Chemical Control of the Immature Stages of Musca Domestica Linn

THE CHEMICAL CONTROL OF THE IMMATURE STAGES OF MUSCA DOMESTICA LINN.

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PREFACE

For many years, the house fly has been recognized as an important factor in the spread of diseases such as typhoid fever, epidemic or summer diarrhea, dysenteries, or cholera. The causal organisms may be picked up by the fly during feeding or egg deposition, and then scattered about in human food. Esten and Mason (1908) found that the hairy body of the house fly was an admirable carrier of bacteria, and that an average of 1,250,000 bacteria was present on the 414 flies examined. Howard (1911) reported that in a survey of Massachusetts, New York, Pennsylvania, Virginia, Florida, Georgia, Louisiana, Nebraska, and California, 98.8 per cent of the flies collected in kitchens and pantries belonged to this species.

For a number of years, borax has been recommended as the most effective, economical, and practical chemical for destroying larvae; but experimental work has shown that unless care is taken, this chemical may be applied in quantities which will render the manure injurious for fertilizer purposes.

In an effort to determine the toxicity of borax and some other insecticides for house fly larvae, a series of experiments were undertaken which were preliminary in nature, and should be considered as a basis for further work rather than a completed project.

Indebtedness is acknowledged to Dr. D. E. Howell, Assistant Professor of Entomology, who assigned the writer this problem and gave valuable assistance, suggestions and criticisms; to Dr. F. A. Fenton, Head of the Department of Entomology; Dr. F. E. Whitehead, Professor of Entomology, and Mr. Ephriam Hixson, Assistant Professor of Entomology, for their numerous valuable suggestions; and to Messrs. L. B. Cobb, Gaines Eddy, and T. H. Mailen for their assistance in the experimental work.

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INTRODUCTION

Eaton (1935) found that boron present in irrigation water in amounts above two parts per million would affect nearly all crops; suggesting that if borax were used too freely as a larvicide, it might prove injurious when the manure was used as a fertilizer. Hellebore, which has previously been recommended, has been proved by several workers to be very unreliable and at times may be too expensive for use in controlling fly larvae.

The above facts clearly indicate that there is a necessity for a chemical which will: (1) be highly toxic to housefly larvae, and (2) which can be used in reasonable amounts without affecting the manure for fertilizing purposes. The work just completed by the author deals only with the former, and it is realized that to make the project complete, a series of tests should be undertaken to find out if they are toxic to plants.

During the winter of 1939-40, at the Department of Entomology of the Oklahoma Agricultural and Mechanical College, the author began a series of tests to determine the relative toxicity of a large number of chemicals.

Previously, Dr. F. A. Fenton, Head of the Department of Entomology of Oklahoma Agricultural and Mechanical College, had conducted a number of experiments dealing with the same problem, and it was with his aid and suggestion that the work was resumed. Data obtained by Dr. Fenton are not included in this paper.

REVIEW OF LITERATURE

The house fly, Musca domestica Linn., breeds in large numbers in barnyard manure, and sanitary disposal is recognized as the best control, but it somestimes becomes necessary to use other means, and it was the chemical treatment of this breeding media that attracted the attention of the early American workers as a means of control.

Dr. L. O. Howard in 1911 concluded that kerosene emulsion, or calcium chloride could be used with some degree of success if used in small amounts. He further reports that Professor S. A. Forbes found lime, borax, borax and sodium arsenate mixture, iron sulphate, and carbon disulphide to be effective larvicides. Herms (1910) said that many of the common insecticides were more or less effective if used in proper concentrations and amounts.

Berlese (1913) recommended a spray of 10 parts of molasses, 2 parts of potash or soda and 100 parts of water, to be used every 10 days or after rains.

Cook et al. (1914), from a list of 17 chemicals tested, recommended borax at the rate of 0.62 pound per ten cubic feet of manure as sufficient to kill the eggs and maggots, or calcined colemanite, if it could be obtained, at the rate of 0.75 pound per ten cubic feet of manure. The same authors (1915) in a continuation of their experiments tried 21 additional chemicals. Five inorganic chemicals were tried, but none were recommended. Aniline, pyridine, and nitrobenzene gave satisfactory results from the list of organic substances, while hellebore proved the most efficient of all the substances tested. The rate of application suggested was one-half pound of powdered hellebore in ten gallons of water per each ten feet of manure.

Howard (1914) was successful by spraying every week with a mixture of 4 pounds of sodium arsenite and 4 quarts of molasses dissolved in 50 gallons of water.

Richardson (1915) was successful by treating horse stalls with iron sulphate. Cook and Hutchison (1916) found that potassium cyanid, paris green, arsenic dip, pyridine, calcium cyanimid and acid phosphate gave good control. They recommended only the latter two as being safe enough for common usage.

Saunders (1916) recommended surface dressing with tar oil or control by the application of tetrachlorethane at the rate of 2 ounces to 10 cubic feet of manure. Foreman and Graham-Smith (1914) found that the best oil was coal tar cresote oil containing about 14 percent tar acids, and a high flash point; and that it should be sprayed on the manure daily for good control.

Berlese (1926) recommended a spray of sugar beet molasses 100 parts, sodium or potassium arsenite 5 parts, and milk 10 parts to be diluted for use with 5 to 10 parts by volume of water. Carr (1927) found that when the surface was covered with lime or cinders and sprayed once a week with a solution of 3 percent bone oil in coal tar cresote oil containing at least 14 percent tar acids and 3 percent bases, that the solution acted both as a larvicide and a repellent. Buchmann (1929) obtained good control with pyrethrum powder mixed 1-320 to 1-500 with stable manure.

Marcovitch and Anthony (1931) in a large series of tests, found that borax was inferior to sodium fluosilicate in destroying fly maggots in manure. Best results were obtained by sprinkling the manure with a saturated solution (1-154) of sodium fluosilicate each day. Anonymous (1932) found that arsenite of soda acted slowly at the rate of 1 pound per 100 gallons of manure, and that it required 5-6 days to kill all the larvae. Chebotarevich (1934) recommended a 5 percent solution of crude carbolic acid in crude oil applied at the rate of 1 pint to 12 square feet of manure.

Gorodetzkii and Sukhora (1936) found that the polychlorides were effective, but that the rate of application was 0.32 cc per square centimeter of medium. Paradichlorobenzene crystals at the rate of 0.05 gram per square centimeter of medium killed all the larvae and pupae. A 20 percent solution of paradichlorobenzene at the rate of 0.25 cc per square centimeter killed all larvae in 24 hours. Richardson (1936) recommended: hellebore, borax, calcium cyanimid, and calcium chloride in the rates of application as found effective by the earlier workers.

Fenton and Bieberdorf (1936) recommended hellebore and borax as of Cook et al. (1914). Fenton (1939) found that mixture of 90 parts superfine dusting sulphur to 10 parts of air floated paris green by weight, used at the rate of 1½ ounces per 2½ quarts manure, killed 95.2 percent of the house fly larvae.

MATERIALS AND METHODS

Rearing and testing. The chemical composition of manure is so variable that a more suitable rearing media was desired. A simple medium of water and crimped oats, as recommended by Eagleson (1937), has been successfully used. For convenience in handling, ease in cleaning, and small cost, large mouth quart mason fruit jars were selected as the container for the medium. 100 grams of oats and 100 cc. of water per jar proved to be sufficient food for several hundred larvae; however, only 100 second instar larvae per jar were used. The excess of oats furnished a medium which, while sufficiently moist on the bottom to allow proper development of the larvae, supplied a satisfactory place for pupation in the upper, drier region. The stock adults were reared under standard Peet-Grady methods as modified by Eagleson (1938).

Each test consisted of a check and five samples treated with varying amounts of the chemical being tested. The chemical was first tested using 0.05, 0.1, 0.5, 1.0, 5.0 grams and a check per test. If this included a fifty percent mortality, the test was repeated. If not, the amounts were then reduced to include a fifty percent mortality, and repeated with the lower concentrations.

After the oats and water were placed in the jars and thoroughly mixed, 100 second instar larvae were counted and placed in each container. When water soluble chemicals were used, they were dissolved in the 100 cc. of water and mixed with the oats. When insoluble chemicals were used, they were mixed in the dry oats, and the water added, and the whole then thoroughly mixed. After the medium was prepared, the 100 larvae were added. Each jar was then covered with a small screen to prevent the other flies entering the containers, and to keep the adults which emerged from escaping.

The entire unit of six jars was placed in a constant temperature room at 85° F. until the adults had emerged and died. They were then immediately counted, before disintegration destroyed them, and the data recorded. The number of tests per chemical varied from one to ten, depending upon the effectiveness and the amount of variation between tests. Those not replicated were chemicals which showed very little toxicity, and none were tested at concentrations greater than 5.0 percent.

Methods of calculation. The various points on the mortality curve were obtained as an arithmetic mean of the series. The median lethal dose was taken from the mortality curve as shown by the tests, but does not represent a true median lethal dose calculated from the number of grams per kilogram of body weight necessary to produce a 50 percent mortality. It is the mean percent concentration of the poison in the medium which killed 50 percent of the larvae, as calculated from the differences of mortality in the samples and the check of each test.

The classification of chemicals used is that of Shepard (1939), and he offers no explanation for the groupings used.

CONTACT AND FUMIGANT COMPOUNDS

Introduction. Insecticides of this group are used in liquid or dust form to kill insects by coming in contact with or entering their bodies, other than by the mouth, and especially through the spiracles. They kill the insects by entering the tracheae as liquids or gases, and producing a chemical action on the body contents, or, rarely, by their physical action in clogging the breathing tubes and smothering the insects.

This group contains a greater variety and diversity of substances in general use than is the case with the stomach poisons. All of the chemicals of this group which were available to the author were tested; many of which had not been used previously for insect control.

Carbon disulphide. This chemical has received much attention as a soil fumigant. Fleming (1926) recommends a homogeneous, concentrated emulsion consisting of carbon disulphide 700 ml., 95 percent ethyl alcohol 193 ml., oleic acid 77 ml., cottonseed oil 30 ml., and potassium hydroxide 13.5 ml., injected directly into holes in the soil as a method of controlling the Japanese beetle. The chemical is very flammable, and the gas and air mixture is explosive. It is limited to use in the fumigation of stored grains, soils, or household pests.

The chemical used was carbon disulfide, technical grade. The results of four tests showed that 0.5 percent concentration was sufficient to kill all larvae, and that a calculated median lethal dose was obtained with 0.032 percent concentration.

Carbon tetrachloride. The cost of this insecticide has prevented its use other than for household use or in small amounts for stored products. Morse (1910) recommended it as being more agreeable than carbon disulphide for use in fumigating stored products.

The chemical used was carbon tetrachloride, technical grade. All larvae were killed with 5.00 percent concentration, and a calculated median lethal dose was obtained with 0.180 percent concentration for five tests.

Ethylene dichloride. Snapp (1938) recommended this chemical in an emulsion for soil treatment for peach-tree borer control in place of paradichlorobenzene crystals.

The chemical used for nine tests was ethylene dichloride, technical grade. A 100 percent mortality was obtained with 0.10 percent concentration, while the calculated median lethal dose was produced with only 0.013 percent concentration.

Ethylene chlorohydrin. The writer could find no literature pertaining to the use of this chemical as an insecticide. A large amount of this chemical, which was closely allied to the previous one, was available, and was used in nine tests.

The chemical used for these tests was a commercial chemical of an unknown composition and grade. A 0.1 percent concentration killed all the larvae, and a 0.032 percent concentration was necessary to produce a calculated median lethal dose.

Trichlorethylene. This chemical has been tested as a substitute for carbon tetrachloride in ethylene dichloride mixtures, but no work could be found where this chemical had been used as the sole toxic agent.

A C.P. grade chemical was used for four tests, which resulted in 100 percent mortality with a 5.0 percent concentration, and a calculated median lethal dose of 0.281 percent concentration.

Naphthalene. Hargreaves (1924) found that a 1.00 percent paste fed to *Pieris* larvae killed two out of seven in seven days. Fleming (1925) found that naphthalene was more effective against the larvae of the

Japanese beetle, than para-dichlorobenzene, but the latter was more effective than the former against the egg and adult. Lehman (1930) states "on the basis of the time required to kill 50 percent of the insects, naphthalene is from 10 to 14 times as toxic to Tribolium confusum Duval as para-dichlorobenzene at the same concentrations."

The chemical used was naphthalene flakes of a technical grade. The calculated lethal dose was 0.087 percent concentration, while 5.00 percent concentration was necessary to produce a 100 percent mortality.

Para-dichlorobenzene. Duckett (1915) states "para-dichlorobenzene acts as an excellent fumigant against the following insects: (1) stored-product insects, (2) case-bearing clothes moths, (3) roaches and ants, (4) museum pests, and (5) miscellaneous house insects." Hargreaves (1924) found that a 1.00 percent paste fed to Pieris larvae killed two out of seven in seven days, and a 0.50 percent paste did not kill any of the larvae. Metcalf and Flint (1939) recommend this chemical for controlling: wireworms, borers, wooly apple aphids, Japanese beetles, Oriental fruit moths, silverfish, and clothes moths.

The chemical used was of technical grade, and six tests gave a calculated lethal dose at 0.368 percent concentration, and all were killed with 0.50 percent concentration.

Ortho-dichlorobenzene. Kofoid et al. (1934) recommend this for the control of termites. The chemical used in the tests completed by the author was of technical grade. In five tests, all larvae were killed with 1.00 percent concentration, and the calculated median lethal dose was 0.19 percent concentration.

Benzene dibromide. The author could find no literature dealing with this chemical as an insecticide. Four tests with a C.P. grade chemical revealed that all were killed with 1.00 percent concentration, and that the median lethal dose could be obtained with 0.042 percent concentration.

Hexachlorobenzene. The author could find no reference to this chemical having been tried as an insecticide, but, being somewhat related to those just listed, it was tested.

The chemical used was of C.P. grade. Two tests revealed that 5.00 percent concentration was necessary to kill all the larvae, and that the calculated median lethal dose was 0.079 percent concentration.

Anthracene. Hargreaves (1924) found that a 1.00 percent paste on leaves fed to Pieris larvae did not kill within seven days. Fink, et al. (1938) killed all the culicine larvae in 16 hours with a 100 parts per million dilution. Siegler et al. (1939) found it ineffective against codling moth larvae; it only reduced the population of wormy apples to 81 percent.

The chemical used for two tests was Anthracene 90%, and a 5.00 percent concentration killed all the larvae, while the calculated median lethal dose was obtained with 0.079 percent concentration.

Cresylic acid. Many derivities of this compound have been tested for their toxicity, but the writer could find no reference to work using it as an insecticide.

The chemical used was "Saponated cresylic acid #339" furnished by the Baird and McGuire Company. Six tests gave the calculated median lethal dose as 1.15 percent concentration, and 94.32 percent of the larvae were killed with a 5.00 percent concentration.

Ethyl mercaptan. Several of the mercaptans are being tested by various workers, and a few have been proven to be quite toxic. A C.P. grade of this chemical was available to the writer, so with two tests, the following results were obtained: A calculated median lethal dose with 0.068

percent concentration, and 1.00 percent was sufficient to kill all larvae.

N-butyl mercaptan. This chemical proved to be more effective than the closely related chemical listed above. Six tests with a C.P. grade chemical revealed that 0.5 percent concentration would produce a 100 percent mortality, while the calculated median lethal dose required 0.20 percent concentration.

2, 4 Dinitro-6-cyclohexylphenol. Kagy, (1936) obtained a median lethal dose (micrograms per gram of body weight) with 0.087 gram for *Heliothis obsoleta* Fab., and 0.056 gram for *Melanoplus femur-rubrum* Thomas. Boyce *et al.* (1939) state "Field investigations have shown that certain oil emulsions containing dinitro-O-cyclohexylphenol are effective in the control of the black scale, the citricola scale, the citrus red mite, the citrus whitefly, the European elm scale, the walnut scale, and the frosted scale."

The chemical used was of unknown composition furnished by the Dow Chemical Company. Six tests proved that 0.5 percent concentration was sufficient to produce a 100 percent mortality, and that the calculated median lethal dose was 0.072 percent concentration.

Summary. Two chemicals, ethylene dichloride and ethylene chlorohydrin, were more toxic than borax to housefly larvae. Carbon disulphide, dinitro-O-cyclohexylphenol, N-butyl mercaptan, and para-dichlorobenzene were as toxic as borax to housefly larvae. The remaining nine chemicals of this group tested were not equal to borax as a housefly larvicide.

Table 1. lists the fifteen chemicals tested, in the order of their toxicity to housefly larvae as found by the author.

Table 1. Relative toxicity of some contact and fumigant compounds as found with house fly larvae

Chemical	Number of tests	100 percent mortality level	Median lethal dose**
Ethylene dichloride	9	0.10	0.013
Ethylene chlorohydrin	9	0.10	0.032
Carbon disulphide	4	0.50	0.032
Dinitro-O-Cyclohexylphenol	6	0.50	0.072
N-butyl mercaptan	6	0.50	0.200
Para-dichlorobenzene	6	0.50	0.368
Benzene dibromide	4	1.00	0.042
Ethyl mercaptan	2	1.00	0.068
Ortho-dichlorobenzene	5	1.00	0.155
Anthracene	2	5.00	0.079
Naphthalene	2	5.00	0.087
Hexachlorobenzene	2	5.00	0.090
Carbon tetrachloride	5	5.00	0.192
Trichlorethylene	4	5.00	0.281
Cresylic acid	6	----*	2.560

* 5.00 percent concentration failed to produce a 100 percent mortality.

** Percent concentration necessary to produce a calculated median lethal dose.

PLANT DERIVATIVE AND RELATED COMPOUNDS

Introduction. A number of plants contain substances which are poisonous to insects. Many depend upon the alkaloids which they contain, others contain poisonous esters or compounds less easily classified. The stability of the active principles of plant products varies and determines to considerable extent the use of each product.

Due to the instability of this group, there has been a vigorous search for synthetic chemicals which are similar in killing action. Seven plant derivatives and two synthetic compounds were tested by the author, and a discussion of each follows.

Pine oil. Pierpont (1939) found that terpene ethers increased the toxicity of pyrethrum fly sprays; however, no other work with the toxicity of this chemical could be found by the author.

A steam distilled pine oil of an unknown composition was used for two tests, and the results proved that 5.00 percent concentration was necessary to kill all the larvae, while 0.455 percent concentration would produce a calculated median lethal dose.

Nicotine. McIndoo (1916) states "Aphids, caterpillars, and beetles and honeybees were dipped into and sprayed with nicotine solutions. All the treated aphids died, but only a portion of the caterpillars and beetles succumbed, and the bees could not be killed by spraying them," and again "aphids, coccids, caterpillars, larvae of the Colorado potato beetle, houseflies, and honeybees fumigated with 40 percent nicotine sulphate were killed." This chemical is used often as the active agent in fumigating sprays and dusts for controlling various insects of economic importance. Extensive studies have been made by various workers with this chemical, but they are of a nature that does not permit them to be compared with the work just completed by the author. Many of these experiments were just for population reductions under field conditions, while most of the studies conducted under strict supervision and exactness, deal with the toxicity in relation to the pH of the base, or with the various nicotine derivatives.

The chemical used was commercial "Black-leaf 40", containing 40 percent nicotine, and five tests showed that 0.065 percent concentration would kill a calculated 50 percent, and that 0.50 percent concentration killed all larvae.

Hellebore. Cook et al. (1915) recommended "Powdered hellebore, using one-half pound to 10 gallons of water and applying this to eight bushels of manure, as an effective larvicide against the house fly larvae." Since that time it has been used rather commonly as a dust applied against leaf-feeding larvae, but has the advantage or disadvantage of losing its effectiveness rapidly upon exposure to the air.

Three types of hellebore were used: white hellebore derived from Veratrum album, American hellebore from Veratrum viride, and black hellebore obtained from Helleborus niger. They varied considerably in their killing action, American hellebore being the most active of the three, white hellebore was second, and black hellebore was the least toxic. American hellebore produced a total mortality at 1.00 percent concentration, white hellebore at 5.00 percent concentration, and black hellebore only killed 97.37 percent of the larvae when 5.00 percent concentration was used. The calculated median lethal dose for American hellebore was 0.133 percent concentration, for white hellebore 0.074, and for black hellebore 0.275 percent concentration.

Pyrethrum. Shepard (1939) states "Many biological methods are proposed for the evaluation of pyrethrum. Dilutions of alcoholic extracts of pyrethrum in water have been applied to Aphis rumicis Linn., a method suitable for the testing of horticultural sprays. Other methods, the most important being the Peet-Grady chamber method, involved the spraying of adult house flies with petroleum base pyrethrum preparations."

The chemical used for nine tests, was a twenty to one alcoholic extract. The results obtained were: a 100 percent mortality with a 1.00 percent solution, and the calculated median lethal dose was obtained with a 0.058 percent concentration.

Derris. This is another plant derivative that has been successfully used under field conditions to obtain reasonable population reductions. Shepard and Campbell (1932) working with the silkworm showed that the micrograms per gram of body weight necessary to produce a median lethal dose varied from 0.003 to 1.54 grams, depending upon the composition of the chemical used. The composition of the product used in the tests was also unknown, so rather than list the data which would be difficult to compare, all are omitted.

The chemical used was "Protexted derris extract #6, containing 5.00 percent derris extracts" furnished by the Whitmire Research Corporation. Five tests revealed that a 5.00 percent solution was sufficient to kill all the larvae, and that a 0.075 percent solution produced a calculated 50 percent mortality.

Thiocyanate. This name refers to a large group of compounds, some of which have proven to be very effective as insecticides. The composition of the chemical under test was unknown, so it was impossible to present the findings of other workers with the chemical.

The chemical used for five tests was "Lethane #384" furnished by the Rohm and Haas Company, and believed by the author to be a solution of n-butyl carbitol thiocyanate and kerosene. Results obtained were a 100 percent mortality at 1.00 percent concentration, and a calculated median lethal dose with 0.093 percent concentration.

Phenothiazine. Campbell, et al. (1934) and Fink, et al. (1938) found that one part per million killed culicine larvae in 16 hours. Hansberry and Richardson (1936) obtained a median lethal dose with 1.12 grams per kilogram of body weight for *Pieris rapae* Linn. larvae. Knipling (1938) found that a 0.1 gram per kilogram of body weight fed to cattle prevented horn fly larvae from developing in the manure. Bruce (1939) states "the minimum lethal dose of phenothiazine was 4 milligrams per 100 grams of feces."

In one test, this chemical was ineffective against house fly larvae. The median lethal dose was calculated with 0.31 percent concentration, while a 5.00 percent concentration killed only 65.67 percent of the larvae.

Summary. Table 2. lists the nine chemicals tested, in the order of their toxicity to house fly larvae as found by the author. "Black-leaf 40" was the only chemical of this group equal to borax in toxicity to the house fly larvae. Pyrethrum and lethane #384 produced low calculated median lethal doses, but required 1.00 percent concentrations to kill all the larvae. The remaining six chemicals were less effective for control of the house fly larvae.

Table 2. Relative toxicity of the plant derivative and related compounds as found with house fly larvae.

Chemical	Number of tests	100 percent mortality level	Median lethal dose**
"Black-leaf 40"	5	0.50	0.065
Pyrethrum	9	1.00	0.058
Lethane #384	5	1.00	0.095
American hellebore	2	1.00	0.133
White hellebore	2	5.00	0.074
"Protexed derris"	5	5.00	0.087
Pine oil	2	5.00	0.455
Black hellebore	2	----*	0.275
Phenothiazine	1	----*	0.310

* Failed to produce a 100 percent mortality with a 5.00 percent concentration.

**Percent concentration necessary to produce a calculated median lethal dose.

STOMACH POISONS--NON-ARSENICAL INORGANIC COMPOUNDS

Introduction. A very promising group of arsenical substitutes is included in the various flourine compounds; they are soluble enough to be effective as insecticides, but are, however, usually too soluble for use on living plants. Four of this group were tested against house fly larvae by the author.

Some of the very poisonous heavy metal salts which kill by coagulation of the protein content of the body were tested. Also included in this group were borax, tartar emetic, paraformaldehyde, and zinc phosphide. The latter is a chemical which has shown much promise for insect control.

Barium fluosilicate. McAllister and Van Leeuwen (1930) obtained a 95.7 percent mortality with a 10.0 percent dust against codling moth larvae. Shepard and Carter (1933) found that the median lethal dose for *Bombyx mori* Linn. was 0.12 gram per kilogram of body weight.

The chemical used was of technical grade. The results of five tests gave a calculated median lethal dose with 0.250 percent concentration, and 5.00 percent concentration killed all the larvae.

Cryolite. The findings of the various workers with this chemical are compiled in Table 3.

Table 3. The grams per kilogram of body weight necessary to produce a median lethal dose for various insects.

Workers	Insect used	Median lethal dose
Richardson and Haas, 1932	Melanopus femur-rubrum DeGeer	0.16
Shepard and Carter, 1933	Bombyx mori Linn.	0.07
Ellisor and Floyd, 1938*	Hypantria cunea Drury	0.45
	Anticarsia gemmatilis Hbn.	0.17
	Autographa brassicae Riley	0.42
	Pieris rapae Linn.	0.68

* Only a 86 percent mixture was used

The chemical used was natural cryolite of an unknown composition. Five tests gave a calculated median lethal dose with 0.475 percent concentration, while a 5.00 percent concentration killed all the larvae.

Barium fluoride. Hargreaves (1924) found that a 1 percent paste fed to Pieris larvae killed all larvae in nine days, and that a 0.5 percent paste killed 66.67 percent of the larvae in nine days. McAllister and Van Leeuwen (1930) obtained a 60.7 percent efficiency against codling moth larvae when they used a 10 percent dust.

The chemical used was of C. P. grade. Five tests gave a calculated median lethal dose when 0.515 percent concentration was used; while a 5.00 percent concentration gave only 89.86 mortality.

Calcium fluoride. Hargreaves (1924) found that a 0.5 percent paste was not toxic to Pieris larvae in the 11 days after feeding, but if fed a two percent paste, all were killed in three days.

A technical grade chemical was used in five tests, and did not affect the larvae when used at a 5.00 percent concentration.

Barium chloride. The author could find no evidence that this chemical had been used in toxicological work under controlled conditions. Metcalf and Flint (1939) say that it is used in poisoned sweet baits for flies and moths.

A large supply of this chemical, technical grade, was available, so five tests were completed. They showed that 0.515 percent concentration was sufficient to obtain the calculated median lethal dose, and that a 5.00 percent concentration produced a 100 percent mortality.

Tartar emetic. Burdette (1934) used two pounds of the chemical and 50 gallons of water containing an invert sugar syrup, to attract adult *Heliothis obsoleta* Fab., but the poison was too slow to be effective. Gilmore and Milam (1933) found that tartar emetic could be used in the field to reduce the population of tobacco hornworm moths, *Phlegethontius sexta* John. and *P. quinque maculata* Haworth. Nelson (1938) states "combinations of tartar emetic and brown sugar are not injurious to gladiolus foliage, result in thrips control equal to that obtained with paris green and brown sugar and have no deleterious effect upon new corn production."

The chemical used was of technical grade. Results obtained from two tests were that a 0.583 percent concentration produced a calculated 50 percent mortality and 5.00 percent concentration was necessary to kill all larvae.

Borax. Practically all workers recommending this chemical for the control of the house fly larvae base their actions upon the work of Cook *et al.* (1914) in which they recommended an application of 0.62 pound per 10 cubic feet of manure. McAllister and Van Leeuwen (1930) obtained a

41 percent efficiency with borax against the codling moth larvae when used in a ten percent dust.

The chemical used was commercial "20 Mule Team Borax," and it produced a calculated 50 percent mortality with 0.175 percent concentration, and all were killed with a 0.50 percent concentration.

Paraformaldehyde. Hargreaves (1924) found that a one percent paste fed to *Pieris* larvae failed to kill in the seven days allowed. Elmore and Richardson (1936) found that 2.24 grams per kilogram of body weight was necessary to kill adult *Musca domestica* Linn.

Three tests with a chemical of U.S.P. grade were completed. The results showed that a 5.00 percent concentration was necessary to kill all the flies, while 0.761 percent concentration would produce a calculated 50 percent mortality.

Zinc phosphide. Table 4. compiles the findings of the various workers that have used this chemical under controlled conditions.

Table 4. The grams per kilograms of body weight necessary to produce a 50 percent mortality with zinc phosphide for various insects.

Worker	Insect used	Median lethal dose
Richardson and Thurber, 1933	*Melanoplus differentialis* Thos.	0.52
Hansberry and Richardson, 1936	*Datana perspicua* G. & R.	0.47
	Heliothis obsoleta Fab.	0.87
	Pieris rapae Linn.	3.50

Richardson and Seiferle (1938) rated this chemical as highly toxic to Melanoplus m. mexicanus (Saussure), producing 93 to 100 percent mortality.

The chemical used was of C.P. grade. Results of six tests gave the calculated median lethal dose as 0.018, and all larvae were killed with the 0.10 percent concentration.

Thallous sulphate. Munch and Silver (1931) determined the minimum lethal dose of thallium for rats to be 25 micrograms per kilogram of body weight. Richardson and Seiferle (1938) rated this chemical as moderately toxic (77 percent mortality) to Melanoplus m. mexicanus (Saussure).

The chamical used was of C.P. grade. Four tests gave a calculated median lethal dose with 0.056 percent concentration, while 0.50 concentration killed all the larvae.

Thallous acetate. The author could find no literature dealing with this chemical as an insecticide. The chemical used for four tests was C.P. grade. A calculated median lethal dose was obtained with 0.095 percent concentration, and 1.00 concentration killed all the larvae.

Mercurous chloride. Richardson and Seiferle (1938) rated this chemical as slightly toxic (15 to 20 percent mortality) to Melanoplus m. mexicanus (Saussure).

The calculated median lethal dose as shown by four tests was 0.0078 percent concentration, and the larvae were all killed with 0.10 percent concentration.

Mercuric chloride. McAllister and Van Leeuwen (1930) found that when applied as a 10 percent dust, it gave a 65.6 percent efficiency against codling moth larvae.

The chemical used was of C.P. grade, and four tests showed the calculated median lethal dose to be 0.057 percent concentration, and that all the larvae were killed with 0.50 percent concentration.

Summary. Table 5. lists the various chemicals of this group, tested by the author in the order of their toxicity to house fly larvae.

Mercuric chloride and zinc phosphide were much better than borax, and killed all larvae with a 0.10 percent concentration. Thallous sulphate and mercurous chloride were equal to borax as a killing agent for house fly larvae. The remaining eight chemicals of this group were not as toxic as borax.

Table 5. The toxicity of some Stomach Poisons, Non-Arsenical Inorganic Compounds to house fly larvae as found by the author

Chemical	Number of tests	100 percent Mortality level	Median lethal dose**
Mercuric chloride	4	0.10	0.0078
Zinc phosphide	6	0.10	0.0180
Thallous sulphate	4	0.50	0.0560
Mercurous chloride	4	0.50	0.0570
Borax	8	0.50	0.2500
Thallous acetate	4	1.00	0.0950
Barium fluosilicate	5	5.00	0.3500
Barium chloride	5	5.00	0.5300
Tartar emetic	2	5.00	0.5830
Paraformaldehyde	3	5.00	0.7610
Cryolite	5	---*	0.4750
Barium fluoride	5	---*	0.5280
Calcium fluoride	5	---*	-----***

* Failed to produce a 100 percent mortality with a 5.00 percent concentration
**Percent concentration necessary to produce a calculated medial lethal dose
*** A 5.00 percent concentration did not produce a calculated 50 percent mortality

STOMACH POISONS--ARSENICAL COMPOUNDS

Introduction. The arsenicals met nearly all requirements for a satisfactory stomach poison for many years, and as a result, they are still the most common group of insecticides. They are sufficiently active to kill quickly, which is desirable, but are usually soluble enough to enter living parts of the plant foliage and poison them.

Six of the more common arsenicals were tested for their toxicity to house fly larvae.

Sodium arsenite. Richardson and Haas (1932) obtained a median lethal dose of 0.10 gram per kilogram of body weight for *Melanoplus femur-rubrum* DeGeer. Hoskins (1934) found that a 0.02 percent solution produced a 50 percent mortality of the mosquito pupae used; and he obtained a median lethal dose with 2 micrograms of the chemical when fed to adult honey-bees. Gaines *et al.* (1937) produced a 70 percent mortality of adult house flies with a 0.03 percent concentration. Richardson and Seiferle (1938) rated it as highly toxic to *Melanoplus m. mexicanus*, producing 93 to 100 percent mortality.

The chemical used in the eight tests was sodium arsenite (meta) C.P. grade. The results obtained were: a calculated median lethal dose at 0.015 percent concentration, and a 100 percent mortality at 0.05 percent concentration.

Lead arsenate. The toxicity of this chemical as found by the various workers is presented in Table 6.

Table 6. The median lethal dose (grams per kilogram of body weight) of lead arsenate as found by various workers for different insects

Workers	Insect used	Median lethal dose
Richardson and Haas, 1931	*Leptinotarsa decemlineata* Say.	0.30
Bulger, 1932	*Ceratomia catalpae* Boisd.	0.062
	Hyphantria cunea Dru.	0.16
Hansberry and Richardson, 1936	*Bombyx mori* Linn.	0.09
	Datana perspicua G. & R.	0.07
	Heliothis obsoleta Fab.	0.17
	Cirphis unipuncta Haw.	0.25
	Datana ministra Dru.	0.05
	Polygonia interrogationis Fab.	0.06
	Vanessa cardui Linn.	0.16
Gaines, 1938	*Alabama argillacea* Hbn.	0.02
Ellisor and Floyd, 1938	*Pieris rapae* Linn.	0.10

The chemical used was "Acme brand arsenate of lead, containing 98 percent arsenate of lead." The results of four tests gave a calculated median lethal dose of 0.31 percent concentration, and all were killed with 0.50 percent concentration.

Calcium arsenate. Hargreaves (1924) working with *Pieris* sp. larvae obtained a 100 percent mortality with a 0.5 percent concentration of the chemical. Table 7. lists the results of several workers that have used the chemical with various species of insects.

Table 7. The median lethal dose (grams per kilogram of body weight) of calcium arsenate as found by various workers for different insects

Workers	Insect used	Median Lethal dose
Hansberry and Richardson, 1936	_Bombyx mori_ Linn.	0.26
Gaines, 1938	_Alabama argillacea_ Hbn.	0.72
Ellisor and Floyd, 1938	_Autographa brassicae_ Riley	0.50
	Anticarsia gemmatilis Hbn.	0.11
	Pieris rapae Linn.	0.74
	Hyphantria cunea Dru.	2.00

The chemical used was commercial cotton dusting grade, "Delta brand", containing 48 percent active ingredients. The results of five tests gave a calculated median lethal dose of 0.9 percent concentration, and at 5.0 percent concentration 93.93 percent of the larvae were killed.

Copper arsenate. In tests with the Mexican bean beetle, Colorado potato beetle, southern armyworm, velvetbean caterpillar, fall webworm, and catalpa sphnix worms, Waters _et al._ (1939) found that basic copper arsenate was as effective as acid lead arsenate or calcium arsenate.

Basic copper arsenate containing 95 percent basic copper arsenate was used in four tests. All larvae were killed with 0.50 percent concentration, and the calculated median lethal dose was obtained with 0.033 percent concentration.

Sodium arsenate. Metcalf and Flint (1939) state "this is a highly soluble form of arsenical which cannot be used for spraying the foliage of plants. It is used in poison baits and for making other more stable insecticides." Kofoid et al. (1934) found that 0.001 percent concentration required 121 days to kill 100 percent of the termites used.

The chemical used in seven tests was of C.P. grade. The results obtained were a calculated median lethal dose of 0.022 percent concentration, and all were killed with 0.10 percent concentration.

Paris green. The results of toxicology studies completed with this chemical by various workers are compiled in Table 8.

Table 8. The median lethal dose (gram per kilogram of body weight) of paris green as found by various workers for different insects

Workers	Insect used	Median lethal dose
Richardson and Haas, 1931	*Leptinotarsa decemlineata* Say.	0.10
Richardson and Haas, 1932	*Melanoplus femur-rubrum* DeGeer	0.19
Hansberry and Richardson, 1936	*Pieris rapae* Linn.	0.04
Gaines, 1938	*Alabama argillacea* Hbn.	0.01

Commercial paris green of an unknown composition was used. The results of six tests were: The calculated median lethal dose at 0.016 percent concentration, and a 100 percent mortality at 0.05 percent concentration.

Summary. Table 9. lists the six arsenicals tested, in the order of their toxicity to house fly larvae, as found by the author.

Sodium arsenite, paris green, copper arsenate, and sodium arsenate were more toxic to the house fly larvae than was borax. Lead arsenate was as toxic as borax, while calcium arsenate was far below borax in toxicity.

Table 9. The relative toxicity of the arsenical compounds as found by the author with the house fly larvae

Chemical	Number of tests	100 percent mortality level	Median lethal dose**
Sodium arsenite	8	0.05	0.015
Paris green	6	0.05	0.016
Copper arsenate	6	0.05	0.033
Sodium arsenate	7	0.10	0.022
Lead arsenate	4	0.50	0.310
Calcium arsenate	5	---*	0.925

* 5.0 percent concentration failed to produce a 100 percent mortality.
**Percent concentration necessary to produce a calculated median lethal dose.

MISCELLANEOUS COMPOUNDS

Diphenylamine. Hargreaves (1924) found that a 1.00 percent paste fed to Pieris larvae killed two out of seven in seven days. McAllister and Van Leeuwen (1930) found it to have a 99.0 percent efficiency against codling moth larvae. Richardson and Seiferle (1938) rated this chemical as slightly toxic (15 to 20 percent mortality). Melvin et al. (1939) found that this compound prevents the development of the young stages of the screw-worm fly in wounds, without repelling the adult female.

Using a chemical of technical grade for one test, the author found it quite ineffective against house fly larvae. A 5.00 percent concentration killed only 60.67 percent of the larvae, and 3.960 percent concentration was necessary to obtain the calculated median lethal dose.

Numbered chemicals. All the chemicals tested were furnished by the United States Rubber Company. The composition of these has not been revealed to the author; however, several of these proved to be highly toxic to house fly larvae. The reader is referred to Table 10. for the data concerning these 14 chemicals. The composition of these compounds will be released by the company after the patents have been obtained.

Included in this table is a chemical known as Dow K-58, the composition of which is also unknown. It was furnished by the Dow Chemical Company.

Table 10. The relative toxicity of some miscellaneous compounds as found with house fly larvae

Chemical	Number of tests	100 percent mortality level	Median lethal dose"
#14	5	0.075	0.013
#102	6	0.075	0.025
#15	7	0.500	0.005
#250	2	1.000	------*
#305	2	1.000	------*
#244	2	1.000	0.713
#326	2	5.000	------*
#96	2	5.000	0.342
Dow K-58	2	5.000	0.392
#331	2	5.000	0.450
#24	2	5.000	0.560
#11	2	5.000	0.690
#308	2	------**	0.882
Diphenylamine	1	------**	3.960
#343	2	------**	------***
#327	2	------**	------***

* Was not used in concentration dilute enough to give a 50 percent mortality
**Did not kill all the larvae with a 5.00 percent concentration
***A 5.00 percent concentration did not produce a 50 percent mortality
" Percent concentration necessary to produce a calculated median lethal dose

DISCUSSION

Various soil fumigants have been used for other insects with success, and without many serious objections concerning their toxicity to plants. Tests just completed indicate that they are as toxic as borax to house fly larvae, and it is believed that they could be successfully used to replace borax. The mortality curves of the chemicals of this group which are more toxic than borax are shown on Plate I. The mortality curves of the various soil fumigants which are equal to borax in toxicity are shown on Plate II.

A majority of the plant derivatives and related compounds were not highly toxic. The relatively high cost and the fact that they are unreliable would tend to place them in the undesirable group. The mortality curves of the various chemicals of this group which proved to be more toxic to house fly larvae than borax are shown on Plate I, and those equal to borax on Plate II.

Of the non-arsenical inorganic stomach poisons tested, only zinc phosphide, the mercury salts, and the thallium salts were very toxic. The author is of the opinion that the heavy metal salts would prove too toxic to plant growth for common usage. Zinc phosphide has shown some promise and at present, some of the European workers are giving it a thorough testing. The mortality curves of the various chemicals of this group which proved to be more toxic to house fly larvae than borax are shown on Plate I, and those equal to borax on Plate II.

There are many variables which must be considered in connection with the arsenicals. Morris and Swingle (1927) working with sand cultures, found that "even in dilutions of one to one million, arsenicals reduced the transpiration of plants, but that different crops varied with regard to their tolerance of the chemical." Cooper et al. (1931 and 1932) found that gray soils low in reactive iron were sensitive to additions of calcium arsenate; whereas the dark soils relatively high in reactive iron were not seriously affected by large amounts of calcium arsenate. The red and chocolate soils were very tolerant of calcium arsenate, because they contained large quantities of reactive iron, which probably resulted in the formation of insoluble iron arsenate in the soil. High soil acidity seemed to increase the toxic effect of calcium arsenate. Brenchley (1927) showed that the arsenites are frequently ten times as toxic as the arsenates.

On the basis of the above paragraph, it would seem that any recommendation either for or against the use of arsenicals would be subject to question depending upon the several factors involved. The author believes, however, that with the data obtained and the above paragraph, that sodium arsenate might be used as a larvicide. It is more effective than borax, and probably would be less toxic to the plants if the treated manure were used for fertilizing purposes. Sodium arsenite and paris green were both very toxic, but it is believed that they would hinder plant growth too much if used. The mortality curves of the arsenicals to house fly larvae are shown on Plate I.

Included in the numbered compounds were three which were more toxic than borax. Since their composition is unknown, it is useless to speculate as to their toxicity to plants, which would in turn decide their usefulness.

It is the belief of the author that the chemical control of house fly larvae under ordinary conditions is impracticable, but if necessary, it can be accomplished. The results obtained from the tests just completed show the relative toxicity of the various chemicals to house fly larvae, but whether they will give the same results when used in manure is a different problem.

The reader can obtain a complete and clear picture of the mortality curves of all the chemicals which were more toxic to house fly larvae than is borax by referring to Plate I. Plate II, shows the various mortality curves of the chemicals which were equally as toxic as borax to house fly larvae as shown by the tests completed.

SUMMARY

The toxicity of 58 materials other than borax to house fly larvae are reported upon in this paper.

The tests were conducted in accordance with the rearing methods of the Peet-Grady tests as modified by Eagleson. The toxic material was thoroughly mixed with the breeding medium, thus giving a reasonably even distribution. A total of 23,900 second instar larvae were used in 239 tests.

Those chemicals equal to or more toxic than borax as found by the work just completed are listed as follows:

1. Sodium arsenite, paris green and copper arsenate killed all larvae when used in a concentration of 0.05 percent.
2. Those producing a 100 percent mortality when used in a 0.075 percent concentration were #14 and #102 (U. S. Rubber Co. Numbers.)
3. Ethylene dichloride, ethylene chlorohydrin, zinc phosphide, mercuric chloride and sodium arsenate killed all larvae when used in a concentration of 0.10 percent.
4. Para-dichlorobenzene, N-butyl mercaptan, thallous sulfate, dinitro-O-cyclohexylphenol, "black leaf-40", mercurous chloride, lead arsenate, carbon disulphide, and #15 (U. S. Rubber Co. number) were as effective as borax, killing all larvae when used in a concentration of 0.50 percent.

The chemicals tested which proved to be less effective than borax are as follows:

1. Those killing all larvae when used in a 1.00 percent concen-

tration were: Ortho-dichlorobenzene, ethyl mercaptan, benzene dibromide, thallous acetate, pyrethrum (20-1), "Lethane 384", American hellebore, #250, #305, and #244 (U. S. Rubber Co. numbers).

2. The chemicals requiring a 5.00 percent concentration to kill all larvae are: Carbon tetrachloride, trichloroethylene, naphthalene, hexachlorobenzene, anthracene, white hellebore, "protexed derris," pine oil barium fluosilicate, barium chloride, tartar emetic, paraformaldehyde, #326, #96, Dow K-58, #331, #24, and #11 (U. S. Rubber Co. numbers).

3. Some of the chemicals tested failed to produce a 100 percent mortality when used in a 5.00 percent concentration. They are as follows: "Cresylic acid," black hellebore, phenothiazine, cryolite, barium fluoride, calcium fluoride, calcium arsenate, diphenolamine, #308, #343, and #327 (U. S. Rubber Co. numbers).

No attempt has been made to utilize any of these materials mentioned in the above paragraphs in a practical way. The results herein reported deal strictly with the effectiveness of the compounds for the prevention of development of house fly larvae in a medium under the conditions of the experiments.

Explanation of Plate I.

The toxicity curve of the chemicals more toxic than borax.

1. Borax
2. Paris green
3. Sodium arsenite
4. Sodium arsenate
5. Copper arsenate
6. Ethylene dichloride
7. Ethylene chlorohydrin
8. Zinc phosphide
9. Mercurous chloride
10. #102 (U. S. Rubber Co.)
11. #14 (U. S. Rubber Co.)

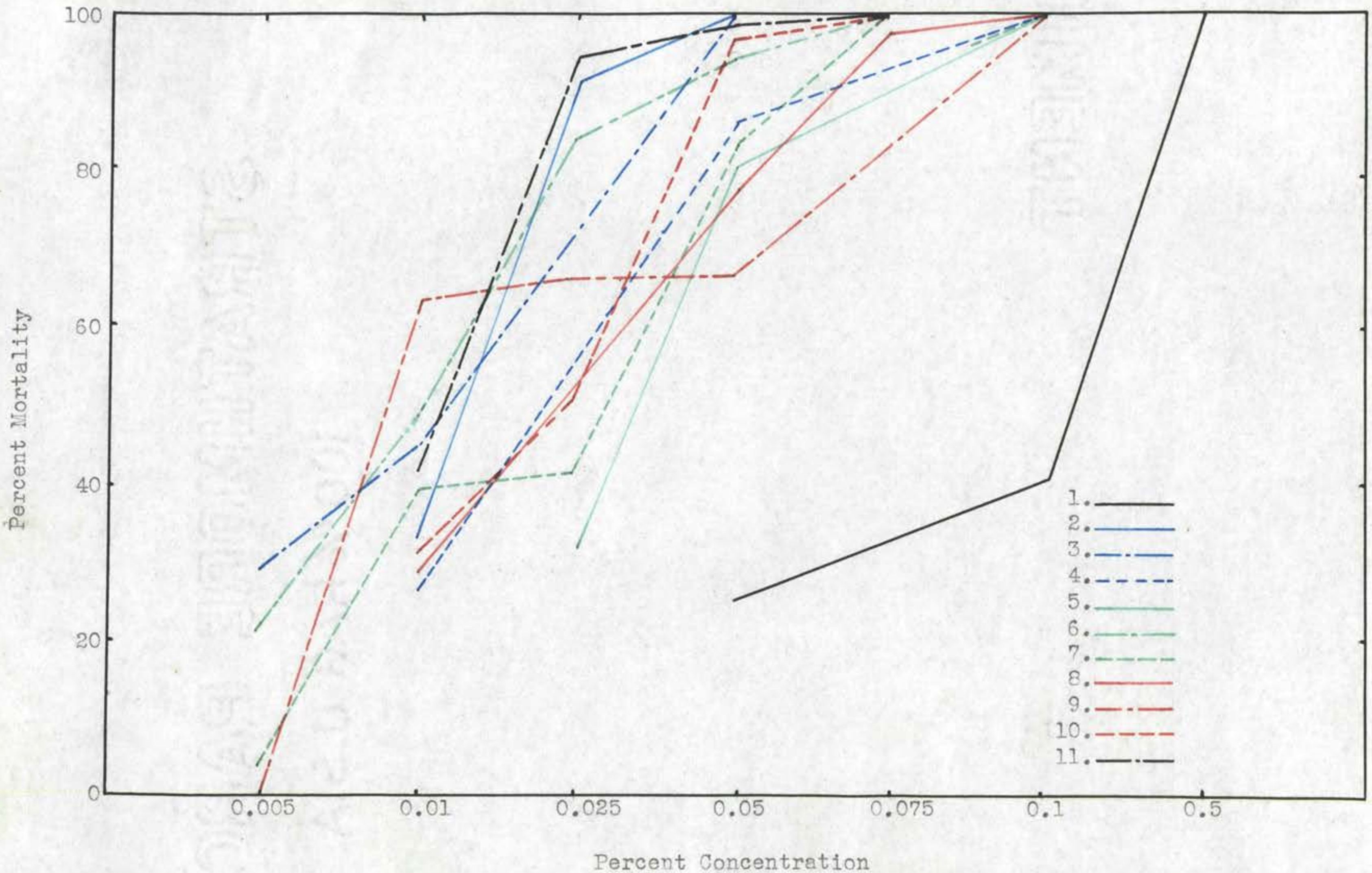

Percent Mortality
100
80
60
40
20
0
0.005
0.01
0.025
0.05
0.075
0.1
0.5
Percent Concentration
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.

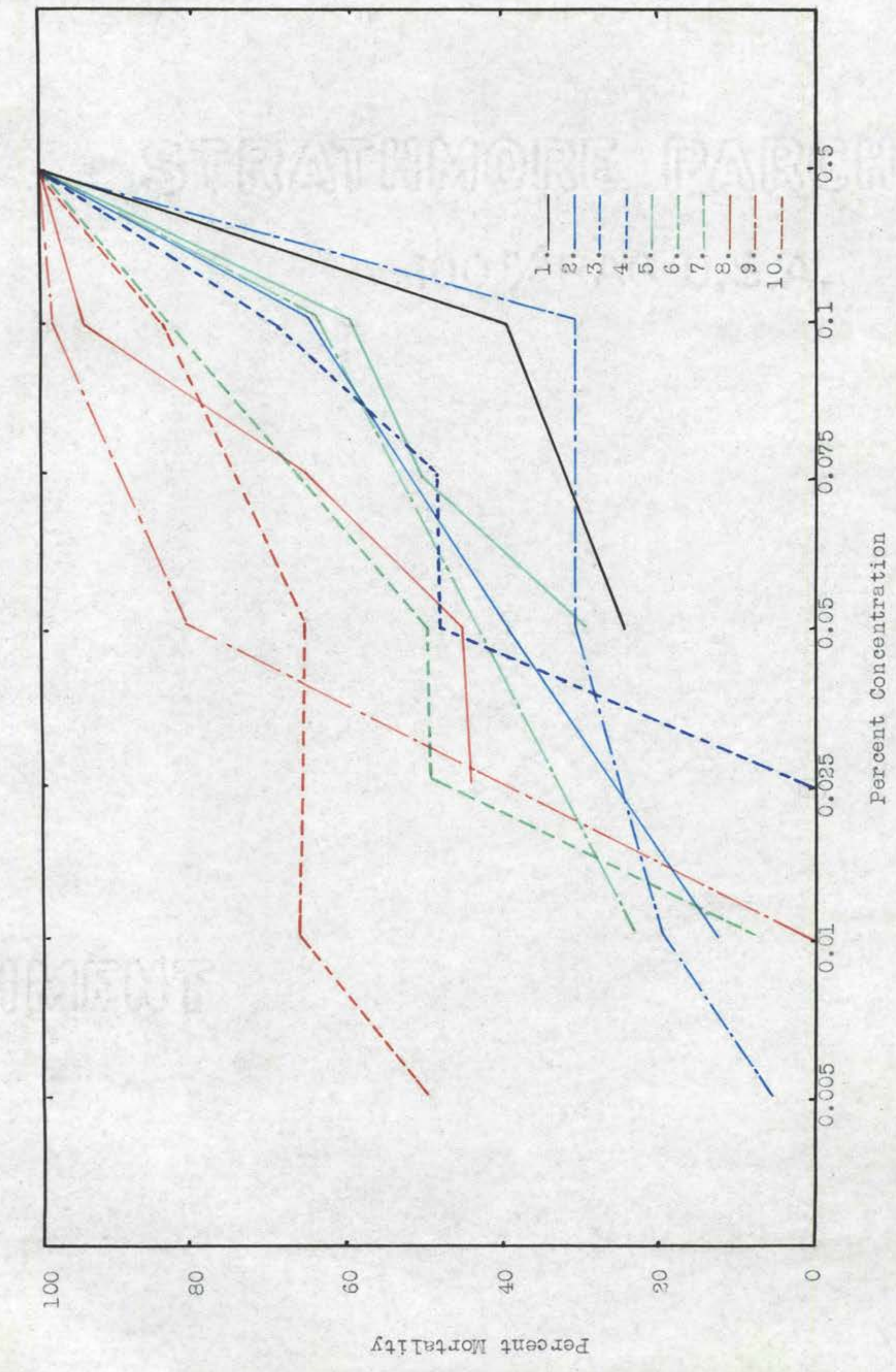
PLATE I

Explanation of Plate II.

The toxicity curve of the chemicals as toxic as borax.

1. Borax
2. Para-dichlorobenzene
3. N-butyl mercaptan
4. Thallous sulfate
5. Dinitro-O-cyclohexylphenol
6. "Black leaf-40"
7. Mercurous chloride
8. Lead arsenate
9. Carbon disulphide
10. #15 (U. S. Rubber Co.)

PLATE II


1.
2.
3.
4.
5.
6.
7.
8.
9.
10.
0.5
0.1
0.075
0.05
0.025
0.01
0.005
Percent Concentration
100
80
60
40
20
0
Percent Mortality

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