Los Alamos Environmental Restoration Records Processing Facility

ER Record I.D.# 59108

**LOS ALAMOS NATIONAL LABORATORY**
**ENVIRONMENTAL RESTORATION**
**Records Processing Facility**
**ER Records Index Form**

*ER ID NO.* 59108 *Date Received:* 9/3/98 *Processor:* YCA *Page Count:* 4

*Privileged: (Y/N)* N *Record Category:* P *Record Package No:* 0

*FileFolder:* N/A

*Correction: (Y/N)* N *Corrected No.* 0 *Corrected By Number:* 0

*Administrative Record: (Y/N)* Y

*Refilmed: (Y/N)* N *Old ER ID Number:* 0 *New ER ID Number:* 0

*Miscellaneous Comments:*

REFERENCE CITED

3035

*THIS FORM IS SUBJECT TO CHANGE. CONTACT THE RPF FOR LATEST VERSION. (JUNE 1997)* culations, including the better vertical resolution of the trajectory model, the absence of horizontal numerical diffusion in the trajectory model, and the effect of boundary and initial conditions on the grid model. The grid-based version of the photochemical airshed model tested here has the advantage of increased spatial coverage when compared to the trajectory model and, thus, can be used to efficiently examine the basinwide consequences of emissions changes. In paper 2 of this series, the effect of a variety of candidate emission control programs on Los Angeles nitrate air quality will be examined.

**Registry No.** PAN, 2278-22-0; $NH_4NO_3$, 6484-52-2; $O_3$, 10028-15-6; $NO_2$, 10102-44-0; $NH_3$, 7664-41-7; $HNO_3$, 7697-37-2.

*Literature Cited*

(1) Russell, A. G.; Cass, G. R. *Atmos. Environ.* 1986, *20*, 2011–2025.
(2) Russell, A. G.; Cass, G. R. *Atmos. Environ.* 1984, *18*, 1815–1827.
(3) Seinfeld, J. H. *Air Pollution: Physical and Chemical Fundamentals*; McGraw-Hill: New York, 1975.
(4) McRae, G. J.; Goodin, W. R.; Seinfeld, J. H. *Atmos. Environ.* 1982, *16*, 679–696.
(5) McRae, G. J.; Tilden, J. W.; Seinfeld, J. H. *Comput. Chem. Eng.* 1982, *6*, 15–25.
(6) Russell, A. G.; McRae, G. J.; Cass, G. R. *Atmos. Environ.* 1983, *17*, 949–964.
(7) McRae, G. J.; Seinfeld, J. H. *Atmos. Environ.* 1983, *17*, 501–522.
(8) Baulch, D. L.; et al. *J. Phys. Chem. Ref. Data* 1982, *11*, 327–496.
(9) Russell, A. G.; McRae, G. J.; Cass, G. R. *Atmos. Environ.* 1985, *19*, 893–903.
(10) McRae, G. J. Ph.D. Thesis, California Institute of Technology, Pasadena, CA, 1981.
(11) Stelson, A. W.; Seinfeld, J. H. *Atmos. Environ.* 1982, *16*, 983–992.
(12) Goodin, W. R.; McRae, G. J.; Seinfeld, J. H. *J. Appl. Meteorol.* 1979, *18*, 761–771.
(13) Ranzieri, A. "1982-SCAB Point and Area Source Emissions"; forwarded magnetic tape AR3288; California Air Resources Board: Sacramento, CA, 1983; personal communication.
(14) Ranzieri, A. "1982-SCAB Mobile Source Emissions"; forwarded magnetic tape AR3292; California Air Resources Board: Sacramento, CA, 1984; personal communication.
(15) Cass, G. R.; Gharib, S. "Ammonia Emissions In The South Coast Air Basin 1982."; open file report 84-2; Environmental Quality Laboratory, California Institute of Technology: Pasadena, CA, 1984.
(16) Blumenthal, D. L.; White, W. H.; Smith, T. B. *Atmos. Environ.* 1978, *12*, 893–907.
(17) Edinger, J. G. *Environ. Sci. Technol.* 1973, *7*, 247–252.
(18) Blumenthal, D. L., Sonoma Technology, personal communication, 1984.
(19) Grosjean, D.; Fung, K. *J. Air Pollut. Control Assoc.* 1984, *34*, 537–543.
(20) Killus, J. P. Presented at the XVth Informal Conference on Photochemistry, Stanford, CA, June 27–July 1, 1984.
(21) Horie, Y. *Ozone Episode Representativeness Study for the South Coast Air Basin*; Valley Research Corp.: Van Nuys, CA, 1987.
(22) Hildemann, L. M.; Russell, A. G.; Cass, G. R. *Atmos. Environ.* 1984, *18*, 1737–1750.
(23) Bencala, K. E.; Seinfeld, J. H. *Atmos. Environ.* 1979, *13*, 1181–1185.
(24) Fox, D. *Bull. Am. Meteorol. Soc.* 1981, *62*, 599–609.
(25) Rao, S. T.; Visalli, J. R. *J. Air Pollut. Control Assoc.* 1981, *31*, 851–860.

*Received for review December 8, 1986. Accepted July 9, 1987. This work was supported by the California Air Resources Board under Agreement A2-150-32 and by gifts to the Environmental Quality Laboratory.*

Received by ER-RPF
SEP 03 1998
MA

# Bioconcentration of Organics in Beef, Milk, and Vegetation

**Curtis C. Travis* and Angela D. Arms**

Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831-6109

■ Biotransfer factors for organic chemicals in beef and milk were found to be directly proportional to octanol–water partition coefficients, while bioconcentration factors for vegetation were inversely proportional to the square root of octanol–water partition coefficients.

*Introduction*

The food chain is the primary source of human exposure to a large class of environmental organics (*1*, *2*). Included in this class are such chemicals as DDT, PCBs, dioxin, and most pesticides. Assessing the magnitude of human exposure to these and other such organics depends largely on the ability to predict the extent of their bioaccumulation in the aquatic and terrestrial food chains (*2*). The octanol–water partition coefficient ($K_{ow}$) has proven a valuable tool for making such predictions. It is correlated with bioconcentration factors in fish (*3–5*) and beef (*5*). The purpose of this paper is to develop correlations between $K_{ow}$ and the bioconcentration of organics in beef, cow milk, and vegetation. Such correlations will be of value in more precisely quantifying human exposure to organics through the terrestrial food chain (*1*, *6*).

*Uptake of Organics in Beef, Milk, and Vegetation*

The traditional measure of a chemical's potential to accumulate in an organism is the bioconcentration factor (BCF), which is defined as a chemical's concentration in an organism or tissue divided by its concentration in water (for aquatic organisms) or in food (for terrestrial organisms). However, the concept of biotransfer factor (BTF) is more useful in risk assessment, since chemical exposure to cattle and cows may occur through both food and water pathways.

The biotransfer factors for beef ($B_b$) and milk ($B_m$) are defined as

$$B_b = \frac{\text{concentration in beef (mg/kg)}}{\text{daily intake of organic (mg/d)}}$$

$$B_m = \frac{\text{concentration in milk (mg/kg)}}{\text{daily intake of organic (mg/d)}}$$

where measured concentrations of organics in beef or milk fat are converted to a fresh meat or whole milk basis,

Not subject to U.S. Copyright. Published 1988 by the American Chemical Society

**Table I. Relationship between Biotransfer Factors in Beef ($B_b$) and Octanol-Water Partition Coefficients ($K_{ow}$)**

| chemical | log $K_{ow}$ | log $B_b$ | ref |
|---|---|---|---|
| aldrin | 5.52 | −1.07 | 5, 11 |
| Aroclor 1254 | 6.47 | −1.28 | 12 |
| benzoylprop-ethyl | 4.57 | −4.81 | 14 |
| chlordane | 6.00 | −2.13 | 5 |
| chlorpyrifos | 4.97 | −3.55 | 5 |
| clopidol | 2.90 | −4.76 | 5 |
| coumaphos | 4.13 | −5.20 | 15 |
| cyhexatin | 5.39 | −4.44 | 5 |
| 2,4-D | 2.81 | −5.32 | 16 |
| DDD | 6.02 | −1.90 | 17 |
| DDE | 5.83 | −1.31 | 17, 18 |
| DDT | 5.76 | −1.55 | 5, 11 |
| dicamba | 3.01 | −4.58 | 19 |
| 3,6-dichloropicolinic acid | 1.75 | −5.50 | 5 |
| dieldrin | 5.16 | −2.10 | 13 |
| endosulfan | 2.23 | −3.66 | 20 |
| endrin | 5.16 | −1.92 | 5, 21 |
| famphur | 2.28 | −4.11 | 15 |
| fenoprop | 3.86 | −4.55 | 5, 16 |
| fenthion | 3.16 | −4.50 | 15 |
| flamprop-isopropyl | 4.41 | −4.20 | 14 |
| heptachlor | 5.44 | −1.81 | 5, 21 |
| heptachlor epoxide | 5.40 | −1.10 | 21, 22 |
| hexachlorobenzene | 5.45 | −1.35 | 18, 23 |
| kerb | 3.18 | −4.69 | 24 |
| lindane | 3.66 | −1.78 | 5, 11 |
| malathion | 2.89 | −4.74 | 25 |
| mirex | 6.89 | −1.25 | 26 |
| oxadiazon | 4.09 | −3.23 | 27 |
| phosphamidon | 1.34 | −4.81 | 28 |
| ronnel | 4.88 | −3.16 | 5 |
| 2,4,5-T | 3.36 | −4.82 | 5 |
| TCDD | 6.15 | −1.26 | 5 |
| toxaphene | 5.50 | −2.79 | 11, 21, 29 |
| trichlopyr | 2.09 | −5.85 | 5 |
| 3,5,6-trichloropyridinol | 2.27 | −4.37 | 5 |

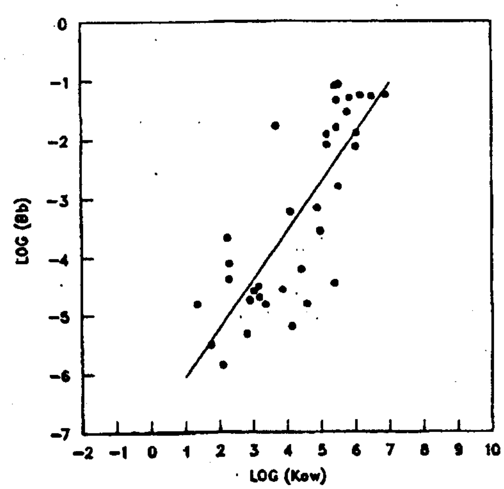


**Figure 1.** Relationship between biotransfer factors in beef ($B_b$) and octanol–water partition coefficients ($K_{ow}$).

**Table II. Relationship between Biotransfer Factors in Milk ($B_m$) and Octanol-Water Partition Coefficients ($K_{ow}$)**

| chemical | log $K_{ow}$ | log $B_m$ | ref |
|---|---|---|---|
| aldrin | 5.52 | −1.62 | 30 |
| Aroclor 1254 | 6.47 | −1.95 | 12 |
| benzoylprop-ethyl | 4.57 | −4.72 | 14 |
| chlordane | 6.00 | −3.43 | 31 |
| chloropropylate | 4.49 | −3.65 | 32 |
| chlorpyrifos | 4.97 | −4.73 | 33 |
| 2,4-D | 2.81 | −5.12 | 34 |
| DDD | 6.02 | −2.52 | 17 |
| DDE | 5.83 | −2.02 | 17, 18 |
| DDT | 5.76 | −2.62 | 17, 30, 35 |
| dicamba | 3.01 | −4.60 | 19 |
| dieldrin | 5.16 | −1.97 | 30, 36 |
| endrin | 5.16 | −2.76 | 37 |
| fenthion | 3.16 | −5.60 | 38 |
| fenvalerate | 6.20 | −3.09 | 39 |
| flamprop-isopropyl | 4.41 | −4.42 | 14 |
| heptachlor | 5.44 | −2.49 | 30 |
| heptachlor epoxide | 5.40 | −1.45 | 40 |
| hexachlorobenzene | 5.45 | −2.07 | 18, 23 |
| lindane | 3.66 | −2.60 | 30 |
| methoxychlor | 4.40 | −3.83 | 30 |
| mirex | 6.89 | −2.02 | 41 |
| naphthalene | 3.59 | −3.70 | 42 |
| naphthol | 2.84 | −3.92 | 42 |
| oxadiazon | 4.09 | −3.72 | 27 |
| 2,4,5-T | 3.36 | −4.55 | 34 |
| TCDD | 6.15 | −1.99 | 43 |
| toxaphene | 5.50 | −3.20 | 30 |

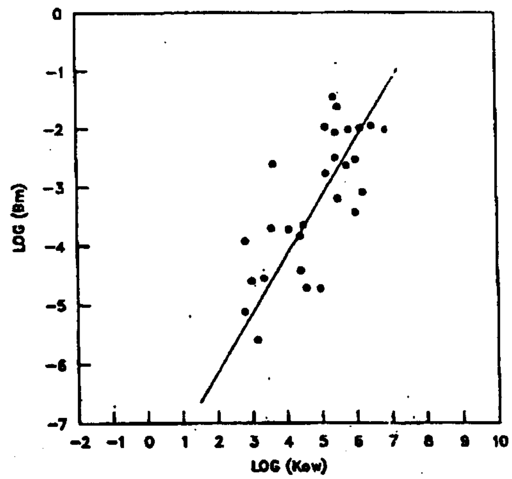


**Figure 2.** Relationship between biotransfer factors in milk ($B_m$) and octanol–water partition coefficients ($K_{ow}$).

assuming meat is 25% fat and whole milk is 3.68% fat. Daily intakes were computed, where necessary, assuming an average dry feed ingestion rate of 16 kg/day for lactating cows and 8 kg/day for nonlactating cattle and cows (*7, 8*). The exposure period for beef, with the exception of three chemicals, was for 4 weeks or longer. BTFs for beef meat and milk can be converted to BCFs in units of [mg (kg of beef or milk)$^{-1}$]/[mg (kg of dry feed)$^{-1}$] by multiplying by 16 kg/day for lactating animals and 8 kg/day for nonlactating animals.

The bioconcentration factor for vegetation ($B_v$) is defined here as the ratio of the concentration in aboveground parts (mg of compound/kg of dry plant) to the concentration in soil (mg of compound/kg of dry soil). The geometric mean functional regression method (*9*) was used to determine the proper correlation between bioconcentration factors and $K_{ow}$.

**Beef.** Table I lists biotransfer factors for 36 chemicals in beef ($B_b$) together with octanol–water partition coefficients (also see Figure 1). A geometric mean regression of these data yields

$$\log B_b = -7.735 + 1.033 \log K_{ow} \qquad n = 36, r = 0.81 \quad (1)$$

Halfon (*9*) and Mackay (*10*) have argued that the bioconcentration factor in fish should be linearly related to $K_{ow}$. Equation 1 indicates the same is true for the biotransfer factor in beef. Constraining the slope in eq 1 to be 1 and refitting the data yields

$$\log B_b = -7.6 + \log K_{ow} \qquad n = 36, r = 0.81 \quad (2)$$

Thus, the biotransfer factor of an organic compound is

**Table III. Relationship between Bioconcentration Factors in Vegetation ($B_v$) and Octanol-Water Partition Coefficients ($K_{ow}$)**

| chemical | log $K_{ow}$ | log $B_v$ | ref |
|---|---|---|---|
| aldicarb | 1.15 | 0.85 | 44, 45 |
| aldrin | 5.52 | −1.67 | 46, 47 |
| Aroclor 1254 | 6.47 | −1.77 | 48 |
| atrazine | 2.65 | −2.00 | 49 |
| benfluralin | 4.69 | −3.12 | 50 |
| benomyl | 3.11 | −0.47 | 51, 52 |
| benzo[a]pyrene | 6.19 | −1.25 | 53 |
| chlordane | 6.00 | −1.81 | 54, 55 |
| cyanazine | 2.02 | −0.06 | 49 |
| DDE | 5.83 | −0.98 | 56 |
| DDT | 5.76 | −1.80 | 56, 57 |
| diazinon | 3.31 | −0.59 | 58 |
| 3,4-dichloroaniline | 2.69 | −0.30 | 59 |
| dieldrin | 5.16 | −1.01 | 57 |
| diflubenzuron | 3.82 | −0.53 | 60 |
| endrin | 5.16 | −1.82 | 57, 58 |
| ethofumesate | 3.27 | −0.32 | 61 |
| fluchloralin | 4.79 | −1.07 | 62 |
| heptachlor | 5.44 | −1.48 | 46, 58 |
| heptachlor epoxide | 5.40 | −1.62 | 40 |
| hexachlorobenzene | 5.45 | −0.32 | 63, 64 |
| lindane | 3.66 | −0.41 | 56, 65 |
| mirex | 6.89 | −1.14 | 66 |
| PCNB | 4.18 | −0.35 | 63 |
| phorate | 4.70 | −1.70 | 62 |
| polybrominated biphenyl | 9.35 | −4.00 | 67 |
| simazine | 2.22 | 0.22 | 49 |
| TCDD | 6.15 | −1.87 | 68 |
| trifluralin | 5.33 | −0.37 | 62 |

directly proportional to its octanol–water partition coefficient.

**Milk.** Table II lists biotransfer factors for 28 chemicals in milk ($B_m$) together with octanol–water partition coefficients (also see Figure 2). A geometric mean regression of these data yields

$$\log B_m = -8.056 + 0.992 \log K_{ow} \qquad n = 28, r = 0.74 \quad (3)$$

or

$$\log B_m = -8.10 + \log K_{ow} \qquad n = 28, r = 0.74 \quad (4)$$

Note that the fresh weight biotransfer factor for meat is 3.2 times larger than that for milk. On a lipid basis, the biotransfer factor for milk is 21.5 times larger than that for meat.

**Vegetation.** Table III lists bioconcentration factors for 29 chemicals in vegetation ($B_v$) together with octanol–water partition coefficients (also see Figure 3). A geometric mean regression of these data yields

$$\log B_v = 1.588 - 0.578 \log K_{ow} \qquad n = 29, r = 0.73 \quad (5)$$

Thus, the vegetation bioconcentration factor is inversely proportional to the square root of $K_{ow}$. The inverse proportionality is not surprising since transport from soil to aboveground plant parts is dependent on a chemical's solubility in water, which is inversely proportional to $K_{ow}$.

## Conclusions

Biotransfer factors for organics in beef and milk are directly proportional to octanol–water partition coefficients, while the bioconcentration factor for an organic in vegetation is inversely proportional to the square root of the octanol–water partition coefficient. These regression equations provide a useful addition to the risk assessor's techniques for predicting a chemical's BTF in beef and milk and BCF in vegetation. Consequently, they will be of value in more precisely quantifying human exposure to organics through the terrestrial food chain.

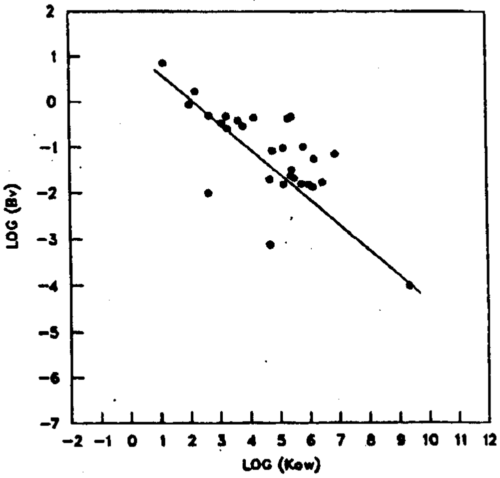


**Figure 3.** Relationship between bioconcentration factors in vegetation ($B_v$) and octanol–water partition coefficients ($K_{ow}$).

**Registry No.** Aldrin, 309-00-2; aroclor 1254, 11097-69-1; benzoylprop-ethyl, 22212-55-1; chlordane, 12789-03-6; chlorpyrifos, 2921-88-2; clopidol, 2971-90-6; coumaphos, 56-72-4; cyhexatin, 13121-70-5; 2,4-D, 94-75-7; DDD, 72-54-8; DDE, 72-55-9; DDT, 50-29-3; dicamba, 1918-00-9; 3,6-dichloropicolinic acid, 1702-17-6; dieldrin, 60-57-1; endosulfan, 115-29-7; endrin, 72-20-8; famphur, 52-85-7; fenoprop, 93-72-1; fenthion, 55-38-9; flamprop-isopropyl, 52756-22-6; heptachlor, 76-44-8; heptachlor epoxide, 1024-57-3; hexachlorobenzene, 118-74-1; kerb, 23950-58-5; lindane, 58-89-9; malathion, 121-75-5; mirex, 2385-85-5; oxadiazon, 19666-30-9; phosphamidon, 13171-21-6; ronnel, 299-84-3; 2,4,5-T, 93-76-5; TCDD, 1746-01-6; toxaphene, 8001-35-2; triclopyr, 55335-06-3; 3,5,6-trichloropyridinol, 6515-38-4; chloropropylate, 5836-10-2; fenvalerate, 51630-58-1; methoxychlor, 72-43-5; naphthalene, 91-20-3; naphthol, 1321-67-1; aldicarb, 116-06-3; atrazine, 1912-24-9; benfluralin, 1861-40-1; benomyl, 17804-35-2; benzo[a]pyrene, 50-32-8; cyanazine, 21725-46-2; 3,4-dichloroaniline, 95-76-1; diflubenzuron, 35367-38-5; ethofumesate, 26225-79-6; fluchloralin, 33245-39-5; PCNB, 82-68-8; phorate, 298-02-2; simazine, 122-34-9; trifluralin, 1582-09-8.

## Literature Cited


(1) Travis, C. C.; Arms, A. D. In *Toxic Chemicals, Health and the Environment*; Lave, L. B.; Upton, A. C., Eds.; The Johns Hopkins University Press: Baltimore, MD, 1987; Chapter 5.
(2) Mackay, D.; Paterson, S.; Cheung, B. *Chemosphere* 1986, *14*, 859.
(3) Chiou, C. T.; Freed, V. H.; Schmedding, D. W.; Kohnert, R. L. *Environ. Sci. Technol.* 1977, *11*, 475.
(4) Neely, W. B.; Branson, D. R.; Blau, G. E. *Environ. Sci. Technol.* 1974, *8*, 1113.
(5) Kenaga, E. E. *Environ. Sci. Technol.* 1980, *14*, 553.
(6) Travis, C. C.; Holton, G. A.; Etnier, E. L.; Cook, S. C.; O'Donnell, F. R.; Hetrick, D. M.; Dixon, E. *Environ. Int.* 1986, *12*, 533.
(7) *A Statistical Analysis of Selected Parameters for Predicting Food Chain Transport and Internal Dose of Radionuclides*; Hoffman, F. O., Baes, C. F., Eds.; Oak Ridge National Laboratory: Oak Ridge, TN, 1979; ORNL/NUREG/TM-282.
(8) National Research Council, Subcommittee on Feed Intake, Committee on Animal Nutrition Board *Predicting Feed Intake of Food-Producing Animals*; National Academy Press: Washington, DC, 1987.
(9) Halfon, E. *Environ. Sci. Technol.* 1985, *19*, 747.
(10) Mackay, D. *Environ. Sci. Technol.* 1982, *16*, 274.
(11) Radeleff, R. D.; Bushland, R. C.; Claborn, H. V. *Insects: The Yearbook of Agriculture*; U.S. Department of Agri-

culture: Washington, DC, 1952.
(12) Fries, G. F.; Marrow, G. S.; Gordon, C. H. *J. Agric. Food Chem.* **1973**, *21*, 117.
(13) Potter, J. C.; Marxmiller, R. L.; Barber, G. F.; Young, R.; Loeffler, J. E.; Burton, W. B.; Dixon, L. D. *J. Agric. Food Chem.* **1974**, *22*, 889.
(14) Crayford, J. V.; Harthoorn, P. A.; Hutson, D. H. *Pestic. Sci.* **1976**, *7*, 559.
(15) MacDougall, D. *Toxicity, Biodegradation*; Swets-Zeitlinger: Lisse, The Netherlands, 1972.
(16) Clark, D. E.; Palmer, J. S.; Radeleff, R. D.; Crookshank, R. C.; Farr, F. M. *J. Agric. Food Chem.* **1975**, *23*, 573.
(17) Fries, G. F.; Marrow, G. S.; Gordon, C. H. *J. Dairy Sci.* **1969**, *52*, 1.
(18) Fries, G. F.; Marrow, G. S. *J. Dairy Sci.* **1976**, *59*, 475.
(19) Oehler, D. D.; Ivie, G. W. *J. Agric. Food Chem.* **1980**, *28*, 685.
(20) Beck, E. W.; Johnson, J. C., Jr.; Woodham, D. W.; Leuck, D. B.; Dawsey, L. H.; Robbins, J. E.; Bowman, M. C. *J. Econ. Entomol.* **1966**, *59*, 1444.
(21) Claborn, H. V.; Radeleff, R. D.; Bushland, R. C. *Pesticide Residues in Meat and Milk*; Agricultural Research Service, U.S. Department of Agriculture: Washington, DC, Dec 1960; ARS-33-63.
(22) Radeleff, R. D.; Polen, P. B. *J. Econ. Entomol.* **1963**, *56*, 71.
(23) Borzelleca, J. F.; Larson, P. S.; Crawford, E. M.; Hennigar, G. R., Jr.; Kuchar, E. J.; Klein, H. H. *Toxicol. Appl. Pharmacol.* **1971**, *18*, 522.
(24) Adler, I. L.; Haines, L. D.; Wargo, J. P., Jr. *J. Agric. Food Chem.* **1972**, *20*, 1233.
(25) Pasarela, N. R.; Brown, R. G.; Shaffer, C. B. *J. Agric. Food Chem.* **1962**, *10*, 7.
(26) Bond, C. A.; Woodham, D. W.; Ahrens, E. H.; Medley, J. G. *Bull. Environ. Contam. Toxicol.* **1975**, *14*, 25.
(27) Guardigli, A.; Lefar, M. S.; Gallo, M. A. *Arch. Environ. Contam. Toxicol.* **1976**, *4*, 145.
(28) Geissbuhler, H.; Voss, G.; Anliker, R. *Residue Rev.* **1971**, *37*, 39.
(29) Claborn, H. V.; Bowers, J. W.; Wells, R. W.; Radeleff, R. D.; Nickerson, W. J. *Agric. Chem.* **1953**, *8*, 37.
(30) Saha, J. G. *Residue Rev.* **1969**, *26*, 39.
(31) Dorough, H. W.; Hemken, R. W. *Bull. Environ. Contam. Toxicol.* **1973**, *10*, 208.
(32) St. John, L. E., Jr.; Lisk, D. J. *J. Agric. Food Chem.* **1973**, *21*, 644.
(33) McKellar, R. L.; Dishburger, H. J.; Rice, J. R.; Craig, L. F.; Pennington, J. *J. Agric. Food Chem.* **1976**, *24*, 283.
(34) Bjerke, E. L.; Herman, J. L.; Miller, P. W.; Wetters, J. H. *J. Agric. Food Chem.* **1972**, *20*, 963.
(35) Whiting, F. M.; Brown, W. H.; Stull, J. W. *J. Dairy Sci.* **1973**, *56*, 1324.
(36) Wilson, K. A.; Cook, R. M. *J. Agric. Food Chem.* **1972**, *20*, 391.
(37) Baldwin, M. K.; Crayford, J. V.; Hutson, D. H.; Street, D. L. *Pestic. Sci.* **1976**, *7*, 575.
(38) Johnson, J. C., Jr.; Bowman, M. C. *J. Dairy Sci.* **1972**, *55*, 777.
(39) Wszolek, P. C.; Lein, D. H.; Lisk, D. J. *Bull. Environ. Contam. Toxicol.* **1980**, *24*, 296.
(40) Bruce, W. N.; Link, R. P.; Decker, G. C. *J. Agric. Food Chem.* **1965**, *13*, 63.
(41) Dorough, H. W.; Ivie, G. W. *J. Environ. Qual.* **1974**, *3*, 65.
(42) Eisele, G. R.; Traylor, T. D.; Schwarz, O. J.; Chertok, R. J. "Food Chain Transport of Synfuels"; annual report prepared for the Environmental Protection Agency; Oak Ridge Associated Universities: Oak Ridge, TN, Jan 17, 1983.
(43) Jensen, D. J.; Hummel, R. A. *Bull. Environ. Contam. Toxicol.* **1982**, *29*, 440.
(44) Maitlen, J. C.; Powell, D. M. *J. Agric. Food Chem.* **1982**, *30*, 589.
(45) Iwata, Y.; Westlake, W. E.; Barkley, J. H.; Carman, G. E.; Gunther, F. A. *J. Agric. Food Chem.* **1977**, *25*, 933.
(46) Lichenstein, E. P. *J. Agric. Food Chem.* **1960**, *8*, 448.
(47) Weisgerber, I.; Kohli, J.; Kaul, R.; Klein, W.; Korte, F. *J. Agric. Food Chem.* **1974**, *22*, 609.
(48) Iwata, Y.; Gunther, F. A. *Arch. Environ. Contam. Toxicol.* **1976**, *4*, 44.
(49) Beynon, K. I.; Stoydin, G.; Wright, A. N. *Pestic. Biochem. Physiol.* **1972**, *2*, 153.
(50) Businelli, M.; Tafuri, F.; Scarponi, L.; Marucchini, C. *Pestic. Sci.* **1975**, *6*, 475.
(51) Popov, V. I.; Sboeva, J. N. *Environ. Qual. Saf.* **1974**, *3*.
(52) Jalali, I.; Anderson, J. P. E. *J. Agric. Food Chem.* **1976**, *24*, 431.
(53) Edwards, N. T. *J. Environ. Qual.* **1983**, *12*, 427.
(54) Tafuri, F.; Businelli, M.; Scarponi, L.; Marucchini, C. *J. Agric. Food Chem.* **1977**, *25*, 353.
(55) Dorough, H. W.; Pass, B. C. *J. Econ. Entomol.* **1972**, *65*, 976.
(56) Voerman, S.; Besemer, A. F. H. *Bull. Environ. Contam. Toxicol.* **1975**, *13*, 501.
(57) Beall, M. L., Jr.; Nash, R. G. *J. Environ. Qual.* **1972**, *1*, 283.
(58) Nash, R. G. In *Pesticides in Soil and Water*; Guenzi, W. D., Ed.; Soil Science Society of America: Madison, WI, 1974.
(59) Viswanathan, R.; Scheunert, I.; Kohli, J.; Klein, W.; Korte, F. *J. Environ. Sci. Health, Part B* **1978**, *B13(3)*, 243.
(60) Bull, D. L.; Ivie, G. W. *J. Agric. Food Chem.* **1978**, *26*, 515.
(61) Eshel, J.; Zimdahl, R. L.; Schweizer, E. E. *Pestic. Sci.* **1978**, *9*, 301.
(62) University of Oklahoma data base, Sept 3, 1986.
(63) Dejonckheere, W.; Steurbaut, W.; Kips, R. H. *Bull. Environ. Contam. Toxicol.* **1975**, *13*, 720.
(64) Beall, M. L., Jr. *J. Environ. Qual.* **1976**, *5*, 367.
(65) Lichenstein, E. P. *J. Agric. Food Chem.* **1959**, *7*, 430.
(66) De La Cruz, A. A.; Rajanna, B. *Bull. Environ. Contam. Toxicol.* **1975**, *14*, 38.
(67) Jacobs, L. W.; Chou, S.; Tiedje, J. M. *J. Agric. Food Chem.* **1976**, *24*, 1198.
(68) Helling, C. S.; Isensee, A. R.; Woolson, E. A.; Ensor, P. D. J.; Jones, G. E.; Plimmer, J. R.; Kearney, P. C. *J. Environ. Qual.* **1973**, *2*, 171.

*Received for review February 24, 1987. Accepted September 9, 1987. Oak Ridge National Laboratory is operated by Martin Marietta Energy Systems, Inc., for the U.S. Department of Energy under Contract DE-AC05-840R21400. This work was partially supported by the U.S. Environmental Protection Agency.*