THE EFFECT OF IRRADIATION WITH ULTRAVIOLET LIGHT ON CHLORINATED HYDROCARBON INSECTICIDES: A REVIEW

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INTRODUCTION

Pesticide chemists have recognized since the 1940's that ultraviolet light was deleterious to the insecticidal properties of certain compounds. However, it has been only within the last 15 years that a number of photodecomposition products of the chlorinated hydrocarbon insecticides have been isolated and identified. The degradation of insecticides by ultraviolet light may result in products which are more or less toxic than the parent compounds. This implies that photodecomposition of insecticides may in certain cases increase residual toxicities. Thus, this subject should be of vital concern to all persons involved in the use of insecticidal chemicals. This paper summarizes a number of published reports concerning the photodecomposition of chlorinated hydrocarbon insecticides.

PHOTODEGRADATION OF DDT AND ITS ANALOGS

Much of the work on the ultraviolet degradation of DDT (2,2-Bis-(p-chlorophenyl)-1,1,1-trichloroethane) (Compound I, Figure I) was done between 1940 and 1950. Fleck and Haller (1945), active workers during this time, first reported that DDT was apparently relatively

stable to ultraviolet rays. They found that irradiation of a thin film of DDT for 35 hours caused the melting point of the resulting material to be lowered by only 2°C. This would imply that the material remaining in the film was relatively pure DDT since small amounts of an impurity generally depress melting points considerably. They also reported that no change was observed in DDT after exposure to sunlight for over a year in an alcoholic solution. Lindquist et al (1946) showed, however, that the effectiveness of DDT against houseflies was reduced by exposure to ultraviolet light in the laboratory or sunlight. They also concluded that DDT is more rapidly decomposed in certain organic solutions than as a solid deposit. Wichmann et al (1946) reported that neither DDT nor DDE (4,4'-dichlorodiphenyldichloro-ethylene) (Compound II, Figure I) were decomposed when irradiated in their crystalline state. In a benzene solution, however, 50% of the DDT was degraded in a few hours, and DDE was degraded even more rapidly. Wichmann's group also isolated p,p'-dichlorobenzophenone (Compound III, Figure I) as its 2,4-dinitrophenylhydrazone derivative from the irradiation products of DDT. The production of this phenone was later confirmed by Fleck (1948). Wichmann et al reported that the isolated ketone was apparently stable to ultraviolet light. They concluded from volatility and exposure tests, that the ultraviolet decomposition products of DDT are more volatile than the parent com-pound and are removed nearly as fast as they are formed under normal field conditions. This theory was further substantiated in a two-year study by Fahey and Rusk (1947). The hypothesis of Wichmann et al may

explain why several investigators (Lindquist et al, 1946; Vendramini, 1947; Sazonov and Andreev, 1949; Gunther, 1945; Srivastava et al, 1955; Blackith, 1952; and Hadaway and Barlow, 1949) found decreased effectiveness of DDT following exposure to artificial ultraviolet light or sunlight. If the degradation products are volatilized very quickly, then the data of these workers fail to reveal the possible toxicity of the degradation products themselves.

Other possible degradation compounds of irradiated DDT are: 2,3-dichloro-1,1,1-tetrakis-(p-chlorophenyl)-2-butene (Fleck, 1949) (Compound IV, Figure I), and DDE (Roburn, 1963). From existing data it is possible to derive a scheme for the ultraviolet degradation of DDT as shown in Figure I. Reaction (A) is the result of Fleck's investigations (1949) and according to that author requires the presence of a solvent which acts as a chlorine acceptor. Reaction (B) has been observed by Wichmann et al (1946) and Fleck (1946), while reactions (C), (D), and (E) have been reported by Roburn (1963). Harrison et al (1967) reported the formation of DDD via Route (F). Gas chromatographic patterns of the degradation products of DDT irradiated in hexane indicate that Route (G) may also exist (Banks and Bills, 1968).

Although the proposed scheme may not be considered complete or conclusive, it does show the complexity of the ultraviolet degradation of DDT.

Other workers who have observed ultraviolet light induced degradation of DDT, but have not identified breakdown products or

studied toxicity effects, are Li and Bradley (1967) and Mitchell (1961).

Fleck (1949) reported that DDD (2,2,-Bis-(p-chlorophenyl)-1,1-dichloroethane) (Compound V, Figure I) was not altered by ultraviolet light. However, since that time Mitchell (1961), Roburn (1963) and Banks and Bills (1968) have shown that DDD is degraded at a rate much slower than DDT or DDE. The fast rate of degradation for DDE first observed by Wichmann et al (1946) has also been observed by Mitchell (1961) and Banks and Bills (1968).

It should be pointed out that most investigators who have studied the effects of ultraviolet light on DDT and its analogs, have not carefully described the amounts of energy nor the wavelengths produced by the light sources used in their experiments. Variations in the ultraviolet light sources could easily account for deviations in results that have been observed by different laboratories. Also, as has been reported by Sazonov and Andreev (1949), the amount of degradation of DDT by sunlight is decreased by haze, dust and water vapor present in the air. Obviously, the intensity of sunlight itself will vary with the geographic location and the date.

PHOTODEGRADATION OF DIELDRIN, ALDRIN, ENDRIN AND ISODRIN

In his extensive investigation of the effect of ultraviolet light on pesticide chemicals, Mitchell (1961) reported on the photo-decomposition of the aldrin (1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4-endo-exo-5,8-dimethanonaphthalene) (Compound I, Figure

II) family of insecticides. Upon irradiation he found that aldrin and

dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-

octahydro-1,4-endo-exo-5,8-dimethanonaphthalene) were extensively

decomposed, and endrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,

7,8,8a-octahydro-1,4-endo-exo-5,8-dimethanonaphthalene) (Compound I,

Figure IV) was substantially degraded. In the same year Bird et al

(1961) presented evidence to show that isodrin (1,2,3,4,10,10-

hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-endo-endo-dimethanonapthalene)

was converted to a cage compound (Figure III) when irradiated with a

mercury arc.

Dieldrin: Roburn (1963) reported the presence of an unknown compound

on grass which had been treated with dieldrin and exposed to sunlight.

He showed that the same compound could be produced by the ultraviolet

irradiation of a thin film of dieldrin on a glass plate. By irradi-

ating solutions of dieldrin or thin layers of dieldrin on filter paper

at a wavelength of 2537 $\overset{\circ}{A}$, Robinson et al (1966) obtained a degradation

product which exhibited chromatographic properties similar to those of

the derivative observed by Roburn. Robinson and co-workers tentatively

concluded that the structure of the conversion product was a hexacyclo

isomer (10-oxa-3,6-exo-4,5,13,13-hexachlorohexacyclo($6.3.1.1^{3,6}.1^{9.11}$

$.0^{2,7}.0^{5,12}$)tridecane) as shown in Figure II, Compound III. In a

report which appeared at the same time as that of Robinson et al, the

identity of this isomer was confirmed by Rosen et al (1966). Rosen

and co-workers also confirmed Roburn's (1963) observation that the

same photodecomposition product was formed upon exposure of dieldrin

to sunlight or artificial irradiation at a wavelength of 2537 Å.
Harrison et al (1967) reported on field irradiation and laboratory
irradiation of dieldrin. When dieldrin was applied in the field in
solutions of 0.2%, four conversion products were detected by gas
liquid chromatography (GLC); three of the products were found to have
GLC retention times identical to those of compounds produced by the
ultraviolet irradiation of pure dieldrin at 2540 Å wavelength in the
laboratory. Following irradiation in the field or in the laboratory,
the product present in the largest amount behaved similarly on silicone
GLC columns to the hexacyclo isomer reported by Roburn and identified
by Robinson and Rosen. Harrison proposed that this primary product
was Compound I of Figure V which could exist in several isomeric
forms. This derivative is the same as the one reported by Rosen and
Robinson except for a shift of the epoxide linkage.

When a dilute solution of dieldrin in hexane was irradiated at
a wavelength of 2537 Å, Henderson and Crosby (1967) reported that
dieldrin was converted to a single degradation product which differed
from the hexacyclo compound previously reported. They identified this
product as a pentachloro derivative of dieldrin (Compound II, Figure
V). When dieldrin was exposed to sunlight, they found it was con-
verted only to the hexacyclo derivative. Conversely, when dieldrin
treated leaves were exposed to ultraviolet light of 2537 Å wavelength
in the laboratory, there was considerable conversion to the pentachloro
derivative. To simulate field conditions of irradiation in the
presence of a hydrocarbon solvent, a hexane solution of dieldrin was

irradiated with light of varying wavelengths between 2500 and 3000 Å.

Under these conditions, the hexacyclo compound was not formed, and the

pentachloro derivative was produced only at wavelengths less than

2600 Å. These results seemingly contradict those of Robinson et al

(1966), Rosen et al (1966) and Harrison et al (1967). Henderson and

Crosby explained this diversity by indicating that the hexacyclo

compound had always been obtained under conditions of high concentra-

tion which they assumed would favor the intramolecular reaction

between carbon 2 and the closely adjacent hydrogens of the methylene

bridge. They also concluded that in dilute solutions of a solvent,

such as hexane, which can act as a hydrogen donor, the replacement by

hydrogen of one chlorine atom bonded to one of the carbon atoms

involved in the carbon-to-carbon double bond appears to predominate.

Banks and Bills (1968) added support to the latter conclusion when

they irradiated hexane solutions of dieldrin ranging in concentration

from 0.2 to 10.0 ppm and found a single degradation product which had

GLC characteristics very similar to those of the pentachloro derivative

described by Henderson and Crosby (1967). It is doubtful that all of

the parameters influencing the production of either derivative are well

enough known at this time to permit a complete explanation of the

various observations.

There is evidence to show that the photodecomposition products

of dieldrin are more toxic than the parent compound. Rosen et al (1966)

tested the hexacyclo derivative against adult houseflies, Musca

domestica, and larval mosquitoes, Aedes aegypti. They found that the

derivative was approximately two times more toxic to these species than dieldrin. In addition, the derivative produced a much faster toxic response in houseflies. In a later study, Rosen and Sutherland (1967) reported that the toxicity of the degradation compound against Musca domestica was not as great as first reported, but that it was faster acting than dieldrin. They also showed evidence that the compound was two to four times more toxic to male mice than dieldrin. Harrison et al (1967) reported that the isomer they had isolated (Compound I, Figure V) exhibited mammalian toxicity similar to that of dieldrin. Henderson and Crosby (1967) found the pentachloro derivative to be only 60% as effective as dieldrin against Musca domestica, but about five times more toxic to mice.

Robinson et al (1966) has conducted a survey of the occurrence of the hexacyclo derivative of dieldrin under natural conditions. He concluded that the compound occurs in very small amounts, if at all, in the environment. None of the isomer was found in the pooled body fat of ten people.

Aldrin: Mitchell (1961) found that aldrin on paper chromatograms was converted to three compounds when exposed to ultraviolet light. From GLC data, Roburn (1963) later reported that thin films of aldrin on glass plates were converted chiefly to dieldrin plus a smaller amount of an unknown substance. In field trials, Harrison et al (1967) also found a conversion of aldrin to dieldrin and one unknown substance. The unknown compound had the same GLC retention times as the

photodecomposition product of dieldrin which he isolated. Rosen and
Sutherland (1967) confirmed these findings and isolated a rearranged
aldrin isomer (Compound IV, Figure II). They exposed aldrin, in
carbon tetrachloride, to sunlight and identified the four compounds
shown in Figure II. Furthermore, they noted a large amount of an
unidentified polymeric material. In addition to the scheme shown in
Figure II, the authors theorized that the aldrin isomer (Compound IV,
Figure II) might be converted to the dieldrin hexacyclo isomer (Com-
pound III, Figure II). However, they did not observe such a reaction
when the aldrin isomer was exposed to ultraviolet light in the
laboratory. Henderson and Crosby (1967) obtained a pentachloro
derivative (Compound III, Figure V) when a hexane solution of aldrin
was irradiated at a wavelength of 2537 $\overset{\circ}{A}$. The production of this
compound is completely analogous to the production of the pentachloro
derivative of dieldrin. It occurs only when the wavelength of the
light is below 2600 $\overset{\circ}{A}$ and the parent compound is present in a dilute
solution of a hydrogen donor solvent. Banks and Bills (1968) obtained
similar results based on GLC data.

Rosen and Sutherland (1967) found the rearranged aldrin
degradation product to be approximately two times as toxic as aldrin
against Musca domestica in 24 hours exposures. In 48 hour exposure
tests, the two compounds were nearly equal in toxicity. This suggests
that the aldrin isomer is faster acting in houseflies rather than
being more toxic. These authors also reported that the polymeric
material obtained by exposing aldrin in carbon tetrachloride to

sunlight was only about 2.5% as toxic to houseflies as aldrin.

Endrin: Mitchell (1961, 1962) showed that endrin was degraded upon irradiation with ultraviolet light to yield at least two new compounds. He also found that these degradation compounds were different than the products obtained when dieldrin was irradiated. From a study of the decomposition of endrin during GLC analysis, Phillips et al (1962) presented a scheme for its heat induced degradation (Figure IV). When endrin was irradiated with ultraviolet light, Rosen et al (1966) reported its conversion to two compounds, an aldehyde and a ketone (Compounds II and III, Figure IV). These degradation products are the same as those formed in Routes A and C of the scheme of Phillips et al (Figure IV). Harrison et al (1967) also has reported formation of the aldehyde and ketone under field conditions.

From existing evidence, the decomposition products of endrin appear to have little, if any, toxicity. Phillips et al (1962) tested the aldehyde against eight insects and found it to be non-toxic. Against male mice the compound had an acute LD_{50} greater than 500 mg per kilogram. Rosen et al (1966) reported that both the aldehyde and ketone were non-toxic to adult houseflies and larval mosquitoes.

PHOTODEGRADATION OF BHC AND OTHER CHLORINATED HYDROCARBON INSECTICIDES

Although 14 stereoisomers of BHC (1,2,3,4,5,6-hexachlorocyclo-hexane) are known, only lindane, the gamma isomer, (Figure VI) displays an appreciable degree of insecticidal activity. There seems to be good evidence that none of the isomers of BHC which have been

investigated are degraded by ultraviolet light. These results could

be expected since the molecule has no unsaturated bonds to absorb

light of wavelengths of 2500 Å and above. Blackith (1952) irradiated

the pure gamma isomer of BHC on filter paper and found no decrease in

its insecticidal capacity. When Klosa (1953) irradiated the alpha,

beta, gamma, and delta isomers of BHC with ultraviolet light at

elevated temperatures and in the presence of heavy metal catalysts,

he observed neither degradation nor conversion of one isomer to

another. Neither Mitchell (1961) nor Roburn (1963) observed any

degradation when solid deposits of all four of the above BHC isomers

were irradiated. Since then, Banks and Bills (1968a) have observed no

decomposition of the pure gamma isomer when irradiated in hexane

solution.

The photodecomposition of other chlorinated hydrocarbon

insecticides has not received as much attention as those previously

discussed. Although a few investigators have noted that other com-

pounds are degraded, there have been no reports of identification of

degradation products or of the changes in toxicity upon irradiation.

When pesticides were irradiated on paper chromatograms, Mitchell

(1961) observed extensive decomposition of methoxychlor (2,2-Bis-

(p-methoxyphenol)-1,1,1-trichloroethane), heptachlor (1,4,5,6,7,8,8-

heptachloro-2,3-epoxy-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene) and

heptachlor epoxide (1,4,5,6,7,8,7-heptachloro-2,3-epoxy-2,3,3a,4,7,7a-

hexahydro-4,7-methanoindene). Banks and Bills (1968) also observed

degradation of heptachlor and heptachlor epoxide when these compounds

were irradiated in hexane solution.

POSSIBLE USES OF ULTRAVIOLET DEGRADATION

Although the photodecomposition of insecticides under field conditions may be detrimental to insecticidal activity, some reports have dealt with the possible usefulness of ultraviolet degradation. Mitchell (1962) found that dieldrin and endrin could not be readily separated by paper chromatography. However, by exposing the spotted chromatograms to a germicidal ultraviolet lamp and chromatographing the degradation products, the two compounds could be easily distinquished. The method was applicable for the two pesticides alone or in mixtures. Banks and Bills (1968) have presented a GLC method for confirming residue identities. The technique involves comparison of standards and unknowns before and after irradiation with ultraviolet light. They found that some of the chlorinated hydrocarbon insecticides yield characteristic degradation patterns that can be observed by electron-capture GLC. These authors also determined the p-values (Beroza and Bowman, 1965) of the major degradation products.

Li and Bradley (1967) have described a method for removing insecticides from milk by decomposing them with ultraviolet light. When they irradiated thin films of milk or milk fat flowing over a surface cooler, they found substantial decreases in the parent compounds. However, they did not consider the possible toxicities of degradation products that were formed.

SUMMARY

Substantial evidence has been accumulated to demonstrate that many of the insecticides classed as chlorinated hydrocarbons are degraded by ultraviolet light. Degradation of certain compounds by sunlight in the field and by artificial ultraviolet light in the laboratory has been observed. Much of the work, however, has been carried out under ill-defined experimental conditions which have led to confusion concerning the products of such photochemical reactions. Future workers should strive to record more carefully such parameters as wavelength of light, intensity of light, irradiation time, and concentration of insecticide being irradiated.

The photochemical degradation of insecticides under field conditions is significant for several reasons. The products of degradation may be more or less toxic than the original compound; degradation products are frequently more volatile and are more easily removed from the site of application; and degradation products of toxicological significance may go undetected during an analysis for the parent compound.

It now seems reasonably conclusive that a solvent such as hexane can participate in the photochemical reaction of compounds such as dieldrin and aldrin under certain laboratory conditions. In such cases, the solvent apparently supplies the hydrogen atom which replaces the chlorine atom at the double bond position of the insecticide. Because sunlight provides insufficient irradiation of the wavelengths required for this reaction, there is reason to doubt that the reaction

1 is significant under field conditions.

2   Irradiation of certain insecticides in solution in the

3 laboratory, however, may prove to be a very useful tool for identifi-

4 cation purposes. Irradiation in solution can be controlled more

5 precisely and is thus more readily reproducible than irradiation of

6 crystals or films. A number of chlorinated hydrocarbon insecticides

7 have been shown to yield characteristic degradation patterns under

8 controlled conditions. Such degradation patterns provide a means of

9 identifying certain insecticides at low concentrations for which

10 other identification methods are not applicable.

REFERENCES

Banks, K. A. and D. D. Bills. 1968. Gas Chromatographic Identification of Chlorinated Insecticides Based on Their U.V. Degradation. J. Chromatog. 33:450-455.

Banks, K. A. and D. D. Bills. 1968a. Unpublished data.

Beroza, M. and M. C. Bowman. 1965. Identification of Pesticides at Nanogram Level by Extraction p-Values. Anal. Chem. 37:291-292.

Bird, C. W., R. C. Cookson and E. Crundwell. 1961. Cyclizations and Rearrangements in the Isodrin-aldrin Series. J. Chem. Soc. 4809.

Blackith, R. E. 1952. Stability of Contact Insecticides. III. Allethrin, DDT and BHC in Ultraviolet Light. J. Sci. Food Agr. 3:482-487.

Fahey, J. E. and H. W. Rusk. 1947. Ratio of Labile Chlorine to Total Chlorine in DDT Spray Residue Deposits in Northern Indiana Apple Orchards. J. Assoc. Offic. Agr. Chemists. 30:349-354.

Fleck, E. E. and H. L. Haller. 1945. Compatibility of DDT with Insecticides, Fungicides and Fertilizers. Ind. Eng. Chem. 37:403-405.

Fleck, E. E. 1948. Residual Action of Organic Insecticides. Ind. Eng. Chem. 40:706-708.

Fleck, E. E. 1949. The Action of Ultraviolet Light on DDT. J. Am. Chem. Soc. 71:1034-1036.

Gunther, F. A., D. L. Lindgren, M. I. Elliot and J. P. LaDue. 1946.
Persistence of Certain DDT Deposits Under Field Conditions.
J. Econ. Entomol. 39:624.

Hadaway, A. B. and F. Barlow. 1949. Further Studies on the Loss of
Insecticides by Absorption into Mud and Vegetation. Bull.
Entomol. Res. 40:323.

Harrison, R. B., D. C. Holmes, J. Roburn and J. O. Tatton. 1967.
The Fate of Some Organochlorine Pesticides on Leaves. J. Sci.
Food Agr. 18:10-15.

Henderson, G. L. and D. G. Crosby. 1967. Photodecomposition of
Dieldrin and Aldrin. J. Agr. Food Chem. 15:888-893.

Klosa, J. 1953. Stability of Gammexene. Arch Pharm. 286:216-217.
(Chem. Abst. 48:4265, 1954).

Li, C. F. and R. L. Bradley Jr. 1967. Degradation of Chlorinated
Hydrocarbons in Fluid Milk Systems by Ultraviolet Light. J.
Dairy Sci. 50:944. (Abst.)

Lindquist, A. W., H. A. Jones and A. H. Madden. 1946. DDT Residual-
type Sprays as Affected by Light. J. Econ. Entomol. 39:55-59.

Mitchell, L. C. 1961. The Effect of Ultraviolet Light (2537 A) on
141 Pesticide Chemicals by Paper Chromatography. J. Assoc.
Offic. Agr. Chemists. 44:643-712.

Mitchell, L. C. 1962. Identification and Differentiation of Dieldrin
and Endrin by Paper Chromatography. J. Assoc. Offic. Agr.
Chemists. 45:682-688.

Phillips, D. D., G. E. Pollard and S. B. Soloway. 1962. Thermal Isomerization of Endrin and Its Behavior in Gas Chromatography. J. Agr. Food Chem. 10:217-221.

Robinson, J., A. Richardson and B. Bush. 1966. A Photoisomerization Product of Dieldrin. Bull. Environ. Contam. Toxicol. 1:127-132.

Roburn, J. 1963. Effect of Sunlight and Ultraviolet Radiation on Chlorinated Pesticide Residues. Chem. Ind. 38:1555-1556.

Rosen, J. D., D. J. Sutherland and G. R. Lipton. 1966. The Photochemical Isomerization of Dieldrin and Endrin and Effects on Toxicity. Bull. Environ. Contam. Toxicol. 1:133-140.

Rosen, J. D. and D. J. Sutherland. 1967. The Nature and Toxicity of the Photoconversion Products of Aldrin. Bull. Environ. Contam. Toxicol. 1:1-9.

Sazonov, P. V. and S. W. Andreev. 1949. Factors that Decrease the Efficiency of DDT and Similar Compounds. Boklady Vsesoyuz Akad. Sel'sko-Khoz. Nauk im. V. I. Lenina. 7:44-48. (Chem. Abst. 44:1638, 1950).

Srivastava, R. S. and A. K. Chakrabarti. 1955. Study of Chemical and Photodynamic Deterioration of DDT when Applied to Solid Surfaces. Indian J. Malariol. 9:27-35.

Vendramini, R. 1947. DDT Inactivation by Light. Boll. Soc. Med. - Chir. Modena. 47:259-266. (Chem. Abst. 43:7183, 1949).

Wichmann, H. J., W. I. Patterson, P. A. Clifford, A. K. Klein and H. V. Claborn. 1946. Decomposition and Volatility of DDT and Some of Its Derivatives. J. Assoc. Offic. Agr. Chemists. 29:218-233.
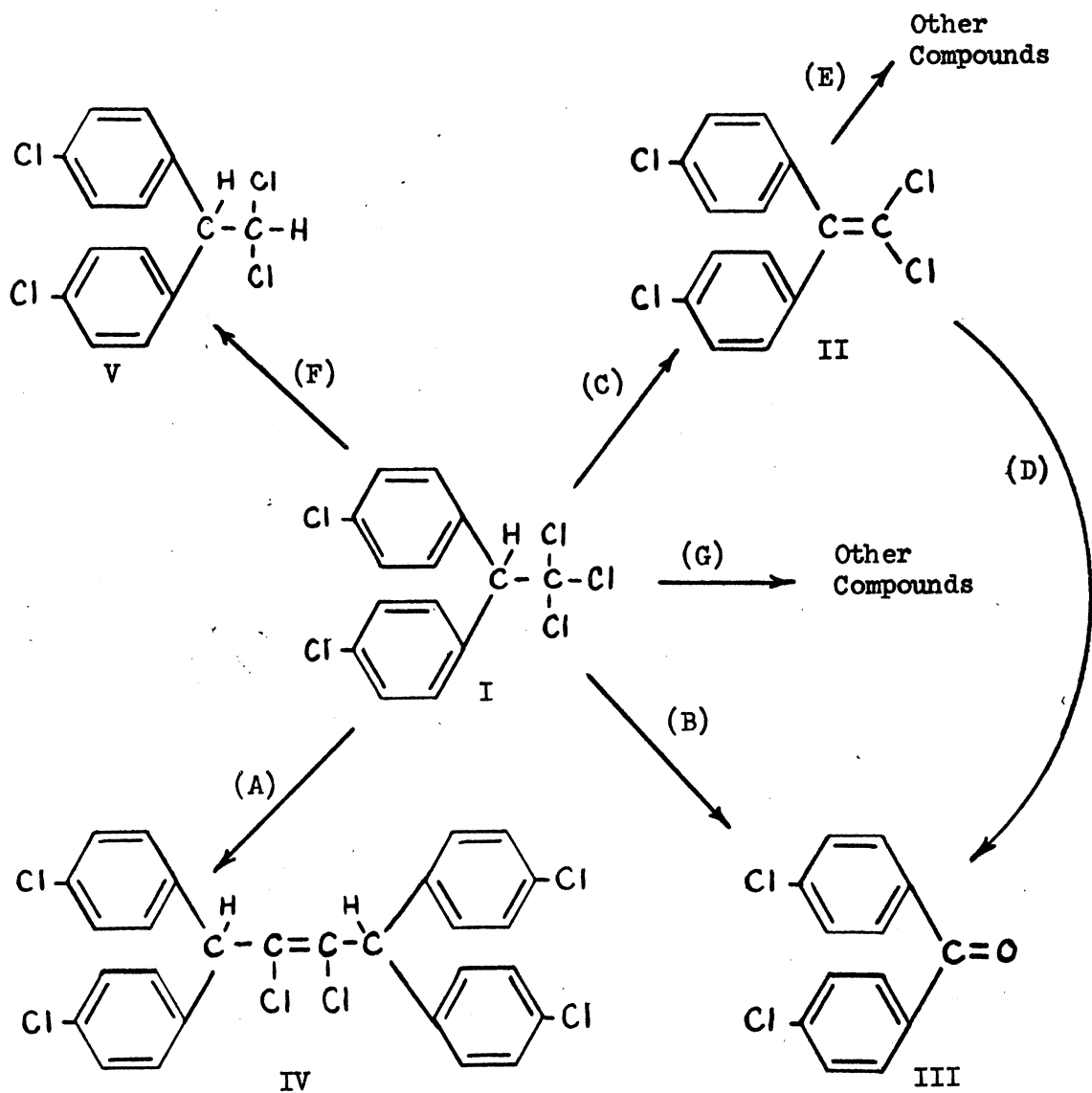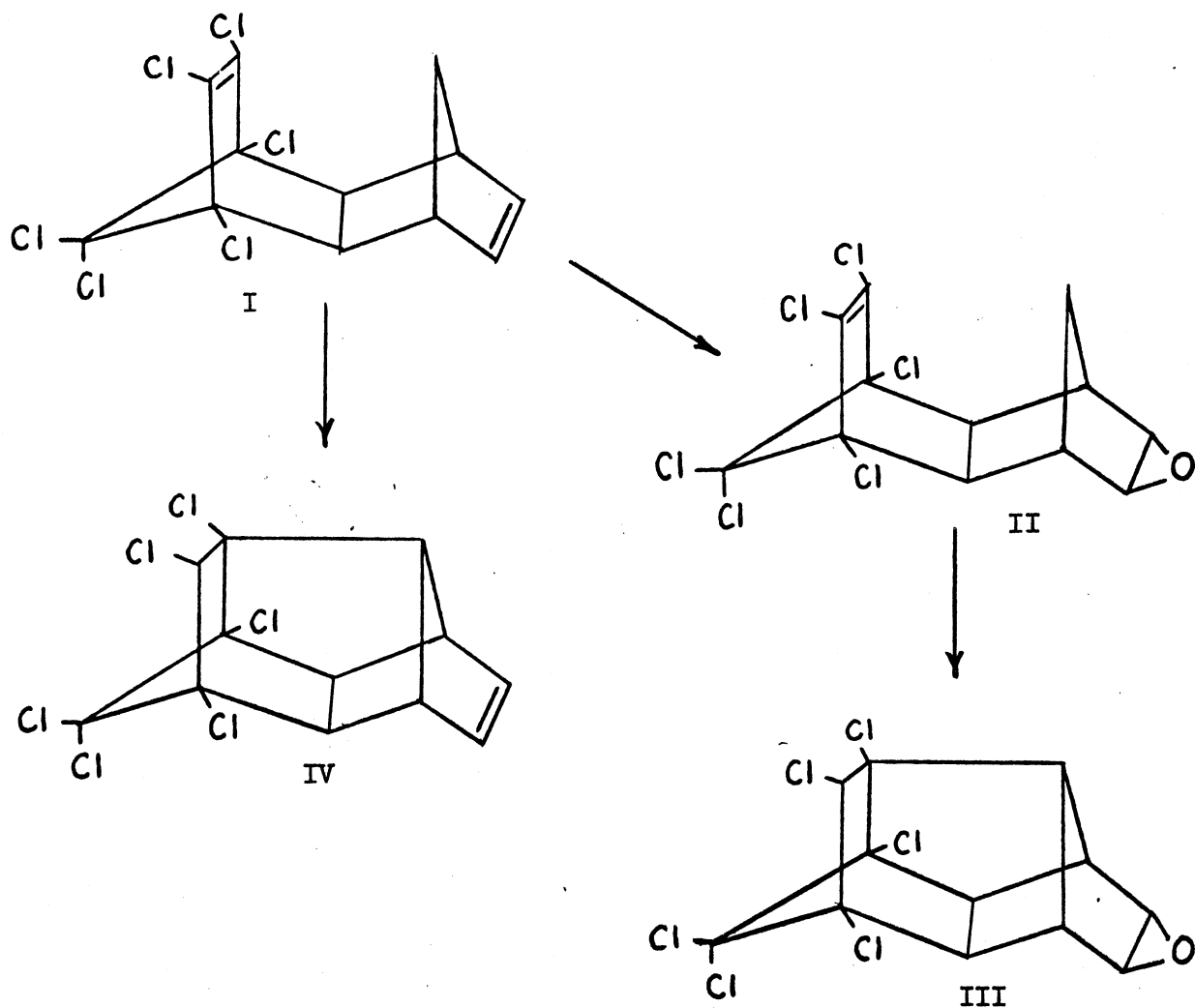
I   = DDT

II = DDE

III = 4,4'-p-dichlorobenzophenone

IV = 2,3-dichloro-1,1,4,4-tetrakis-(p-chlorophenyl)-2-butene

V   = DDD

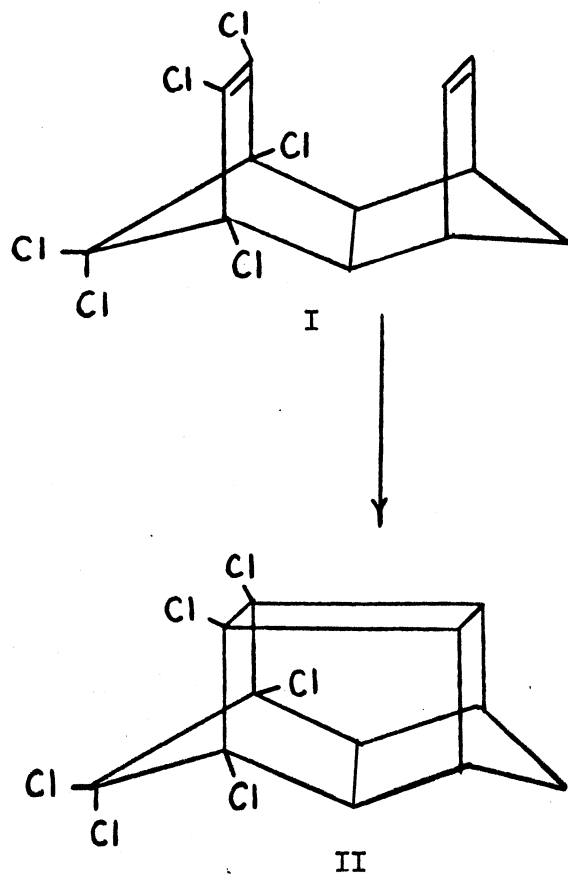FIGURE I. Degradation of DDT by Ultraviolet Light

I = Aldrin

II = Dieldrin

III = Hexacyclo dieldrin isomer
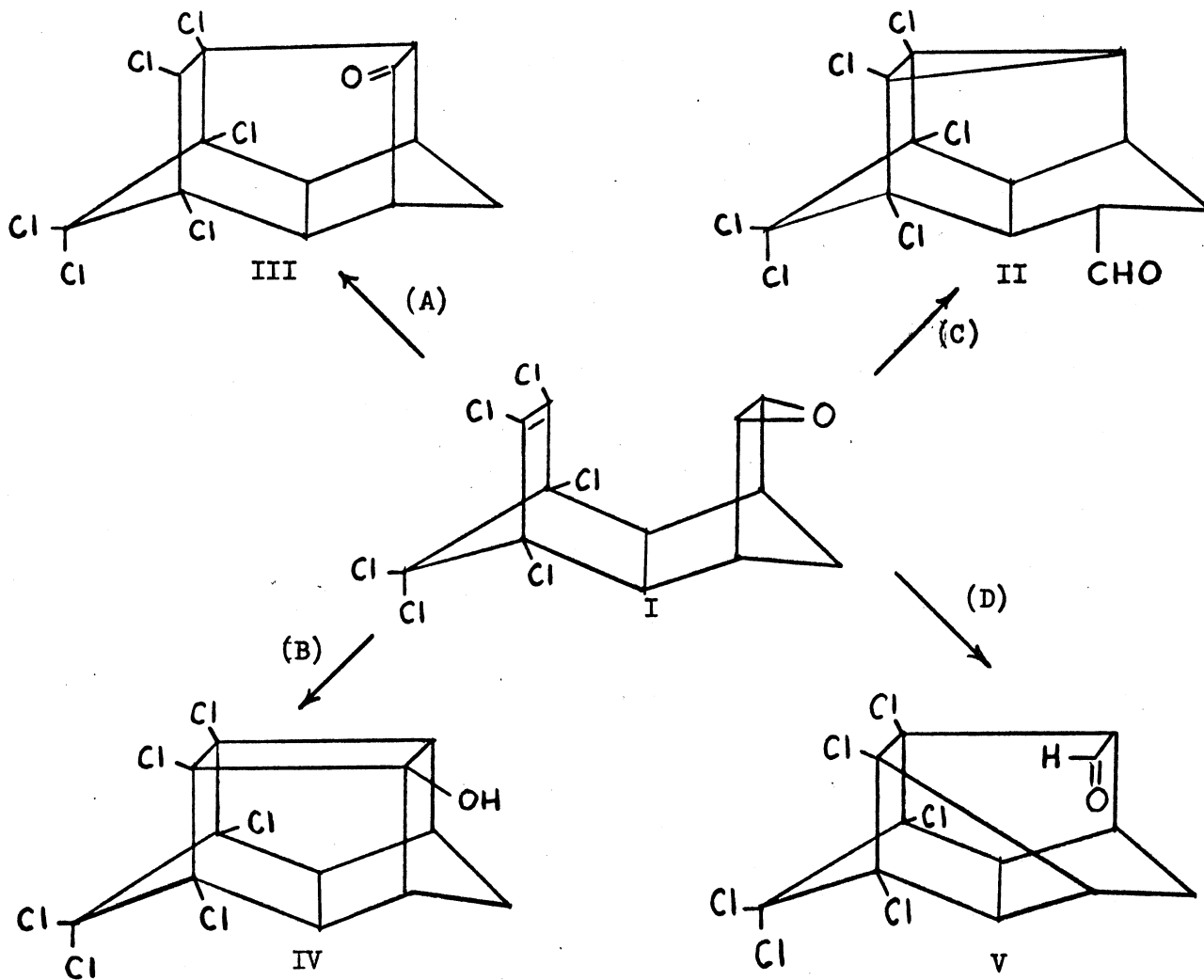
IV = Hexacyclo aldrin isomer

FIGURE II. Degradation of Aldrin by Ultraviolet Light

I = Isodrin

II = Cage derivative of isodrin

FIGURE III. Degradation of Isodrin by Ultraviolet Light

I = Endrin

II = Aldehyde derivative of endrin obtained by heat or photochemical degradation.

III = Ketone derivative of endrin obtained by thermal or photochemical degradation.

IV = Alcohol derivative of endrin obtained by thermal degradation.

V = Aldehyde derivative of endrin obtained by thermal degradation.

FIGURE IV. Thermal and Photochemical Degradation of Endrin
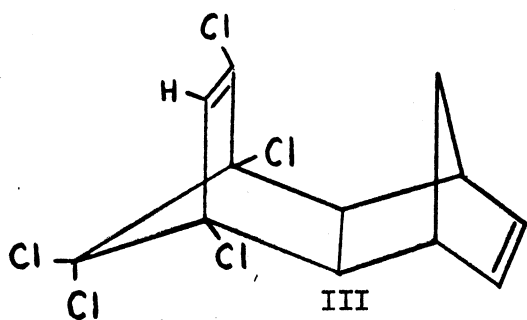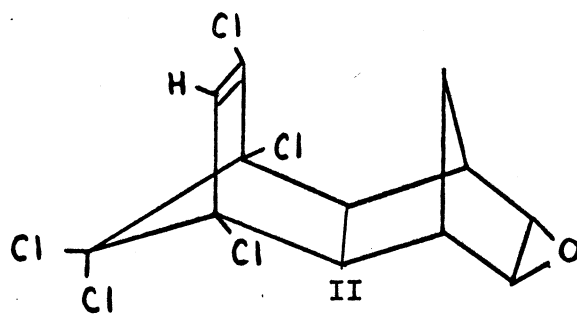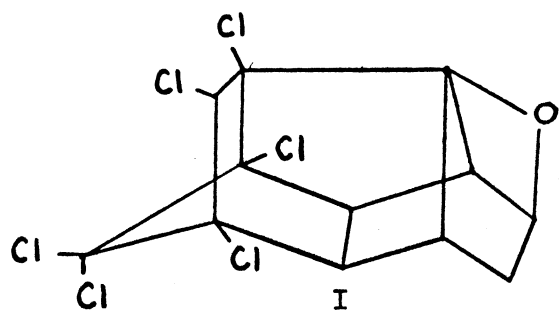
I = Rearranged product of dieldrin

II = Pentachloro derivative of dieldrin

III = Pentachloro derivative of aldrin

FIGURE V. Photodecomposition Products of Dieldrin and Aldrin

Alpha Isomer

Beta Isomer

Gamma Isomer
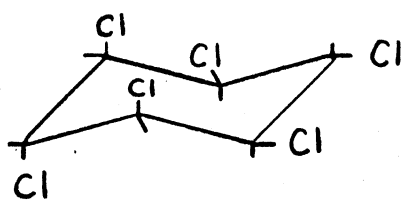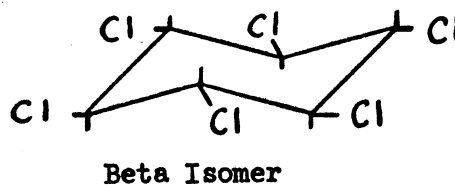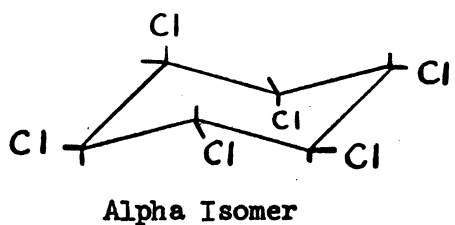
(lindane)

Delta Isomer
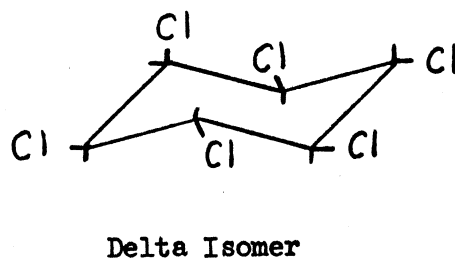
FIGURE VI. Some Isomeric Structures of BHC

(1,2,3,4,5,6-hexachlorocyclohexane) Which Have Been Found to be Stable

to Ultraviolet Light