A LABORATORY EVALUATION OF THE EFFECTS OF CONDITIONS AND MATERIALS FOUND IN FOOD-HANDLING ESTABLISHMENTS ON INSECTICIDES USED FOR THE CONTROL OF *BLATTELLA GERMANICA* (LINNEAUS)

By

WILLIAM OSCAR REE, JR.

Bachelor of Science in Agriculture

Oklahoma State University

Stillwater, Oklahoma

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Thesis Approved:

Richard L. Rice
Thesis Adviser

Lloyd B. Young

Laurence D. Roth

Norman N. Durham
Dean of the Graduate College

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CHAPTER I

INTRODUCTION

Through the years of man's existence one of his constant companions has been the cockroach, and through these years there has been a variety of control methods. At first it was a simple type of physical control but later man learned that chemicals could provide a more efficient and constant control against these pests.

Besides being associated with unsanitary conditions, cockroaches have also been associated with diseases. Frishman and Alcamo (1977) discovered German cockroaches carrying Coliforms, Escherichia coli, and Staphylococcus. This fact and the fact that German cockroaches are found almost everywhere man stores and/or prepares food makes their control necessary. Since the use of insecticides for cockroach control can also be harmful to humans, the methods used and insecticides applied are of great importance.

In order to provide some type of guidelines for chemical use, the Federal government established agencies to govern their use. This duty is now the responsibility of the Environmental Protection Agency (EPA).

The majority of pesticides used today is in the area of agriculture but one area of pesticide application that is in close contact with many people is the application of insecticides in food-handling establishments. As defined by the EPA a food-handling establishment is "an area or

place other than a private residence in which food is held, processed, prepared and/or served" (Mampe, 1976). Insecticide application to these areas is restricted to crack and crevice treatment.

The subject of this thesis is to test the effects of materials and conditions on insecticides applied for cockroach control rather than the method of application. The objectives of this thesis are to: (1) examine the effects of six building materials found in food-handling establishments on the residual effectiveness of four commonly used insecticides applied for the control of cockroaches, and (2) to determine if the surface condition of the material has any immediate or prolonged effect on the insecticide. The building materials selected for this research are: glazed ceramic tile, vinyl wall base, vinyl asbestos tile, painted wood, varnished wood and unfinished wood. Each of these six materials will be treated under the following conditions: clean, flour coated, grease coated, coke syrup coated and washed with a detergent. For the rest of this manuscript the words surface coating will replace the word condition. Ten adult German cockroaches will be exposed for twenty-four hours the day of treatment and for twenty-four hours at 7, 14, 21, and 28 days after treatment. The insecticides used for this test are Diazinon 4E, Dursban 4E, Ficam 76WP, and Killmaster II.

CHAPTER II

LITERATURE REVIEW

During the last 35 years there has been some consideration given to the effects of insecticides incorporated in surface coatings. Most of the early testing was for the control of houseflies.

Lindquest, Madden, Wilson, and Jones (1944) considered the possibility of combining DDT in cold water paints to give both a decorative and insecticidal treatment at the same time.

Campbell and West (1944) tested the effectiveness of DDT in several kinds of paints including cold water, oil-in-water emulsion, white lead oil paint and synthetic varnish enamel paints. They found that oil paints and synthetic enamel were not insecticidal at all to houseflies but that cold water and emulsion paint gave good results. In their tests it was shown that the insecticidal effectiveness of the coating increased with age.

The effect of insecticides on different types of surfaces was reported by Keller, Clark, Lofgren, and Wilson (1956). They selected 27 compounds with good knock down capabilities for residual tests against German cockroaches. Testing consisted of treating plywood panels with acetone solutions of insecticides at a rate of 100 mg AI/sq. ft. Ten adult male cockroaches were exposed two hours after treatment for 30 minutes. Knock down was recorded after 24 and 48

hours at 1, 2, and 4 weeks provided the treatment killed 80% or more of the test insects during the previous test. Diazinon gave 50% mortality at the end of 24 and 48 hours on the one week test as compared to the standard (chlordane) which gave 40 and 70% mortality at the end of 24 and 48 hours for the same test.

Flynn and Schoof (1966) tested 22 compounds as a residual against Musca domestica (L.) and Blattella germanica (L.) on painted and unpained galvanized metal, tempered masonite panels and asphalt tile surfaces. Each formulation was sprayed (40 lb./sq. in.) onto 4 panels of each surface type at a rate of 4 ml/sq. ft. using three different concentrations (50, 100, and 200 mg/sq. ft.). Twenty to twenty-five adult cockroaches of the Ft. Rucker strain (resistant to chlordane, dieldrin, and lindane) were used in each test. Insects were confined for three hours then placed in a pint jar, provided with food and water and held at 80°F and 70% RH for the 24 hour mortality count. These tests indicated considerable variation between and within the four classes of compounds (phosphate, phosphorothioate, phosphorodithioate, carbamate) involved but also emphasized that efficiency of the compounds is influenced by the surface material treated. Diazinon gave up to eight weeks control on unpainted tile at 200 mg/sq. ft. but was only effective one week on the unpainted galvanized metal. Of all the formulations in this test a carbamate H-9699 obtained the longest control.

Whitney, Harrison and Howe (1967) used a variety of test methods to simulate the many ways cockroaches were exposed to toxicants in the field. One of the test methods consisted of treating a 6 in. x 6 in. (15.24 cm x 15.24 cm) plywood panel with 10, 20 and 40 mg AI/sq. ft.

using oil base and water emulsions. Of the formulations tested Dursban EC at 40 mg provided the best control with 100% mortality up to nine weeks.

Bodenstein, Foles and Walker (1970) tested Diazinon, Chlordane, Baygon and Dieldrin for residual effectiveness against American, Australian brown and smokey brown cockroaches. Acetone solutions of insecticides were laid down on the inner surfaces of glass fruit jars and any material that killed 100% of a species after 48 hours or less was retested at two weeks. If the formulation was still effective, it was retested after another two weeks, and then every four weeks until it was no longer effective. At the end of two weeks Diazinon was ineffective while a two week residue of Chlordane killed 100% of the small nymphs of all species in 4-7 hours and 100% of the adult males of the Asutralian and American cockroaches in 18 and 27 hours respectively. Baygon killed 100% of all stages of all species after 3 hours exposure on a 4 week residue.

In 1970, studies by the National Communicable Disease Center showed that the activity of insecticidal residues is markedly influenced by the type of material to which the formulation is applied. Diazinon, Dursban, and Baygon at a rate of 50 mg/sq. ft. were tested on painted and unpainted metal, masonite and tile. The test consisted of exposing 100 German cockroaches at periodic intervals for a maximum of 15 days. Diazinon gave up to 52 weeks control on the tile surface but only seven weeks control on unpainted metal. Dursban was effective for 60 weeks on tile and 19 weeks on unpainted metal while Baygon was effective for only two weeks on tile but 23 weeks on unpainted metal.

Burden and Madden (1975) conducted studies to determine the

comparative susceptibility of the American cockroach to pesticide residues on plywood. Plywood panels were treated at a rate of 100 mg AI/sq. ft. with Diazinon, Dursban, Baygon and Trichorfon. These solutions were applied in perpendicular swaths with a small atomizer. Panels were allowed to dry for two hours before exposing the cockroaches to the surface. Cockroaches were exposed for one hour, checked, then transferred to pint mason jars until the 48 hour check. Panels were restored and tested again at weekly intervals through four weeks and then biweekly until less than 80% control was obtained. Diazinon, Trichorfon, Dursban and Baygon were effective (80%-100%) for minimums of one, two, four, and six weeks respectively.

Research at Virginia Polytechnical Institute

In 1956 the National Pest Control Association (NPCA) set up a research study at VPI for the investigation of insecticide residual effectiveness against German cockroaches. Most of this work has been headed by Dr. J. M. Grayson.

In early tests by Jarvis and Grayson (1957) also Grayson and Perkins (1960), treatment of test materials (tempered masonite panels, unpainted wood or sheetmetal) was accomplished by dipping the panels into insecticide solutions. Grayson and Townsend (1962) attempted to estimate the rates of insecticide deposit obtained in previous years from dipping. By two different types of procedures it was estimated that the deposit per panel was approximately 5 ml from oil base formulations, 2.5 ml from formulations involving water extensions of soluble concentrates and 3 ml from emulsion formulations.

In 1962 through 1977, the treatment of tempered masonite panels

was changed from dipping to applying formulations by pipette. Immediately following application, a camels hair brush was used to facilitate spreading over the panel in order to insure a more uniform deposit. The pipette application method produced 2.0 ml of solution per panel. The general procedure for testing was to put three treated panels (4.5 in. x 4.5 in.) (11.43 cm x 11.43 cm) in a battery jar. Twenty female German cockroaches were placed in each jar and continuously exposed from one to three days with a few tests running for six days. Tests were conducted at two, seven, fifteen, thirty and sixty days after treatment using resistant and non-resistant strains of German cockroaches. In all tests, experimental formulations were compared to a standard (Diazinon 0.5% oil base).

Grayson (1966) conducted another test and included Dursban 1% oil base, Baygon 1% oil base and Diazinon 1% oil base. From these tests some of the best results were obtained by Dursban. Diazinon achieved 100% control after a 3 day exposure at the 30 day test against malathion resistant and non-resistant strains but only 44% control against diazinon resistant strains of German cockroaches.

Grayson (1969) tested eleven experimental materials in 1967 and eight materials in 1968 for effectiveness in killing normal and resistant German cockroaches. Using Diazinon 1% oil base and Baygon 1% oil base as standards, Diazinon provided 90% control at the end of one day exposure during the 30 day test in 1967 and 100% control for the same test in 1968. Baygon 1% oil base provided 100% control for the same test in 1967 and 1968.

Results by Grayson (1969, 1970, 1974, 1977) and Grayson and Robinson (1976) obtained approximately the same effect with oil base

solutions of 1% Diazinon and 0.5% Dursban. In all cases tests were performed as in 1962. Diazinon and Dursban continued to give 97%-100% control at the end of one day exposure during the 30 day test.

Insecticide Review

In order to provide some understanding of the insecticides used in this test a short summary will be given for each insecticide tested.

Diazinon 4E is an organophosphate containing 4 pounds of Diazinon per gallon. In food areas or food-handling establishments, use is limited to crack and crevice treatment only. A 1% rate is recommended for cockroach control and is prepared by mixing 2.5 oz. (70 ml) with one gallon (3.8 L) of water.

Dursban 4E is an organophosphate containing 4 pounds of Dursban per gallon. In food areas or food-handling establishments, 0.5% and 0.25% rates are recommended for cockroach control as spot and/or crack and crevice treatment. To prepare a 0.5% solution, 1.33 oz. (40 ml) is mixed with one gallon (3.8 L) of water.

Ficam W is a carbamate containing 76% active ingredient by weight. For cockroach control a 0.25% and 0.125% solutions are recommended. A 0.25% solution is prepared by mixing one packet (0.4 oz.) per one gallon (3.8 L) of water.

Killmaster II is a 2% solution of Dursban in a petroleum solvent which contains 2.33 oz. of Dursban per gallon. Killmaster II is applied directly from the can by brush, roller or sponge applicator or as a crack and crevice treatment. Crack and crevice treatment should be made as a coarse low pressure (20 psi or less) spray with equipment capable of delivering a pin stream of insecticide. Killmaster II is a slow

release formulation and after 36 hours may be washed or cleaned. The label on the container of Killmaster II used for this research did not contain the crack and crevice statement or the 36 hour waiting period statement.

CHAPTER III

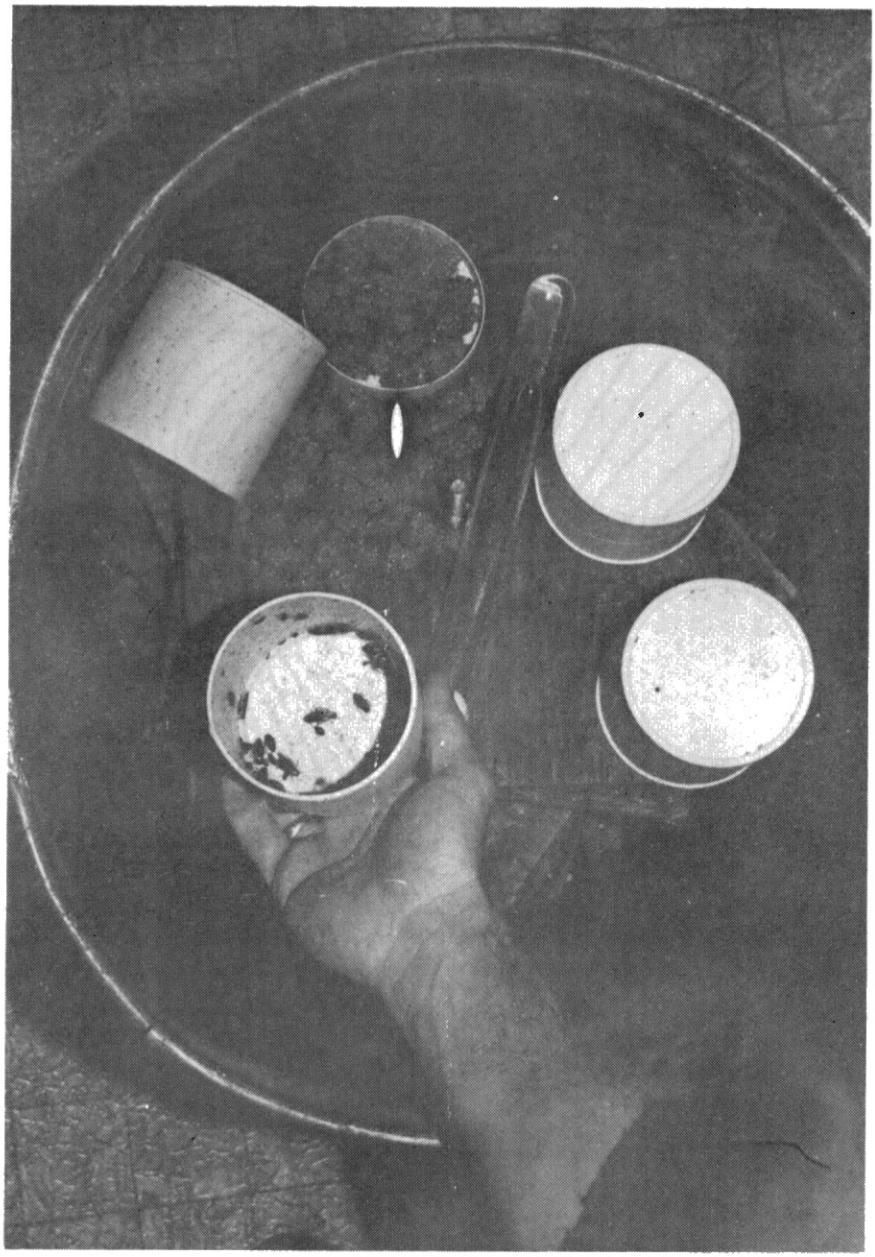
METHODS AND MATERIALS

Cockroach Rearing and Collecting

All specimens used in these tests were taken from non-resistant colonies of Blattella germanica (L.) raised by the Oklahoma State University Entomology Department. Cockroaches are raised in 20 gallon galvanized and plastic cans with layered plywood structures for harborage areas. The rim of each can is coated with a layer of vaseline to keep cockroaches from escaping. Cockroaches are maintained on a diet of dry dog food and water. To assist in the collection of specimens, several one pint paper cans 3.25 in. (8.26 cm) diameter are inverted and placed over the edge of the top plywood structure (Figure 1).

To collect specimens for testing in such a manner as to reduce injury, a 12 in. x 6 in. x 7 in. (30.48 cm x 15.24 cm x 17.78 cm) aquarium was submerged in a 18 in. x 10 in. x 16 in. (45.72 cm x 25.4 cm x 40.64 cm) styrafoam ice chest containing ice and allowed to cool for about 20 minutes. At this time the paper cans from the colonies were removed, and the cockroaches from these containers placed in the aquarium. As soon as cockroach activity was reduced enough to allow collection, forceps were used to remove adults by grasping a leg or wing, being careful not to injure the specimen. Collecting was done at least eight hours before testing to insure all cockroaches were viable so that

Figure 1. German Cockroach Colony and Harborage Containers



any death in testing could be attributed to the surface coating rather than handling. One pint paper cans served as holding containers with each container holding ten adults.

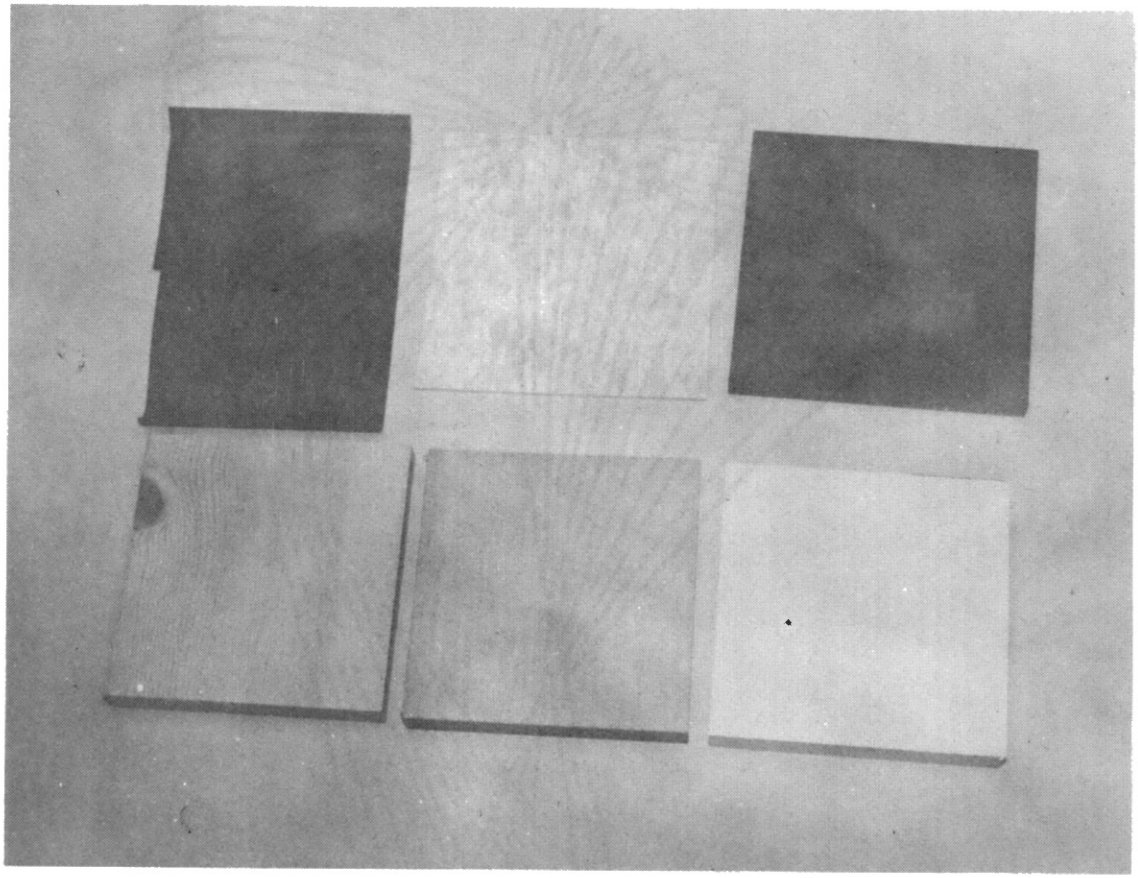
Test Materials

The materials and conditions selected for this thesis are a few of the typical building materials, surface coatings and insecticides which might be found in the construction of a food-handling establishment.

The building materials used were divided into two classes for treatment: floor materials (glazed ceramic tile, vinyl wall base, vinyl asbestos tile) and building materials (painted wood, varnished wood, unfinished wood). Floor materials used are: 6 in. x 6 in. x 1/2 in. (15.24 cm x 15.24 cm x 1.27 cm) glazed ceramic tile manufactured by American Olean Tile, 12 in. x 12 in. x 1/16 in. (30.48 cm x 30.48 cm x 16 cm) vinyl asbestos tile manufactured by Kentile Inc. and a vinyl wall base also manufactured by Kentile. White pine was selected for the building material because of its wide use in cabinet construction. This material was prepared in 3 ways: painted with one coat of white interior latex paint, varnished with one coat of clear satin finish varnish, and as an unfinished surface (Figure 2).

Each of these six materials was then subjected to seven different surface coatings. The test coatings choosen are a few of the subtances under which an insecticide might function. These test coatings are: (a) a clean surface; (b) a coating of cooking flour; (c) a coating of cooking flour treated then given an additional coating of flour; (d) a coating of grease; (e) a coating of grease, treated then given an

Figure 2. Building Materials Used in Tests. Left to Right: Top - Vinyl Wall Base, Vinyl Asbestos Tile, Glazed Ceramic Tile; Bottom - Unfinished Wood, Varnished Wood, Painted Wood



additional coating of grease; (f) a coating of coke syrup; and (g) a clean surface which is washed with a commercial detergent after treatment.

Flour coatings were applied with a flour sifter at a rate of 3 grams per sample with an additional 2 grams added after treatment to those samples that require it. Vegetable grease obtained from a local restaurant was melted in a hot plate and painted on the surface with a paint brush. Coke syrup was applied to samples through a plant mister. Samples that required a washing were washed with a Carroll Cardinal brand of detergent at a concentration of 2 fl. oz. (60 ml) per gallon of water. This is the daily maintenance suggestion. Each sample that was washed received eight circular wipings with a sponge and detergent then allowed to dry.

For the treatment of the samples, four commonly used insecticides were chosen: Diazinon 4EC, Dursban 4E, Ficam W, and Killmaster II. Diazinon, Dursban, and Ficam were applied at the two recommended rates for cockroach control while Killmaster II was used directly from the container. Diazinon was applied at 1% and 0.5% rates; Dursban at the 0.5% and 0.25% rates, and Ficam at the 0.25% and 0.125% rates. All rates used are in accordance with the label. In addition to the treated samples, control tests were run on flour, grease, coke syrup, clean and detergent surfaces.

Spraying Apparatus and Technique

The spray tank used for these tests is a B&G tank, model number 104-S modified by Karner (1976). Modification included the removal of the regular pump assembly and replacing it with a pressure regulator,

pressure guage and an air inlet and outlet petcock. This type of assembly allowed for an accurate and constant pressure. Air source for the sprayer was a 17.6 kg/cm portable air tank.

To provide a constant speed of application a motorized track device designed by the Oklahoma State University Agriculture Engineering Department was used. The track is 10 ft. (3.05 m) long and the chain is driven by a 1/3 HP motor. Speed of the chain is regulated by a Zero-max 0-400 model JK2 gear box.

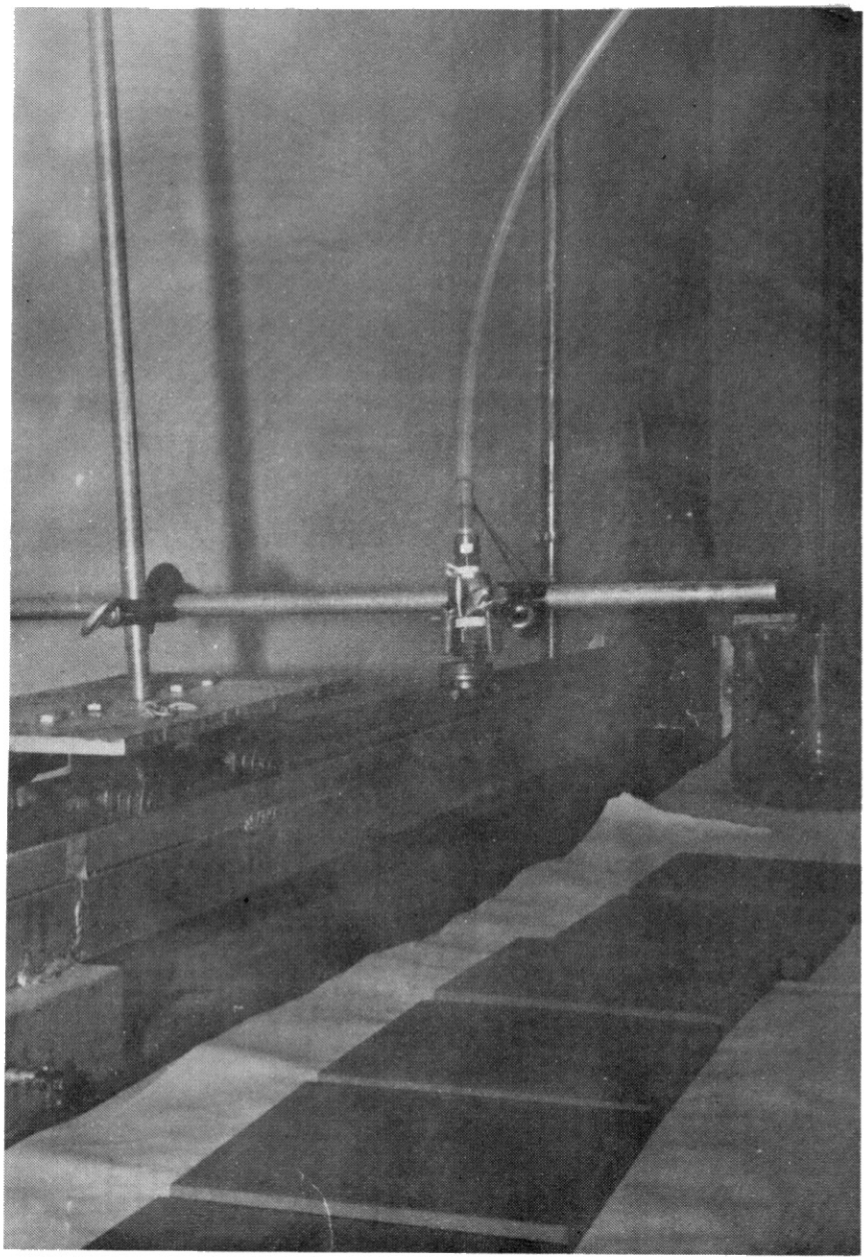
A nozzel stand consisting of a base plate and two bars, one permante vertical bar and a detachable horizontal bar was propelled by the chain. The detachable horizontal bar allowed for correct nozzle height adjustment. A multi-teejet 800067 nozzle (fan spray) was clamped to the horizontal bar. A 9 ft. (2.74 m), 1/8 in. (.32 cm) ID hose connected the nozzle to the tank.

Treatment consisted of treating all samples of one class (ex. floor materials) on the same day. One pass of the spray was used to treat all seven samples of one material group (ex. glazed ceramic tile) (Figure 3).

After spraying, the treated materials were allowed to dry for one hour before the predesignated samples received their post spray coatings. Thirty minutes were allowed following post spray coatings before the cockroaches were placed on the surface. This allowed time for post spray grease applications to cool and the washed samples to dry.

Since Killmaster II had to be applied with a brush instead of as a spray, some modifications had to be made. Only one flour test surface coating was used and this was applied after the surface had been treated. The application of coke syrup was also applied after the

Figure 3. Spraying of Test Materials



material had been treated. All other surface coatings were treated the same as the materials receiving a spray treatment.

Cockroach containment to the surface was accomplished by using 16 oz. (488 g) cottage cheese containers with the bottoms cut out. These containers had an opening of 4 3/4 in. (12.07 cm) diameter which determined the sample size. To prevent the cockroaches from climbing up the sides, the inside of the container was coated with a fine clay powder. This powder was applied with a small brush. To prevent any cockroaches from escaping, containers were covered with a fine mesh nylon fabric and fastened with a rubber band. When placing the cockroaches in the test container the sample and container were placed in a 12 in. (30.5 cm) diameter, 6 in. (15.25 cm) high ring (Figure 4). Cockroaches from the holding containers were then placed on the surface.

Mortality counts were made at 4, 6, 8, 12, and 24 hours after spraying on the first day. Testing was repeated at the end of 7, 14, 21, and 28 days. For these tests, mortality counts were made after 24 hours exposure. Death was determined when a cockroach was on its back but unable to right itself or if the cockroach produced no motion when probed. After each test, dead and alive cockroaches were removed from the samples and destroyed. The samples were then stored until time for the next test. To determine whether there was adequate coverage of spray on the sample, a fluorescent dye was mixed with water and sprayed over some non-test samples. After drying samples were exposed to a black light for observation. Spray coverage can be seen in Figure 5.

During spraying, certain constants had to be used. Tests by Rogers and Price (1973) determined that an application speed of 2.5

Figure 4. Treated Surface With Cockroaches and Cottage Cheese Container Inside Placement Ring

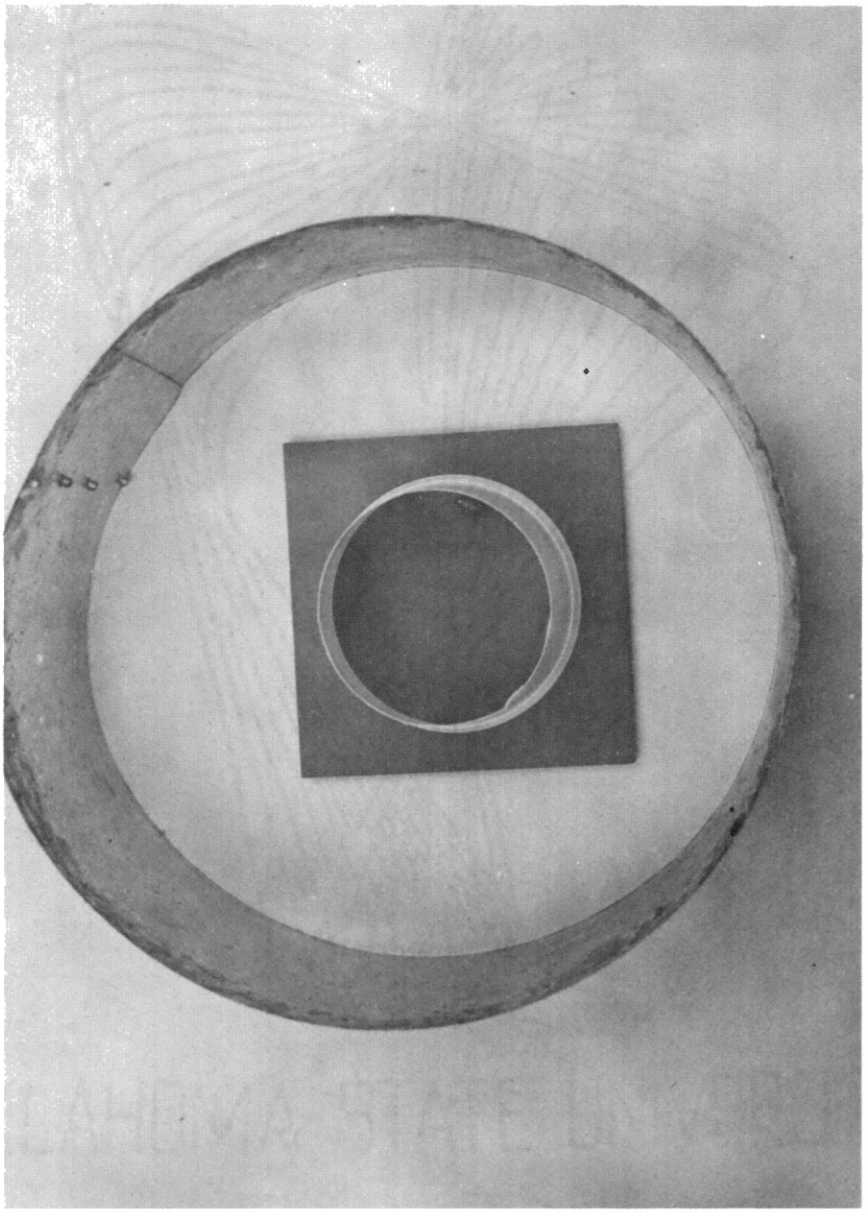
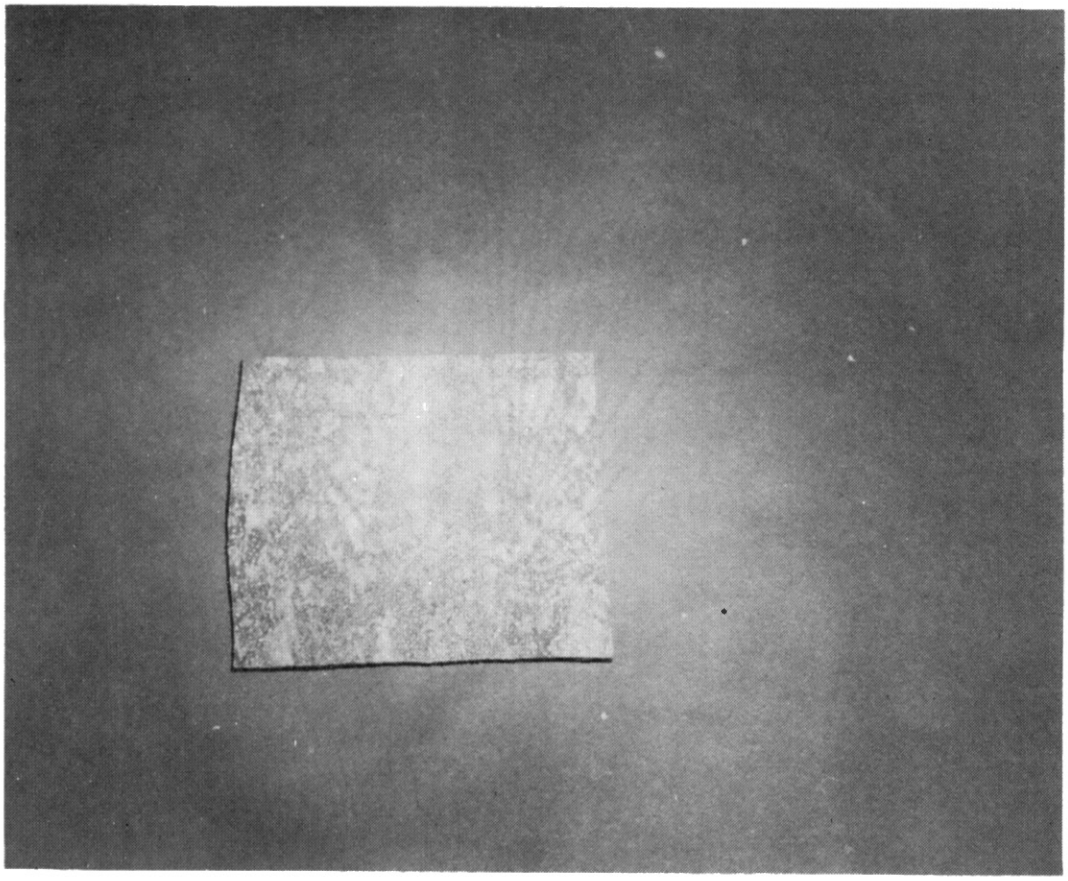


Figure 5. Spray Pattern Showing a Fluorescent Dye on Vinyl Asbestos Tile



ft./second (.76 m/second) at 20 psi was the most economical for an 800067 nozzle. A nozzle height of 6 in. (15.24 cm) was selected because it was low enough to cover the sample area. Using these constants and a 800067 nozzle it was calculated that each sample area received 0.0047 oz. (0.14 ml) of spray deposit.

Pretest Problems

One of the major problems which had to be solved before testing could begin was how to keep the cockroaches confined to the treated surface. If all or even some of the cockroaches were to climb the sides of the confinement container, the results could be influenced.

The first tests were tried with paper cans with a ring of vaseline on the inside lip. The vaseline proved to be less than adequate for keeping the cockroaches confined to the surface. Next, plastic pipe was tried with the inside surface coated with wax, vaseline and clay powder. None of these solutions proved to be adequate. The final solution was to use cottage cheese containers with the inside surface coated with a clay powder.

Another major question was how long to expose the cockroaches to the treated surface to obtain significant results. During some pretest experiments, cockroaches were exposed for one hour before removing them to holding containers. Cockroach mortality was so low that the time they were exposed to the treated surface had to be extended.

CHAPTER IV

RESULTS AND DISCUSSION

Effects of Materials on Insecticides

One aspect of this thesis was to determine if the different materials used in the construction of food-handling establishments have any effect on insecticides used for the control of German cockroaches. As seen in Tables I-VI, mortality was highest, when comparing all time periods, at the end of 24 hours for clean treated surface. The only exception being Killmaster II which obtained 100% control for the 7, 14, 21 and 28 day test as compared to 93% control for the 24 hour test.

When comparing mortality rates at the end of 24 hours for clean treated materials, the data in Table VII shows a wide range of mortality provided by the insecticides over the different materials and by the insecticides for the individual materials. The only exceptions were Killmaster II which was consistant in obtaining 80%-100% mortality on all surfaces and glazed ceramic tile which had 86%-100% control from all insecticides. For the individual surfaces the lowest average control was obtained on vinyl wall base with a 3.5 mortality mean averaged over all insecticides while the highest mortality rate was obtained on glazed ceramic tile with a 9.6 mortality mean. In comparing the effectiveness of the two rates used for each insecticide the higher rate produced the highest mortality except on vinyl wall base

treated with Diazinon and glazed ceramic tile treated with Ficam. In two cases the low rate was equal to the high rate, on vinyl asbestos tile and glazed ceramic tile treated with Dursban. In two cases no control was provided by Dursban 0.25% on vinyl wall base and Ficam 0.125% on painted wood.

In Table VIII mortality rates are averaged over a 28 day period for clean treated materials. Under this situation Killmaster II again obtained the highest mortality rates on each of the six materials tested while Ficam 0.125% provided the least amount of control except on vinyl asbestos tile and vinyl wall base. When comparing mortality on the individual surfaces, treatment of glazed ceramic tile produced the highest mortality mean over all treatments while vinyl wall base had the lowest overall mortality mean. Insecticides applied at the higher rates obtained the highest mortality except for Diazinon on vinyl wall base and Dursban on glazed ceramic tile.

Effect of Surface Coatings on Materials and Treatments

During the process of preparing food, surrounding surfaces may become coated with substances such as grease, flour or soft drink syrup which can influence the effectiveness of insecticides.

In Table IX mortality rates are averaged after the first 24 hours over all treatments for the seven surface coatings tested for each material. From this data it can be seen that grease has the greatest influence on reducing mortality. Averaged over all materials, mortality rates were lowest on surfaces with two coatings of grease. When averaging the mortality rates of the surface coatings over the six

materials, only surfaces with one application of flour and coke syrup were greater than that of clean treated materials.

From Table XI it can be seen that all surface coatings are significantly different at the 0.05% level except between one application of flour and coke syrup coated surfaces. These mortality rates are averaged over a 28 day period for materials and treatments.

In Table XV the data shows mean German cockroach mortality for surface coatings for each treatment averaged over all materials for a 28 day period. With the use of Diazinon at 0.5%, there is a significant difference at the 0.05% level between the seven surface coatings tested while the use of Diazinon at 1.0% produced no significant difference between the two grease conditions. The application of Dursban at 0.25% produced no significant difference between the two grease coatings and no difference between materials with one coat of flour and a coating of coke syrup. For Dursban at 0.5% there was a significant difference between all seven surface coatings. The application of Ficam at 0.125% produced no significant difference between materials washed with a detergent and materials with two coats of grease while Ficam 0.25% produced no difference between materials with grease coatings. With the use of Killmaster II which provided the highest mortality rates for all seven surface coatings, there was a significant difference between all seven coatings.

Effect of Materials and Surface Coatings on Length of Control

The second major aspect of this research was to see if the length of control was affected by the material on which the insecticide was

applied. Testing was continued for four weeks. This time period was selected because this is the usual length of time that pest control operators wait between treatments.

In Table XVI the data shows mean German cockroach mortality for 1, 7, 12, 21 and 28 days after treatment averaged over all materials and surface coatings. When mortality rates are averaged over all insecticides, mortality was highest at the end of the one day and continued to decrease for 21 days and then increase slightly at the end of the 28 days. For the insecticides tested, Killmaster II obtained the highest mortality rates during each time period while Ficam at the 0.125% rate obtained the lowest average for 1, 7 and 14 days, Ficam at 0.25% obtained the lowest rates during the 21 and 28 day periods.

In Table XVII the data shows mortality rates for the seven surface coatings, averaged over all materials and treatments for 1, 7, 14, 21 and 28 day periods. This data shows that mortality rates are highest at the end of the one day test for all surface coatings except for coatings of one and two applications of grease. For these two conditions mortality rates were highest at the end of the seven day test. The highest mortality rate at the end of the one day test was obtained on coke syrup coated surfaces. After the one day test, mortality rates decreased for all surface coatings except for the two conditions where grease was applied with the greatest reduction of mortality on coke syrup. At the end of the 28 day test only surfaces with coatings of flour had higher mortality than clean treated surfaces.

CHAPTER V

CONCLUSION

In looking at the effectiveness of the insecticides tested, there is a significant difference between all insecticides tested and between all rates tested. The data in Table XIII shows that, averaged over a 28 day period for all materials and surface coatings, Killmaster II provided the highest mortality which is almost twice that of Diazinon at the 1.0% rate which obtained the second highest average. The two lowest mortality averages were obtained by Ficam at the 0.125% and 0.25% rates with an 8.32% and 13.14% mortality respectively. In all cases the highest rate of an insecticide provided a more efficient control.

When comparing the overall effect of the seven surface coatings tested only two coatings, one coat of flour and coke syrup, had mortality rates greater than that of a clean treated surface. These two coatings also had the highest mortality rates on the control surfaces (Table X). The reason for the high mortality on the control surfaces is uncertain. Cockroaches exposed to flour and coke syrup coated surfaces would become coated with flour or coke syrup. This could cause mortality by interfering with respiration or the flour and coke syrup was able to absorb the insecticide, therefore, increasing the contact of the insecticide with the cockroach. In actual field

conditions it is unlikely that a cockroach would spend much time on a heavily floured or syrup coated surface. Better results for these types of coatings could possibly be obtained by some other method of testing.

Comparing the effect of the materials over all treatments, surface coatings and time periods (Table XIV) there was no significant difference at the 0.05% level between varnished wood and vinyl asbestos tile. Mortality rates on vinyl wall base were the lowest of the six materials tested while glazed ceramic tile obtained the highest average followed by unfinished wood. This could be due to the fact that they are both porous materials.

For controlling cockroaches in food-handling establishments, the main objective is to keep a clean environment. This will not only limit the food sources for the cockroaches but will increase the effectiveness of insecticides applied for their control. When applying insecticides, control will be more effective if the insecticide is applied to the cracks and crevices. This type of application will increase the contact time with the cockroach and prolong its effectiveness.

For future research in the area of cockroach control there is a wide variety of conditions and insecticides that can be tested. The future of insecticides is always uncertain; hopefully this research will help the pest control operator understand the effects of insecticides on different types of surfaces.

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APPENDIXES

TABLE I

MEAN GERMAN COCKROACH MORTALITY[1] ON CLEAN TREATED GLAZED CERAMIC TILE AT DIFFERENT PERIODS AFTER TREATMENT USING 4 DIFFERENT INSECTICIDES

Insecticides and Dosage Rates	Hours and Days After Treatment								
	4	6	8	12	24	7	14	21	28
Diazinon 1%	9.0	10.0	10.0	10.0	10.0	3.6	3.0	2.3	2.3
Dursban 0.5%	8.3	10.0	10.0	10.0	10.0	3.3	0.6	0.0	0.6
Ficam 0.25%	2.3	4.0	5.6	7.0	8.6	6.6	4.6	0.3	0.0
Killmaster II[2]	9.3	9.6	10.0	10.0	10.0	10.0	10.0	10.0	10.0

[1]Mean number of dead cockroaches out of a total of 10.

[2]2% solution of Dursban.

TABLE II

MEAN GERMAN COCKROACH MORTALITY[1] ON CLEAN TREATED VINYL ASBESTOS TILE AT DIFFERENT PERIODS AFTER TREATMENT USING 4 DIFFERENT INSECTICIDES

Insecticides and Dosage Rates	Hours and Days After Treatment								
	4	6	8	12	24	7	14	21	28
Diazinon 1%	0.3	3.0	6.0	8.6	8.6	3.3	1.3	0.3	0.3
Dursban 0.5%	0.0	0.0	0.0	3.0	5.6	3.3	0.3	0.0	0.3
Ficam 0.25%	2.6	4.0	6.0	7.3	8.3	0.3	0.0	0.0	0.0
Killmaster II[2]	0.0	0.0	0.3	1.0	8.0	7.6	8.3	7.3	7.3

[1]Mean number of dead cockroaches out of a total of 10.

[2]2% solution of Dursban.

TABLE III

MEAN GERMAN COCKROACH MORTALITY[1] ON CLEAN TREATED VINYL WALL BASE AT DIFFERENT PERIODS AFTER TREATMENT USING 4 DIFFERENT INSECTICIDES

Insecticides and Dosage Rates	Hours and Days After Treatment								
	4	6	8	12	24	7	14	21	28
Diazinon 1%	0.0	0.3	1.3	2.0	2.6	0.0	0.0	0.0	0.0
Dursban 0.5%	0.0	0.0	0.0	1.0	1.0	0.0	0.0	1.3	0.6
Ficam 0.25%	3.0	4.3	5.3	5.6	5.6	0.0	0.0	0.0	0.0
Killmaster II[2]	0.0	0.0	1.0	2.6	9.0	5.0	4.6	1.6	1.6

[1]Mean number of dead cockroaches out of a total of 10.

[2]2% solution of Dursban.

TABLE IV

MEAN GERMAN COCKROACH MORTALITY[1] ON CLEAN TREATED UNFINISHED WOOD AT DIFFERENT PERIODS AFTER TREATMENT USING 4 DIFFERENT INSECTICIDES

Insecticides and Dosage Rates	Hours and Days After Treatment								
	4	6	8	12	24	7	14	21	28
Diazinon 1%	0.3	5.0	7.6	9.0	10.0	6.6	3.3	1.6	2.3
Dursban 0.5%	0.6	4.0	7.0	9.3	10.0	9.6	7.6	6.3	6.6
Ficam 0.25%	0.0	0.0	0.6	1.6	5.0	3.6	1.6	0.0	0.6
Killmaster II[2]	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0

[1]Mean number of dead cockroaches out of a total of 10.

[2]2% solution of Dursban.

TABLE V

MEAN GERMAN COCKROACH MORTALITY[1] ON CLEAN TREATED PAINTED WOOD AT DIFFERENT PERIODS AFTER TREATMENT USING 4 DIFFERENT INSECTICIDES

Insecticides and Dosage Rates	Hours and Days After Treatment								
	4	6	8	12	24	7	14	21	28
Diazinon 1%	0.0	1.6	5.3	9.6	9.6	6.6	2.3	3.0	1.6
Dursban 0.5%	0.0	0.0	0.3	3.6	8.0	4.0	2.0	0.0	0.3
Ficam 0.25%	0.0	0.0	0.3	0.6	1.3	1.0	0.0	0.0	0.0
Killmaster II[2]	0.0	1.0	3.3	6.3	9.3	10.0	10.0	10.0	10.0

[1]Mean number of dead cockroaches out of a total of 10.

[2]2% solution of Dursban.

TABLE VI

MEAN GERMAN COCKROACH MORTALITY[1] ON CLEAN TREATED VARNISHED WOOD AT DIFFERENT PERIODS AFTER TREATMENT USING 4 DIFFERENT INSECTICIDES

Insecticides and Dosage Rates	Hours and Days After Treatment								
	4	6	8	12	24	7	14	21	28
Diazinon 1%	0.3	3.3	5.3	6.6	8.3	7.3	1.3	1.6	0.6
Dursban 0.5%	0.0	2.0	4.3	5.6	6.6	6.3	4.0	5.6	3.6
Ficam 0.25%	0.0	0.0	0.3	1.6	2.3	0.0	0.0	0.0	0.0
Killmaster II[2]	0.3	3.6	6.0	8.6	10.0	10.0	10.0	10.0	10.0

[1]Mean number of dead cockroaches out of a total of 10.

[2]2% solution of Dursban.

TABLE VII

MEAN GERMAN COCKROACH MORTALITY[1] AFTER BEING EXPOSED FOR THE FIRST 24 HOURS ON CLEAN TREATED SURFACE MATERIALS

	Insecticides and Dosage Rates							
	Diazinon		Dursban		Ficam		Killmaster[3]	
Materials	1.0%	0.5%	0.5%	0.25%	0.25%	0.125%	II	Mean
Vinyl Asbestos Tile	8.66c[2]	7.66c	5.66b	5.66c	8.33e	6.00e	8.00a	7.14d
Vinyl Wall Base	2.66a	3.66a	1.00a	0.00a	5.66d	3.00d	9.00b	3.57a
Glazed Ceramic Tile	10.00e	9.33e	10.00e	10.00f	8.66f	9.66f	10.00d	9.66f
Painted Wood	9.66d	8.00d	8.00d	3.33b	1.33a	0.00a	9.33c	5.66b
Varnished Wood	8.33b	7.00b	6.66c	6.33d	2.33b	1.00b	10.00d	5.95c
Unfinished Wood	10.00e	8.00d	10.00e	9.10e	5.00c	2.00c	10.00d	7.73e
Mean	8.22	7.28	6.89	5.74	5.22	3.56	9.39	

[1]Mean number of dead cockroaches out of a total of 10.

[2]Significant at the 0.05% level using Duncans multiple range test.

[3]2% solution of Dursban.

TABLE VIII

MEAN GERMAN COCKROACH MORTALITY[1] ON CLEAN TREATED MATERIALS
AVERAGED OVER A 28 DAY PERIOD

	Insecticides and Dosage Rates							
	Diazinon		Dursban		Ficam		Killmaster[3]	
Materials	1.0%	0.5%	0.5%	0.25%	0.25%	0.125%	II	Mean
Vinyl Wall Base	0.70a[2]	0.74a	0.44a	0.04a	2.67c	0.85c	2.85a	1.17a
Vinyl Asbestos Tile	3.56b	2.52b	1.41b	1.67d	3.31d	1.56e	4.48b	2.64c
Varnished Wood	3.89c	2.85c	4.26d	1.40c	0.48a	0.37b	7.85d	3.01d
Painted Wood	4.44d	3.52d	2.03c	0.56b	0.48a	0.00a	6.67c	2.51b
Unfinished Wood	5.11e	4.41e	6.81f	3.92e	1.48b	1.14d	10.00f	4.69e
Glazed Ceramic Tile	6.70f	5.04f	5.89e	6.42f	4.37e	3.74f	9.89e	6.00f
Mean	4.07	3.18	3.47	2.32	2.15	1.25	6.96	

[1]Mean number of dead cockroaches for 3 replications of 10 cockroaches exposed for a 24 hour period.

[2]Significant at the 0.05% level using Duncans multiple range test.

[3]2% solution of Dursban.

TABLE IX

MEAN GERMAN COCKROACH MORTALITY[1] FOR THE SEVEN SURFACE COATINGS AVERAGED OVER ALL TREATMENTS AFTER THE FIRST 24 HOURS

Materials	Surface Coatings[2]							
	CS	FS	FFS	GS	GGS	CKS	DS	Mean
Vinyl Wall Base	3.57a[3]	7.42a	6.01ab	1.85c	2.28c	8.33d	2.19a	4.52a
Vinyl Asbestos Tile	7.14d	7.33a	6.47e	1.71b	2.28c	8.28cd	5.57d	5.54d
Glazed Ceramic Tile	9.61f	7.90cd	6.28cd	2.00e	1.42b	8.90e	6.38e	6.07e
Painted Wood	5.66b	7.71b	6.38de	2.44d	1.14a	7.38a	3.90b	4.94b
Varnished Wood	5.95c	7.76bc	6.23c	2.47d	1.23a	7.71b	4.71c	5.15c
Unfinished Wood	7.80e	8.00d	5.85a	1.33a	1.28a	8.33d	6.24f	5.57d
Mean	6.62	7.69	6.20	1.97	1.61	8.16	4.86	

[1]Mortality rates averaged over all insecticides, mean number of dead cockroaches out of a total of 10.

[2]Surface Coatings: (CS) clean surface, (FS) one coat flour, (FFS) two coats flour, (GS) one coat grease, (GGS) two coats grease, (CKS) coke syrup, (DS) washed with a detergent.

[3]Significant at the 0.05 level using Duncans multiple range test.

TABLE X

MEAN GERMAN COCKROACH MORTALITY[1] FOR CONTROL SURFACES AVERAGED OVER 28 DAYS

Materials	Clean	Flour	Coke	Detergent	Coke
Vinyl Asbestos Tile	0.04	2.00	1.90	0.00	0.00
Vinyl Wall Base	0.00	2.00	1.50	0.00	0.00
Glazed Ceramic Tile	0.00	1.76	0.00	0.00	1.00
Painted Wood	0.00	2.00	2.00	0.00	0.00
Varnished Wood	0.00	1.80	1.30	0.00	0.04
Unfinished Wood	0.00	2.00	1.14	0.04	0.04

[1]Average number of dead cockroaches from 3 replications of 10 cockroaches per replication.

TABLE XI

MEAN GERMAN COCKROACH MORTALITY FOR THE SEVEN SURFACE COATINGS TESTED AVERAGED OVER ALL MATERIALS AND TREATMENTS FOR A 28 DAY PERIOD

Surface Coatings	Percent Mortality
Two coatings of grease	11.41a[1]
One coating of grease	13.89b
Detergent	24.24c
Two coatings of flour	28.77d
Clean surface	33.51e
One coating of flour	38.64f
Coke syrup	38.89f

[1]Significant at the 0.05% level using Duncans multiple range test.

TABLE XII

ANALYSIS OF VARIANCE OF GERMAN COCKROACH MORTALITY RATES OVER A 28 DAY PERIOD
ALL TREATMENTS, MATERIALS AND SURFACE COATINGS

Sources of Variance	DF	SS	MS	F Value	Prob F
Treatment	6	106.28	17.71	508.50	0.0001
Period	8	102.56	12.82	420.15	0.0001
Treatment*Period	48	29.99	0.62	20.48	0.0001
Material	5	21.59	4.32	141.48	0.0001
Treatment*Material	30	13.77	0.46	15.04	0.0001
Period*Material	40	4.97	0.12	4.07	0.0001
Trt*Per*Material	240	14.74	0.06	2.01	0.0001
Condition	11	289.01	26.27	861.04	0.0001
Treatment*Condition	66	194.32	2.94	96.49	0.0001
Period*Condition	88	127.06	1.44	47.32	0.0001
Trt*Per*Condition	528	73.39	0.14	4.56	0.0001
Material*Condition	55	44.79	0.81	26.69	0.0001
Trt*Mat*Condition	330	34.61	0.10	3.44	0.0001
Per*Mat*Condition	440	20.28	0.05	1.51	0.0001
Trt*Per*Mat*Condition	2640	68.88	0.03	0.86	1.0000
Residual	9072	276.82	0.03		

TABLE XIII

MEAN GERMAN COCKROACH MORTALITY FOR TREATMENTS AVERAGED OVER ALL MATERIALS AND SURFACE COATINGS FOR A 28 DAY PERIOD

Treatment	Percent Mortality
Ficam 0.125%	8.32a[1]
Ficam 0.25%	13.14b
Dursban 0.25%	21.95c
Diazinon 0.5%	24.98d
Dursban 0.5%	29.06e
Diazinon 1.0%	34.45f
Killmaster II	67.37g

[1]Significant at the 0.05% level using Duncans multiple range test.

TABLE XIV

MEAN GERMAN COCKROACH MORTALITY FOR MATERIALS AVERAGED OVER ALL TREATMENTS AND SURFACE COATINGS FOR A 28 DAY PERIOD

Materials	Percent Mortality
Vinyl Wall Base	16.20a[1]
Painted Wood	23.16b
Vinyl Asbestos Tile	25.68c
Varnished Wood	26.42c
Unfinished Wood	32.72d
Glazed Ceramic Tile	38.11e

[1]Significant at the 0.05% level using Duncans multiple range test.

TABLE XV

MEAN GERMAN COCKROACH MORTALITY[1] FOR SURFACE COATINGS FOR EACH TREATMENT AVERAGED OVER ALL MATERIALS FOR A 28 DAY PERIOD

Surface Coatings	Insecticides and Dosage Rates							
	Diazinon		Dursban		Ficam		Killmaster[3]	
	1.0%	0.5%	0.5%	0.25%	0.25%	0.125%	II	Mean
One Coat Grease	0.43a[2]	0.20a	0.26a	0.28a	0.59b	0.23a	7.72f	1.39ab
Two Coats Grease	0.43a	0.32b	0.50b	0.34a	0.52b	0.50b	5.37a	1.14a
Detergent	3.17b	2.16c	2.83c	1.44b	0.31a	0.52b	6.59b	2.43bc
Clean	4.06c	3.18d	3.47d	2.38c	2.11e	1.28e	6.96d	3.35c
Two Coats Flour	5.11d	3.66e	4.42f	3.95e	1.90d	1.09d	--[4]	3.36cd
Coke	5.37e	3.79f	4.09e	3.46d	2.27f	1.46f	6.76c	3.89d
One Coat Flour	5.53f	4.07g	4.73g	3.49d	1.49c	0.70c	7.01e	3.86d
Mean	3.44	2.48	2.94	2.19	1.31	0.83	6.74	

[1]Mean number of dead cockroaches out of a total of 10.

[2]Significant at the 0.05% level using Duncans multiple range test.

[3]2% solution of Dursban.

[4]The method of application of Killmaster II did not allow the collection of data for this condition.

TABLE XVI

MEAN GERMAN COCKROACH MORTALITY[1] FOR 1, 7, 14, 21 AND 28 DAYS AFTER TREATMENT AVERAGED OVER ALL MATERIALS AND SURFACE CONDITIONS

Insecticides and Dosage Rates	Days After Treatment					
	1	7	14	21	28	Mean
Diazinon 0.5%	5.93d[2]	3.63b	3.13e	1.76d	1.68e	3.23d
Diazinon 1.0%	6.66e	4.51c	2.30c	0.72a	1.49d	3.16d
Dursban 0.25%	5.74c	3.30b	2.34c	0.94b	1.12c	2.69c
Dursban 0.5%	5.89d	4.59c	2.79d	2.37e	3.04f	3.74e
Ficam 0.125%	1.57a	2.05a	0.35a	1.05c	0.59b	1.12a
Ficam 0.25%	3.21b	2.10a	1.62b	0.74a	0.32a	1.60b
Killmaster II[3]	9.07f	8.74d	8.49f	7.64f	7.65f	8.32f
Mean	5.44	4.15	3.00	2.17	2.27	

[1]Mean number of dead cockroaches out of a total of 10.

[2]Significant at the 0.05% level using Duncans multiple range test.

[3]2% solution of Dursban.

TABLE XVII

MEAN GERMAN COCKROACH MORTALITY[1] FOR 1, 7, 14, 21 AND 28 DAYS AFTER TREATMENT AVERAGED OVER ALL MATERIALS AND TREATMENTS

Surface Coatings	Days After Treatment					
	1	7	14	21	28	Mean
Two Coats of Grease	1.61a[2]	2.08a	1.66a	1.50a	1.88b	1.74a
One Coat of Grease	1.97b	2.06a	1.62a	1.41a	1.67a	1.75a
Detergent	4.86c	3.76b	2.35b	1.92b	1.92b	2.96b
Two Coats of Flour	6.21d	5.59e	4.22d	2.77d	2.73d	3.61c
Clean	6.63e	4.12d	2.89c	2.11c	2.02c	3.55c
One Coat of Flour	7.69f	6.57f	4.60e	3.48e	3.06e	4.83e
Coke Syrup	8.16g	3.95c	2.36b	1.83b	1.59a	4.55d
Mean	5.30	4.02	2.81	2.15	2.12	

[1]Mean number of dead cockroaches out of a total of 10.

[2]Significant at the 0.05% level using Duncans multiple range test.

2

VITA

William Oscar Ree, Jr.

Candidate for the Degree of

Master of Science

Thesis: A LABORATORY EVALUATION OF THE EFFECTS OF CONDITIONS AND MATERIALS FOUND IN FOOD-HANDLING ESTABLISHMENTS ON INSECTICIDES USED FOR THE CONTROL OF BLATTELLA GERMANICA (LINNEAUS)

Major Field: Entomology

Biographical:

Personal Data: Born in Stillwater, Oklahoma, July 7, 1952, the son of Mr. and Mrs. William O. Ree.

Education: Graduated from C. E. Donart High School, Stillwater, Oklahoma, in May, 1970; attended Grays Harbor Junior College, Aberdeen, Washington, 1970-1972; received a Bachelor of Science degree in Agriculture with an emphasis in Forestry from Oklahoma State University in May, 1976.

Professional Experience: Graduate research assistant, Oklahoma State University, 1978-1980.

Societies: Entomological Society of America, Society of American Foresters.