4. TERRESTRIAL ENDPOINTS

The quotient method, as discussed in Sect. 3.1, consists of dividing the ambient concentrations of toxicants by the concentration at which some toxic effect is induced. It is used in this section to provide an indication of the likelihood of effects due to emissions of the individual RACs. The other risk analysis methods are not readily applicable to terrestrial organisms because of the small toxicological data base for most terrestrial taxa, the lack of standard tests and toxicological benchmarks in the data base, and the lack of agreed-upon standard responses for terrestrial biota.

4.1 VEGETATION

The phototoxicity data for the gaseous and volatile RACs are presented in Table B-1, the concentrations in ambient ground-level air are in Tables 2.3-1 and 2.3-2, and the quotients of the ratios of these values are in Tables 4.1-1 and 4.1-2. The ambient concentrations are the increment of the entire RAC to the background concentration at the point of maximum ground-level concentration (Sect. 2.3). It is assumed that the RAC is composed entirely of the representative chemical and that the background concentration is zero. Quotients were calculated from two classes of data: (1) the lowest toxic concentration found in the literature for any flowering plant species, as an indication of maximum toxic potential of the RAC, and (2) the range across studies of the lowest concentrations causing effects on growth or yield of the whole plant or some plant part. The latter set of responses is relatively consistent and closely related to crop and forest yield.

The worst atmospheric toxicants in the emissions of both technologies are hydrocarbon gases (RAC 6). This rank is biased, since the worst-case representative chemical (ethylene) is a plant hormone, whereas most members of this RAC are essentially inert (National Research Council 1976). However, since atmospheric ethylene has caused significant damage to crops near urban areas and near petrochemical plants (National Research Council 1976), the emission rate of this gas

Table 4.1-1. Toxicity quotients for terrestrial plants for the Lurgi/Fischer Tropsch process. Ambient concentrations in air (annual, median, ground-level) and soil (soil solution or whole dry soil basis) are divided by concentrations causing reductions in growth, yield, or other toxic responses.[a]

RAC	RAC name	Air concentration/ lowest toxic concentration	Range of air concentration/ growth-effects concentration	Soil concentration/ lowest toxic concentration	Range of soil concentration/ growth-effects concentration
1	Carbon monoxide	2.57 E-04	4.21 E-08	b	b
2	Sulfur oxides	1.31 E-01	2.18 E-02 - 6.54 E-02	b	b
3	Nitrogen oxides	1.76 E-02	9.23 E-04 - 1.76 E-02	b	b
4	Acid gases	3.00 E-05	3.00 E-05	b	b
5	Alkaline gases	1.74 E-06		b	b
6	Hydrocarbon gases	34	1.64 E-02 - 5.71 E-02		
7	Formaldehyde	c	c	c	c
8	Volatile organochlorines	c	c	c	c
9	Volatile carboxylic acids	c	c		
10	Volatile O & S heterocyclics	d	d	d	d
11	Volatile Nheterocyclics	c	c	c	c
12	Benzene	3.93 E-07			
13	Aliphatic/alicyclic hydrocarbons	4.77 E-12		3.91 E-04	
14	Mono- or diaromatic hydrocarbons	2.81 E-05		6.14 E-06	6.14 E-06
15	Polycyclic aromatic hydrocarbons			1.02 E-01[e]	3.16 E-02 - 1.02 E-01[e]
16	Aliphatic amines	c	c	c	c
17	Aromatic amines	c	c	c	c
18	Alkaline nitrogen heterocyclics	c	c	c	c
19	Neutral N, O, S heterocyclics			4.72 E-10	4.72 E-11 - 4.72 E-10
20	Carboxylic acids	c	c	c	c
21	Phenols			8.95 E-07	
22	Aldehydes and ketones	3.64 E-03		3.11 E-05	3.11 E-05
23	Nonheterocyclic organosulfur	3.03 E-07	1.67 E-06	2.33 E-09[e]	
24	Alcohols			9.01 E-08	
25	Nitroaromatics	c	c	c	c
26	Esters	c	c	c	c
27	Amides	c	c	c	c
28	Nitriles	c	c	c	c
29	Tars	c	c	c	c
30	Respirable particles			b	b
31	Arsenic			1.23[e]	5.78 E-02[e] - 1.23[e]
32	Mercury	1.91 E-06		3.04 E-07	2.79 E-09 - 3.04 E-07
33	Nickel			9.84 E-02[e]	1.17 E-04 - 9.84 E-02[e]
34	Cadmium			7.6 E-03	1.69 E-04 - 7.6 E-03
35	Lead			2.58 E-02[e]	2.31 E-04 - 2.58 E-02[e]
36	Other trace elements			b	b
37	Radioactive materials			b	b

[a]Air, soil, and soil solution concentrations are presented in Table 2.3-1. Toxic concentrations are presented in Appendix B.

[b]No accumulation in soil.

[c]No emissions.

[d]No phytotoxicity data.

[e]Quotients calculated from concentrations in soil and results of tests performed in soil. Quotients without superscript e were calculated from concentrations in soil solution and results of tests performed in nutrient solution.

Table 4.1-2. Toxicity quotients for terrestrial plants for the Koppers-Totzek/Fischer-Tropsch process. Ambient concentrations in air (annual, median, ground-level) and soil (soil solution or whole dry soil basis) are divided by concentrations causing reductions in growth, yield, or other toxic responses.[a]

RAC	HAC name	Air concentration/ lowest toxic concentration	Range of air concentration/ growth-effects concentration	Soil concentration/ lowest toxic concentration	Range of soil concentration/ growth-effects concentration
1	Carbon monoxide	1.24 E-02	2.04 E-06	b	b
2	Sulfur oxides	1.06 E-01	1.76 E-02 - 5.28 E-02	b	b
3	Nitrogen oxides	2.82 E-02	1.48 E-03 - 2.82 E-02	b	b
4	Acid gases	4.82 E-04	4.82 E-04	b	b
5	Alkaline gases	1.76 E-08		b	b
6	Hydrocarbon gases	43.5	2.09 E-02 - 7.30 E-02		
7	Formaldehyde	c	c	c	c
8	Volatile organochlorines	c	c	c	c
9	Volatile carboxylic acids	c	c	c	c
10	Volatile O & S heterocyclics	c	c	c	c
11	Volatile Nheterocyclics	c	c	c	c
12	Benzene	1.90 E-09			
13	Aliphatic/alicyclic hydrocarbons	5.85 E-12		4.80 E-04	
14	Mono- or diaromatic hydrocarbons	3.47 E-05		7.57 E-06	7.57 E-06
15	Polycyclic aromatic hydrocarbons			4.78 E-02	4.78 E-02 - 7.75 E-02[b]
16	Aliphatic amines	c	c	c	c
17	Aromatic amines	c	c	c	c
18	Alkaline N heterocyclics	c	c	c	c
19	Neutral N, O, S heterocyclics	c	c	c	c
20	Carboxylic acids	c	c	c	c
21	Phenols	c	c	c	c
22	Aldehydes and ketones	3.94 E-03		4.39 E-05	4.39 E-05
23	Nonheterocyclic organosulfur	2.47 E-04	8.10 E-04	1.13 E-06[d]	
24	Alcohols			3.45 E-06	
25	Nitroaromatics	c	c	c	c
26	Esters	c	c	c	c
27	Amides	c	c	c	c
28	Nitriles	c	c	c	c
29	Tars	c	c		
30	Respirable particles			b	b
31	Arsenic			0.12[d]	5.63 E-03[d] - 0.12[d]
32	Mercury	4.28 E-04		6.83 E-05	6.27 E-07 - 6.83 E-05
33	Nickel			6.0 E-02[d]	7.12 E-05 - 6.0 E-02[d]
34	Cadmium			1.36 E-02	3.01 E-04 - 1.36 E-02
35	Lead			1.95 E-03[d]	1.74 E-05 - 1.95 E-03[d]
36	Other trace elements			b	b
37	Radioactive materials			b	b

[a]Air, soil, solution concentrations are presented in Table 2.3-2. Toxic concentrations are presented in Appendix B.

[b]No accumulation in soil.

[c]No emissions.

[d]Quotients calculated from concentrations in soil and results of tests performed in soil. Quotients without superscript d were calculated from concentrations in soil solution and results of tests performed in nutrient solution.

should be specifically considered in the future. The most serious phytoxicants in air (ignoring ethylene) are SO_x and NO_x. The maximum annual average concentrations predicted for SO_2 (RAC 2) from Lurgi and Koppers-Totzek are within a tenth of those that cause visible injury to needles of sensitive white pines, and both SO_2 and NO_x (RAC 3) concentrations are greater than a hundredth of those that reduce growth or yield of several plant species.

Because of its ubiquity and importance as a phytotoxicant, SO_2 (RAC 2) has been well studied for its effects on crop yield. McLaughlin and Taylor (in press) proposed the following dose-response relationship for yield reduction in beans as a function of SO_2 exposure:

% yield reduction = -17.4 + 29.2 (log dose in ppmh).

This empirical relationship is based on a regression of 20 points from five field experiments on soybeans and snap beans. Eighty percent of the variation in yield reduction was associated with variation in dosage, and the equation was significant at $\alpha = 0.0001$.

Because SO_2 appears to be the most serious phytotoxic air pollutant, we use this relationship to examine the potential effects of full-growing-season exposure to SO_2 from Koppers-Totzek on crop yield. If we assume a 200-d growing season for soybeans on the eastern site and a 12-h exposure day, the SO_2 dose at 6.87 $\mu g/m^3$ SO_2 is 6.25 ppmh. That dose results in a 5.8% reduction in yield by McLaughlin and Taylor's formula.

This predicted effect is remarkable in that it results from an SO_2 concentration that is more than 10 times lower than the lowest concentration reported to affect yield. This anomaly is due to the great length of a growing season relative to the length of experiments. The longest fumigation available to McLaughlin and Taylor was 337 h. Thus, use of their formula for a full growing season requires an extrapolation of almost a factor of 10 in the duration component of the dose. Because the experimental field fumigations are typically carried out in the most sensitive stage (assumed to be the pod-fill in the case of beans), use of the formula for the full growing season probably overestimates effects.

We might place a lower bound on the level of effect by assuming that effects occur only during pod-fill. If that stage is assumed to last 30 d, the dose is 0.99 ppmh. This is less than a quarter of the threshold dose for effects on yield (3.92 ppmh).

For an actual synfuels plant, this SO_2 emission would be added to a background SO_2 concentration that may reach 80 $\mu g/m^3$ under the current annual average ambient air quality standard and would interact with ozone, which reaches phytotoxic levels in many areas of the United States. This analytical exercise demonstrates the need for the full-season field experiments on effects of SO_2 and $SO_2 + O_3$ originally planned for the USEPA's National Crop Loss Assessment Network.

The phytotoxicity of materials deposited on the landscape is a more complex phenomenon than that of gases and vapors. Because the atmospheric transport model AIRDOS-EPA has a deposition velocity of zero for inorganic gases and does not model the formation of aerosols, it is assumed that RACs 1 through 5 do not accumulate in the soil. This assumption is likely to be acceptable except in the case of SO_4 deposition in forests with acid soils. The effects of SO_4 deposition in forests result from regional-scale emissions and atmospheric processes and are therefore beyond the scope of this report. Deposited nongaseous RACs were assumed to accumulate in the soil over the 35-year life of the liquefaction plant. Losses due to decomposition and leaching from the root zone were calculated by the terrestrial food chain model (Sect. 2.3). The toxicity data (Table B-3) were primarily derived from exposure of plants or plant parts to solutions of the chemicals rather than to contaminated soil because few data are available on toxicity in soil. Whereas the results of tests done in soil can be directly compared with concentrations in whole soil, results of tests done in solution must be compared with a calculated concentration in soil solution. Because the concentration in soil solution is more difficult to model than concentration in whole soil and requires more simplifying assumptions, solution concentrations are less reliable. In addition, as with the gases and vapors, the toxicity

data are from a wide variety of tests and measured responses that are not equivalent. Finally, for most of the RACs, only one or two chemicals have been tested. We cannot determine if the chemicals used are representative of the entire RAC.

The most phytotoxic RACs deposited in soil are polycyclic aromatic hydrocarbons (PAHs) (15), arsenic (31), cadmium (34), nickel (33), and lead (35). The high rank of RAC 15 is suspect because benzo(a)pyrene and some other PAHs appear to act as plant hormones and can stimulate growth at very low concentrations. Thus, while PAHs can modify plant growth at concentrations as low as 0.5 ng/g soil, there is no evidence that they reduce plant growth, even at relativity high experimental concentrations (Edwards, 1983). Therefore, heavy metals appear to be the most serious soil pollutants, and methods for predicting their effects require attention.

4.2 WILDLIFE

Tables 4.2-1 and 4.2-2 present the lowest toxicity quotients for terrestrial animals for the two technologies. The quotients are calculated from the lowest lethal concentration for any species and from the lowest concentration producing any toxic effect (Table B-3) divided by the highest annual average ground-level concentration in air. Data from all species were pooled because there were not enough data on the nonmammalian taxa for separate treatment. Carcinogenesis and other genotoxic effects were not included.

Lethality is considered because it is a consistent and frequently determined response that has clear population implications, but all predicted concentrations are well below lethal levels. The lowest toxic concentrations include a diversity of endpoints, most of which cannot be readily related to effects on wildlife populations but which occur at concentrations that are as low as a ten-thousandth of lethal concentrations. These responses range from increased airway resistance in 1-h exposures of guinea pigs to impaired lung and liver function in human occupational exposures. The most toxic RACs by this sublethal criterion are the conventional combustion products sulfur oxides

Table 4.2-1. Toxicity quotients for terrestrial animals for the Lurgi/Fischer-Tropsch process. Concentrations in air (annual, median, ground-level) are divided by lethal concentrations and the lowest toxic concentrations.[a]

RAC	Name	Lowest lethal concentration	Lowest toxic concentration
1	Carbon monoxide	5.03 E-10	1.08 E-05
2	Sulfur oxides	4.72 E-04	8.5 E-02
3	Nitrogen oxides	1.60 E-04	3.93 E-03
4	Acid gases	4.00 E-08	1.20 E-07
5	Alkaline gases	5.21 E-06	2.81 E-07
6	Hydrocarbon gases		1.06 E-07
7	Formaldehyde	b	b
8	Volatile organochlorines	b	b
9	Volatile carboxylic acids	b	b
10	Volatile O & S heterocyclics	2.62 E-11	2.62 E-11
11	Volatile Nheterocyclics	b	b
12	Benzene	6.21 E-08	6.21 E-08
13	Aliphatic/alicyclic hydrocarbons	5.80 E-08	3.81 E-06
14	Mono- or diaromatic hydrocarbons	3.53 E-06	6.70 E-05
15	Polycyclic aromatic hydrocarbons		
16	Aliphatic amines	b	b
17	Aromatic amines	b	b
18	Alkaline N heterocyclics	b	b
19	Neutral N, O, S heterocyclics		
20	Carboxylic acids	b	b
21	Phenols		
22	Aldehydes and ketones	5.06 E-05	1.78 E-03
23	Nonheterocyclic organosulfur	5.45 E-09	8.18 E-08
24	Alcohols	3.04 E-06	5.27 E-05
25	Nitroaromatics	b	b
26	Esters	b	b
27	Amides	b	b
28	Nitriles	b	b
29	Tars	b	b
30	Respirable particles		6.28 E-02
31	Arsenic		3.06 E-05
32	Mercury		1.12 E-07
33	Nickel	4.42 E-09	4.42 E-09
34	Cadmium	2.78 E-09	1.39 E-06
35	Lead		2.56 E-05

[a]Ambient air concentrations are presented in Table 2.3-1. Toxic concentrations are presented in Appendix B.

[b]No emissions.

Table 4.2-2. Toxicity quotients for terrestrial animals for the Koppers-Totzek/Fischer-Tropsch process. Concentrations in air (annual, median, ground-level) are divided by lethal concentrations and the lowest toxic concentrations.[a]

RAC	Name	Lowest lethal concentration	Lowest toxic concentration
1	Carbon monoxide	2.43 E-08	5.21 E-04
2	Sulfur oxides	3.82 E-04	6.87 E-02
3	Nitrogen oxides	2.57 E-04	6.30 E-03
4	Acid gases	6.43 E-07	2.93 E-06
5	Alkaline gases	5.29 E-11	2.85 E-09
6	Hydrocarbon gases		1.35 E-07
7	Formaldehyde	b	b
8	Volatile organochlorines	b	b
9	Volatile carboxylic acids	b	b
10	Volatile O & S heterocyclics	b	b
11	Volatile Nheterocyclics	b	b
12	Benzene	3.01 E-10	3.01 E-10
13	Aliphatic/alicyclic hydrocarbons	7.12 E-08	4.68 E-06
14	Mono- or diaromatic hydrocarbons	4.35 E-06	8.25 E-05
15	Polycyclic aromatic hydrocarbons		
16	Aliphatic amines	b	b
17	Aromatic amines	b	b
18	Alkaline N heterocyclics	b	b
19	Neutral N, O, S heterocyclics	b	b
20	Carboxylic acids	b	b
21	Phenols	b	b
22	Aldehydes and ketones	5.48 E-05	1.93 E-03
23	Nonheterocyclic organosulfur	2.65 E-06	3.97 E-05
24	Alcohols	7.92 E-06	1.37 E-04
25	Nitroaromatics	b	b
26	Esters	b	b
27	Amides	b	b
28	Nitriles	b	b
29	Tars	b	b
30	Respirable particles		2.76 E-01
31	Arsenic		6.08 E-06
32	Mercury		2.52 E-05
33	Nickel	7.92 E-09	7.92 E-05
34	Cadmium	1.14 E-08	5.68 E-06
35	Lead		3.66 E-06

[a]Ambient air concentrations are presented in Table 2.3-2. Toxic concentrations are presented in Appendix B.

[b]No emissions.

(2) and respirable particulates (30). Although these concentrations may constitute a locally significant increment to the background concentration of these major pollutants, the significance of ambient air pollution to wildlife is largely unknown. The assumption that protection of human health will automatically protect wildlife is not scientifically defensible.

5. EVALUATION OF RISKS

5.1 EVALUATION OF RISKS TO FISH

Table 5.1-1 lists, for each technology, the RACs determined to be potentially ecologically significant by one or more of the three methods employed in this report. The significance criterion for the quotient method is an acute-effects quotient greater than 0.01, i.e., the lowest observed LC_{50} or TL_{M96} less than a hundred times the estimated environmental concentration. For analysis of extrapolation error, RACs are considered to be significant if the risk that the environmental concentration may exceed the PGMATC of one or more of the reference fish species is greater than 0.1. For ecosystem uncertainty analysis, RACs are considered to be significant if the risk of a 25% reduction in game fish biomass is greater than 0.1.

A total of nine RACs were determined to be significant for one or more technologies. RAC 5 (ammonia) and RAC 34 (cadmium) were the only RACs found to be significant for both technologies and all risk analysis methods. RAC 4 (acid gases) was significant for both technologies according to the quotient method and analysis of extrapolation error; however, this RAC could not be addressed using ecosystem uncertainty analysis. In general, analysis of extrapolation error rated the organic RACs substantially more hazardous, relative to the inorganic RACs, than did the other two methods. The reasons for these differences in sensitivity among methods are not clear at this time.

The exposure analyses, the significance criteria, and the methods themselves are conservative; therefore, it would be premature to conclude that adverse consequences would result from the contaminant releases assessed in this report. These nine RACs should, however, be used in future refinements of the risk analyses and in future toxicological and ecological research. In addition to the RACs listed in Table 5.1-1, there are three RACs for which nonzero exposures were estimated but no applicable toxicity data were available: RACs 10 (volatile O & S heterocyclics), 19 (neutral N, O, and S heterocyclics, and 24 (alcohols).

Table 5.1-1. RACs determined to pose potentially significant risks to fish populations by one or more of three risk analysis methods: quotient method (QM), analysis of extrapolation error (AEE), and ecosystem uncertainty analysis (EUA)

Lurgi/Fischer-Tropsch process	Koppers-Totzek/Fischer-Tropsch process
4 (acid gases) - QM, AEE	4 (acid gases) - QM, AEE
5 (alkaline gases) - QM, AEE, EUA	5 (alkaline gases) - QM, AEE, EUA
9 (volatile carboxylic acids) - AEE	9 (volatile carboxylic acids) - QM, AEE
20 (carboxylic acids, excluding volatiles) - AEE	34 (cadmium) - QM, AEE, EUA
31 (arsenic) - AEE	
32 (mercury) - AEE, EUA	
33 (nickel) - EUA	
34 (cadmium) - QM, AEE, EUA	

There are two ways to compare the two technologies for ecological risk. It was shown, using the toxic units approach (Sect. 3.2-3), that the Lurgi/Fischer-Tropsch effluent has a somewhat greater potential for acute toxicity to fish. A similar conclusion can be reached by inspecting Table 5.1-1. The differences between the two processes appear to be less important than their similarities. For both, conventional pollutants, especially acid gases (RAC 4) and ammonia (RAC 5), appear to be substantially more hazardous than the complex organic contaminants usually associated with synfuels.

5.2 EVALUATION OF RISKS OF ALGAL BLOOMS

Algal toxicity data were available for only ten RACs. Moreover, because of the diversity of experimental designs and test endpoints used in algal bioassays, it is not meaningful to rank the RACs using the quotient method. Finally, as noted in Sect. 3.1, there is no clear distinction between acute effects and chronic effects in algal bioassays.

It does appear, however, that most of the quotients that can be calculated are lower for algae than for fish; only RACs 33 and 34 would be judged significant for any technology using the quotient method.

Ecosystem uncertainty analysis suggests greater risks of effects on algae than does the quotient method. Risks of 10% or more of a fourfold increase in algal biomass for one or more technologies were estimated for six of the nine RACs examined: 5, 31, 32, 33, 34, and 35. The effects pathway postulated in ecosystem uncertainty analysis is indirect rather than direct. All of the RACs are toxic to algae. The increases in algal biomass are caused by reductions in grazing intensity related to the effects of contaminants on zooplankton and fish.

5.3 EVALUATION OF RISKS TO VEGETATION AND WILDLIFE

The greatest threat to terrestrial biota from indirect coal liquefaction appears to be the gases SO_2 (RAC 2 - sulfur oxides) and NO_2 (RAC 3 - nitrogen oxides). The concentrations of SO_2 for both technologies are near phytotoxic levels. Interactions between these

gases and their combined effects with background ambient pollution deserve additional attention. The effects of acute exposures from "plume strikes" are also likely to be important and deserve attention. Air pollutants do not appear to be a threat to mammalian wildlife, but the sensitivity of nonmammalian species is largely unknown.

Of the materials deposited on the soil, the trace elements arsenic, cadmium, and nickel cause the greatest concern. However, they are unlikely to be a problem except when deposited on soils having preexisting high concentrations of trace elements and chemical properties that favor the solution phase.

5.4 VALIDATION NEEDS

There are no uniquely correct methods of quantifying ecological risks. There are several plausible ways to combine uncertainties concerning differential sensitivities of fish taxa and acute-chronic relationships. Similarly, there are many aquatic ecosystem models, and different models produce different estimates of uncertainty and risk. Validation studies of the methods used in these risk analyses would greatly increase the credibility of the results.

There are two ways in which these synfuels risk analyses can be validated. A specific validation would involve building a synfuels industry and monitoring the resulting environmental effects. A generic validation would involve checking the assumptions and models used in the risk analyses against the results of field and laboratory studies. Given the current state of the synfuels industry, a generic validation seems more practical.

Generic validation of the environmental risk analysis methods would begin with an examination of the capability of existing published evidence to support or refute the models or their component assumptions. To a certain extent, this has been done by us as a part of our methods development (e.g., Suter et al. 1983, Suter and Vaughan 1984), and by others for generally used models such as the Gaussian plume atmospheric dispersion model. However, there has been no systematic consideration of such major assumptions as the validity of

hydroponic phytotoxicity studies nor of the risk analysis methodology as a whole. The results of validation studies would indicate not only the level of confidence that can be placed in environmental risk analyses, but also the research needed for further development and validation of risk analysis methods.

6. ACKNOWLEDGMENTS

The authors thank R. E. Millemann and J. W. Webb for their thorough reviews of this report. We also thank S. G. Hildebrand and A. A. Moghissi for their support and encouragement in this project.

7. REFERENCES CITED IN TEXT AND APENDIXES

Adelman, I. R., and L. L. Smith, Jr. 1970. Effects of hydrogen sulfide on northern pike eggs and sac fry. Trans. Am. Fish. Soc. 99:501-509.

Agarwala, S. C., S. S. Bisht, and C. P. Sharma. 1977. Relative effectiveness of certain heavy metals in producing toxicity and symptoms of iron deficiency in barley. Can. J. Bot. 55:1299-1307.

Alabaster, J. S., J. H. N. Garland, I. C. Hart, and J. F. De L. G. Solbe. 1972. An approach to the problem of pollution and fisheries. Symp. Zool. Soc. Lond. 29:87-114.

Alabaster, J. S., and R. Lloyd. 1982. Water Quality Criteria for Freshwater Fish, 2nd ed., Butterworths, London.

Allen, W. R., W. L. Askew, and K. Schreiber. 1961. Effect of insecticide-fertilizer mixtures and seed treatments on emergence of sugar beet seedlings. J. Econ. Ent. 54:181-187.

Anderson, B. G. 1946. The toxicity thresholds of various sodium salts determined by the use of Daphnia magna. Sewage Works J. 18:82-87.

Angelovic, J. W., W. F. Sigler, and J. M. Newhold. 1961. Temperature and fluorosis in rainbow trout. J. Water Pollut. Control Fed. 33:371-381.

Ashendon, T. W., and T. A. Mansfield. 1978. Extreme pollution sensitivity of grasses when SO_2 and NO_2 are present in the atmosphere together. Nature 273:142-143.

Badilescu, T., S. Botis-Simon, and Z. Simon. 1967. Response of some seeds of different ploidies towards alkylating agents and some common phytotoxica. Rev. Roum. Biochim. 4:279-285.

Barnthouse, L. W., S. M. Bartell, D. L. DeAngelis, R. H. Gardner, R. V. O'Neill, C. D. Powers, G. W. Suter II, G. P. Thompson, and D. S. Vaughan. 1982. Preliminary environmental risk analysis for indirect coal liquefaction. Report to the Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.

Batterton, J., K. Winters, and C. Van Baalen. 1978. Anilines: Selective toxicity to blue-green algae. Science 199:1068-1070.

Baughman, G. L., and R. R. Lassiter. 1978. Prediction of environmental pollution concentration. pp. 35-54. IN J. Cairns, K. L. Dickson, and A. W. Maki, (eds.), Estimating the Hazard of Chemical Substances to Aquatic Life. ASTM STP 657. American Society for Testing and Materials, Philadelphia, Pennyslvania.

Bazzaz, F. A., G. L. Rolfe, and P. W. Windle. 1974. Differing sensitivity of corn and soybean photosynthesis and transpiration to lead contamination. J. Environ. Qual. 3:156-157.

Biesinger, K. E., and G. M. Christensen. 1972. Effects of various metals on survival, growth, reproduction, and metabolism of Daphnia magna. J. Fish. Res. Board Can. 29:1691-1700.

Birge, W. J., and J. A. Black. 1981. Aquatic toxicity tests on organic contaminants originating from coal conversion. University of Kentucky Report to the Advanced Fossil Energy Program, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee. University of Kentucky, Lexington.

Brenniman, G., R. Hartung, and W. J. Weber, Jr. 1976. A continuous flow bioassay method to evaluate the effects of outboard motor exhausts and selected aromatic toxicants on fish. Water Res. 10:165-169.

Briggs, G. G. 1981. Theoretical and experimental relationships between soil adsorption, octanol-water partition coefficients, water solubilities, bioconcentration factors, and the parachor. J. Agric. Food Chem. 29:1050-1059.

Canton, J. H. and D. M. M. Adema. 1978. Reproducibility of short-term and reproduction toxicity experiments with Daphnia magna and comparison of the sensitivity of Daphnia magna with D. pulex and D. cucullata in short-term experiments. Hydrobiologia 59:135-140.

Cardwell, R. D., D. G. Foreman, J. R. Payne, and D. J. Wilker. 1976. Acute toxicity of selected toxicants to six species of fish. EPA-600/3-76-008. U.S. Environmental Protection Agency. Duluth, Minnesota.

Carlson, R. W., F. A. Bazzaz, and G. L. Rolfe. 1975. The effects of heavy metals on plants. Part II, Net photosynthesis and transpiration of whole corn and sunflower plants treated with Pb, Cd, Ni, and Tl. Environ. Res. 10:113-120.

Carlson, R. L., and F. A. Bazzaz. 1977. Growth reduction in American sycamore (Platanus occidentalis L.) caused by Pb-Cd interaction. Environ. Pollut. 12:243-253.

Cassidy, D. R., and A. Furr. 1978. Toxicity of inorganic and organic mercury compounds in animals. pp. 303-330. IN F. W. Oehme (ed.), Toxicity of Heavy Metals in the Environment. Marcel Dekker, Inc., New York.

Cheeseman, J. M., and T. O. Perry. 1977. Suspect identification through biological assay (The Wake County, N.C., pine kill). Plant Physiol. 59:123.

Chen, S.-C., and R. M. Olofson. 1978. Phytotoxicity of organic and inorganic iodines to Avena fatua. J. Agric. Food Chem. 26:287-289.

Chou, C.-H., and Z. A. Patrick. 1976. Identification and phytotoxic activity of compounds produced during decomposition of corn and rye residues in soil. Phytopathology 58:41-45.

Clubb, R. W., A. R. Gaufir, and J. L. Lords. 1975. Acute cadmium toxicity studies upon nine species of aquatic insects. Environ. Res. 9:332-341.

Cleland, J. G., and G. L. Kingsbury. 1977. Multimedia Environmental Goals for Environmental Assessment. Vol. II. EPA-600/7-77-136b. U.S. Environmental Protection Agency, Washington, D.C.

Cushman, R. M., S. G. Hildebrand, R. H. Strand, and R. M. Anderson. 1977. The toxicity of 35 trace elements in coal to freshwater biota: A data base with automated retrieval capabilities. ORNL/TM-5793. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 46 pp.

Davies, W., G. A. Atkins, and P. C. B. Hudson. 1937. The effect of ascorbic acid and certain indole derivatives on the regeneration and germination of plants. Ann. Bot. 1:329-351.

Davies, P. H., J. P. Goetth, J. R. Sinley, and N. F. Smith. 1976. Acute and chronic toxicity of lead to rainbow trout (Salmo gairdneri) in hard and soft water. Water Res. 10:199-206.

DeGraeve, D. M., R. G. Elder, D. C. Woods, and H. L. Bergman. 1982. Effects of naphthalene and benzene on fathead minnows and rainbow trout. Arch. Environ. Toxicol. 11:487-490.

Deubert, K. H., R. M. Devlin, R. M. Kisiel, and M. J. Koslusiak. 1979. The influence of benzo(a)pyrene on the growth of wheat and corn. Environ. Int. 1:91-93.

Deuel, L. E., and A. R. Swoboda. 1972. Arsenic toxicity to cotton and soybeans. J. Environ. Qual. 1:317-320.

Dilling, W. L. 1977. Interphase transfer processes II. Evaporation rates of chloromethanes, ethanes, ethylenes, propanes, and propylenes from dilute aqueous solution. Comparison with theoretical predictions. Environ. Sci. Technol. 11(4):405-409.

Dowden, B. F., and H. J. Bennett. 1965. Toxicity of selected chemicals to certain animals. J. Water Pollut. Control Fed. 37:1308-1316.

Dutta, T. R., J. Prasad, and R. P. Singh. 1972. Evaluation of herbicides for submerged weeds in Chambal and Bhakra-Nangal canal systems. Indian J. Agric. Sci. 42:70-75.

Edwards, N. T. 1983. Polycyclic aromatic hydrocarbons (PAH's) in the terrestrial environment: A review. J. Environ. Qual.12:427-441.

European Inland Fisheries Advisory Commission. 1970. Water quality criteria for European freshwater fish. Report on ammonia and inland fisheries. EIFAC Tech. Paper II: FAO (UN), 1970. 12 pp.

European Inland Fisheries Advisory Commission. 1980. Working party on water quality criteria report on combined effects on freshwater fish and other aquatic life of mixtures of toxicants in water. EIFAC Tech. Paper 37.

Gaur, A. C., and R. P. Pareek. 1976. A study on the effect of certain phenolic acids and fumaric acid in soil on the development of paddy seedlings and nitrogen-fixing bacteria. Zbl. Bakt. Abt. II. 131:148-156.

Gledhill, W. E., R. G. Kaley, W. J. Adams, O. Hicks, P. R. Michael, and V. W. Saeger. 1980. An environmental safety assessment of butyl benzyl phthalate. Environ. Sci. Technol. 14:301-305.

Gräf, W., and W. Nowak. 1966. Promotion of growth in lower and higher plants by carcinogenic polycyclic aromatics. Arch. Hyg. Bakt. 150:513-528.

Haghiri, F. 1973. Cadmium uptake by plants. J. Environ. Qual. 2:93-95.

Hale, J. G. 1977. Toxicity of metal mining wastes. Bull. Environ. Contam. Toxicol. 17:66-73.

Halstead, R. L., B. J. Finn, and A. J. MacLean. 1969. Extractability of nickel added to soils and its concentration in plants. Can. J. Soil Sci. 49:335-342.

Hammons, A. S., J. E. Huff, H. M. Braunstein, J. S. Drury, C. R. Shiner, E. B. Lewis, B. L. Whitfield, and L. E. Torvill. 1978. Reviews of the Environmental Effects of Pollutants: IV. Cadmium. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Heck, W. W., and D. T. Tingey. 1979. Nitrogen Dioxide: Time-Concentration Model to Predict Acute Foliar Injury. EPA 600/3/-79-057. U.S. Environmental Protection Agency, Corvallis, Oregon.

Heck, W. W., and E. G. Pires. 1962. Growth of Plants Fumigated with Saturated and Unsaturated Hydrocarbon Gases and Their Derivatives. MP-603. The Agricultural and Mechanical Experiment Station, College Station, Texas.

Herbert, D. W. M., and D. S. Shurben. 1963. A preliminary study of the effect of physical activity on the resistance of rainbow trout (Salmo gairdnerii Richardson) to two poisons. Ann. Appl. Biol. 52:321-326.

Hilton, H. W., and N. Nomura. 1964. Phytotoxicity of herbicides as measured by root absorption. Weed Res. 4:216-222.

Hohreiter, D. W. 1980. Toxicities of selected substances to freshwater biota. ANL/ES-94. Argonne National Laboratory, Argonne, Illinois.

Huange, C. Y., F. A. Bazzaz, and L. N. Vanderhoef. 1974. The inhibition of soybean metabolism by cadmium and lead. Plant Physiol. 54:122-124.

Ivens, G. W. 1952. The phytotoxicity of mineral oils and hydrocarbons. Ann. Biol. 39:418-422.

John, M. K., and C. J. VanLaerhoven. 1972. Lead uptake by lettuce and oats as affected by lime, nitrogen, and sources of lead. J. Environ. Qual. 1:169-171.

Johnson, W. W., and M. T. Finley. 1980. Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates. U.S. Fish and Wildlife Service Resource Publication 137. U.S. Department of the Interior, Washington, D.C. 98 pp.

Karickhoff, S. W., D. S. Brown, and T. A. Scott. 1979. Sorption of hydrophobic pollutants on natural sediments. Water Res. 13:241-248.

Kingsbury, G. L., R. S. Sims, and J. B. White. 1979. Multimedia Environmental Goals for Environmental Assessment. EPA-600/7-79-176,Vol. IV. U.S. Environmental Protection Agency, Washington, D.C.

Leo, A. C., C. Hansch, and D. Elkins. 1971. Partition coefficients and their uses. Chem. Rev. 71(6):525-616.

Lloyd, R. (in press). The toxicity of mixtures of chemicals to fish. IN Hazard Assessment of Complex Effluents, Proceedings of the 5th Pellston Workshop. Valley Randi, Wyoming.

Lloyd, R., and L. D. Orr. 1969. The diuretic response by rainbow trout to sublethal concentrations of ammonia. Water Res. 3:335-349.

Lynch, J. M. 1977. Phytotoxicity of acetic acid produced in the anaerobic decomposition of wheat straw. J. Appl. Bacteriol. 42:81-87.

Mattson, V. R., J. W. Arthur, and C. T. Walbridge. 1976. Acute Toxicity of Selected Organic Compounds to Fathead Minnows. EPA-600/3-76-097. Environmental Research Laboratory, U.S. Environmental Protection Agency, Duluth, Minnesota.

Mayer, F. L., and H. O. Sanders. 1973. Toxicology of phthalic acid esters in aquatic organisms. Environ. Health Perspect. 3:153-157.

McKee, J. E., and H. W. Wolf (eds.). 1963. Water Quality Criteria. 2nd ed. Publ. No. 3-A. California State Water Quality Control Board.

McKim, J. M., G. F. Olson, G. W. Holcombe, and E. P. Hunt. 1976. Long-term effects of methylmercuric chloride on three generations of brook trout (Salvelinus fontinalis): Toxicity, accumulation, distribution, and elimination. J. Fish. Res. Board Can. 33:2726-2739.

McLaughlin, S. B., Jr., and G. E. Taylor, Jr. (in press). Effects of SO_2 on dicot crops: Some issues, mechanisms and indicators. IN W. E. Winner, H. A. Mooney, and R. A. Goldstein (eds.), The Effects of SO_2 on Plant Productivity. Stanford University Press.

Meyer, H., and A. M. Mayer. 1971. Permeation of dry seeds with chemicals: Use of dichloromethane. Science 171:583-584.

Millemann, R. E., W. J. Birge, J. A. Black, R. M. Cushman, K. L. Daniels, P. J. Franco, J. M. Giddings, J. F. McCarthy, and A. J. Stewart. 1984. Comparative acute toxicity of components of coal-derived synthetic products to aquatic organisms. Trans. Am. Fish. Soc. 113:74-85.

Moore, R. E., C. F. Baes, III, L. M. McDowell-Boyer, A. P. Watson, F. O. Hoffman, J. C. Pleasant, and C. W. Miller. 1979. AIRDOS-EPA: A computerized methodology for estimating environmental concentrations and dose to man from airborne releases of radionuclides. ORNL-5532. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Mount, D. I., and C. E. Stephan. 1969. Chronic toxicity of copper to the fathead minnow (Pimephales promelas) in soft water. J. Fish. Res. Board Can. 26:2449.

Mukhiya, Y. K., KU. C. Gupta, N. Shrotriya, J. K. Joshi, and V. P. Singh. 1983. Comparative responses of the action of different mercury compounds on barley. Int. J. Environ. Stud. 20:323-327.

Muska, C. F., and L. J. Weber. 1977. An approach for studying the effects of mixtures of environmental toxicants on whole organism performances. pp. 71-87. IN R. A. Tubb (ed.), Recent Advances in Fish Toxicology. Corvallis Environmental Research Laboratory, U.S. Environmental Protection Agency, Corvallis, Oregon.

Nag, P., A. K. Paul, and S. Mukherji. 1980. Effects of mercury, copper, and zinc on the growth, cell division, GA-induced α-amylase synthesis and membrane permeability of plant tissues. Indian J. Exp. Biol. 18:822-827.

Naik, M. N., R. B. Jackson, J. Stokes, and R. J. Swaby. 1972. Microbial degradation and phytotoxicity of Picloram and other substituted pyridines. Soil Biol. Biochem. 4:313-323.

National Air Pollution Control Administration. 1970. Air Quality Criteria for Hydrocarbons. AP-64. U.S. Government Printing Office, Washington, D.C.

National Research Council. 1972. Lead. National Academy of Sciences, Washington, D.C.

National Research Council. 1975. Nickel. National Academy of Sciences, Washington, D.C.

National Research Council. 1976. Vapor-phase Organic Pollutants. National Academy of Sciences, Washington, D.C.

National Research Council. 1977a. Carbon Monoxide. National Academy of Sciences, Washington, D.C.

National Research Council. 1977b. Nitrogen Oxides. National Academy of Sciences, Washington, D.C.

National Research Council. 1977c. Arsenic. National Academy of Sciences, Washington, D.C.

National Research Council. 1979a. Hydrogen Sulfide. University Park Press, Baltimore, Maryland.

National Research Council. 1979b. Ammonia. University Park Press, Baltimore, Maryland.

National Research Council. 1979c. Airborne Particles. University Park Press, Baltimore, Maryland.

National Research Council. 1981. Formaldehyde and Other Aldehydes. National Academy Press, Washington, D.C.

O'Neill, R. V., and J. M. Giddings. 1979. Population interactions and ecosystem function. pp. 103-123. IN G. S. Innis and R. V. O'Neill (eds.), Systems Analysis of Ecosystems. International Cooperative Publishing House, Fairland, Maryland.

O'Neill, R. V., R. H. Gardner, L. W. Barnthouse, G. W. Suter, S. G. Hildebrand, and C. W. Gehrs. 1982. Ecosystem risk analysis: A new methodology. Environ. Toxicol. Chem. 1:167-177.

Oseid, D. M., and L. L. Smith, Jr. 1974. Chronic toxicity of hydrogen sulfide to Gammarus pseudolimnaeus. Trans. Am. Fish. Soc. 103:819-822.

Page, A. L., F. T. Bingham, and C. Nelson. 1972. Cadmium absorption and growth of various plant species as influenced by solution cadmium concentration. J. Environ. Qual. 1:288-291.

Park, R. A., R. V. O'Neill, J. A. Bloomfield, H. H. Shugart, R. S. Booth, R. A. Goldstein, J. B. Mankin, J. F. Koonce, D. Scavia, M. S. Adams, L. S. Clesceri, E. M. Colon, E. H. Dettmann, J. Hoopes, D. D. Huff, S. Katz, J. F. Kitchell, R. C. Kohberger, E. J. LaRow, D. C. McNaught, J. Petersen, J. Titus, P. R. Weiler, J. W. Wilkinson, C. S. Zahorcak. 1974. A generalized model for simulating lake ecosystems. Simulation 23:33-50.

Parkhurst, B. R. 1981. Unpublished data on acute toxicity of coal organics to Daphnia magna. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Parkhurst, B. R., J. S. Meyer, G. M. DeGraeve, and H. L. Bergman. 1981. A reevaluation of the toxicity of coal conversion process waters. Bull. Environ. Contam. Toxicol. 26:9-15.

Pickering, Q. H., and C. Henderson. 1966a. Acute toxicity of some important petrochemicals to fish. J. Water Pollut. Control. Fed. 38(9):1419-1429.

Pickering, Q. H., and C. Henderson. 1966b. The acute toxicity of some heavy metals to different species of warm water fishes. Air Water Pollut. 10:453-463.

Pickering, Q. H. 1974. Chronic toxicity of nickel to the fathead minnow. J. Water Pollut. Control Fed. 37:1308-1316.

Pizey, J. S., and R. L. Wain. 1959. Pre-emergent herbicidal activity of some substituted amides and related compounds. J. Sci. Food Agric. 10:577-584.

Rehwoldt, R., L. Lasko, C. Shaw, and E. Wirhouski. 1973. The acute toxicity of some heavy metal ions toward benthic organisms. Bull. Environ. Contam. Toxicol. 10:291-294.

Rice, S. O., and R. M. Stokes. 1975. Acute toxicity of ammonia to several developmental stages of rainbow trout, Salmo gairdneri. Fish. Bull. U.S. Nat. Mar. Fish. Serv. 73:207-211.

Ruesink, R. G., and L. L. Smith, Jr. 1975. The relationship of the 96-hour LC_{50} to the lethal threshold concentration of hexavalent chromium, phenol, and sodium pentachlorophenate for fathead minnows (Pimephales promelas Rafinesque). Trans. Am. Fish. Soc. 3:567-570.

Sanders, H. O., and O. B. Cope. 1966. Toxicities of several pesticides to two species of cladocerans. Trans. Am. Fish. Soc. 95:165-169.

Sanders, H. O., and O. B. Cope. 1968. The relative toxicities of several pesticides to naiads of three species of stoneflies. Limnol. Oceanogr. 13:112-117.

Schell, W. R., and T. H. Sibley. 1982. Distribution coefficients for radionuclides in aquatic environments. U.S. Nuclear Regulatory Commission. U.S. Government Printing Office, Washington, D.C.

Schlesinger, A. H., and D. T. Mowry. 1951. Benzothiophenes and their 1-dioxides. J. Am. Chem. Soc. 73:2614-2616.

Schultz, T. W., M. Cajina-Quezada, and J. N. Dumont. 1980. Structure-toxicity relationships of selected nitrogenous heterocyclic compounds. Arch. Environ. Contam. Toxicol. 9:591-598.

Shukla, S. P. 1972. The effects of some chemicals on the germination of a weed, Psoralea corylifolia L. Weed Res. 12:293-300.

Scientific Group on Methods for the Evaluation of Chemicals. (in press). Joint report of the workshop on methods for assessing the effects of mixtures of chemicals. John Wiley & Sons, Ltd., Chichester, England.

Siegel, B. Z., and S. M. Siegel. 1979. Biological indicators of atmospheric mercury. pp. 131-159. IN J. O. Nriagu (ed.), The Biogeochemistry of Mercury in the Environment. Elsevier/North-Holland Biomedical Press, New York.

Smith, L. L., D. M. Oseid, G. L. Kimball, and S. M. Elkandelgy. 1976. Toxicity of hydrogen sulfide to various life history stages of bluegill (Lepomis macrochirus). Trans. Am. Fish. Soc. 105:442-449.

Southworth, G. R. 1979. Transport and transformation of anthracene in natural waters. pp. 359-380. IN L. L. Marking and R. A. Kimmerle (eds.), Aquatic Toxicology. ASTM STP 667. American Society for Testing and Materials, Philadelphia.

Sprague, J. B. and B. A. Ramsay. 1965. Lethal levels of mixed copper-zinc solutions for juvenile salmon. J. Fish. Res. Board Can. 22:213-234.

Stahl, Q. R. 1969. Air Pollution Aspects of Mercury and Its Compounds. Litton Systems, Inc., Bethesda, Maryland.

Suter, G. W., II, and D. S. Vaughan. 1984. IN K. E. Cowser and C. R. Richmond (eds.), Synthetic Fossil Fuel Technologies: Results of Health and Environmental Studies. Ann Arbor Science Publishers, Ann Arbor, Michigan.

Suter, G. W., II, D. S. Vaughan, and R. H. Gardner. 1983. Risk assessment by analysis of extrapolation error: A demonstration for effects of pollutants on fish. Environ. Toxicol. Chem. 2:369-378.

Taylor, G. E., Jr. (in press). The significance of the developing energy technologies of coal conversion to plant productivity. J. Am. Soc. Hort. Sci.

Travis, C. C., C. F. Baes III, L. W. Barnthouse, E. L. Etnier, G. A. Holton, B. D. Murphy, S. J. Niemczyk, G. P. Thompson, G. W. Suter II, and A. P. Watson. 1983. Exposure assessment methodology and reference environments for synfuel risk analysis. ORNL/TM-8672. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

TRW Energy Technology Division (TRW). 1983. Source term estimates for synthetic fuels technologies: IN direct coal liquefaction technologies. TRW Energy Technology Division, Redondo Beach, California.

Underhill, G. W., and J. A. Cox. 1940. Carbon disulphide and dichloroethyl ether as soil fumigants for the woolly aphid, Eroisoma lanigerum Hausm. Virginia Fruit 28:20-26.

U.S. Environmental Protection Agency. 1980a. Ambient Water Quality Criteria for Carbon Tetrachloride. EPA 440/5-80-026. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980b. Ambient Water Quality Criteria for Chloroform. EPA 440/5-80-033. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980c. Ambient Water Quality Criteria for Benzene. EPA 440/5-80-018. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980d. Ambient Water Quality Criteria for Toluene. EPA 440/5-80-075. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980e. Ambient Water Quality Criteria for Napthalene. EPA 440/5-80-059. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980f. Ambient Water Quality Criteria for Fluoranthene. EPA 440/5-80-049. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980g. Ambient Water Quality Criteria for Phenol. EPA 440/5-80-066. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980h. Ambient Water Quality Criteria for 2,4-Dimethylphenol. EPA 440/5-80-044. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980i. Ambient Water Quality Criteria for Acrolein. EPA 440/5-80-016. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980j. Ambient Water Quality Criteria for Phthalate Esters. EPA 440/5-80-067. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980k. Ambient Water Quality Criteria for Acrylonitrile. EPA 440/5-80-017. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980l. Ambient Water Quality Criteria for Arsenic. EPA 440/5-80-021. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980m. Ambient Water Quality Criteria for Mercury. EPA 440/5-80-058. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980n. Ambient Water Quality Criteria for Nickel. EPA 440/5-80-060. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980o. Ambient Water Quality Criteria for Cadmium. EPA 440/5-80-025. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1980p. Ambient Water Quality Criteria for Lead. EPA 440/5-80-057. Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C.

U.S. Environmental Protection Agency. 1982. Air Quality Criteria for Particulate Matter and Sulfur Oxides. EPA-600/8-82-029c. Environmental Criteria and Assessment Office, Research Triangle Park, North Carolina.

U.S. Geological Survey (USGS). 1977. Water Resources Data for Kentucky WY-1976. USGS Water Data Report KY 76-1. Water Resources Division, Louisville, Kentucky.

U.S. Geological Survey (USGS). 1979. Water Resources Data for Pennsylvania WY-1978. Vol. 3. Ohio River and St. Lawrence River Basins. USGS Water Data Report PA-78-3. Water Resources Division, Harrisburg, Pennsylvania.

Vergnano, O., and J. G. Hunter. 1953. Nickel and cobalt toxicities in oat plants. Ann. Bot. 17:317-328.

Verschueren, K. 1977. Handbook of Environmental Data on Organic Chemicals. Van Nostrand Reinhold Co., New York.

Wakabayashi, M., B. G. Bang, and F. B. Bang. 1977. Mucociliary transport in chickens infected with newcastle disease virus and exposed to sulfur dioxide. Arch. Environ. Health 32:101-108.

Waldron, L. J., and N. Terry. 1975. Effect of mercury vapor on sugar beets. J. Environ. Qual. 4:58-60.

Wallen, I. E., W. C. Greer, and R. Lasater. 1957. Toxicity to Gambusia affinis of certain pure chemicals in turbid waters. Sewage Ind. Wastes 29:695-711.

Warnick, S. L., and H. L. Bell. 1969. The acute toxicity of some heavy metals to different species of aquatic insects. J. Water Pollut. Control Fed. 41:280-284.

Weast, R. C. (ed.). 1980. Handbook of Chemistry and Physics. CRC Press, Cleveland, Ohio.

Woolson, E. A., J. H. Axley, and P. C. Kearny. 1971. Correlation between available soil arsenic, estimated by six methods, and response of corn (Zea mays L.). Soil Sci. Soc. Am. Proc. 35:101-105.

Zahn, R. 1975. Begasungsuerusche mit NO_2 in Kleingewächshäuserun. Staub Reinhalt. Luft. 35:194-196.

Zepp, R. G., and P. M. Cline. 1977. Rates of direct photolysis in aquatic environment. Environ. Sci. Technol. 11:359-366.

Zepp, R. G., and P. F. Schlotzhauer. 1979. Photoreactivity of selected aromatic hydrocarbons in water. IN P. W. Jones and P. Leber (eds.), Polynuclear Aromatic Hydrocarbons. Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan.