE-HCS-3260
1	CHLORDECONE
1	CHLORDIMEFORM
1	CHLORENDATE DIBUTYL
2	CHLORENDATE DIMETHYL
1	CHLORFENETHOL
1	CHLORMEQUAT CHLORIDE
2	CHLOROWAX 500C
1	CHLOROXURON
1	CHLORPYRIFOS
2	CORREX
1	COUMAPHOS
1	CROTOXYPHOS
1	CUMYLPHENYL DIPHENYL PHOSPHATE
3	CYANAZINE
2	CYTROL AMITROLE-T
1	D-D SOIL FUMIGANT
2	D-TRANS ALLETHRIN
1	DDD
6	DDT
2	DEF
1	DEMETON
1	DICHLOFENTHION
1	DICOFOL
1	DICROTOPHOS
2	DIELDRIN
2	DIFLUBENZURON
2	DIMETHRIN
1	DINITRAMINE
1	DISULFOTON
1	DITHIANON
1	ENDOSULFAN
1	ENDOTHALL
2	ENDOTHALL AQUATHOL K
1	ENDOTHALL HYDROTHOL 191
2	ENDRIN
1	EPN
1	ETHION
1	ETHYLBENZENE
2	FENBUTATIN-OXIDE
8	FENITROTHION
2	FENTHION
2	FENVALERATE
3	FLAMPROP-METHYL
2	FLUCHLORALIN
3	FLUOMETURON
1	FLUORODIFEN
10	FLURIDONE
1	FOLPET
1	FOSAMINE AMMONIUM
1	FYRQUEL GT
6	GLYPHOSATE
1	HALOWAX 1099
1	HEPTACHLOR
3	HEXACHLOROBENZENE
1	HEXACHLOROBUTADIENE
3	HOUGHTO-SAFE 1120
1	JODFENPHOS
1	LEAD ARSENATE
1	LEPTOPHOS
2	LINDANE
2	LINURON
2	MALATHION
5	MBC
2	MERPHOS
6	METHOMYL
1	METHOPRENE
1	METHOXYCHLOR
1	METHYL PARATHION
1	METHYL TRITHION
2	METRIBUZIN
1	MEVINPHOS
2	MEXACARBATE
1	MON 0818
1	MONOCROTOPHOS
1	MSMA
1	NALED
1	NEODOL 25-12
1	NEODOL 25-9
1	NITRAPYRIN
1	ORTHO 11775
2	OXAMYL
1	OXYDEMETON-METHYL
1	PARAQUAT
1	PARATHION
1	PARATHION DITHIOATE ANALOGUE
1	PAROIL 1032
1	PAROIL 1048

Table A3. *Continued.*

(CONT.) CHANNEL CATFISH 341 TESTS

1	PAROIL 160
3	PCB AROCLOR 1016
1	PCB AROCLOR 1242
1	PCB AROCLOR 1248
1	PCB AROCLOR 1254
1	PCB AROCLOR 1260
2	PENTACHLOROPHENOL
2	PENTACHLOROPHENOL COPPER SALT
2	PENTACHLOROPHENOL SODIUM SALT
1	PERMETHRIN
1	PHORATE
1	PHOSFLEX 31P
2	PHOSMET
1	PHOSPHAMIDON
1	PHOTO-DIELDRIN
1	PHOXIM
2	PHTHALATE DI-2-ETHYLHEXYL
2	PHTHALATE DIBUTYL
7	PICLORAM
2	PROFENOFOS
2	PROPACHLOR
1	PROPYL ISOME
1	PURIFLOC C-3
3	PYDRAUL 115E
4	PYDRAUL 50E
4	PYRETHRUM
3	RESMETHRIN
1	RONNEL
2	ROTENONE
2	RU-11679
1	RYANIA
1	S-BIOALLETHRIN
2	SILVEX
1	SODIUM SELENITE
5	TEMEPHOS
1	TERBUFOS
1	TETRACHLORVINPHOS
1	TETRADIFON
1	TOLUENE
26	TOXAPHENE
2	TRIALLATE
3	TRICHLORFON
1	TRICHLOROMANDELIC ACID
1	TRICRESYL PHOSPHATE
6	TRIFLURALIN
1	TRIPHENYL PHOSPHATE
1	UREABOR
1	WARFARIN
2	XYLENOL DIMETHYLAMINO
1	Z-200
1	2,3,4,6-TETRACHLOROPHENOL
2	2,4-D BUTOXYETHANOL ESTER
6	2,4-D DIMETHYLAMINE SALT
2	2,4-D DODECYL/TETRADODECYL AMINE SALT
1	2,4-D OLEYLPROPYLENEDIAMINE SALT
1	2,4-D/2,4,5-T 24%/28%
1	2,4,5-T TRIETHYLAMINE SALT
1	6-CHLORO-2-PICOLINIC ACID

WALKING CATFISH 1 TESTS

1	ANTIMYCIN A

MOSQUITOFISH 2 TESTS

1	DICHLORVOS
1	ENDRIN

MOSQUITOFISH NON-RESISTANT 2 TESTS

1	ANTIMYCIN A
1	PARATHION

MOSQUITOFISH RESISTANT 2 TESTS

1	ANTIMYCIN A
1	PARATHION

GREEN SUNFISH 32 TESTS

1	ANTIMYCIN A
1	AZINPHOS-METHYL
1	BINAPACRYL
2	CARBARYL
1	CARBOPHENOTHION
2	COPPER SULFATE
3	DDT
2	DICHLOBENIL
2	ENDOTHALL COPPER SALT
1	FENITROTHION
3	FENTHION
2	LINDANE
3	MALATHION
2	METHYL PARATHION
2	MEXACARBATE
2	PARATHION
2	TOXAPHENE

BLUEGILL 959 TESTS

7	ACEPHATE
1	AERO XANTHATE 343
1	AEROFROTH 71
1	AKTON
2	ALACHLOR
2	ALDICARB
6	ALDRIN
1	ALLETHRIN
1	AMDRO
1	CHLOROWAX 70
5	CHLORPYRIFOS
1	COPPER OXYCHLORIDE
2	COPPER SULFATE
1	COPPER-COUNT-N
1	COPPER-COUNT-NS
2	CORREX
1	COUMAPHOS
1	CROTOXYPHOS

Table A3. *Continued.*

(CONT.) BLUEGILL 959 TESTS

1	AMETRYN
21	AMINOCARB
1	ANILAZINE
17	ANTIMYCIN A
1	APHOLATE
1	AQUA COP
1	AQUA-VATOR
1	ARAMITE
1	ATRAZINE 4L
1	AZIDE POTASSIUM
1	AZIDE SODIUM
1	AZINPHOS-ETHYL
7	AZINPHOS-METHYL
1	BACILLUS THURINGIENSIS
12	BENOMYL
1	BENSULIDE
2	BENTHIOCARB
1	BENZALKONIUM CHLORIDE
9	BENZENE
1	BENZENE HEXACHLORIDE
4	BENZOTHIAZOLE 2-MERCAPTO
4	BENZOTHIAZOLE 2-METHYL MERCAPTO
3	BENZOYLPROP ETHYL
1	BINAPACRYL
1	BOMYL
3	BUTYLATE
1	CACODYLIC ACID
2	CAPTAFOL
1	CAPTAN
14	CARBARYL
2	CARBOFURAN
1	CARBOPHENOTHION
1	CCA TYPE III
1	CHLORAMBEN
3	CHLORDANE
1	CHLORDANE CIS
1	CHLORDANE TRANS
3	CHLORDANE-HCS-3260
1	CHLORDECONE
2	CHLORENDATE DIBUTYL
2	CHLORENDATE DIMETHYL
2	CHLORFENVINPHOS
1	CHLORINATED ALPHA OLEFIN 22/44
1	CHLORMEQUAT CHLORIDE
1	CHLORONITROPROPANE
1	CHLOROWAX LV
1	CHLOROWAX 40
1	CHLOROWAX 50
4	CHLOROWAX 500C
7	ENDRIN
1	EPN
1	ETHION
2	ETHOFUMESATE
1	ETHYLAN
10	ETHYLBENZENE
1	ETHYLENE GLYCOL
2	FENAC
1	FENAMINOSULF
1	FENAZAFLOR
1	FENBUTATIN-OXIDE
26	FENITROTHION
1	FENSON
1	FENSULFOTHION
2	FENTHION
11	FENVALERATE
1	FIRE-TROL 100
1	FIRE-TROL 931
2	FLAMPROP-METHYL
2	FLUCHLORALIN
2	FLUOMETURON
2	CRUFOMATE
1	CRYOLITE
2	CUTRINE-PLUS
2	CYANAZINE
4	CYHEXATIN
2	CYPRAZINE
2	CYTROL AMITROLE-T
1	D-D SOIL FUMIGANT
13	D-TRANS ALLETHRIN
1	DALAPON
1	DCPA
1	DDD
1	DDE
7	DDT
1	DEAD-X
11	DEF
1	DEMETON
1	DIAZINON
1	DICAMBA
2	DICHLOBENIL
1	DICHLOFENTHION
1	DICHLONE
1	DICHLORVOS
1	DICLOFOP METHYL
1	DICOFOL
1	DICROTOPHOS
8	DIELDRIN
8	DIFLUBENZURON
1	DILAN
1	DIMETHOATE
14	DIMETHRIN
1	DIMETHYLSULFOXIDE
1	DINITRAMINE
1	DINOBUTON
2	DINOCAP
1	DIOXATHION
1	DIPHENAMIDE
10	DIQUAT
1	DISULFOTON
12	DIURON
1	DNOC
1	EMCOL AD-410
1	ENDOSULFAN
1	ENDOTHALL
9	ENDOTHALL AQUATHOL K
1	ENDOTHALL COPPER SALT
1	ENDOTHALL HERBICIDE 282
1	ENDOTHALL HYDROTHOL 191
1	ENDOTHALL POTASSIUM SALT
2	MIREX
1	MITIN FF
1	MNFA
1	MOLINATE
4	MON 0818
1	MONOCROTOPHOS
1	MONOETHANOLAMINE
3	MSMA
1	N-BUTANOL
1	N,N-DIMETHYL-2,4-DICHLOROPHENOXYACETAMIDE
1	NALED
1	NITRALIN
1	NOREA
2	ORTHO 11775
1	OVEX
2	OXAMYL
1	OXYDEMETON-METHYL
1	OXYTHIOQUINOX
1	PARAQUAT
7	PARATHION
1	PARATHION DITHIOATE ANALOGUE

Table A3. *Continued.*

(CONT.) BLUEGILL 959 TESTS

1	FLUORENE
2	FLURIDONE
1	FOLPET
1	FONOFOS
1	FOSAMINE AMMONIUM
9	FYRQUEL GT
16	GLYPHOSATE
3	HEPTACHLOR
1	HEPTACHLOR EPOXIDE
1	HERCULES 7175
2	HEXACHLOROBENZENE
1	HEXACHLOROBUTADIENE
1	HEXAZINONE
3	HOUGHTO-SAFE 1120
1	HOUGHTO-SAFE 520
1	HYDROXY-S-TRIAZINYL ALANINE
1	KOMEEN
9	KRONITEX 200
1	LANDRIN
2	LEPTOPHOS
1	LIME SULFUR
6	LINDANE
8	MALATHION
1	MCPA DIMETHYLAMINE SALT
1	MCPB
7	MERPHOS
1	METHIDATHION
1	METHIOCARB
21	METHOMYL
2	METHOPRENE
1	METHOPROTRYNE
5	METHOXYCHLOR
3	METHYL PARATHION
2	METHYL TRITHION
1	METRIBUZIN
3	MEVINPHOS
16	MEXACARBATE
11	S-BIOALLETHRIN
6	SANTICIZER 148
9	SANTICIZER 154
2	SD 16898
2	SD 17250
1	SD 7438
1	SD 8339
3	SILVEX
2	SILVEX BUTOXYETHANOL ESTER
2	SILVEX POTASSIUM SALT
2	SILVEX PROPYLENE GLYCOL BUTYL ETHER ESTER
1	SIMAZINE
1	SODIUM ARSENITE
4	TEMEPHOS
3	TEPP
10	TERBUFOS
1	TERBUTRYN
2	TERPENE POLYCHLORINATES
2	TETRACHLORVINPHOS
1	TETRADIFON
1	TETRAMINE
1	TH 285-N
1	TH 336-N
9	TOLUENE
12	TOXAPHENE
1	TRANID
2	TREFMID
65	TRICHLORFON
1	TRICHLORONATE
1	PAROIL 1032
1	PAROIL 1048
1	PAROIL 160
2	PCB AROCLOR 1016
1	PCB AROCLOR 1242
2	PCB AROCLOR 1248
2	PCB AROCLOR 1254
1	PCB AROCLOR 1260
2	PENTACHLOROPHENOL
2	PENTACHLOROPHENOL SODIUM SALT
10	PERMETHRIN
6	PHORATE
1	PHOS-CHEK 202
1	PHOS-CHEK 259
1	PHOSALONE
9	PHOSFLEX 31P
33	PHOSMET
1	PHOSPHAMIDON
1	PHOTO-DIELDRIN
14	PHOXIM
2	PHTHALATE DI-2-ETHYLHEXYL
5	PHTHALATE DIBUTYL
10	PICLORAM
2	PIPERONYL BUTOXIDE
2	PROFENOFOS
1	PROPANIL
1	PROPHAM
1	PROPOXUR
2	PURIFLOC C-3
1	PYDRAUL 115E
3	PYDRAUL 50E
15	PYRETHRUM
3	RESMETHRIN
3	RONNEL
1	ROTENONE
2	RU-11679
1	RYANIA
1	TRICLOPYR
2	TRICRESYL PHOSPHATE
16	TRIFLURALIN
1	TRIPHENYLTIN HYDROXIDE
1	TRITON B-1956
1	UC 10854
4	UREABOR
2	VERNOLATE
1	WATER GLYCOLS 894-44A
1	WATER GLYCOLS 894-44B
1	WATER GLYCOLS 894-44C
12	XYLENE
2	XYLENOL AMINO
2	XYLENOL DIMETHYLAMINO
1	Z-200
1	2-ETHYLHEXANOL
1	2,3,4,6-TETRACHLOROPHENOL
1	2,4-D
3	2,4-D BUTOXYETHANOL ESTER
8	2,4-D DIMETHYLAMINE SALT
5	2,4-D DODECYL/TETRADODECYL AMINE SALT
1	2,4-D OLEYLPROPYLENEDIAMINE SALT
2	2,4-D PROPYLENE GLYCOL BUTYL ETHER ESTE
2	2,4-D/2,4,5-T 24%/28%
1	2,4-D/2,4,5-T 30%/28%
1	2,4-D/2,4,5-T 34%/17%
2	2,4-DB
1	2,4,5-T TRIETHYLAMINE SALT
1	2,6-DICHLOROBENZOIC ACID

Table A3. *Continued.*

REDEAR SUNFISH 18 TESTS

1	AKTON
1	ANILAZINE
5	CHLORDECONE
1	DDT
1	FENAC
5	HEPTACHLOR
1	MALATHION
1	SILVEX BUTOXYETHANOL ESTER
2	2,4,5-T BUTOXYETHANOL ESTER

SMALLMOUTH BASS 9 TESTS

1	D-TRANS ALLETHRIN
1	FOLPET
1	PHOSMET
2	PYRETHRUM
1	RU-11679
1	2,4-D DIMETHYLAMINE SALT
2	2,4-D DODECYL/TETRADODECYL AMINE SALT

LARGEMOUTH BASS 74 TESTS

1	ALDRIN
1	AMINOCARB
5	ANTIMYCIN A
1	AZINPHOS-METHYL
1	BENZENE HEXACHLORIDE
1	CARBARYL
5	CHLORDANE
1	COUMAPHOS
1	CROTOXYPHOS
2	CYHEXATIN
1	D-D SOIL FUMIGANT
1	D-TRANS ALLETHRIN
1	DDD
2	DDT
1	DEMETON
1	DICHLOFENTHION
1	DICHLOROPROPENE
1	DICOFOL
1	DIELDRIN
2	DIOXATHION
1	DISULFOTON
1	ENDRIN
1	EPN
1	ETHION
1	FENAZAFLOR
3	FENTHION
1	FIRE-TROL 100
1	FIRE-TROL 931
1	HEPTACHLOR
1	HEXACHLOROBENZENE
1	LEPTOPHOS
1	LINDANE
2	MALATHION
2	METHOMYL
2	METHOXYCHLOR
1	METHYL PARATHION
1	METHYL TRITHION
1	MEVINPHOS
1	MEXACARBATE
1	MIREX
1	NALED
1	OXYDEMETON-METHYL
1	PARATHION
1	PHORATE
1	PHOS-CHEK 202
1	PHOS-CHEK 259
1	PHOSMET
1	PYRETHRUM
1	RESMETHRIN
1	RU-11679
4	TEMEPHOS
2	TOXAPHENE
1	TRICHLORFON
1	TRIFLURALIN

WHITE CRAPPIE 1 TESTS

1	ANTIMYCIN A

BLACK CRAPPIE 3 TESTS

1	AZINPHOS-METHYL
1	CARBARYL
1	DDT

YELLOW PERCH 133 TESTS

7	ACEPHATE
14	AMINOCARB
1	ANTIMYCIN A
17	AZINPHOS-METHYL
1	CAPTAN
14	CARBARYL
3	CARBOFURAN
1	CHLORDANE
1	D-TRANS ALLETHRIN
1	DDT
1	METHYL PARATHION
3	MEXACARBATE
1	MIREX
1	PAROIL 1032
1	PAROIL 1048
1	PAROIL 160
1	PCB AROCLOR 1016
1	PCB AROCLOR 1242
1	PCB AROCLOR 1248
1	PCB AROCLOR 1254

Table A3. *Continued.*

(CONT.) YELLOW PERCH 133 TESTS

2	DIFLUBENZURON	1	PCB AROCLOR 1260
1	DIMETHRIN	3	PHOXIM
2	DINITRAMINE	1	PHTHALATE DIBUTYL
2	DIQUAT	1	PYDRAUL 50E
1	ENDRIN	1	PYRETHRUM
13	FENITROTHION	1	RESMETHRIN
1	FENTHION	1	RU-11679
1	FOLPET	1	S-BIOALLETHRIN
1	HOUGHTO-SAFE 1120	1	TOXAPHENE
15	LEPTOPHOS	1	TRICHLORFON
2	LINDANE	1	TRICRESYL PHOSPHATE
1	MALATHION	2	XYLENOL DIMETHYLAMINO
4	METHOXYCHLOR		

WALLEYE 17 TESTS

1	AMINOCARB	1	EPN
1	COUMAPHOS	1	MALATHION
1	D-D SOIL FUMIGANT	1	MIREX
1	DDD	1	OXYDEMETON-METHYL
2	DDT	2	PHORATE
1	DEMETON	1	PYRETHRUM
1	DICHLOFENTHION	1	TRIFLURALIN
1	DICHLOROPROPENE		

TILAPIA 10 TESTS

3	DDT	2	MALATHION
2	DIELDRIN	1	METHOXYCHLOR
1	ENDRIN	1	METHYL TRITHION

FOWLERS TOAD 25 TESTS

1	ALDRIN	1	LINDANE
1	AZINPHOS-METHYL	1	MALATHION
1	BENZENE HEXACHLORIDE	1	METHOXYCHLOR
1	DDD	1	MOLINATE
5	DDT	1	PARAQUAT
1	DEF	1	PARATHION
1	DIELDRIN	1	SILVEX PROPYLENE GLYCOL BUTYL ETHER E
1	ENDOTHALL HYDROTHOL 191	1	TOXAPHENE
1	ENDRIN	2	TRIFLURALIN
1	HEPTACHLOR	1	2,4-D BUTOXYETHANOL ESTER

WESTERN CHORUS FROG 13 TESTS

1	AZINPHOS-METHYL	1	METHYL PARATHION
1	DDT	1	MEVINPHOS
1	DIELDRIN	1	PARAQUAT
1	ENDRIN	1	PARATHION
1	LINDANE	1	PIPERONYL BUTOXIDE
1	MALATHION	1	TOXAPHENE
1	METHOXYCHLOR		

Table A4. *Common and alternate names of chemicals used for aquatic toxicity testing.*

Common name	Alternate name
ACEPHATE	Orthene; Ortho 12420; Ortran
ACETONE	dimethylformaldehyde; dimethylketol; dimethyl ketone; ketone propane; methy ketone; propanone; pyroacetic acid; pyroacetic ether
AKTON	Axiom
ALACHLOR	Alanex; Pillarzo
ALDICARB	Temik; OMS 771; UC21149
ALDRIN	Aldrex 30; Aldrine; Aldrite; Aldrosol; Altox; Drinox; HHDN; Octalene
ALLETHRIN	Pallethrine; Pynamin
ALUMINUM NITRATE	Aluminum trinitrate; nitric acid aluminum salt; nitric acid aluminum (3+) salt
ALUMINUM SULFATE	Alum; aluminum sulfate (2:3); aluminum trisulfate; cake alum; dialuminum sulfate; dialuminum trisulfate; luminum alum; sulfuric acid aluminum salt (3:2)
AMDRO	AC 217,300; CL 217,300
AMETRYN	Ametrex; Crisatrine; Evik; G-34162; Gesapax
AMINOCARB	A 363; aminocarbe; Bay 44646; Matacil
AMITROLE	Amerol; Amino-triazole; Amino Triazole Weedkiller 90; Amitrol T; Amizol; AT-90; ATA; AT Liquid; Azolan; Azole; Cytrol; Cytrol Amitrole-T; Diurol; Herbizole; Simazol; Weedazol; Weedazol TL, Amitrol
ANILAZINE	Direz; Dyrene; Kemate; Triasyn
ANTIMYCIN A	Antipiricullin; Virosin
APHOLATE	APN; ENT-26,316; NSC-26812; OLIN MO. 2174; pholate; SQ 8388
ARAMITE	Aracide; Niagaramite; 88-R
AROCLOR 1221	Arochlor 1221; chlorodiphenyl (21% Cl); polychlorinated biphenyl (Aroclor 1221)
AROCLOR 1232	Arochlor 1232; chlorodiphenyl (32% Cl); polychlorinated biphenyl (Aroclor 1232)
AROCLOR 1242	Arochlor 1242; chlorodiphenyl (42% Cl); polychlorinated biphenyl (Aroclor 1242)
AROCLOR 1248	Arochlor 1248; chlorodiphenyl (48% Cl); polychlorinated biphenyl (Aroclor 1248)
AROCLOR 1254	Arochlor 1254; chlorodiphenyl (54% Cl); NCI-CO2664; polychlorinated biphenyl (Aroclor 1254)
AROCLOR 1260	Arochlor 1260; chlorodiphenyl (60% Cl); Clophen A60; Phenoclor DP6; polychlorinated biphenyl (Aroclor 1260)
AROCLOR 1262	Arochlor 1262; chlorodiphenyl (62% Cl); polychlorinated biphenyl (Aroclor 1262)
AROCLOR 1268	Arochlor 1268; chlorodiphenyl (68% Cl); polychlorinated biphenyl (Aroclor 1268)
AROCLOR 4465	Arochlor 4465; polychlorinated biphenyl (Aroclor 4465)
AROCLOR 5442	Arochlor 5442; polychlorinated triphenyl (Aroclor 5442)
AROCLOR 5460	Arochlor 5460; polychlorinated triphenyl (Aroclor 5460)
ATRAZINE 4L	AAtrex; Atranex; Atred; Crisatrina; Crisazine; Farmco Atrazine; Griffex; Shell Atrazine Herbicide; Vectal SC
AZIDE (SODIUM)	
AZINPHOS ETHYL	Azinos; Bay 16259; Cotnion-Ethyl; Crysthion; Gusathion A; Triazotion
AZINPHOS METHYL	Bay 17147; Carfene; Cotnion-Methyl; Gusathion M; Guthion; metiltriazotion
BARBAN	barbamate; barbane; Carbyne; chlorinat
BENEFIN	Balan; Balfin; benfluralin; Benefex; Bethrodine; Quilan
BENOMYL	Benlate; Tersan 1991
BENSULIDE	Betamec; Betasan; Exporsan; Prefar; Pre-San
BENTHIOCARB	Bolero; Saturn; Saturno; Siacarb; Tamariz; Thiobencarb
BENZALKONIUM CHLORIDE	Barquat MB-50; Barquat MB-80; BTC; Roccal; Zephiran
BENZENE	Benzol
BENZENE HEXACHLORIDE	Benzahex; Benzex; BHC; Dol; Dolmix; Gammexane; Gexane; HCCH; HCH; Hexablanc; hexachlor; hexachloran; Hexafor; Hexamul; Hexapoudre; Hexyclan; Hilbeech; Kotol; Soprocide; Submar; 666

Table A4. *Continued.*

Common name	Alternate name
BENZOTHIAZOLE 2-METHYL MERCAPTO	USAF EK-4008
BENZOYLPROP ETHYL	SD 30053; Suffix; Suffix 25; WL 17731
BENZYL BENZOATE	Ascabin; Ascabiol; Benzylets; Colebenz; Novoscabin; Peruscabin; Vanzoate; Venzonate
BINAPACRYL	Acricid; Ambox; Dapacryl; dinoseb; Endosan; FMC 9044; Hoe 2784; methacrylate; Morocide; Morrocid; NIA 9044
BOMYL	Fly Bait Grits; GC-3707; Swat
BUFENCARB	Bux; Ortho 5353
BUTOXYL POLYPROPYLENE GLYCOL	Stabilene Fly Repellent
BUTYLATE	R-1910; Sutan
CACODYLIC ACID	Dilic; Rad-E-Cate 25
CALCIUM HYPOCHLORITE	bleaching powder; chloride of lime
CAPTAFOL	Difolatan; Haipen; Merpafol; Pillartan; Sanspor
CAPTAN	Captane; Merpan; Orthocide; Pillarcap; Vondcaptan
CARBARYL	Carbamine; Cekubaryl; Denapon; Devicarb; Dicarbam; Hexavin; Karbaspray; Nac; Ravyon; Septene; Sevin; Tercyl; Tricarnam; UC 7744
CARBOFURAN	Bay 70143; Curaterr; D 1221; ENT 27164; FMC 10242; Furadan; NIA 10242; Yaltox
CARBOPHENOTHION	Dagadip; Garrathion; R 1303; Trithion
CHLORAMBEN	Amiben; Amiben DS; chlorambene; Ornamental Weeder
CHLORBROMURON	C6313; chlorobromuron; Maloran
CHLORDANE	Belt; Chlordan; Chlor Kil; Chlortox; Corodane; Kypchlor; Niran; Niran 5% granular bait; Octachlor; Octa-Klor; Ortho-Klor; Snyklor; Topiclor 20; Velsicol 1068
CHLORDANE CIS	*alpha*-Chlordane
CHLORDANE TRANS	*gamma*-Chlordane
CHLORDECONE	GC 1189; Kepone
CHLORDIMEFORM	Bermat; C 8514; ENT 27567; EP-333; Fundal; Galecron; SN 36268
CHLORFENETHOL	BCPE; DCPC; dichlorodiphenylethanol; Dimite; DMC; Qikron
CHLORFENVINPHOS	Apachlor; Birlane; Birlane 24; C 8949; CFV; CGA 26351; Compound 4072; Sapecron; SD 7859; Steladone; Supona; Vinylphate
CHLORMEQUAT CHLORIDE	CeCeCe; Chlormequat-chloride + cholin chloride; Cycocel; Cycocel-Extra; Cyogan; Hico CCC; Hormocel-2CCC; Increcel; Lihocin
CHLOROBENZILATE	Acaraben; Akar; Benzilan; Folbex smoke-strips; Kop-Mite
CHLORONITROPROPANE	Korax; Lanstan
CHLOROWAX 40	NCI-C53543
CHLOROWAX 500C	NCI-C53587
CHLOROXURON	C-1983; chloroxifenidim; Tenoran
CHLORPYRIFOS	Brodan; Dursban; Eradex; Lorsban; Pyrinex
CHLORPYRIFOS-METHYL	DOWCO 214; Ent 27520; Reldan
CLONITRALIDE	Bay 6067; Bayluscid; Niclosamide; SR73
COPPER-COUNT-N	
COPPER OXYCHLORIDE	BASF-Grunkupfer; basic copper chloride; Blitox; Chempar; Cobox; Coprantol; Cop Tox; Cupramar; Cupravit; Cuprokylt; Cuprosana; Cuprovinol; Cuprox; Devicopper; Fytolan; Kauritil; Kilex; Recop; Rhodiacuivre; Viricuivre; Vitigran
COPPER SULFATE	Bluestone; blue copperas; blue vitriol; Triangle
CORREX	
COUMAPHOS	Asuntol; Bay 21/199; Baymix; Co-Ral; Diolice; Meldane; Muscatox; Resistox
CROTOXYPHOS	Ciodrin; Ciovap; Cypona E.C.; Decrotox; Duo-Kill; Duravos; SD 4294
CRUFOMATE	Dowco 132; Ruelene
CRYOLITE	Kryocide

Table A4. *Continued.*

Common name	Alternate name
CUTRINE-PLUS	
CYANAZINE	Bladex; Fortral; SD 15418; WL 19805
CYANO (METHYLMERCURI) GUANIDINE	Morsodren; Panodrin A-13; Panogen Turf Fungicide
CYHEXATIN	Dowco 213; Plictran
CYPRAZINE	Outfox; S-9115
CYTROL AMITROLE-T	Amitril T.L.; Amitrol T
2,4-D ACID	Agrotect; Amoxone; Aqua-Kleen; BH 2,4-D; Chipco Turf Herbicide "D"; Chloroxone; Crop Rider; D50; Dacamine; Debroussaillant 600; Ded-Weed; Desormone; Dinoxol; DMA 4; Dormone, Emulsamine BK; Emulsamine E-3; Envert 171; Envert DT; Esteron Brush Killer; Esteron 99 Concentrate; Estone; Farmco; Fernesta; Fernimine; Fernoxone; Ferxone; Formula 40; Hedonal; Herbidal; Lawn-Keep; Macrondray; Miracle; Netagrone 600; Pennamine D; Planotox; Plantgard; Rhodia; Salvo; Spritz-Hormin/2,4-D; Spritz-Hormit/2,4-D; Super D Weedone; Superormone Concentre; Transamine; Tributon; U 46; U 46 D-Ester; U 46 D-Fluid; Visko-Rhap; Weedar; Weedatul; Weed-B-Gon; Weedone; Weed-Rhap; Weed Tox; Weedtrol
2,4 DB	Butoxon; Butoxone; Butoxone amine; Butoxone ester; Butyrac; Butyrac 200; Butyrac ester; Embutox; Embutox E
2,4-D BUTOXYETHANOL ESTER	Bladex-B; Brush Killer 64; 2,4-D-Bee; 2,4-D butoxyethyl ester; Planotox; Weedone LV4
2,4-D BUTYL ESTER	Butyl 2,4-D; butyl dichloro-phenoxyacetate; Esso Herbicide 10; Fernesta; Lironox; Shell 40
2,4-D DIMETHYLAMINE SALT	2,4-D amine; 2,4-D amine salt; Bladex G; Formula 40; Hormin; Phordene
2,4-D ISOOCTYL ESTER	
DALAPON	Basfapon/Basfapon N; BH Dalapon; Crisapon; Dalapon 85; Dalapon-Na; Ded-Weed; Devipon; Dowpon; Dowpon M; DPA; Gramevin; Revenge; Unipon
DCPA	chlorthal dimethyl; Dacthal
D-D SOIL FUMIGANT	Nemafene
DDD	Rhothane; TDE
DDE	
DDT	Anofex; Arkotine; Chlorophenothane; DDT technical; DDT 75% WDP; Dedelo; Didimac; Digmar; Genitox; Gyron; Hildit; Ixodex; Kopsol; Micro DDT 75; Neocid; Pentachlorin; R50; Rukseam; Zeidane; pp'Zeidane; Zerdane
DEET	Detamide; Metadelphene; MGK Diethyltoluamide; OFF
DEF	De-Green; E-Z-Off D; Fos-Fall "A"; Ortho Phosphate Defoliant
DEMETON	Bay 10756; demeton-O + demeton-S; E 1059; mercaptofos; Systemox; Systox
DIAZINON	Basudin; Dazzel; Diagran; Dianon; Diaterr-Fos; Diazajet; Diazatol; Diazide; Diazol; Dizinon; Dyzol; G-24480; Gardentox; Kayazinon; Kayazol; Neocidol; Nipsan; Sarolex; Spectracide
DICAMBA	Banex; Banvel 45; Banvel CST; Banvel D; Banvel Herbicide; Banvel II Herbicide; Banvel 4WS; CST; dianat
DICHLOBENIL	Casoron; Decabane
DICHLOFENTHION	dDichlofention; dichlorofenthion; Mobilawn; Tri-VC13; VC-13 Nemacide
DICHLONE	Phygon; Quintar
DICHLOROPROPENE	Telone II Soil Fumigant
DICHLORVOS	Apavap; Benfos; Cekusan; Cypona; DDVP; Dedevap; Devikol; Divipan; Duo-Kill; Duravos; Fly-Die; Fly Fighter; Herkol; Mafu; Marvex; Nogos; No-Pest; Nuvan; Oko; Phosvit; Tetravos, UDVF; Vapona; Vaponite; Vapora II; Verdican; Verdipor; Verdisol
DICLOFOP METHYL	Hoe-23408; Hoe-Grass; Hoelon; Hoelon 3 EC; Illoxan; Iloxan

Table A4. *Continued.*

Common name	Alternate name
DICOFOL	Acarin; Cekudifol; FW-293; Hifol; Kelthane; Mitigan
DICROTOPHOS	Bidrin; C 709; Carbicron; Diapadrin; Ektafos; SD 3562
DIELDRIN	Dieldrex; Dieldrine; Dieldrite; Octalox; Panoram D-31
DIFLUBENZURON	Dimilin; DU 112307; ENT-29054; OMS 1804; PDD 6040-I; PH 60-40; TH 6040
DILAN	
DIMETHOATE	AC-12880; Bi 58 EC; Cekuthoate; Cygon; Daphene; De-Fend; Demos-L40; Devigon; Dimate 267; Dimethoate technisch 95%; Dimethogen; Fosfamid; Fostion MM; Perfekthion; Rebelate; Rogodial; Rogor; Roxion; Trimetion
DIMETHRIN	Dimethrine
DIMETHYL FORMAMIDE	DMF; NCI-C60913; NSC 5356; U-4224
DIMETHYLSULFOXIDE	Demasorb; Demavet; Demeso; Dermasorb; dimethyl sulfoxide; dimethyl sulphoxide; DMS-70; DMS-90; DMSO; Doligur; Dromisol; Gamasol 90; Hyadur; Infiltrina; methyl sulfoxide; Somipront; SQ 9453; Syntexan
DINITRAMINE	Cobex; Cobexo; Dinitroamine; USB-3584
DINOBUTON	Acrex; Dessin; Dinofen; Drawinol; UC 19786
DINOCAP	Arathane; Crotothane; Iscothane; Karathane; Mildex
DINOSEB	Basanite; Caldon; Chemox General; Chemox PE; Chemsect DNBP; dinitro; Dinitro-3; Dinitro General; dinosebe; DNBP; Dynamyte; Elgetol 318; Gebutox; Hel-Fire; Kiloseb; Nitropone C; Premerge 3; Sinox General; Subitex; Unicrop DNBP; Vertac Dinitro Weed Killer 5; Vertac General Weed Killer; Vertac Selective Weed Killer
DIOXATHION	Delnav; Detic; Hercules AC528
DIPHENAMIDE	DIF 4; Dimid; diphenamid; Dymid; Enide; Enide 50; Fenam; L-34314; Lilly 34,314; U 4513; 80W
DIQUAT	Aquacide; Deiquat; Dextrone; reglon; Reglone; Reglox; Weedtrine-D
DISULFOTON	Bay 19639; Bay S276; Di-Syston; Disyston; dithiodemeton; dithiosystox; Ethylthiodemeton; Frumin AL; M-74; Solvirex; thiodemeton
DITHIANON	Delan; Thynon
DIURON	Cekiuron; Dailon; Diater; dichlorfenidim; Di-on; Direx 4L; Diurex; Diurol; Drexel Diuron 4L; Dynex; Farmco Diuron; Karmex; Unidron; Urox "D"; Vonduron
DNOC	Chemsect DNOC; DNC; Elgetol 30; Nitrador; Selinon; Sinox; Trifocide; Trifrina
DODINE	AC 5223; Apadodine; Carpene; Curitan; Cyprex; Doquadine; Melprex; Syllit; tsitrex; Venturol; Vondodine
DOWELL A170	corrosion inhibitor A170
DOWELL F75A	Ezeflo F75A surfactant
DOWELL F75N	Ezeflo F75N surfactant
DOWELL L47	Gypban L47 scale inhibitor
DOWELL M38N	silicate control additive M38W
DOWELL W35	emulsion and sludge preventor W35
DOWICIDE EC-7 (PENTACHLOROPHENOL)	88% pentachlorophenol; 12% other chlorophenols
d-TRANS ALLETHRIN	Bioallethrin
ENDOSULFAN	Benzoepin thiodan; Beosit; Chlorthiepin; Crisulfan; Cyclodan; Devisulphan; Endocel; Endosol; EnSure; FMC 5462; Hildan; Hoe 2671; Insectophene; Kop Tiodan; Malix; N1A 5462; Thifor; Thimul; Thiodan; Thiofor; Thionex; Thiosulfan; Tiovel
ENDOTHALL	Accelerate; Aquathol; Aquathol K; Des-i-cate; Endothal; Endothal Turf Herbicide; Endothal Weed Killer; Herbicide 273; Hydout; Hydrothol; Hydrothol 47; Hydrothol 191
ENDRIN	Endrex; Hexadrin; Nendrin
EPN	
EPTC	Eptam
ETHANOL	Alcohol; ethyl alcohol

Table A4. *Continued.*

Common name	Alternate name
ETHION	Diethion; Ethanox; Ethiol; Hylemox; Rhodiacide; Rhodocide; Vegfru Fosmite
ETHOFUMESATE	NC 8438; Nortranese; Nortron; Tramat
ETHYLAN	Perthane
ETHYLBENZENE	EB; ethylbenzol; NCI-C56393; phenylethane
ETHYLENE DICHLORIDE	EDC
ETHYLENE GLYCOL	ethylene alcohol; ethylene dihydrate; glycol; glycol alcohol; Lutrol-9; Macrogol 400 BPC; M.E.G.; monoethylene glycol; NCI-C00920; Tescol
2-ETHYLHEXANOL	
FENAC	chlorfenac; Tri-Fen; Trifene
FENAMINOSULF	Bay 22555; Bayer 5072; Lesan
FENAZAFLOR	Fenozaflor
FENBUTATIN-OXIDE	SD 14114; Torque; Vendex
FENITROTHION	Accothion; Agrothion; Bay 41831; Bay S 5660; Cekutrothion; Cytel; Dybar; Fenitox; Folithion; MEP; Novathion; Nuvanol; S 5660; Sumithion
FENSON	CPBS; Fenizon; Murvesco; PCPBS
FENSULFOTHION	Bay 25141; Dasanit; S 767; Terracur P
FENTHION	Bay 29493; Baycid; Baytex; Entex; Lebaycid; mercaptophos; S 1752; Tiguvon
FENVALERATE	Belmark; Ectrin; Pydrin; S-5602; Sanmarton; SD 43775; Sumicidin; Sumifly; Sumipower
FLAMPROP-METHYL	Lancer; WL 29761
FLIT MLO	
FLUCHLORALIN	Basalin
FLUMETURON	C-2059; Cotoran; Cottonex; Lanex
FLUORODIFEN	C 6989; Preforan
FLURIDONE	Sonar
FOLPET	Folpan; Phaltan; Thiophal
FONOFOS	Dyfonate; N-2790
FOSAMINE AMMONIUM	Krenite brush control agent
FOSPIRATE	Dowco 217; ENT 27521; Torelle
GERANIOL	geraniol alcohol; geraniol extra; geranyl alcohol; Guaniol; Lemonol
GLENBAR	OCS-21944
GLYCEROL	glycerin; glycerine; glyceritol; glycyl alcohol; synthetic glycerin; 90 technical glycerine; trihydroxypropane
GLYODIN	Crag Fruit Fungicide 341
GLYPHOSATE	glyphosate isopropylamine salt; Roundup
HEPTACHLOR	Drinox H-34; Heptachlore; Heptamul; Heptox
HEPTACHLOR EPOXIDE	ENT 25,584; epoxyheptachlor; HCE; heptachlor epoxide; Velsicol 53-CS-17
HERCULES 7175	
HEXACHLOROBENZENE	Anticarie; Ceku C.B.; HCB; No Bunt
HEXACHLOROBUTADIENE	C-46; Dolen-Pur; GP-40-66:120; HCBD; hexachlorbutadiene; perchlorobutadiene
HEXAZINONE	Velpar weed killers
JODFENPHOS	C-9491; iodofenphos; Nuvanol N
KOMEEN	
LANDRIN	
LEAD ARSENATE	Gypsine; Soprabel; Talbot
LEPTOPHOS	MBCP; Phosvel
LETHANE 384	
LIME SULFUR	Security Lime Sulphur
LINDANE	Gamma BHC; Exagama; Forlin; Gallogama; Gamaphex; Gamma-col; Gammalin; Gammex; Gammexane; gamma HCH; Inexit; Isotox; Lindafor; Lindagam; Lindagrain; Lindagranox; Lindalo; Lindamul; Lindapoudre; Lindaterra; Lintox; Novigam; Silvanol

Table A4. *Continued.*

Common name	Alternate name
LINURON	Afalon; Hoe 2810; Linex 4L; Linorox; Linurex; Lorox; Sarclex
MALATHION	Calmathion; carbofos; Celthion; Cythion; Detmol MA 96%; Emmatos; Emmatos Extra; For-Mal; Fyfanon; Hilthion; Karbofos; Kop-Thion; Kypfos; Malamar; Malaphele; Malaspray; Malathion ULV Concentrate; Malatol; maldison; Malmed; Maltox; Mercaptothion; mercaptotion; MLT; Sumitox; Vegfru Malatox; Zithiol
MBC	
MCPB	Can-Trol; 2,4-MCPB; 2M-4K*h*-M; PDQ; Thistrol; Tropotox
MERPHOS	Deleaf Defoliant; Easy Off-D; Folex
METAM-SODIUM	A7 Vapam; carbam; Karbation; Maposol; Metam-Fluid BASF; SMDC; Solasan 500; Sometam; Trimaton; Vapam; VPM
METHANOL	Alcohol
METHIDATHION	GS-13005; Somonil; Supracide; Ultracide
METHIOCARB	Bay 37344; Draza; H 321; mercaptodimethur; Mesurol; metmercapturon
METHOMYL	Lannate; Nu-Bait II; Nudrin; SD14999
METHOPRENE	ZR-515
METHOPROTRYNE	G 36393; Gesaran; Metoprotryn
METHOXYCHLOR	Chemform; Flo Pro Mc Seed Protectant; Marlate
METHYL DEMETON	Bay 15203; demeton methyl
METHYL PARATHION	Cekumethion; Devithion; Dimethyl Parathion; Drexel Methyl Parathion 4E; E601; Folidol M; Fosferno M50; Gearphos; Metacide; metafos; Metaphos; Nitrox 80; Parataf; Parathion-methyl; Paratox; Partron M; Penncap-M; Tekwaisa; Vertac Methyl Parathion technisch 80%; Wofatox
METHYL TRITHION	
METOLACHLOR	Bicep; CGA-24705; Codal; Cotoran Multi; Dual; Milocep; Ontrack 8E; Primagram; Primextra
METRIBUZIN	Bay 94337; Bay DIC 1468; Lexone; Sencor; Sencoral; Sencorex
MEVINPHOS	Apavinphos; Duraphos; Gesfid, Menite; OS-2046; Phosdrin; Phosfene
MEXACARBATE	Zectran
MIREX	Dechlorane; GC-1283
MITIN FF	
MNFA	FAM; Nissol
MOLINATE	Hydram; Ordram
MONOCROTOPHOS	Apadrin; Azodrin; Bilobran; C 1414; Crisodrin; Hazodrin; Monocil 40; Monocron; Nuvacron; Pillardrin; Plantdrin; SD 9129; Susvin
MONOETHANOLAMINE	Colamine; ethanolamine; ethylolamine; glycinol; MEA; olamine; Thiofaco M-50; USAF EK-1597
MSMA	Ansar 170 H.C.; Ansar 529 H.C.; Arsonate Liquid; Bueno 6; Daconate 6; Dal-E-Rad; Herb-All; Merge 823; Mesamate; Monate; Target MSMA; Trans-Vert; Weed-E-Rad; Weed-Hoe
NALED	Bromchlophos; Bromex; Dibrom; RE 4355
N-BUTANOL	1-butanol; butan-1-ol; butyl hydroxide; butyric or normal primary butyl alcohol; CCS 203; 1-hydroxybutane; methylolpropane; n-butyl alcohol; propylcarbinol; propylmethanol
NEODOL 25-9	
NEODOL 25-12	
NITRALIN	Planavin
NITRAPYRIN	Dowco 163; N-Serve
NITROFEN	nitrofene; nitrophen; Nip; Tok; Tok E-25; Tok WP-50; Trizilin
NOREA	Herban; Hercules 7531; noruron
ORTHO 11775	

Table A4. *Continued.*

Common name	Alternate name
S-BIOALLETHRIN	Esbiol; Esbiol Concentrate 90%
SD 7438	ENT 25,739; Shell SD 7,438
SD 8339	Accel
SD 16898	
SD 17250	
SILVEX ACID	Amchem 2,4,5-TP; Aqua-Vex; Double Strength; fenoprop; Fruitone T; Kuron; Kurosal; Silvex; Silvi-Rhap; Weed-B-Gon
SILVEX PROPYLENE GLYCOL BUTYL ETHER ESTER	Kuron
SIMAZINE	Aquazine; Cekusan; Farmco Simazine; Framed; G-27692; Gesatop; Primatol S; Princep; Simadex; Simanex; Sim-trol
SODIUM ARSENITE	
SODIUM SELENITE	disodium selenite
2,4,5-T BUTOXYETHANOL ESTER	Bladex H; Hormoslyr 500T; Trinoxol
TEMEPHOS	Abate; Abathion; Difenthos; Ecopro; Nimitox
TEPA	Aphoxide; APO
TEPP	Tetron; Vapotone
TERBUFOS	Counter 15G Soil Insecticide-Nematicide
TERBUTRYN	GS 14260; Igran; Prebane; Terbutrex
TERPENE POLYCHLORINATES	Strobane
2,3,4,6-TETRACHLOROPHENOL	Dowicide 6; tetrachlorophenol
TETRACHLORVINPHOS	Appex; CVMP; Debantic; Dust M; Gardcide; Gardona; Rabon; Rabond; ROL; SD 8447; Stirofos
TETRADIFON	Nia 5488; Tedion; Tedion V-18
TETRAMINE	TEM
TETRASUL	Animert V-101
TFM	Hoe 02770; Lamprecid; Lamprecide; TFN
THANITE	
TOLUENE	Methacide; methylbenzene; methylbenzol; NC1-CO7272; phenylmethane; Toluol
TOXAPHENE	Attac 4-2; Attac 4-4; Attac 6; Attac 6-3; Attac 8; camphechlor; Camphoclor; Camphofene Huileux; Motox; Phenacide; Phenatox; Polychlorocamphene; Strobane T-90; Toxakil; Toxon 63; Vertac Toxaphene 90
TRANID	UC 2047A
TREFMID	
TRIALLATE	Avadex BW; Far-Go
TRICHLORFON	Bovinox; Briten; Cekufon; Ciclosom; clorofos; Crinex; Danex; dipterex; Dylox; Equino-Aid; Leivasom; Neguvon; Proxol; Trichlorphon; Trinex; Tugon
2,3,6-TRICHLOROBENZOIC ACID	Benzac; HC-1281; 2,3,6-TBA; TCBA; Tribac; trichlorobenzoic acid
TRICHLORONATE	Agrisil; Agritox; Bay 37289; fenophosphon; Phytosol; S4400; trichloronat
TRICLOPYR	Garlon 3A; Garlon 4
TRICRESYL PHOSPHATE	Celluflex 179C; cresyl phosphate; Disflamoll TKP; Fyrquel 150; IMOL S 140; Kronitex; Lindol; NCI-C61041; tris (tolyloxy) phosphine oxide; tritolyl phosphate
TRIFLURALIN	Crisalina; Digermin; Elancolan; Farmco Trifluralin; Ipersan; Sinflouran; Trefanocide; Treflan; Trifluraline; Triflurex
TRI-N-BUTYL PHOSPHATE	Celluphos 4; TBP; tributyl phosphate

Table A4. *Continued.*

Common name	Alternate name
ORYZALIN	Dirimal; Ryzelan; Surflan
OVEX	chlorofenizon; Chlorfenson; Corotran; CPCBS; difenson; ephirsulphonate; Estonmite; Niagaratran; ovatran; Ovochlor; Ovotran; Sappiran
OXAMYL	DPX 1410; Vydate L insecticide/nematicide
OXYDEMETON-METHYL	Bay 21097; demeton-S-methyl sulfoxid; metasystemox; Metasystox-R; metilmercaptofosoksid
OXYTHIOQUINOX	Bay 36205; chinomethionat; chinomethionate; Morestan; quinomethionate; SS 2074
PARA-DICHLOROBENZENE	Paracide; PDB
PARAQUAT	Cekuquat; Crisquat; Dextrone; Dexuron; Esgram; Gramonol; Gramoxone; Gramuron; Herbaxon; Herboxone; Paracol; Pathclear; Pillarquat; Pillarxone; Sweep; Terraklene; Totacol; Toxer Total; Weedol
PARATHION	AC 3422; Alkron; Alleron; Aphamite; Bladan; Corothion; Drexel parathion 8E; E-605; ENT 15108; Ethyl Parathion; Etilon; Folidol E-605; Fosferno 50; Niran; Orthophos; Panthion; Paramar; Paraphos; Parathene; Parawet; Phoskil; Rhodiatox; Soprathion; Stathion; Thiophos
PEBULATE	PEBC; R-2061; Tillam
PENTACHLOROPHENATE SODIUM	Santobrite; sodium pentachlorophenate; Weedbeads
PENTACHLOROPHENOL	Dow Pentachlorophenol; DP-2 Antimicrobial; PCP; penchlorol; penta; Pentacon; Penwar; Priltox; Santobrite; Santophen; Sinituho; Weedone
PERMETHRIN	Ambush; BW-21-Z; Ectiban; FMC-33297; Indothrin; Kafil; Permasect; Perthrine; Pounce; PP 557
PHORATE	AC 3911; Phorate-10G; Rampart; Thimet; Timet; Vegfru Foratox
PHORAZETIM	Bay 38819; Gophacide
PHOSALONE	Azofene; RP 11974; Rubitox; Zolone
PHOSMET	Appa; Imidan; Kemolate; phosmet; PMP; Prolate R-1504
PHOSPHAMIDON	Apamidon; C 570; Dimecron; Dixon
PHOTO-DIELDRIN	NCI-C00599
PHOXIM	Baythion; Bay 77488; phoxime; Volaton
PICLORAM	Amdon; Grazon; Tordon
PIPERALIN	Pipron
PIPERONYL BUTOXIDE	Butacide; Piperonyl Butoxide technical; Prentox Piperonyl Butoxide technical
PROFENOFOS	CGA-15324; Curacron; Polycron; Selecron
PROPACHLOR	
PROPANIL	Bay 30130; Chem Rice; DPA; Farmco Propanil; FW-734; Herbox technical; Propanex; Prop-Job; Riselect; Stam F-34; Stam M-4; Stam Supernox; Stampede 3E; Strel; Supernox; Surcopur; Surpur; S 10165; Vertac
PROPHAM	Ban-Hoe; Beet-Kleen; Chem-Hoe; IFC; IPC; Premalox; Triherbide-IPC; Tuberite
PROPOXUR	Aprocarb; Bay 39007; Baygon; Blattenex; Propyon; Suncide; Tugon Fliegenkugel; Unden
PROPYL ISOME	N-Propyl isome
PROPYLENE GLYCOL	Methyl glycol; Methylethylene glycol; monopropylene glycol; PG 12; Sirlene; trimethyl glycol
PYRETHRUM	Pyrethrins
RESMETHRIN	Benzofuroline; Chrysron; Premgard; Pynosect; Pyretherm; Synthrin
RONNEL	Ectoral; Etrolene; fenchlorfos; fenchlorphos; Nankorl; Korlan; Trolene; Viozene
ROTENONE	Chem Fish; Derris; Nicouline; Prentox; Tubatoxin
ROWMATE	Sirmate; UC 22463
RYANIA	Bonide Ryatox; ground Ryania specisa (Vahl) stemwood (alkoloid ryanodine); Ryanexel; Ryania powder; Ryania speciosa; Ryanicide; Ryanodine

Table A4. *Continued.*

Common name	Alternate name
TRIPHENYL PHOSPHATE	Celluflex TPP; TPP
TRIPHENYLTIN HYDROXIDE	Du-Ter; Duter; fentin hydroxide; Haitin; Suzu H; TPTH; TPTOH; Tubotin
UC 10854	Hercules AC 5727
UREABOR	
VERNOLATE	Surpass; Vernam
WARFARIN	Co-Rax; Coumafene; Cov-R-Tox; Kypfarin; Liqua-Tox; Mouse Pak; Rat Pak; Ratox; RAX; Rodex; Rodex Blox; Rutoxin; Tox-Hid; Warfarin Q; Zoocoumarin
XYLENE	Xylol
ZINC SULFATE	NU-Z