Identifying the Pesticides: Pesticide Names, Classification, and History of Use

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The insects tell us when it is time to go back to the earth. They were made by our Creator and they serve a purpose. We shouldn't have to be killing the bugs because they are on these things.

—Jeanette Cassa

PESTICIDES AND WHY THEY WERE USED IN MUSEUMS

PESTICIDES, INCLUDING HERBICIDES, FUNGICIDES, and various other substances, have been used to prevent, destroy, repel, or mitigate pests in order to preserve museum collections. This means that these materials, now contaminated with pesticide residues, are again being handled and used in traditional ways. Information about pests and how pesticides were applied to museum objects may provide some understanding for why pesticides were applied.

BIODETERIORATION

Biodeterioration is the term applied to the process that involves the combination of an organism (the pest), a food source (the museum object), and a suitable environment (a quiet, dark, comfortable place). Most museums' storage areas are particularly vulnerable to pests. The primary organisms that threaten museum objects include people, fungi, bacteria, insects, and rodents. Pesticides have been primarily used to counter the adverse effects of insects (fig. 2.1).

Insects

Insects are the most numerous, resilient, and persistent of all the agents of deterioration that affect museum collections. Only people are more destructive. Insects are very prolific, and where humans go, the insects go. Fortunately, relatively few species from the insect world can survive in the conditions that are created by museums. The insects that are most commonly associated with museum objects are clothes moths, carpet beetles, furniture beetles or wood borers, silverfish, firebrats, odd beetles, crickets, cockroaches, and book lice. These species tend to flourish in museums because the food source within the objects and the environmental conditions are desirable to the organism. The damage caused by insect pests may destroy the structure of an object, disfigure the surface, and destroy or diminish important symbolic or aesthetic decorative features.

Insects are divided into two groups. Silverfish, crickets, cockroaches, and book lice undergo an incomplete metamorphosis that includes egg, nymph, and adult. Moths and beetles undergo a complete metamorphosis that includes egg, larvae, pupa, and adult.

- Clothes moths in museums are usually identified as the common or webbing clothes moth, *Tineola bisselleilla* (figs. 2.2 and 2.3), or the case-making or fur moth,

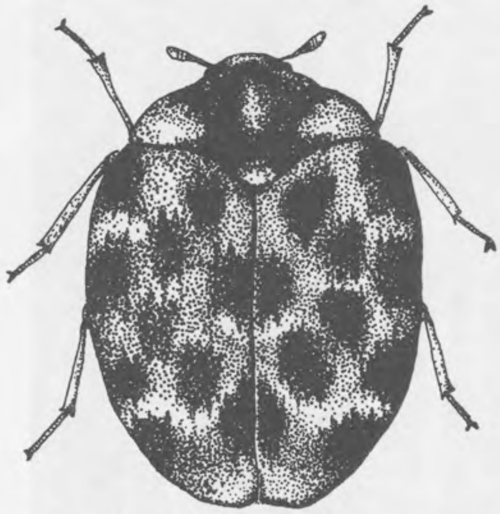


Figure 2.8. Varied carpet beetle, *Anthrenus verbasci* (2–3 mm).

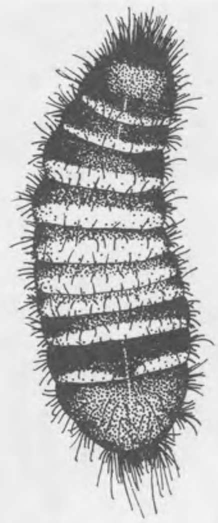


Figure 2.9. Varied carpet beetle larva, *Anthrenus verbasci* (4–5 mm).

horn, and other protein-based materials. They will also eat leather, silk, linen, rayon, and woods with animal glue. The larvae shun light and will hide in floor cracks and baseboards. The pupae are attracted to light. The adults prefer to feed on outdoor plant pollens and flower nectar and are more common in the summer months.

- The odd beetle, *Thylodrias contractus* (figs. 2.20 and 2.21), is known in museums as a destructive pest that moves quickly and damages many proteinous-based objects of residues. The oval-shaped larvae move quickly and contract or curl up when disturbed.
- Wood-boring beetles can be a serious problem in museums. Some of the more common species include the brown powder-post beetle, *Lyctus brunneus* (fig. 2.10); the false powder-post beetle (Stouts Bostrichid), *Polycaon stouti* (fig. 2.11); and the common furniture beetle, *Anobium punctatum* (figs. 2.12 and 2.13). The true powder-post beetle attacks mainly recently seasoned or underseasoned sapwood in hardwoods, furniture, bamboo, gun stocks, sculpture, or other wood objects. It tunnels into the wooden object. The larvae chew into the wood below the egg case and tunnel up and down the

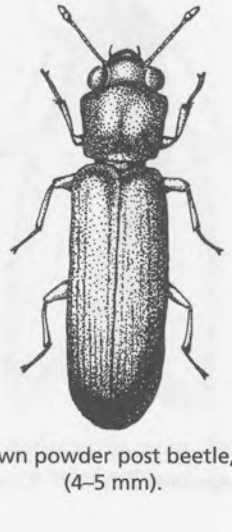


Figure 2.10. Brown powder post beetle, *Lyctus brunneus* (4–5 mm).

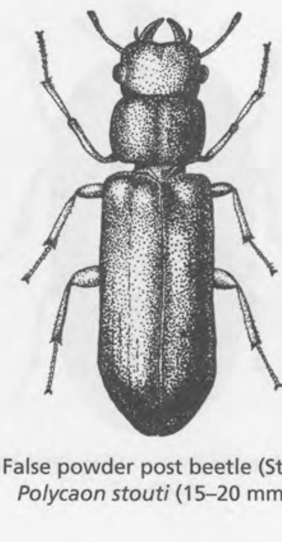


Figure 2.11. False powder post beetle (Stout's Bostrichid), *Polycaon stouti* (15–20 mm).

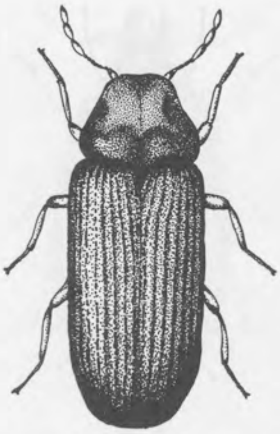


Figure 2.12. Common furniture beetle, *Anobium punctatum* (4–6 mm).

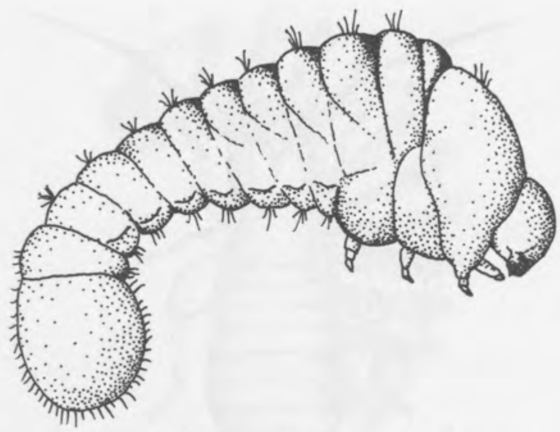


Figure 2.13. Common furniture beetle larva, *Anobium punctatum* (4–6 mm).

wood grain. The tunnels are then filled with powdered wood fibers and fecal pellets known as frass. The emerging adult chews through the wood surface and makes a flight hole that may be used again as a place to deposit new eggs. It can be difficult to determine whether a wood-boring pest is active. The presence of flight holes and frass is proof of a former attack but not necessarily indicative of present activity.

- Silverfish, *Lepisima saccharina* (fig. 2.14), and firebrats, *Thermobia domestica* (fig. 2.15), are insects that do comparatively less damage. Eggs are laid singly or a few at a time. Both nymphs and adults can cause damage by feeding on starch, sugar, and proteins that are found in textiles, papers, books, and paintings. The firebrat prefers a drier environment, so it is more common in the arid areas of the Southwest.
- Book lice, *Liposelis divinatorius* (fig. 2.16), are often found in swarms among the pages of old books where they cause damage to old protein-based glues, starch pastes, and paper bindings. They also feed on mold damage and can produce six to eight generations per year.
- Termites may be known to museums as a structural pest in the building or as a pest to wooden and paper objects. Subter-

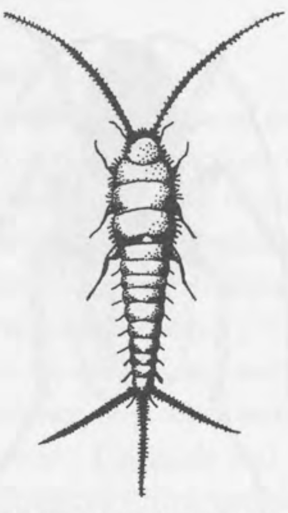


Figure 2.14. Common silverfish, *Lepisima saccharina* (5–7 mm).

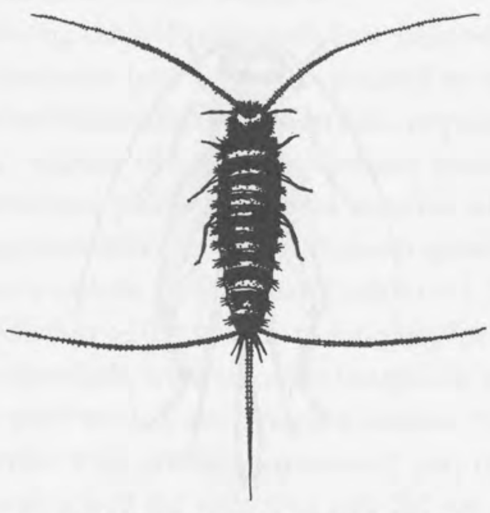


Figure 2.15. Firebrat, *Thermobia domestica* (3–10 mm).

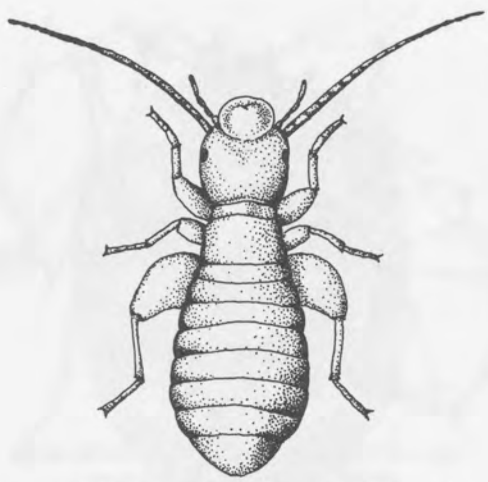


Figure 2.16. Book louse, *Liposelis divinatorius* (<1 mm).

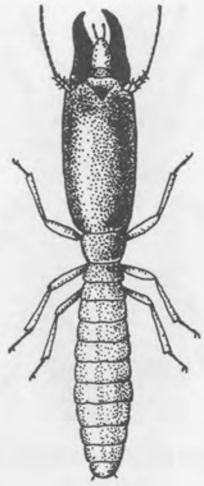


Figure 2.17. Western subterranean termite (soldier), *Reticulitermes hesperus* (5–6 mm).

ranean termites, *Reticulitermes* (fig. 2.17), form colonies deep in the ground and attack dead plant materials, paper, and wood that are in contact with the soil. Dry-wood termites, *Incisitermes*, tunnel into dry sound wood or paper-based materials and do not enter the soil.

- Crickets, such as the Indian house cricket, *Gryllodes supplicans* (fig. 2.18), and cockroaches, such as the brown-banded cockroach, *Supella longipalpa* (fig. 2.19), tend to enter museums during the dry warm months of the year. These insects feed on clothing and papers, particularly those stained by foods or perspiration. Cricket nymphs undergo 7 to 11 molts.

PESTICIDES

Pesticides are poisons or toxins that are used to kill pests by entering the organism through the skin (dermal), the mouth (oral), or nose and mouth (inhalation). Dermal poisons that work primarily by penetrating the cuticle or body wall of the insect are sometimes known as contact poisons. Desiccants can also be used to absorb part of the outer protective wax coating of the insect, causing dehydration and death.

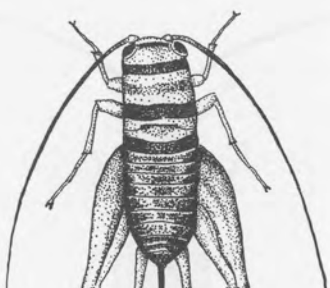


Figure 2.18. Indian house cricket, *Gryllodes supplican* (8–25 mm).

Figure 2.19. Brown banded cockroach (male), *Supella longipalpa* (10–15 mm).

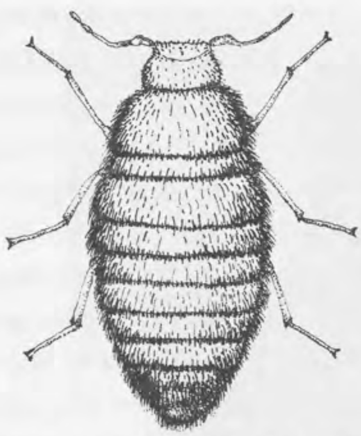


Figure 2.20. Odd beetle (female), *Thylodrias contractus* (2–3 mm).

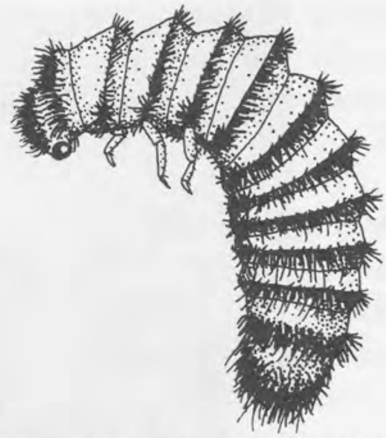


Figure 2.21. Odd beetle larva, *Thylodrias contractus* (3 mm).

Oral poisons enter the body primarily through chewing and are known as stomach poisons. Inhalation poisons enter the insect primarily through the body wall or respiratory openings. Residual poisons contact the insect during or after application but require a period of time to react. While poisons can be placed in categories, most pesticides are effective in more than one category.

Various natural and synthetic repellants have been used to discourage insect activity, and growth-regulating hormones have been used to restrain insect maturation. They are sometimes listed as pesticides.

The Application of Pesticides

Information regarding the use of pesticides and fumigants on museum collections is important to the understanding of past methods of care, historical treatments, and chemical alterations as well as present health hazards (health concerns vary according to application type). Some pesticide chemicals are unrestricted and may be purchased in hardware or grocery stores. Since the Federal Insecticide, Fungicide and Rodenticide Act of 1972, chemicals with a *restricted use* classification must be dispensed by a certified pest control operator. Prior to 1972, many chemical products were available for unregulated museum use.

Tremendous variability in the museum use of pesticides is possible because the chemical poisons can be formulated in many ways (oil concentrate, emulsifying concentrate, wettable powder, dust, baited, or resin pest strip) and can be applied in many ways (spraying, aerosol bombing, fogging, dusting, or fumigation techniques) (fig. 2.22). Approaches to counter the devastation of insect pests have evolved as the formulation methods and application techniques have become available.

During the late nineteenth and early twentieth centuries, both field collectors and museum professionals, called "museum aides or preparators," applied chemical preparations following instructions published by the curators of the larger museums (American Museum of Natural History and the Smithsonian Institution). Documentation of the specific techniques, the specific chemicals, and a record of the specific items that were treated were rarely recorded. These activities were probably considered part of the general care of the collection and did not warrant special documentation.

Figure 2.22. Examples of pesticides products used by museums. Courtesy of the Arizona State Museum, University of Arizona, Jannelle Weakly, Photographer.

Dry and liquid poison preparations were recommended for both field collection and museum use. Botanical examples included tobacco, lavender leaves, cedar wood, creosote leaves, and various seeds. Inorganic chemicals included arsenic compounds, boric acid, and mercuric chloride.

When museums began to purchase closed cabinetry for the storage of artifacts, the use of volatile fumes became popular as repellants and as pesticides. Botanical examples included thymol crystals. Inorganic chemicals included naphthalene, tar camphor, paradichlorobenzene, carbon disulfide, cydrocyanic acid, and fluorosilicate compounds.

As additional pesticides from the agricultural developments of the mid-twentieth century were introduced, museums were able to utilize a greater variety of chemical pesticide products. Botanical examples included pyrethrins and bacteria. Products containing chlorinated hydrocarbons and organic phosphates also became widely available as sprays, dusts, fogs, and resin strips. The use of garden dusts and building crack-and-crevice pesticides included carbamates and boric acid formulations.

For a while in the later twentieth century, the use of pressurized fumigation chambers in museums was considered safer, faster, and more effective in controlling insect pests. Examples of the fumigants used included ethylene oxide, methyl bromide, and sulfuryl fluoride.

Finally, at the end of the twentieth century, the use of chemical pesticides in museums became less appropriate. Greater restrictions regarding the manufacture, distribution, use, and disposal of chemical pesticides were legally mandated. In museums, greater awareness toward the effects of pesticide chemicals on the safety of museum workers and the adverse effect on object appearance were becoming recognized. Likewise, many of the chemicals used in fumigation chambers and fogging were being taken off the market for environmental or human health reasons.

INTEGRATED PEST MANAGEMENT TECHNIQUES

As environmental concerns continued to highlight the problem of pesticides, museum workers were beginning to widely recognize the benefits of nonchemical pest control techniques, particularly with regard to museum objects. Integrated pest management refers to the methods and techniques used to prevent pests in museums and how to take appropriate pest control measures to mitigate the problems. Today the techniques used in museums tend to focus on the monitoring of insects through the use of traps, the removal of bird nests on buildings, the maintenance of building interior and exterior areas, and the development of a plan for when an insect infestation is discovered. Nonchemical techniques for pest eradication include freezing, high heat, and anoxic environments (oxygen deprivation).

USING PESTICIDE TABLES AND CHARTS

The tables and charts presented in this volume were produced as references. The following information is provided as a guide to reading and interpreting these table and charts.

Table of Pesticides: History and Characteristics
Table 2.1 provides a listing of approximately 90 chemicals that are known to have been used in museums. The chemicals are listed alphabetically by common name. The earliest known dates for

BOX 2.1. PESTICIDE HAZARD INFORMATION PRODUCED BY THE NATIONAL PARK SERVICE

The Museum Management program of the National Park Service has produced a number of publications that may help individuals trying to educate themselves about pesticide use on museum collections.

Conserve O Gram leaflets are short, focused leaflets about caring for museum objects, published in a loose-leaf format. As of the end of 2000, pertinent leaflets included the following:

- 2/1 Hazardous Materials Health and Safety Update, 1993
- 2/2 Ethylene Oxide Health and Safety Update, 1993
- 2/3 Arsenic Health and Safety Update, 1993
- 2/4 Dichlorvos (Vapona) Update, 1993
- 2/14 DDT Health and Safety Update, 2000
- 2/16 Chronology of Pesticides Used on National Park Service Collections, 2001
- 2/17 Physical Properties and Health Effects of Pesticides Used on National Park Service Collections, 2001
- 2/19 Guidelines for the Handling of Pesticide Contaminated Collections, 2002
- 3/6 An Insect Pest Control Procedure: The Freezing Process, 1994
- 3/7 Monitoring Insect Pests with Sticky Traps, 1998
- 3/8 Controlling Insect Pests: Alternatives to Pesticides, 1998
- 3/9 Anoxic Microenvironments: A Treatment for Pest Control, 1999

All *Conserve O Gram* leaflets are available on the Web at www.cr.nps.gov/museum/publications/index.htm.

each chemical are provided. These dates may refer to the year the chemical was first described in scientific literature, when it was synthesized, and/or when it was patented in the United States. When available, the year the chemical was registered by the U.S. federal government is also provided. The column for status and dates refers to the legislative status and history for each chemical as listed by the U.S. EPA Office of Pesticide Programs. Unrestricted chemicals are described as being for continued use. Others are listed as restricted and/or canceled. Dates for the legislative determination are provided when available.

The "Method" column describes the common form of application for each chemical. The "Character" column describes the general physical characteristics of each chemical. Target pests are listed in the next column. The "Field Half-Life" column provides the results of tests conducted on some of the pesticide chemicals in the field by the U.S. Department of Agriculture. These data provide a frame of reference for assessing the persistence of the chemicals. The longer the half-life in the field, the more persistent the chemical. In an indoor environment, such as in a museum, the half-life would be much longer, of course. The last column lists the persistence of each chemical qualitatively from low to high.

Charts of Pesticide Use by Classification

Table 2.2 provides a graphic illustration of the legislative status and determination dates for each of the pesticide chemicals as provided by the U.S. EPA Office of Pesticides Programs. The chemicals are grouped by chemical class. To find the specific dates for each chemical, see Table 2.1.

Table of Pesticides: Names and Classification

Table 2.3 provides a listing of approximately 90 chemicals that have been used in museums. The table provides the common name, the chemical class, the chemical formula, and the CAS (Chemical Abstract Service) number. Some chemicals, such as mercuric chloride, were used as the pure 100 percent chemical substance in museum collections. Other chemicals were applied as the smaller percentage active ingredients in commercially manufactured pesticide formulations.

Many pesticides came to be known by their common names, such as DDT, even though they had alternate trade names. Some of the active ingredient chemicals have multiple common names as well. For example, mercuric chloride has also been known as corrosive sublimate. Because of the inevitable confusion resulting from all these different chemical names, the CAS number is included in the table to assist as a reference tool for finding further information about the particular chemicals. Chemical indexes and databases all allow searches by the CAS number, whereas common names and particularly trade names can be too numerous, too long, or even too obsolete to search.

It is important to note here that not all these pesticide chemicals were necessarily applied directly to museum objects. Many of the pesticide formulations used by commercial pesticide applicators from the 1980s on were, in fact, applied only as crack-and-crevice sprays or to the external museum structures. Furthermore, many chemicals used as baits for certain insects and/or rodents would not necessarily have contaminated any artifacts though they were used inside museum buildings.

List of Trade Names

Many of these pesticide formulations have many different trade names, depending on the time of manufacture and the different manufacturing companies. Some trade name formulations are very regional. Because of the large number of possible trade names and synonyms for all the chemicals in Table 2.3, a limited selection has been included.

Table 2.1. Pesticide History and Characteristics

Synonyms	Early Dates	Federal Registration	Status and Dates	Method	Character	Target Pests	Field Half-Life (days)	Persistence
Acephate	1973 U.S. Patent	1973	Continued use	Spray	Colorless to white solid	Moths, larvae, roaches, biting and sucking insects	2–10	Low
Aldrin	1948 synthesis, 1953 U.S. Patent	1949	1975 restricted and most canceled, canceled 1987	Residual	White solid	Ants, soil insects, termites	10–1,237	High
Allethrin	1949 synthesis, 1956 U.S. Patent		Continued use	Spray	Pale yellow oily liquid	Flies, flying insects		Low
Ammonium fluosilicate	1936 described	1987	Canceled	Powder	Odorless crystalline powder	Mothproofer, roaches, crickets, ants, silverfish		Moderate
Arsenic trioxide, arsenous acid	1669 described, 1700s in collections	1972	1977 restricted, most canceled	Dust, paste	White powder	General insecticide, taxidermy		High
Bendiocarb	1968 U.S. Patent	1975	1992 restricted, to be canceled 2001	Fumigant	Colorless solid	Beetles, crickets, roaches, moths, silverfish, wood borers	3–21	Low–moderate
Benzene hexachloride	1825 synthesis, 1940 U.S. Patent	1952	1978 restricted, most canceled	Dust	Colorless crystalline solid	Ants, roaches, crickets, silverfish, wood borers	100–1,424	High
Boric acid	1890s in collections, 1938 described	1948	Continued use	Dust	Colorless crystalline solid	Roaches, silverfish		Moderate–high
Calcium arsenate	1907 described, 1955 U.S. Patent		1977 restricted, 1989 canceled	Granules	White powder tinted pink	Snails, slugs, pillbugs, herbicide		High
Camphor	1830s in collections, ca. 1900, described		Continued use	Fumigant	White crystalline solid	Moth repellant, ingredient in arsenical mixtures for taxidermy		Moderate
Carbaryl	1956 described, 1959 U.S. Patent	1963	Continued use	Dust, spray	Colorless to white solid	Ants, roaches, crickets, mites	4–22	Low–moderate
Carbofuran	1965 U.S. Patent	1979?	1991 restricted	Dust, spray	White crystalline solid	Insecticide, acaricide, nematodicide	17–90	Moderate
Carbolic acid, hydroxybenzene	1887 in collections, 1958 described		Continued use	Fumigant, liquid	Colorless to pink solid, sweet odor	Ingredient in arsenical mixtures for taxidermy, insecticide	1–10	Low
Carbon dioxide, dry ice	1981 circa	1981	1981 restricted	Fumigant	Colorless, odorless gas	Moths, beetles, general insecticide		Low
Carbon disulfide	1854 described, 1887 in collections		Canceled	Fumigant	Colorless liquid	Moths, beetles, roaches, crickets	1–2	Low
Carbon tetrachloride, perchloromethane	1927 described	1950	1985/86 canceled	Fumigant	Colorless liquid	Moths, beetles, roaches, crickets		Low
Chlordane	1945 synthesized, 1952 U.S. Patent	1978	1988 most canceled, all by 1994	Spray	Amber liquid	Beetles, crickets, roaches, ants, termites	283–3,500	High
Chlorinated camphene	1947 described, 1951 U.S. Patent	1974	1982 restricted and most canceled, all by 1994	Dust, spray	Yellow solid	Flies, roaches	9–500	Low–moderate
Chlorinated naphthalene	1901 described, 1933 U.S. Patent		Canceled	Fumigant, liquid crystalline solid	Off-white	Beetles, taxidermy		Low
Chloropicrin	1848 described, 1963 U.S. Patent	1979?	1998 most canceled	Fumigant	Colorless oily liquid	Moths, beetles, roaches	4–139	Low–moderate

(continued)

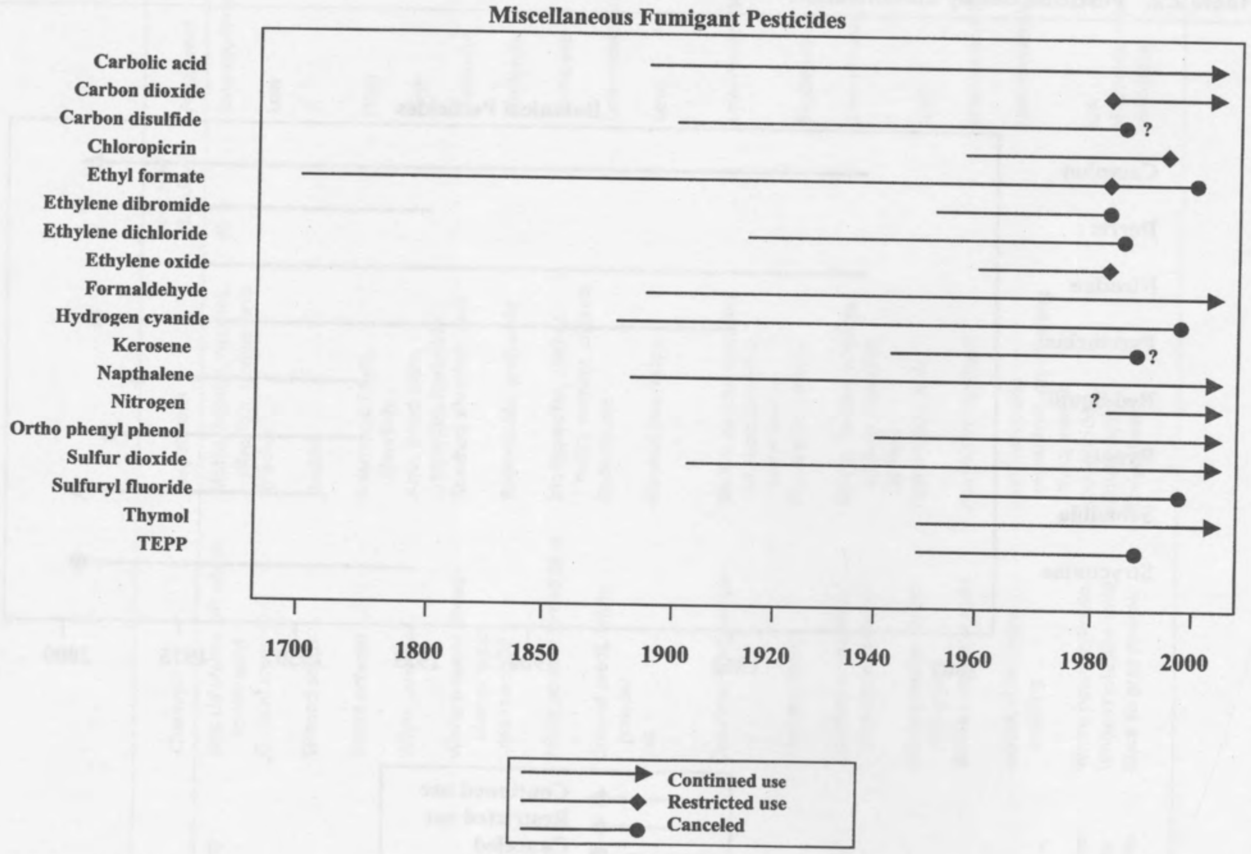
Table 2.1. *(continued)*

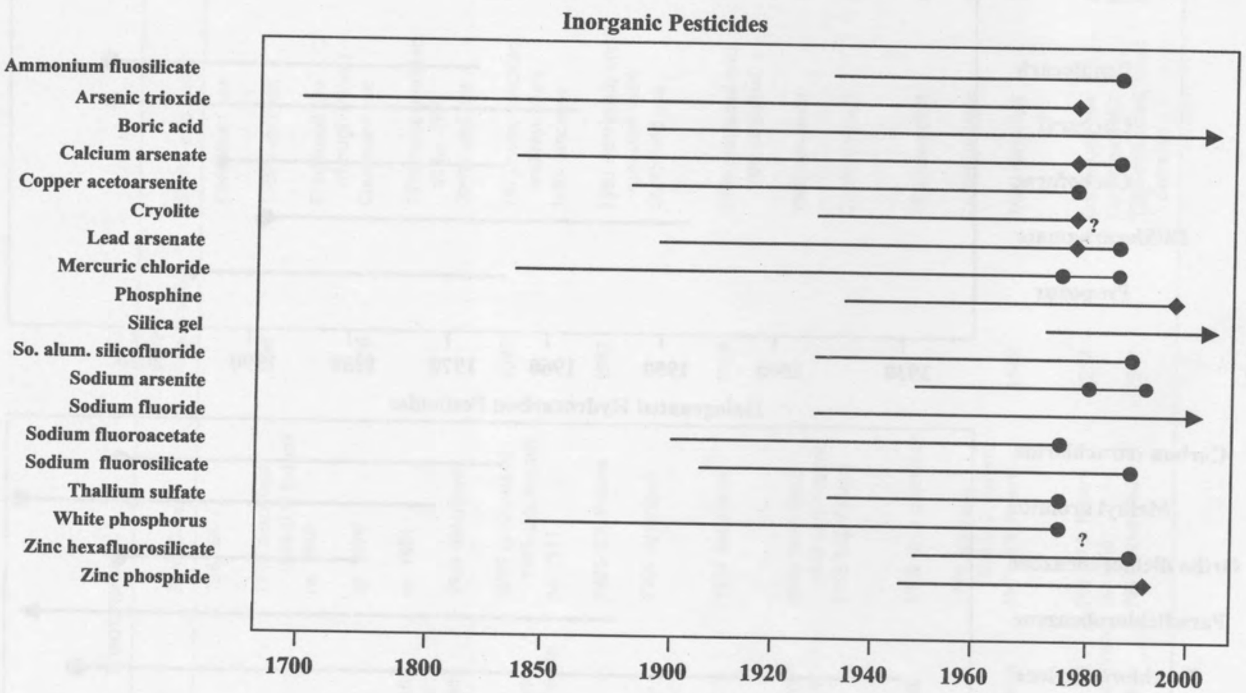
Synonyms	*Early Dates*	*Federal Registration*	*Status and Dates*	*Method*	*Character*	*Target Pests*	*Field Half-Life (days)*	*Persistence*
Chlorpyrifos	1964 U.S. Patent	1965	1997 most canceled, most all by 2001	Dust, spray	Amber to white crystalline solid	Beetles, crickets, moths, flies, silverfish, roaches, wood borers	30.5	Low–moderate
Copper acetoarsenite	1867 described, 1939 U.S. Patent		1977 canceled	Dust	White solid tinted green	Ants, dry wood termites		High
Cryolite	1929 described	1957	Restricted	Dust, spray	White solid	General insecticide	3,000	High
Cyfluthrin	1987	1987	Restricted and general use	Spray	Pasty yellow mass	Roaches, silverfish, beetles	4–90	Low–moderate
Derris, cube	1924 described		Restricted	Dust, spray	Colorless crystalline solid	Roaches, flies	1–3	Low
Diazinon	1953 described, 1956 U.S. Patent		1988 restricted, to be canceled 2001–2004	Dust, spray	Colorless to brown liquid	Beetles, roaches, crickets, moths, silverfish, ants	2.8–13	Low–moderate
(DDT) Dichloro diphenyl trichlorethane	1942 described, 1944 U.S. Patent	1952	1973 canceled insecticide	Dust, spray	White powder	Mothproofer, general	2–15 years	High
(DDVP) Dichlorvos	1960 U.S. Patent	1948	1995 restricted	Fumigant	Liquid	Moths, beetles, roaches, crickets, silverfish, ants	0.08–0.33	Low
Dieldrin	1948 described, 1954 U.S. Patent	1948	1975 restricted, 1986 canceled	Dust, spray	White solid	Mothproofer, termites, ants	225–1,260	High
Dithiocarbamate	1943 described, 1954 U.S. Patent		1989 canceled	Dust, spray powder	Light-colored	Fungicide	23–43	Low–moderate
Edolan-U	1974		1988 canceled	Spray, dip-soak	Liquid	Mothproofer		High
Endosulfan	1956 described, 1961 U.S. Patent		1975–1980, most canceled	Spray, smoke tablets	Colorless crystalline solid	General insecticide/ acaricide	4–200	Moderate–high
Endrin	1951 described, 1954 U.S. Patent	1954	1979 restricted, 1984 canceled	Dust, spray	Crystalline solid	Rodenticide	224–4,300	High
Ethylan	1955 U.S. Patent		1980 restricted, most canceled	Spray	Crystalline solid	Mothproofer, beetles, ants, flies		Moderate
Ethylene dibromide	ca. 1956	1956	1984 canceled	Fumigant	Colorless liquid	Termites, beetles	28–180	Moderate
Ethylene dichloride	1918 described	1950	1986 canceled	Fumigant	Gas	Moths, beetles, roaches, crickets		Low
Ethyl formate, formic acid ethyl ester	1670 described		1980s restricted, most canceled 1999	Fumigant	Gas	Fungicide		
Ethylene oxide	1859 described, 1960 U.S. Patent	1957	1984 restricted	Fumigant	Colorless gas, ether odor	Moths, beetles, roaches, crickets, wood borers, sterilant		High
Formaldehyde, formalin	1890s in collections, 1957 U.S. Patent for gas	1948	Continued use	Spray	Colorless liquid or fumigant	Fungicide, fumigant insecticide gas with odor		
Heptachlor	1949 described, 1951 U.S. Patent	1952	1988 canceled	Dust, spray	White crystalline solid	Termites, ants, roaches	40–2,000	High
Hydrogen cyanide, hydrocyanic acid	1877 described		1989 canceled	Fumigant	Colorless gas	Moths, beetles, roaches, crickets, rodents		Low
Kerosene	1944 described		Canceled	Spray	Yellow to clear oily liquid	Inert ingredient/ carrier in some insecticidal sprays		Low
Lead arsenate	1892 described		1977 restricted, most canceled 1987	Dust	White powder	General insecticide, taxidermy, termites		High
Malathion	1949 described, 1951 U.S. Patent	1950	Continued use	Dust, spray	Clear liquid	Moths, beetles, roaches, crickets, ants, silverfish	0.2–25	Low–moderate

Mercuric chloride	1822 described, 1830s in collections		1976 most canceled, all by 1992	Dust, spray	White crystalline, or powder	Beetles, roaches, termites, taxidermy, herbaria		High
Methoxychlor	1944 described		Continued use, some canceled 2000	Dust, spray, fog	White solid to gray powder	Mothproofer, beetles, flies	7–210	Moderate–high
Methyl bromide	1938 described		1978 restricted, most canceled 1999, all by 2005	Fumigant	Colorless gas	Moths, beetles, roaches, crickets, rodents, wood borers	31–55	Low–moderate
Mitin FF	1938 synthesized, 1948 U.S. Patent	1948	Restricted, all but one use canceled	Spray	Fine white powder	Mothproofer		Moderate
Naphthalene, white tar	1882 described, 1887 in collections		Continued use	Fumigant	White crystalline solid	Moth repellant	14–48	Low–moderate
Nicotine	1773 described, 1830s in collections		1981 restricted	Spray, fumigant	Ground leaf, *Nicotiana tabacum*	General insecticide, taxidermy		
Nitrogen			Continued use	Fumigant gas	Colorless, odorless	Moths, beetles, general insecticide		Low
Ortho dichlorobenzene	ca. 1954 described		Canceled	Spray	Clear liquid	Wood borers, termites		Low–moderate
Ortho phenyl phenol	1939 described, 1958 U.S. Patent		Continued use	Fumigant	White crystalline flaky solid	Fungicide		Moderate
Paradichlorobenzene	1912 described	1949	Continued use	Fumigant	White solid crystals, flakes	Moth and insect repellant, beetles		Low–moderate
Parathion	1946 synthesis	1948	1991 restricted, to be canceled 2002	Dust, spray	Colorless crystalline solid	General insecticide/ acaricide	18–35	Low
Pentachlorophenol	ca. 1948	1948	1986 restricted, most canceled 1988	Flakes, spray	Colorless crystalline solid	Wood borers, fungicide, wood preservative	23–178	Moderate
(LPCP) Pentachlorophenyl laureate	ca. 1955		1984 canceled	Liquid/spray	Liquid	Fungicide, insecticide		Moderate
Perchloroethylene	1821 described, 1960 U.S. Patent	1959	1992 canceled	Spray	Colorless liquid	Mothproofer, dry-cleaning fluid, solvent		Low–moderate
Permethrin	1973 described, 1976 U.S. Patent	1979	Continued use	Dust, spray	UV-stable colorless crystalline solid	Mothproofer, moths, beetles, roaches, crickets, silverfish	6–106	Low–moderate
Phenothrin	1969 U.S. Patent		Continued use	Dust, spray	UV stable	Moths, beetles, roaches, crickets, silverfish, spiders, flies		Low–moderate
Phosphine	1938 U.S. Patent	1958	Restricted use, many canceled 1998	Dust, spray, fumigant	Gray to yellow crystalline solid	Rodenticide, moths, beetles, roaches, crickets		Low
Phosphorus, white	1845 described		Canceled	Gel, paste	Paste, luminous	Rodenticide, roaches		High
Piperonyl butoxide	1949 U.S. Patent		1999 restricted	Spray	Light to pale yellow liquid	Synergist for pyrethrins, rotenone, etc.		Low
Propargite	1976	1976	Continued use	Granules	Acaricide	Mites	50–99	Moderate
Propetamphos	1971 U.S. Patent	1980	2000 restricted, most canceled 1998	Dust, spray	Yellowish liquid	Moths, beetles, roaches, crickets, silverfish, spiders, flies		
Propoxur	1963 U.S. Patent	1959	1995 restricted	Spray, fumigant	Liquid, white crystalline solid	Beetles, roaches, crickets, silverfish, moths, ants,	28	Low–moderate
Pyrethrins	1858 described		Continued use	Dust, spray	Dust, brown liquid	Moths, beetles, roaches, crickets, silverfish, spiders, flies	ca. 12	Low
Red Squill	ca. 1935 described		1980 canceled	Granules	Yellow crystalline solid	Rodenticide (worldwide)	N/A	

(continued)

Table 2.2. *(continued)*





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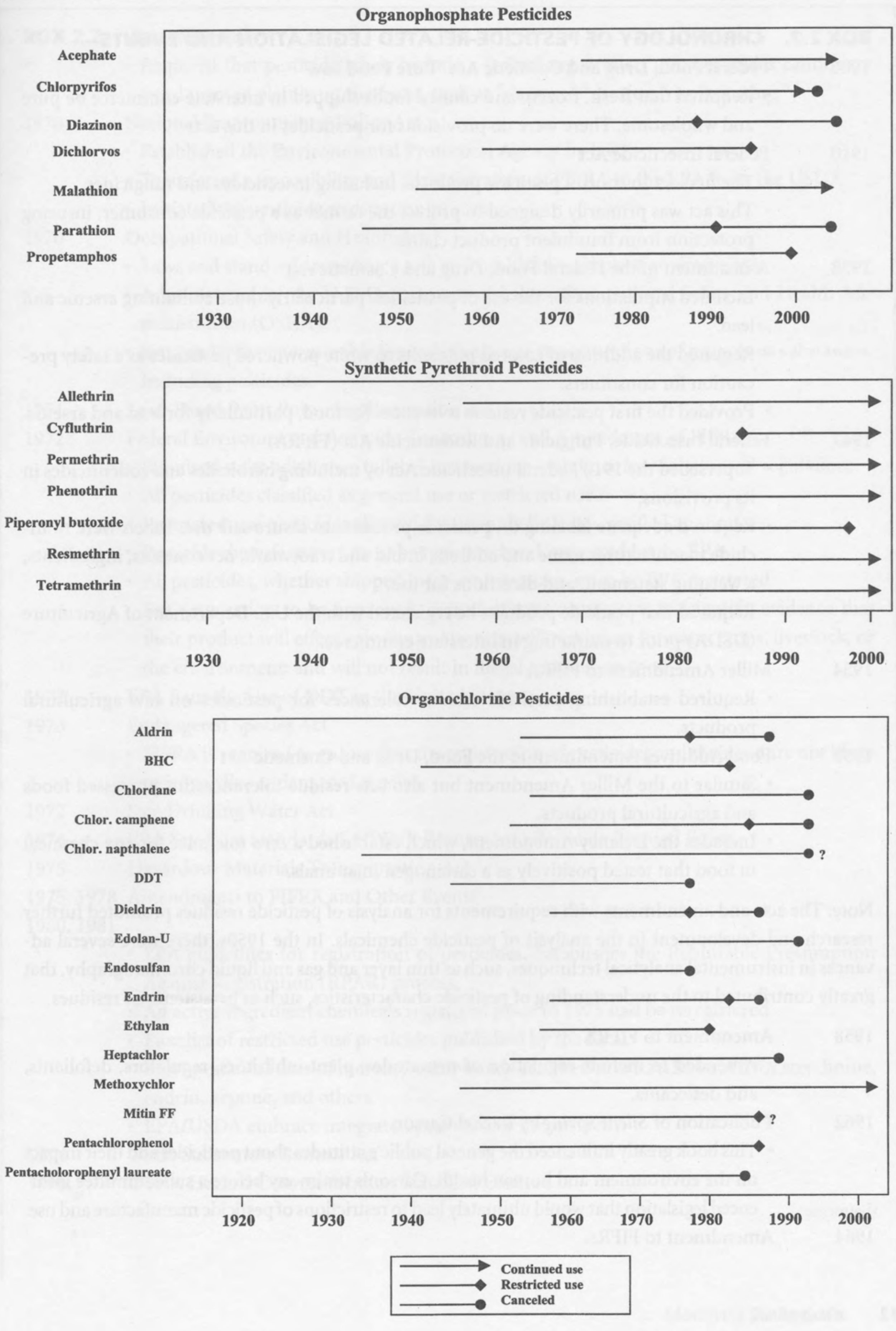

BOX 2.2. CHRONOLOGY OF PESTICIDE-RELATED LEGISLATION AND EVENTS

1906 Federal Food, Drug and Cosmetic Act "Pure Food Law"

- Required that fresh, frozen, and canned foods shipped in interstate commerce be pure and wholesome. There were no provisions for pesticides in this act.

1910 Federal Insecticide Act

- The first act to control pesticide products, including insecticides and fungicides.
- This act was primarily designed to protect the farmer as a pesticide consumer, insuring protection from fraudulent product claims.

1938 Amendment of the Federal Food, Drug and Cosmetic Act

- Included stipulations for the use of pesticides, particularly those containing arsenic and lead.
- Required the addition of colored pigments to white powdered pesticides as a safety precaution for consumers.
- Provided the first pesticide residue tolerances for food, particularly for lead and arsenic.

1947 Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)

- Superseded the 1910 Federal Insecticide Act by including herbicides and rodenticides in its provisions.
- Required adequate labeling on pesticide products to insure safe use. Labels were to include manufacturer name and address, brand and trademark, net contents, ingredients, a warning statement, and directions for use.
- Required that pesticide products be registered with the U.S. Department of Agriculture (USDA) prior to marketing in interstate commerce.

1954 Miller Amendment to FIFRA

- Required establishing pesticide residue tolerances for pesticides on raw agricultural products.

1958 Food Additives Amendment to the Food, Drug and Cosmetic Act

- Similar to the Miller Amendment but also sets residue tolerances for processed foods and agricultural products.
- Includes the Delaney Amendment, which established a zero tolerance for any chemical in food that tested positively as a carcinogen in animals.

Note: The acts and amendments with requirements for analysis of pesticide residues promoted further research and development in the analysis of pesticide chemicals. In the 1950s, there were several advances in instrumental analytical techniques, such as thin layer and gas and liquid chromatography, that greatly contributed to the understanding of pesticide characteristics, such as persistence of residues.

1958 Amendment to FIFRA

- Amended to include regulation of nematodes, plant inhibitors, regulators, defoliants, and desiccants.

1962 Publication of *Silent Spring* by Rachel Carson

- This book greatly influenced the general public's attitudes about pesticides and their impact on the environment and human health. Carson's testimony before a subcommittee influenced legislation that would ultimately lead to restrictions of pesticide manufacture and use.

1964 Amendment to FIFRA

BOX 2.2. *(continued)*

	• Required that pesticide labels include a federal registration number and a cautionary word printed plainly on the front, such as "danger," "caution," or "warning."
1970	National Environmental Policy Act
	• Established the Environmental Protection Agency by law.
	• Transferred responsibility and administration of FIFRA to the EPA from the USDA.
	• Initiated the pesticide registration process.
1970	Occupational Safety and Health Act
	• Laws and standards ensuring a safe and healthful workplace environment.
	• Administered by the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA).
	• Set standards of permissible limits for airborne concentrations of hazardous substances, including pesticides.
1971	Lead-Based Paint Poisoning Prevention Act
1972	Federal Environmental Pesticide Control Act (Full Amendment of FIFRA)
	• Required strict adherence to label instructions with fines for violations of regulations.
	• All pesticides classified as general use or restricted use.
	• Restricted-use pesticides allowed for use only by state-certified applicators.
	• Pesticide manufacturers must be registered and inspected by the EPA.
	• All pesticides, whether shipped inter- or intrastate, must be EPA registered.
	• For registration to be approved, manufacturers must provide scientific evidence that their product will effectively control insects; will not injure humans, crops, livestock, or the environment; and will not result in illegal residues on food.
1972	EPA Bans the Use of DDT in the United States
1973	Endangered Species Act
	• FIFRA is required to ensure that the registration of pesticides and their use are not likely to jeopardize endangered species.
1972	Safe Drinking Water Act
1974	EPA Sets First Standards for Work Reentry into Pesticide-Treated Fields
1975	Hazardous Materials Transportation Act
1975, 1978 1980, 1981	Amendments to FIFRA and Other Events
	• EPA guidelines for registration of pesticides. Establishes the Rebuttable Presumption Against Registration (RPAR) process.
	• All active ingredient chemicals registered prior to 1975 had be reregistered.
	• First list of restricted use pesticides published by the EPA.
	• Most pesticidal uses of mercury compounds canceled and RPARs issued for strychnine, endrin, kepone, and others.
	• EPA/USDA embrace integrated pest management (IPM).
1974	Toxic Substances Control Act
1986	OSHA Hazard Communication Standard Enacted

(continued)

BOX 2.2. *(continued)*

- Provided employees with the "right to know" the hazards and identities of chemicals in the workplace in the industrial sector.
- Required employers to establish hazards communication programs through the use of proper labeling, material safety data sheets, and training programs.

1986 EPA "Right to Know" Act

- Similar to OSHA's above standard but requires employers in almost all facilities that manufacture, use, or store numerous hazardous materials to report the presence of these materials to federal, state, and local authorities.

1986 EPA "RPAR" Process Changed to "Chemicals in Special Review"

1988 Amendment to OSHA Hazard Communication Standard

- Requires all employers with more than one employee, including in the agricultural sector, to comply with the standard. Prior to 1988, the standard had to be met only by employers in the manufacturing/industrial sector.
- If an employee is to be exposed to what is considered a hazardous chemical, then the employer is required to develop a written hazard communication program. Again, this program includes provision of material safety data sheets, a written hazards communications plan, and an employee training program.

1988 Amendment to FIFRA

- Strengthened EPA authority in reregistration fees and other responsibilities in regard to the reregistration process for pesticides.
- All active ingredient chemicals registered prior to November 1984 had be reevaluated according to stricter scientific standards in order to become reregistered in pesticide products.

1990 Pollution Prevention Act

1990 Resource Conservation And Recovery Act (RCRA) Title 40, CFR, Part 261

- Specifies wastes containing certain constituents at or above listed regulatory levels as hazardous. Persons who generate, transport, treat, store, or dispose of solid wastes must decide if their solid waste is hazardous based on the lists provided in this section.

1996 Food Quality Protection Act (FQPA)

- Amends FIFRA and the Food, Drug and Cosmetics Act.
- Mandates a single, health-based standard for all pesticides in all foods; provides special protections for infants and children; expedites approval of safer pesticides; creates incentives for the development and maintenance of effective crop protection tools for American farmers; and requires periodic reevaluation of pesticide registrations and tolerances to ensure that the scientific data supporting pesticide registrations will remain up to date in the future.

Table 2.3. Pesticide Names and Classifications

Common Name	*Chemical Class*	*Chemical Formula*	*CAS #*
Acephate	Organophosphorus	$C_4H_{10}NO_3PS$	30560-19-1
Aldrin	Organochlorine	$C_{12}H_8Cl_6$	309-00-2
Allethrin	Synthetic pyrethroid	$C_{19}H_{26}O_3$	584-79-2
Ammonium fluosilicate	Inorganic	NH_4SiF_6	16919-19-0
Arsenic trioxide, arsenous acid	Inorganic	As_2O_3	1327-53-3
Bendiocarb	Carbamate	$C_{11}H_{13}NO_4$	22781-23-3
Benzene hexachloride	Organochlorine	$C_6H_6Cl_6$	58-89-9
Boric acid	Inorganic	$B(OH)_3$	10043-35-3
Calcium arsenate	Inorganic	$As_2Ca_3O_8$	7778-44-1
Camphor	Botanical	$C_{10}H_{16}O$	76-22-2
Carbaryl	Carbamate	$C_{12}H_{11}NO_2$	63-25-2
Carbofuran	Carbamate	$C_{12}H_{15}NO_3$	1563-66-2
Carbolic acid, hydroxybenzene	Phenol	C_6H_6O	108-95-2
Carbon dioxide, dry ice	Inert gas	CO_2	124-38-9
Carbon disulfide	Misc. fumigant	CS_2	75-15-0
Carbon tetrachloride, perchloromethane	Organochlorine	CCl_4	56-23-5
Chlordane	Organochlorine	$C_{10}H_6Cl_8$	57-74-9
Chlorinated camphene	Organochlorine	$C_{10}H_{10}Cl_8$	8001-35-2
Chlorinated naphthalene	Organochlorine	$C_{10}H_7Cl$	91-58-7
Chloropicrin	Misc. fumigant	CCl_3NO_2	76-06-2
Chlorpyrifos	Organophosphorus	$C_9H_{11}Cl_3NO_3PS$	2921-88-2
Copper acetoarsenite	Inorganic	$C_4H_6As_6Cu_4O_{16}$	12002-03-8
Cryolite	Inorganic	AlF_6Na_3	15096-52-3
Cyfluthrin	Synthetic pyrethroid	$C_{22}H_{18}Cl_2FNO_3$	68359-37-5
Derris, Cube	Botanical	$C_{23}H_{22}O_6$	83-79-4
Diazinon	Organophosphorus	$C_{12}H_{21}N_2O_3PS$	333-41-5
(DDT) Dichloro diphenyl trichlorethane	Organochlorine	$C_{14}H_9Cl_5$	50-29-3
(DDVP) Dichlorvos	Organophosphorus	$C_4H_7Cl_2O_4P$	62-73-7
Dieldrin	Organochlorine	$C_{12}H_8Cl_6O$	60-57-1
Dithiocarbamate	Carbamate	$C_4H_6N_2S_4Zn$	12122-67-7
Edolan-U	Organochlorine	$C_{13}H_6Cl_6NNaO_3S$	69462-14-2
Endosulfan	Organochlorine	$C_9H_6Cl_6O_3S$	115-29-7
Endrin	Organochlorine	$C_{12}H_8Cl_6O$	72-20-8
Ethylan	Organochlorine	$C_{18}H_{20}Cl_2$	72-56-0
Ethylene dibromide	Misc. fumigant	$C_2H_4Br_2$	106-93-4
Ethylene dichloride	Misc. fumigant	$C_2H_4Cl_2$	107-06-2
Ethyl formate, formic acid ethyl ester	Misc. fumigant	$C_3H_6O_2$	109-94-4
Ethylene oxide	Misc. fumigant	C_2H_4O	75-21-8
Formaldehyde, formalin	Misc. fumigant	CH_2O	50-00-0
Heptachlor	Organochlorine	$C_{10}H_5Cl_7$	76-44-8
Hydrogen cyanide, hydrocyanic acid	Misc. fumigant	CHN	74-90-8
Kerosene	Petroleum distillate	C_{10}–C_{16} hydrocarbons	8008-20-6
Lead arsenate	Inorganic	$As_2O_8Pb_3$	7784-40-9
Malathion	Organophosphorus	$C_{10}H_{19}O_6PS_2$	121-75-5
Mercuric chloride	Inorganic	$HgCl_2$	7487-94-7
Methoxychlor	Organochlorine	$C_{16}H_{15}Cl_3O_2$	72-43-5
Methyl bromide	Halogenated hydrocarbon	CH_3Br	74-83-9
Mitin FF	Organochlorine	$C_{19}H_{12}Cl_4N_2O_5S$	3567-25-7
Naphthalene, white tar	Simple hydrocarbon	$C_{10}H_8$	91-20-3
Nicotine	Botanical	$C_{10}H_{14}N_2$	54-11-5
Nitrogen	Inert gas	N_2	7727-37-9
Ortho dichlorobenzene	Halogenated hydrocarbon	$C_6H_4Cl_2$	95-50-1
Ortho phenyl phenol	Phenol	$C_{12}H_{10}O$	90-43-7
Paradichlorobenzene	Halogenated hydrocarbon	$C_6H_4Cl_2$	106-46-7
Parathion	Organophosphorus	$C_{10}H_{14}NO_5PS$	56-38-2
Pentachlorophenol	Organochlorine	C_6HCl_5O	87-86-5
(LPCP) Pentachlorophenyl laureate	Organochlorine	$C_{18}H_{23}O_3$	3772-94-9
Perchloroethylene	Halogenated hydrocarbon	C_2Cl_4	127-18-4
Permethrin	Synthetic pyrethroid	$C_{21}H_{20}Cl_2O_3$	52645-53-1
Phenothrin	Synthetic pyrethroid	$C_{23}H_{26}O_3$	26002-80-2

(continued)

Table 2.3. *(continued)*

Common Name	*Chemical Class*	*Chemical Formula*	*CAS #*
Phosphine	Inorganic	H_3P	7803-51-2
Phosphorus, white	Inorganic	P	7723-14-0
Piperonyl butoxide	Synthetic pyrethroid	$C_{19}H_{30}O_5$	51-03-6
Propargite	Organosulfite	$C_{19}H_{26}O_4S$	2312-35-8
Propetamphos	Organophosphorus	$C_{10}H_{20}NO_4PS$	31218-83-4
Propoxur	Carbamate	$C_{11}H_{15}NO_3$	114-26-1
Pyrethrins	Botanical	(I) $C_{21}H_{28}O_3$; (II) $C_{22}H_{28}O_5$	8003-34-7
Red Squill	Botanical	Natural product	507-60-8
Resmethrin	Synthetic pyrethroid	$C_{22}H_{26}O_3$	10453-86-8
Ryania	Botanical	Natural product extract	15662-33-6
Sabadilla	Botanical	Natural product extract	8051-02-3
Silica gel	Inorganic	SiO_2 amorphous	63231-67-4
Sodium arsenite, arsenous acid	Inorganic	$NaAsO_2$	7784-46-5
Sodium fluoride	Inorganic	NaF	7681-49-4
Sodium fluoroacetate	Inorganic	$C_2H_2FNaO_2$	62-74-8
Sodium fluosilicate	Inorganic	F_6Na_2Si	16893-85-9
Strychnine	Botanical	$C_{21}H_{22}N_2O_2$	57-24-9
Sulfur dioxide, sulfurous anhydride	Misc. fumigant	SO_2	7446-09-5
Sulfuryl flouride	Inorganic fumigant	F_2O_2S	2699-79-8
(TEPP) Tetraethyl pyrophosphate	Misc. fumigant	$C_8H_{20}O_7P_2$	107-49-3
Tetramethrin	Synthetic pyrethroid	$C_{19}H_{25}NO_4$	7696-12-0
Thallium sulfate	Inorganic	O_4STl_2	7446-18-6
Thymol	Phenol	$C_{10}H_{14}O$	89-83-8
Trichloroethylene	Halogenated hydrocarbon	C_2HCl_3	79-01-6
Warfarin	Coumarin	$C_{19}H_{16}O_4$	81-81-2
Zinc hexafluorosilicate	Inorganic	$Zn(SiF_6)$	16871-71-9
Zinc phosphide	Inorganic	P_2Zn_3	1314-84-7

BOX 2.3. PESTICIDES BY TRADE NAME

Registered Trade Name	*Synonym*
Aldrex	*see Aldrin*
Aldrite	*see Aldrin*
Ambush	*see Permethrin*
Antiseptol	*see Resmethrin*
Arko Moth Proof	*see Zinc hexafluorosilicate*
Arrex	*see Zinc phosphide*
Azote	*see Nitrogen*
Baygon	*see Propoxur*
Baythroid	*see Cyfluthrin*
Berlou	*see Zinc hexafluorosilicate*
Bladan	*see Parathion*
Borid	*see Boric acid*
Bromofume	*see Ethylene dibromide*
Bromogas	*see Methyl bromide*
Buhach	*see Pyrethrins*
Butacide	*see Piperonyl butoxide*
Carboxide	*see Ethylene oxide*
Celfume	*see Methyl bromide*
Chlorobenzilate	*see Ortho dichlorobenzene*
Chlor-o-pic	*see Chloropicrin*
Comite	*see Propargite*
Compound 1080	*see Sodium fluoroacetate*
Corrosive sublimate	*see Mercuric chloride*
Cyanogas	*see Hydrocyanic gas*
Cyclon	*see Hydrocyanic gas*
Cythion	*see Malathion*
D-Con	*see Warfarin*
Dethdiet	*see Red Squill*
Dethmor	*see Warfarin*
Dieldrex	*see Dieldrin*
Dowcide 1	*see Ortho phenyl phenol*
Dowfume 75	*see Ethylene dichloride*
Dowicide	*see Pentachlorophenol*
Drax Ant Kill	*see Boric acid*
Dri-Die	*see Silica gel and Ammonium fluosilicate*
Drinox	*see Heptachlor*
Drione	*see Silica gel and Ammonium fluosilicate*
Durotex 7665	*see Pentachlorophenyl laureate, LPCP*
Dursban	*see Chlorpyrifos*
Ectiban	*see Permethrin*

(continued)

BOX 2.3. *(continued)*

Emerald green	*see Copper acetoarsenite*
Endosulfan	*see Endosulfan*
Endrex	*see Endrin*
Ethoxy 12	*see Ethylene oxide*
Eulan-U-33	*see Edolan-U*
Ficam	*see Bendiocarb*
Florocid	*see Sodium fluoride*
Furadan	*see Carbofuran*
Gastoxin	*see Phosphine*
Gesarol	*see DDT*
Gypsine	*see Lead arsenate*
IMPC	*see Propoxur*
Intracide	*see Mitin FF*
Invisi-Gard	*see Propoxur*
It Works	*see Boric acid*
J-O Paste	*see White phosphorus*
Killmaster	*see Chlorpyrifos*
Knox-Out	*see Diazinon*
Kryocide	*see Cryolite*
Kwell	*see Benzene hexachloride*
Kwik-kil	*see Strychnine*
Larvacide	*see Chloropicrin*
Registered Trade Name	*Synonym*
Larvex	*see Sodium fluosilicate*
Lindane	*see Benzene hexachloride*
Lorsban	*see Chlorpyrifos*
Makr carbon dioxide	*see Carbon dioxide*
Malacide	*see Malathion*
Malaspray	*see Malathion*
Marlate	*see Methoxychlor*
Methyl Fume	*see Methyl bromide*
Mop-up	*see Boric acid*
Moth-X	*see Perchlorethylene*
Mystox	*see Pentachlorophenyl laureate, LPCP*
Niran	*see Parathion*
No-Pest Strip	*see Dichlorvos*
Noviguard	*see Carbolic acid*
Octalox	*see Dieldrin*
Omite	*see Propargite*
Orthene	*see Acephate*
Ortho-chlor	*see Chlordane*
Oxyfume	*see Ethylene oxide*

BOX 2.3. *(continued)*

Paracide	*see Paradichlorobenzene*
Paris green	*see Copper acetoarsenite*
PDB	*see Paradichlorobenzene*
Penta	*see Pentachlorophenol*
Permacide	*see Resmethrin*
PermaDust	*see Silica gel*
Permagard	*see Pentachlorophenol*
Perthane	*see Ethylan*
Phostoxin	*see Phosphine*
PMD-77	*see Trichloroethylene*
Pounce	*see Permethrin*
Prokil	*see Cryolite*
Pynamin	*see Allethrin*
Pyrenone	*see Piperonyl butoxide*
Pyrinex	*see Piperonyl butoxide*
Raid Flying Insect Killer	*see Resmethrin*
Raid Moth Proofer	*see Ethylan*
Raid Roach & Ant Killer	*see Tetramethrin*
Ratox	*see Thallium sulfate*
Ridall-Z	*see Zinc phosphide*
Rodex	*see Strychnine*
Rodine	*see Red Squill*
Rotenone	*see Derris*
Safrotin	*see Propetamphos*
Sevin	*see Carbaryl*
Sibur	*see Sodium arsenite*
Spartan	*see Piperonyl butoxide*
Spectracide	*see Diazinon*
Strobane-T	*see Chlorinated camphene*
Sulcofuron	*see Mitin FF*
Sumithrin	*see Phenothrin*
Sure Roach Powder	*see Silica gel and Ammonium fluosilicate*
Tempo	*see Cyfluthrin*
Teratone	*see TEPP*
Torsite	*see Ortho phenyl phenol*
Toxaphene	*see Chlorinated camphene*
Turcam	*see Bendiocarb*
Vapatone	*see TEPP*
Vapona	*see DDVP*
Vaponite	*see DDVP*
Vikane	*see Sulfuryl fluoride*

(continued)

BOX 2.3. *(continued)*

White arsenic	*see Arsenic trioxide*
Whitmire PT-100	*see Resmethrin*
Xylamon	*see Chlorinated naphthalene*
Zineb	*see Dithiocarbamate*
Zoecon	*see Propetamphos*

BOX 2.4. PESTICIDE ABBREVIATIONS

ai	active ingredient
ATSDR	Agency for the Toxic Substances and Disease Registry
CAS	Chemical Abstract Service
CNS	central nervous system. The part of the nervous system that includes the brain and the spinal cord.
EPA	U.S. Environmental Protection Agency
FAO/WHO	Food and Agriculture Organization/World Health Organization
FDA	Food and Drug Administration
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
FFDCA	Federal Food, Drug and Cosmetic Act
FQPA	Food Quality Protection Act
μg/g	micrograms per gram
μg/L	micrograms per liter
GLC	gas liquid chromatography
HDT	highest dose tested
LC50	median lethal concentration. A statistically derived concentration of a substance that can be expected to cause death in 50% of test animals. It is usually expressed as the weight of substance per weight or volume of water, air, or feed, such as mg/I, mg/kg, or ppm.
LD50	median lethal dose. A statistically derived single dose that can be expected to cause death in 50% of the test animals when administered by the route indicated (oral, dermal, inhalation). It is expressed as a weight of substance per unit weight of animal, such as mg/kg.
LDLo	lethal dose—low. Lowest dose at which lethality occurs.
mg/L	milligrams per liter
N/A	not applicable or not available
NOAEL	no-observed-adverse-effects Level
OP	organophosphate
OPP	Office of Pesticide Programs
PAM	pesticide analytical method
PEL	permissible exposure limit
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
Q1*	carcinogenic potential of a compound. Quantified by the EPA's Cancer Risk Model.
RED	reregistration eligibility decision
RfD	reference dose
RS	registration standard
RUP	restricted-use pesticide
STEL	short-term exposure limits
TC	toxic concentration. The concentration at which a substance produces a toxic effect.
TD	toxic dose. The dose at which a substance produces a toxic effect.
TLC	thin-layer chromatography
TLV	threshold limit value
TWA	time-weighted average
WP	wettable powder