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THE DEVELOPMENT AND EVALUATION
OF A PROTECTIVE GARMENT
FOR LAWN CARE SPECIALISTS

presented by

Sharleen Leslie Gay

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Ann C. Slocum
Major professor

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THE DEVELOPMENT AND EVALUATION OF A PROTECTIVE GARMENT FOR LAWN CARE SPECIALISTS

By

Sharleen Leslie Gay

A THESIS

Submitted to
Michigan State University
in partial fufillment of the requirements
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ABSTRACT

THE DEVELOPMENT AND EVALUATION OF A PROTECTIVE GARMENT FOR LAWN CARE SPECIALISTS

by

Sharleen Leslie Gay

The purpose of this study was to develop and test protective clothing for lawn specialists.

The development of the protective garment involved identifying design criteria, experimentation with construction variables, presentation of sketches of protective garments to the client, and construction of the selected prototype for field testing. Design criteria were identified through a review of the clothing and pesticide research literature and analysis of video tapes of the lawn care specialists at work. Three sketches and two prototype garments were developed and submitted with synthesis of observations to company officials who made the final selection. Six sets of the chosen design were constructed for field testing.

Biomonitoring of six lawn care specialists was used to measure the effectiveness of the regular uniform and the protective garment as a barrier to pesticide under normal work conditions. Significantly less pesticide was absorbed while wearing the protective garment.

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I wish to express my sincere appreciation to Dr. Ann C. Slocum for the invaluable guidance she gave me throughout my graduate program and for opening up this new area to me.

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CHAPTER ONE

INTRODUCTION

The use of pesticides has increased dramatically in recent years. Because of this increase and the awareness of their potentially adverse effects on humans and the environment, there has been a growing concern about limiting the harmful effects pesticides can have on those applying them.

Greater interest in the hazards of exposure has led to more research in the area of preventative measures. One way to reduce exposure is to wear specially designed protective clothing. Clothing is a viable and less costly means of protection than the development of new application equipment. The purpose of this research was to evaluate the effectiveness of a protective garment in reducing bodily absorption of a pesticide sprayed by lawn care specialists.

This research is part of a three phase study under the direction of Dr. Ann C. Slocum, Department of Human Environment and Design, Michigan State University, and was supported by The Dow Chemical Company, TruGreen Corporation, and Benham Chemical Company. The researcher was a member of the research team for the second and third phases of the project involving the development and construction of the protective garment and its evaluation. Specific duties of this researcher included designing, sketching, drafting patterns, and supervision of the construction of the

garment along with involvement in all other areas of the study.

Pesticides are potentially dangerous to humans based on their exposure and toxicity. Exposure is dependent on the method of application, and the duration and frequency of use, while toxicity is dependent on the chemical formulation and composition of the pesticide.

The method of application is important in determining where the greatest amount of pesticide is deposited on the body. Although there are a number of ways to apply pesticides, lawn care spraying is different from many application methods in that it involves a very low application (to the ground) as opposed to an overhead spraying of trees. A hand held gun is attached to a hose that distributes insecticide from the holding tank on the truck. The gun distributes the insecticide in a fine mist form and allows the lawn care specialist to cover an area of turf six to ten feet wide with a sweeping arm motion. The flexible equipment allows application of the pesticide under low hanging trees and shrubs and around obstacles. Generally, lawn care specialists walk into the spray, pulling the hose behind them through the treated grass.

Lawn care specialists are exposed to chemicals on a regular and daily basis during the five to ten month spraying season. Generally, they work eight to ten hours per day, five days a week. The particular chemical sprayed for each day is determined by the season of the year, a lawn analysis of soil conditions, and the presence of weeds and pests for that time of season.

In the past few years, shorter acting pesticides, of the organophosphate family, (Freed, et al., 1980) have been among the chemicals used in the lawn care industry. The organophosphate family has, on the average, a somewhat greater toxicity than most other pesticide classes

(Wolfe, 1973). Organophosphates, when absorbed into the human body, depress cholinesterase (ChE), an enzyme critical to the human nervous system. Cholinesterase acts as a messenger to the transmitter substance acetylcholine, which transmits nerve impulses between the nerve and the muscle or gland it controls (see Appendix A). Extreme organophosphate exposure to the point of poisoning may cause neurological inoperation (Savage, et al., 1980). The high toxicity is accompanied by relative ease in absorption (Freed, et al., 1980).

The American National Standards Institute has approved chlorpyrifos as the common name for organophosphate insecticides containing O,O-diethyl (3,5,6-trichloro-2-pyridinol) phosphorothioate. Chlorpyrifos is used for many kinds of household and turf pests such as fleas, ants, and cockroaches and is approved for use in flea collars and pet shampoos (The Dow Chemical Company data sheet).

Because insecticides are usually sprayed in a fine mist form, the human body can readily absorb them through a number of routes. Goodman and Gilman (1965) include the gastrointestinal tract, the lungs, and the mucous membranes. Dermal exposure, however, accounts for approximately ninety-seven percent of the total body exposure and has been deemed the most important route of entry when applying liquid spray (Wolfe, 1973). The widely used anti-cholinesterase (ChE) compounds, of which organophosphates are included, are highly lipid soluble liquids which have vapor pressures at ordinary temperatures (Goodman, Gilman, 1965). Because they are lipidphilic, they not only penetrate insect cuticle easier, but also concentrate in the liver upon entering the human body (Matthews, 1984).

As the use of pesticides continues to increase, comprehensive

protection is becoming of greater importance to the health of human pesticide applicators. Research in the area of chemical pesticide exposure must be supplemented to include studies of actual bodily aborption.

Statement of the Problem

The purpose of this research was to determine if one protective garment significantly reduced the amount of chlorpyrifos absorbed into the bodies of a selected group of lawn care specialists in comparison to the standard uniform. Chlorpyrifos is the active ingredient in Dursban®, an organophosphate.

Although there has been increasing research in the area of penetration of pesticides through fabric/clothing and decontamination of clothing, research on the effect of clothing on actual bodily absorption has been limited (Davies, et al., 1982). This study is unique in that it is a field study, which may provide different information than the previous lab studies of absorption (Maibach, et al., 1971) due to environmental factors.

Objectives:

The structure of the study was based on the following research objectives:

1. To identify, evaluate, and select pesticide protective fabrics and finishes from those available, based on past fabric penetration and decontamination research literature.

2. To explore and evaluate garment design alternatives, based on thermal comfort, motion, aesthetic, and protection criteria.

3. To illustrate designs and present to company officials.

4. To draft and construct six sets of the prototype garment

accepted by the participating lawn care company.

5. To compare the absorption of chlorpyrifos in the selected sample when wearing a protective garment in comparison to the usual uniform.

Hypotheses:

Objectives one through four were not subject to statistical testing. The following hypotheses relate to objective number five.

Ho: There will be no significant difference between the protective garment and the standard uniform in reducing organophosphate absorption into the body.

H1: The proposed protective garment will reduce organophosphate absorption into the body in comparison to the standard uniform.

Definition of terms:

-Protective clothing designed for this study was a two-piece design. The shirt body and sleeves was a white cotton/polyester knit. An extended shoulder yoke was of heavy cotton/polyester twill. It had long sleeves with woven cuffs and a high woven collar. Mesh gussets were placed under the arms. The pants were flourocarbon treated cotton/polyester work weight twill with an added Gore-tex® lining from the knee down and in the lower abdomen area. Gore-tex® is a registered tradmark of W.L. Gore and Associates. See chapter four for full description of the protective garment.

-Standard uniform was a two piece design consisting of a cotton/polyester short sleeve polo style knit shirt and cotton/polyester twill workweight pants.

-Chlorpyrifos is the active ingredient in Dursban®. Dursban® is an organophosphate insecticide manufactured by The Dow Chemical Company. Field dilution of 18.75 fluid ounces of Dursban® 4E (emulsifiable concentrate) per 100 gallons of water was applied on the test days.

-Reduced organophosphate absorption is a decrease in plasma erythrocyte cholinesterase levels and creatinine standardized urinary excretion of 3,5,6-trichloro-2-pyridinol.

-Cholinesterase is an enzyme in the human nervous system that acts as a messenger to the nerve transmitter substance acetylcholine.

-3,5,6-trichloro-2-pyridinol (3,5,6-TCP) is the principle metabolite of chorpyrifos that is excreted primarily in the urine.

-Pesticide is a general term used to include insecticides, herbicides, and rodenticides. Insecticides are intended for exterminating insects.

Limitations:

General limitations include the limited size of the sample in relation to the variability in physiological response to chemicals, the use of one prototype which does not allow comparisons between variations of clothing combinations, and the nonrandom sample which limits conclusions to this sample.

Conceptual Framework

Components:

The conceptual framework underlying this study is the human ecosystem model (Bulbolz, Eicher, Sontag, 1979). This model views the human organism as an interacting force with in the three environments--the natural environment, the human behavioral environment, and the human constructed environment. Because this garment will be measuring the effect of absorption of one chemical, as opposed to human subjective analysis beyond the design stage, it will draw from two of the

three environments--the natural environment and the human constructed environment. Each of these two environments are conceptualized as having interacting subparts. In the natural environment, these include space-time, physical, and biological components. The human constructed components include socio-cultural, socio-physical, and socio-biological. The interaction of these two environments, organophosphate exposure and protective clothing respectively, and their effects on the human pesticide applicator is the focus of this study and is illustrated in the conceptual model in Figure 1.

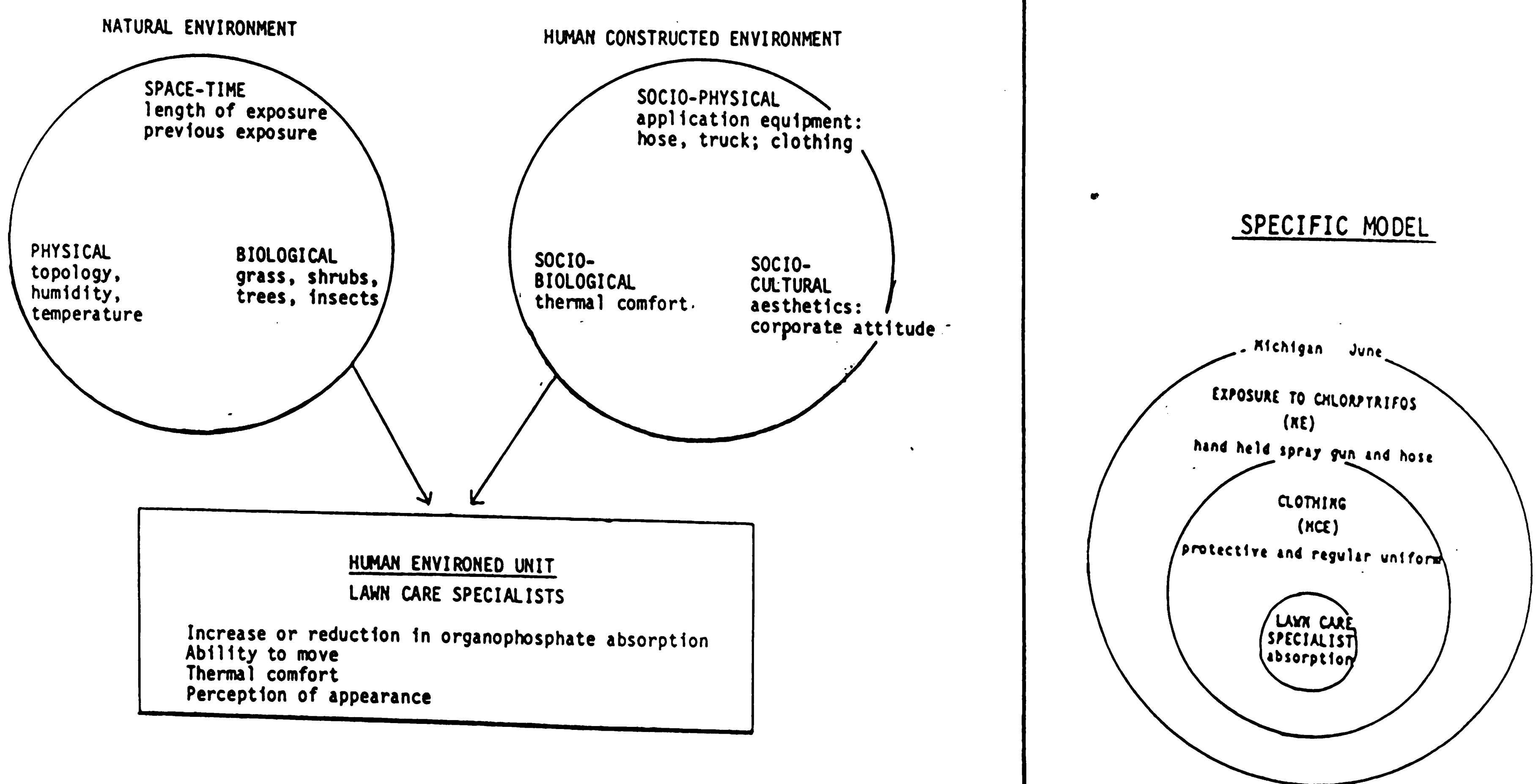


Figure 1.--General human ecosystem conceptual model of the effects of protective clothing on organophosphate absorption in lawn care specialists (adapted from Bulbolz, et al., 1979).

Process:

The interaction between the natural environment and the human constructed environment and the ordered steps towards the human environed unit is conceptualized in the functional design process (see Figure 2.). Clothing that is designed with a particular functional end use, such as chemical/biological protective clothing, requires a designer to work through a basic design process. Functional design process involves a step-by-step designer approach from the initial idea to evaluation of the design. This process involves exploring the effect of movement, impact, thermal, and other factors on the design problem (DeJonge, 1984). The matrix shown on the following page illustrates these steps. This matrix was developed by Jacquelyn DeJonge based on one developed previously by J. Christopher Jones (1970).

The first step in formulating the protective garment is to accept the problem as a challenge and to uncover the basic rationale of the problem. The basic justification behind this design problem is the lawn care specialists' exposure to chemicals. The problem must then be explored in terms of specific design criteria.

After reviewing and assessing the problem, it is necessary to formulate a definition for the particular design problem. This may be accomplished through stating objectives, and by ranking or prioritizing criteria. Kolberg (1974) describes definition in the Universal Traveler as "...necessary to converge all of those data into an overall understanding--into a unifying or 'definite' direction that reflects a determined meaning" (p. 60). He also describes the definition as a "filter" as a designer moves through the remainder of the design process, as it may "filter" irrevelent data. When designing for a client,

this definition of the problem should involve the input of the client, as they may have different priorities.

Prototype development is a culmination of ideation, idea selection, and implementation of the design idea. Ideally, the client is involved in these three phases. In idea selection specifically, negotiating or compromising may be necessary between the designer and client in order to satisfy both of their criteria. Kolberg (1974) describes this implementation as the point of the problem solving process where the design that you have chosen as the one to solve the design problem is finally tested. He calls this implementation of your choice the "moment of truth."

The final stage in the functional design process is design evaluation. DeJonge (Watkins, 1984) suggests both objective and subjective evaluative techniques. Evaluation may not only measure the design prototype against the established criteria, but may provide new ideas for beginning the design process again.

In designing functional clothing, each problem task is unique and may require a different type of thinking. Because of this, DeJonge (1984) states that "for each project, the design process will vary and the selection of strategies will differ. The steps in the process give continuity to designing and direct our thinking beyond a simple intuitive idea to find answers" (p. xi).

	2 Design situation explored	3 Problem structure perceived	4 Specifications described	5 Design criteria established	6 Prototype developed	7 Design evaluation
1 Request made	1.2 State general objective Brainstorming User interview and observation Visual consistency Literature					
2 Design situation explored		2.3 Brainstorming Observation analysis Market analysis Literature search Identification of critical factors Definition of problem				
3 Problem structure perceived	3.2 Brainstorming Visual consistency Reassess critical factors		3.4 Activity assessment Movement assessment Impact assessment Thermal assessment Social-psychological assessment			
4 Specifications described	4.2 State objectives Check specications against objectives	4.3 Reassess critical factors		4.5 Charting Ranking and weighing Prioritizing		
5 Design criteria established	5.2 State objectives Check criteria against objective	5.3 Identify critical factors	5.4 Literature review of assesment areas to check specifications		5.6 Materials testing Technique evaluation Brainstorming Creative integration Solutions weighed against criteria	
6 Prototype developed	6.2 Visual inconsistency Identify objective User interview	6.3 Identify critical factors	6.4 Literature review of assessment areas	6.5 Rank order specifications		6.7 Specification testing User satisfaction

Figure 2.--The functional design process (From DeJonge, 1984, p. viii).

CHAPTER TWO

REVIEW OF LITERATURE

Fabric Criteria

The purpose of this research was to design a protective garment that would establish an interface between the body and the environment, or to create a microclimate interface between the body and the surrounding macroclimate. The properties of textile fabrics and their effectiveness as interfaces to pesticide penetration are dependent upon the intrinsic characteristics of the fiber and its polymeric substances as well as the geometry of the fiber, the yarn, and the fabric structure. The geometric variables include shape, length, cross sectional area, amount of crimp, twist, and degree of compactness or density. The main concern of this study, the effect of a protective garment on chlorpyrifos absorption, mainly involves the selection of materials or fabrics that will resist impact by fine particles or pesticide soiling.

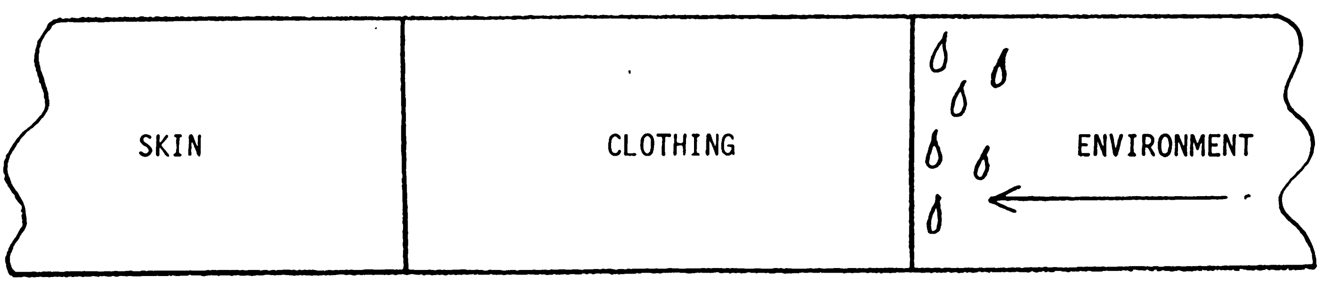


Figure 3.--Clothing as a barrier to the environment.

Watkins (1984) attributes textile molecular impact protectiveness to three main characteristics including "...a pore size smaller than the smallest unit of a hazardous substance; a chemical composition that does not react chemically with the hazardous substance; and a physical composition that does not breakdown when impacted by a particle or drop of the substance" (p. 124).

Textile soiling:

Soiling is attributable to three major sources: deposition of dry solids, soiling from foreign liquid matter, and redeposition of soiling during laundering. The degree of soiling is directly related to characteristics of the fiber, the structure of the yarn and fabric (eg. the twist, nap, or weave), and how they react to the particular soil. For instance, the chemical nature of the fiber influences the attraction or power to hold the soil, whereas the structure of the yarn or fabric may hold soil within its interstices. Another factor that complicates the problem of soiling is the particular type of soil and how it reacts to the dyes or finishes associated with the particular fabric. In this study, the particular formulation of the pesticide Dursban®, an emulsified concentrate formulation, will interact differently with varying fibers.

Once the soil has been placed on the fabric it may move through the fabric in various ways. Movement of liquids through fabrics is again directly related to the type of fiber, and the yarn and fabric structure. Since the concern of this study is to prevent pesticide from travelling to the body surface in order to deter bodily absorption, the facets of liquid movement through textiles are necessary to define.

Sorption includes both adsorption, the attachment of small particles of liquid to the surface of a textile, and absorption, the ability of the fiber to intake moisture. When a fiber intakes moisture readily, it is termed hydrophilic. A hydrophilic fiber may prevent pesticide absorption into the body as the liquid is kept within the fabric structure. Hydrophobia is a low ability to intake moisture. When a fiber is hydrophobic, moisture may instead travel along and through the fabric structure. This is termed wicking. Movement may occur by capillary wicking along the yarns of the structure or by permeation or diffusion of water in the gaseous state (Adler, Walsh, 1981). Water vapor passes through the fabric structure if the structure and the nature of the fiber allow it, and provided there is a relative humidity differential across the fabric surface (Fourt, Hollies, 1970).

Liquid pesticide may be absorbed by the fiber or wicked through the fabric structure. If a fabric absorbs a liquid pesticide, it may then hold the liquid pesticide close to the body so that it is eventually absorbed by the body. On the other hand, if the fabric does not absorb but wicks liquids, the liquid pesticide may then be directly accessible to enter the body dermally.

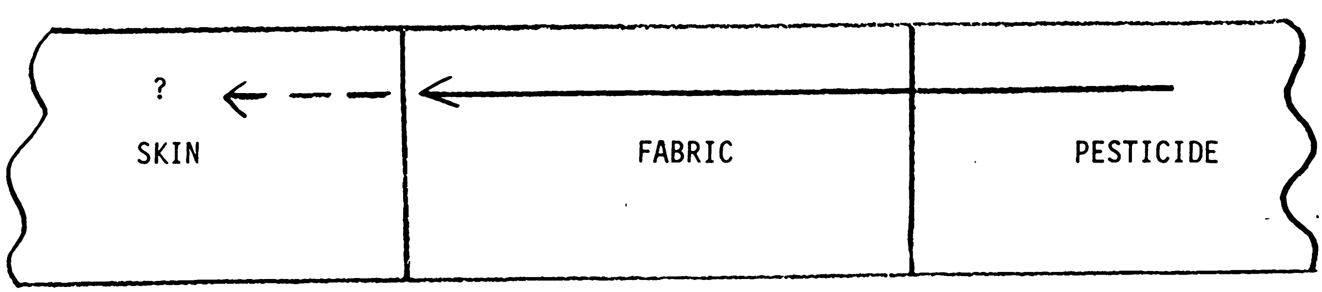


Figure 4.--Liquid pesticide drawn into the fiber or fabric structure. Will the body absorb more pesticide, when it is held close to the body, or if the pesticide wicked through the fabric upon initial contact?

The complexity of the soiling mechanism is also important in the laundering of textiles. Several researchers have tested particular fabrics in regard to ease in removal of pesticides from them and the sometimes consequetial residual build-up of pesticide soiling in the fabric. Redeposition of the pesticide throughout the entire garment may occur in laundering depending on the fiber, the yarn and fabric structure, the temperature of the water, the type of detergent used, and the particular formulation of the pesticide. Increased interest in removing pesticide contamination in laundering has provided needed research in this area.

Aesthetic considerations:

Textile fabrics must also be aesthetically acceptable to the wearer and to the employer. Aesthetic acceptability is particularly subjective and is strongly related to the design of the garment. Aesthetic considerations that must be reviewed in regard to fabric choice include the "hand" of the fabric and the look or image that the fabric portrays.

Thermal comfort:

The transport of water or vapor through the fabric, thermal conductivity of the fiber, and air permeability through the fabric structure are important for thermal comfort for the wearer. The maintainance of air circulation and removal of body liquids away from the body are important factors for establishing thermal comfort and are directly related to the specific fibers thermal conductance (generally its thickness and ability to maintain that thickness) and the product of the amount of open air space area in the fabric structure (Fourt, Hollies, 1970).

Wearer comfort evaluations involve the subjective responses of the wearer. Testing relies on both the variability of the wearer and the environment. Certain objective evaluations, however, are possible and parameters have been set for the thermal equilibrium state (Fourt and Hollies, 1970). Since spraying for lawn care specialists is seasonal and is limited to the warmer months of the year, the concern of the researchers was to increase cooling.

Cooling can be accomplished by several means. Fourt and Hollies (1970) give four ways which include cooling by air motion, air movement between the body and clothing as a result of body motion, wetting out of clothing by sweating (which requires an absorbent fiber), and transient contact effects such as capillary wicking.

Decisions made concerning particular fabrics must be made in light of the above criteria and particular characteristics ascribed to the specific fiber or fabric. A review of research literature on fibers, fabrics, and finishes in regard to pesticide penetration follows. It is difficult to make direct comparisons between studies, however, as such variables as polymeric fiber variations, yarn and fabric constructions, weights, dyes, finishes, and other processing are not consistent across studies.

Fibers, fabrics, and finishes

Cotton:

Cotton, more than any other fiber, has been studied by researchers as a barrier to pesticide penetration. Cotton, a carbohydrate, is hydrophilic due to its water attracting hydroxyl (-OH). Athough its resiliency is fairly low, it is a moderately strong fiber. Water, which swells the fiber when absorbed, makes it even stronger. Cotton is characteristically resistant to organic solvents and has a fairly high resistance to alkalies and weaker acids. It is not, however, particularly resistant to ultraviolet light and atmospheric conditions. Overexposure to light and weathering may breakdown C-O-C linkages, causing it to convert to oxycellulose, a sugar. This is an important consideration for extended outdoor wear.

Cotton, by nature, readily absorbs liquid and therefore promotes wet soiling. Freed, et al. (1980) found that when a 100% cotton denim and 65/35 polyester/cotton denim were compared for effectiveness as a pesticide barrier, the cotton was more protective due to its absorbing ability. When Orlando, et al. (1981) tested tightly woven cotton chambray against flourocarbon treated cotton chambray and various nonwoven synthetics, however, she found that cotton permitted the greatest amount of penetration and determined that it was most likely due to wicking through the closely woven structure of the cotton chambray.

Davies, et al. (1982) compared cotton denim coveralls to a variety of sprayers own choice of clothing using a urinary diethylphosphate measure of absorption of the pesticide Ethion. Davies, et al. found reduced urinary excretions of DEP concentrations when the 100% cotton denim coveralls were worn as compared to wearing their regular clothing alone.

Finley and Rogillo (1969), in regard to DDT, offer additional insight to cotton's ease in absorption of insecticides. They note the similarity that exists between the cotton fiber and the chitin of the insect's exoskeleton and state:

> "...the only difference in the structure of the two polymers is that the chitin has an acetylamine group substituted for the hydroxyl group on the carbon 2 or the gluclose units of the cellulose. The affinity of DDT for chitin has been documented in the literature. This affinity may explain why DDT was absorbed and retained at a higher rate

> in all cotton fabrics. This does not necessarily mean that all cotton fabric is more hazardous to the wearer. Theoretically, cotton could be a safer material since the DDT appears to be 'tightly bound' to the cellulose" (p. 350).

When the pesticide is tightly bound to the cotton, problems in removal in laundering may occur. DeJonge (1983) found that the removal of pesticides was dependent on the kind of pesticide and the amount of pesticide pick-up prior to laundering. Berch, Peper, and Drake (1964) note the consistent relationship between the degree of deposition of soil and the retention of soil after laundering. Therefore, since cotton absorbs to a higher degree, pesticide residue after laundering may correspond accordingly.

Several researchers have studied pesticide residue removal in cotton fabrics. Lillie, et al. (1982) found that residues could be increasingly removed from cotton with higher laundering temperatures. They also found this to be true with detergent and detergent plus bleach. Easley, et al. (1982) suggested the use of heavy duty detergents because of their oil removing abilities, and pre-rinsing or multiple launderings. Kim, et al. (1982) found that immediate launderings also left lower residue levels than launderings after a twenty-four hour period. However, for some pesticides, less residue remains when soiled clothing is stored before laundering (Branson, 1985).

In order to enable cotton fabrics to resist soil deposition, finishes may be added to the surface of the fabric. Typically, the hydroxyl groups are bound, making them hydrophobic. This can be accomplished with a number of substances including waxes and soluble soaps. Although there are many types and kinds of soil resistant finishes, a very commonly applied finish is a flourocarbon or flourophatic resin.

Flourocarbons, which include tetraflouroethylene (TFE), clorotriflouroethylene (CTFE), vinylidene (PVF2), and flouroinated ethylene polypropylene (FEP), are thermoplastic materials that have characteristically very high chemical resistance and anti-stick characteristics, with very low coefficients of friction. Because of this, flourocarbon finishes inhibit the movement of liquids, particularly pesticides, through fabrics. Laughlin, et al. (1984) found that pesticide soiling is reduced approximately 18 to 20% when a flourocarbon finish is applied, as opposed to untreated cotton or durable press finished fabrics. Freed, et al. (1980), Orlando, et al. (1981) also found that flourocarbon treated cotton denim provided a greater barrier to pesticide penetration than untreated cotton denim.

Although researchers found flourocarbon treated cotton to allow less pesticide penetration, several found that pesticide deposit was more difficult to remove than if cotton did not have the flourocarbon treatment. Laughlin, et al. (1981) found that residue removal was of a smaller percentage for flourocarbon treated cotton than with untreated cotton and that soil redeposition was higher in laundering. Berch, et al. (1964) describes this tendency and notes:

> its "...marked contrast to the stain repellent finishes in resiliency due to the ability of liquids to wet surfaces as a consequence of the low energy air-silicone and air-flourocarbon interfaces. When these surfaces are immersed in water, a high energy interface is probably formed" (p. 33).

Cotton is many times blended with other fibers to produce better performance. Most commonly, cotton is blended with polyester, a man-made long chain polymer fiber. The cotton-polyester blends are most commonly available in 65/35, 50/50, or 35/65 cotton/polyester combinations. As the percentage of cotton is increased, insecticide absorption by the

fabric is also increased (Finley, 1969). Freed, et al. (1980) found that 100% cotton denim could absorb twice as much liquids as comparable 65/35 cotton/polyester denim blends.

When cotton-polyester blends were tested in regard to their effectiveness as a pesticide barrier, it was found that 100% cotton denim afforded better protection than the blends (Freed, et al., 1980). Laughlin, et al. (1984), using a 50/50 cotton/polyester bottom weight blend, found that flourocarbon soil resistant finishes increased the blend's ability to resist penetration to the point of being comparable to spunbonded olefin, an nonwoven synthetic.

Polyester:

Polyester differs characteristically from cotton in that it is hydrophobic in nature. Generally, polyester's saturation content has been found to be less than 2% as opposed to cotton's 30% moisture saturation content. Although polyester is hydrophobic, it is oleophilic. Body sebum and other oils easily attach themselves to the polyester fibers and are generally difficult to remove. Bowers and Chantrey (1969) found the fiber encapsulating oils may cause increased oils to adhere to the polyester fibers. When compared to all cotton fabrics, Finley (1974) found that polyester added to the cotton (in a cotton-polyester blend) retained less pesticide residue since less is absorbed before laundering. This may not be an advantage, however, as more pesticide may have been wicked through upon initial contact with the clothing. Because of polyester's hydrophobic nature, it is very crease resistant, however, it is also viewed as being less comfortable and may be warm to wear in hot weather. Therefore a trade-off exists between ease in care and wearer comfort.

Spunbonded olefin:

Tyvek ®, a spunbonded olefin (SBO), Gore-tex ®, and Crowntex® , three unique man-made fabric structures, were found to provide twenty-five times more protection than untreated cotton chambray (Orlando, et al., 1981).

Spunbonded olefin, a lightweight nonwoven fabric, is produced as a disposable. Because it is nonwoven and offers no ease, garments constructed of SBO must be oversized in order to provide mobility. It also does not allow for body heat dissipation. SBO comes in a number of varieties including perforated, polyethylene coated, Saran ®-laminated, and colored. The perforated variety is intended to protect the wearer and still allow thermal comfort.

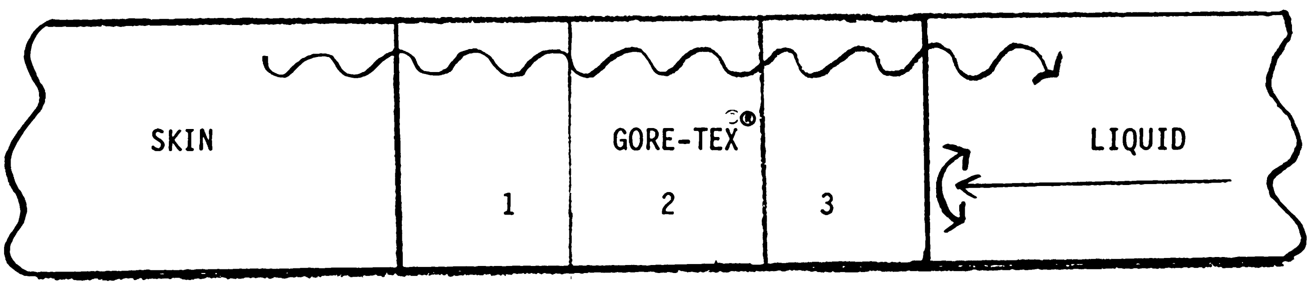
Staiff, et al. (1982) tested a number of types of SBO for pesticide barrier properties including polyethylene coated SBO, perforated SBO, regular SBO, and two colors of regular SBO. He found that only the polyethylene coated SBO provided adequate protection against concentrated pesticides. Several recent lab studies conductd by Arthur D. Schwope (n.d.) for E.I. duPont de Nemours and Company, manufacturers of Tyvek ®, tested several different types of SBO for their effectiveness in protecting against selected pesticides and other hazardous chemicals. Among those tested were regular Tyvek ®, polyethylene-coated Tyvek ®, and Saran ®-laminated Tyvek ®. Concentrated methyl parathion was used in the lab study with an aqueous spray for the simulated field study.

The regular Tyvek ® had an instantaneous breakthrough time in both the field and lab study while the polyethylene coated Tyvek ® had an approximately 15 minute breakthrough time in the lab study and a 30-45 minute breakthrough time in the field study. Only the Saran ®-laminated

SBO was found to have no breakthrough during the four hour field and lab studies. Since SBO's are disposable, laundering is not necessary.

Microporous film laminate:

Although there are a number of microporous film laminates on the market, Gore-tex®, a polytetraflouraethylene (PTFE) film laminate produced by W.L. Gore and Associates, has been tested for penetrability and effectiveness of laundry removal of pesticides. Gore-tex® is known for its unique combination of "waterdroplet-proofness" and breathability achieved through the microporous film inner layer which allows the air and vapor (eg. body heat) to pass through, but does not allow water droplets through. Its thermal comfort has been compared to that of 100% cotton (Easter, 1983). The microporous film is laminated to a variety of fabrics for durability. Gore-tex® is relatively expensive, depending on the fabric to which it is adhered.



Vapor=

1= Gore-tex® inner layer fabric

2= Gore-tex® microporous film

3= Gore-tex® outer layer fabric

Figure 5.--Gore-tex® as a barrier to liquids.

Gore-tex® was found to be an effective barrier to pesticide penetration by Orlando, et al. (1981; DeJonge, 1983). Gore-tex® wearers had lower temperature readings and lower thermal comfort and sensation when compared to SBO wearers (Branson, 1984) and the comfort was similar to that of persons wearing cotton shirts and jeans. Because of the oleophilic fibers, oil based pesticides are difficult to remove from garments in laundering (Easter, 1983).

Polyvinyl alcohol:

Polyvinyl alcohol (PVA) was tested by Williams (1981) in the form of gloves for pesticide penetration and was found to provide sufficient protection. Although PVA is water soluble, it is generally treated with a formaldehyde to make it insoluble. It is known for its high tensile strength and wearer comfort. It has been found to be resistant to most chemicals at moderate temperatures (Lyle, 1982). PVA is not currently produced in the United States, but is produced in Japan under the tradename Vinal.

Polyvinyl chloride:

Polyvinyl Chloride (PVC) was first produced by The Dow Chemical Company in 1940. It is know for its superior strength and resistance to acids, alkalies, moisture (both liquid and vapor), and weather (Lyle, 1982). Because of its lack of pores and interstices, it is very warm to wear unless the design of the garment incorporates some type of cooling system (passive or nonpassive). PVC is a common material for protective wear and is available to the consumer in bio-chemical protective coveralls and in glove form.

Natural and synthetic rubbers:

Both natural and synthetic rubbers have been studied in regard to their protectiveness against pesticides. Most of these studies, however, have been glove studies. Williams (1979) tested a number of synthetic rubbers including neoprene, nitrile, and butyl. These synthetic rubbers, along with natural rubber, are dienne polymers. That is, they have two double bonds. He found that when the rubbers were subjected to chemicals (specifically dichlorobutene) there was no evident physical or chemical change.

Neoprene, which is a polymerized chloroprene (2-chloro-1,3,-butadienne) rubber, is very similar to natural rubber. Although it is relatively expensive, it is considered an excellent synthetic rubber that affords excellent weather resistance (McMurray, 1984). Nitrile and butyl rubber are other commercially produced synthetic rubbers.

Natural rubber is a product or exudate of certain trees. Natural rubber, although not currently produced in the United States, was tested by Sansone and Jonas (1981) in regard to the effect of sunlight and dark storage on permeability. Permeability was not affected.

Staiff, et al. (1982) found rubberized cotton, in the form of rainwear, to provide adequate protection against a number of concentrated pesticides. Although rubbers are an excellent material for protection against liquids and impact by small particles, the lack of air permeation or flow makes them uncomfortable to wear. Rubbers may be used as coatings to woven fabrics (eg. rubberized cotton), however, air ventilation must be achieved through garment design. Often this requires oversized apparel in the form of rainwear and although it may be acceptable to farm and orchard pesticide applicators, it is generally considered unacceptable to lawn care specialists or their employers.

The careful evaluation, comparison, and analysis of a fabric's properties is essential for effective impact protection from toxic liquid and sprays. Selection must be based on prioritization of criteria by the client and the designer. Upon selection of the textiles, equal consideration must be given to garment design in respect to compatibility with selected textile materials and to total garment function.

Design Criteria

The protective needs of the pesticide applicator was the principle concern in the design of the protective garment and was based on the level and complexity of the agent used (Watkins, 1984), and where the pesticide was deposited on the body. Other design aspects and consequences became equally important, however, including thermal comfort for the wearer, ease in motion for proper job performance, and aesthetic standards of the corporation involved. Watkins (1984) addresses the complexity of the design problem stating that:

> "...if impact protection was the only concern of designers, they would have no difficulty creating protective garments from the array of materials on the market. If people were inanimate, unfeeling objects, they could simply be packaged like eggs or china vases--in protective cartons. The real challenge for designers is to create impact-protective clothing that allows people to work and play effectively" (p. 91).

Fourt and Hollies (1970) also state that "...the net worth must be assessed in terms of overall effectiveness in the whole situation" (p. 5).

Pesticide deposition and absorption:

Maibach, et al. (1971), through an anlysis of urinary excretion, quantified the effect of C Parathion absorption for topical anatomic regions. An approximation of percentage of the pesticide absorbed (when applied dermally) in selected anatomic regions is shown in Table 1.:

ANATOMY	% ABSORPTION
scalp	32.1
ear canal	46.5
forehead	36.3
forearm	8.6
palm of hand	11.8
abdomen	18.4
scrotum	100.0
ball of feet	13.5

Table 1.--Pesticide absorption in selected anatomic regions (From Maibach, et al., 1971, p. 209).

Slocum and Shern (1986), in a dye deposition study, established anatomical regions of greatest deposition of pesticides for lawn care specialists and found high deposition on the lower legs, both front and back, and the palms of the hands (see chapter three). Freeborg, et al. (1984), in a deposition study utilizing absorbent pads for pesticide pick-up, found the greatest amount of contamination to be on the wrist and inner thigh just below the scrotal area. This information plus the information provided by Maibach, et al. (1971), emphasizes the great need for protection in the lower abdominal area.

Liquid impact protection:

Although much of the research has dealt with testing the penetration levels of particular fabrics, a few researchers have tested particular garment designs for their effectiveness in preventing pesticide penetration. Through biomonitoring, Davies, et al. (1982), in a field study using Ethion, testing the applicators own clothing against 100% cotton coveralls treated with a flourocarbon finish, found that the coveralls were more protective than their own clothing. Clothing as a barrier to pesticides has also been observed in field study conditions by Orlando, et al (1981; DeJonge, 1983), Staiff, et al. (1982), and Wolfe, et al. (1967).

Protective design ideas for general application for pesticide workers were suggested by Gulbrandson (1983) in an Agriculture Experiment Station Bulletin. She included a bat-wing design sleeve or the placement of cotton strips under the shoulder seams to prevent mist infiltration. She also suggests that if the applicator is in the sitting position, such as on a tractor, that the jacket or shirt should extend down far enough to cover the crotch area. The bulletin encourages closures of some type for all open-ended cylinders (such as sleeves and legs) and also for the neck.

Thermal comfort:

Although the design of the garment does not influence thermal comfort as much as the fabric does when evaluated subjectively (Branson, et al., 1986), in order to be accepted by the wearer and to avoid heat stress, thermal comfort must also be considered in garment design. For example, clothing that fits tightly or has closed-ended cylinders increases the physiological burden for the wearer (Yaglou and Rao, 1947). Fourt and Hollies (1970) emphasize the importance of thermal comfort when they say:

> "...the well being of man depends upon the balance between his high energy production and the exchange of energy with the environment. This energy balance must be maintained within the tolerance for heating and cooling of the body. This concept of balance between the body and the environment is modified by the invention of clothing, which from one point of view can be regarded as an extension and modification of the body itself..." (p. 1).

They go on to discuss the point that "...clothing interacts with the

physiology of the body, and the functions of clothing are essential to man in all but exceptional and limited environments" (p. 1).

Some consideration has been given to thermal comfort by researchers. Davies, et al. (1982), in a field study using 100% cotton coveralls, found that although the prescribed coveralls were full length and had long sleeves, the applicators reported no heat stress discomfort even though working in 90 degree average temperatures and high humidity. Branson (1982) also tested designs for thermal comfort by simulating work conditions and actions in a test chamber and found a jumpsuit of Gore-tex was acceptable to wearers. DeJonge (1983), in experimentation with back inner mesh panels, found that 100% cotton clung to the subject's backs and therefore suggested using a synthetic that would wick away body moisture. Staiff, et al. (1982) found that lighter weight garments were subjectively perceived to be cooler to wear.

The subjective analysis of thermal comfort is critical and researchers can not rely entirely on objective measurements such as body temperatures or inside garment temperatures. Fourt and Hollies (1970) discuss the interaction of the objective and subjective analysis of thermal comfort and the emphasis and importance of thermal qualities of materials versus design by stating that:

> "...the concept that physical, optical, and even subjective differences in clothing materials are responsible for comfort when worn is quite logical. Many test methods have been developed for assessing the physical properties of clothing fabrics and some of these can be measured with great precision. Unfortunately these types of measurements, no matter how precise, can not substitute for actual measurement of comfort on people which takes into account the interaction of the body physiology and its motion--and the motion of the clothing--as well as the microclimate of exposure" (p. 115).

The subjective element in thermal comfort was emphasized by subjects in a Florida field study of citrus applicators (Nigg, et al., 1986). During this study, applicators were to wear a SBO protective uniform over their regular clothing. However, after mid-July, when the weather was becoming warmer, the subjects refused to wear the SBO garments due to heat discomfort. Two other recent studies, one by Branson, DeJonge, and Munson (1986), and another by DeJonge, Vredevoogd, and Henry (1984), have dealt exclusively with subjective analysis of thermal comfort, and attitudes, practices, and preferences towards pesticide protective clothing, respectively.

Mobility:

Mobility is an essential aspect of protective clothing. Watkins (1984) largely attributes the success of a protective garment to the ease in which it is worn and states:

> "Whenever work must be accomplished by straining clothing, energy that could be used to accomplish a task is wasted. Since the metabolic rate also increases when the body tries to work against clothing, unwanted heat production, which may lead to profuse sweating and fatigue, may also occur" (p. 144).

She also notes that protection is often times decreased as mobility is increased.

Aesthetic considerations:

In this proposed study, expectations of the corporation involved was influential in garment design selection and formulation. Much of the research addresses user perceptions as a vital concern and criterion in the development of a totally functional protective garment. In this design evaluation, however, the corporate color schemes and perceptions of public response to the clothing was also important.

Summary

Overall, the design selected should incorporate all aspects of the design problem, including characteristics of the protective fabrics selected, established design criteria (protection, thermal comfort, mobility, aesthetics), and future care of the clothing system. Watkins (1984) describes the ideal impact protective garment and the need for the clothing to:

> "...not interfere with the movement needed to do a specific job. They should provide adequate relief from heat stress. They should allow the wearer maximum use of the sense of touch, hearing, sight, and so on. They also need to be easily cleanable, so that decontamination is possible" (p. 130).

CHAPTER THREE

METHODOLOGY

The purpose of this research was to develop and test if one type of protective clothing significantly reduced the amount of chlorpyrifos absorbed in the bodies of a selected group of lawn care specialists in comparison to the clothing normally worn. In this chapter, consideration is given to the development of the protective garment studied, selection of the sample, description of the measures, and a description of the study structure.

Development of the Protective Garment

The development of the protective garment was a product of collective ideas and experimentation. First, design criteria were established. Videotapes from phase one of the overall study were reviewed. Past research literature in the area of pesticide penetration, thermal comfort, and mobility was reviewed along with current work clothes and uniform catalogs (see chapter two). Design criteria also were developed by observing lawn care specialists at work and talking with company officials, as the client offered more practical information such as worker acceptability and practices (eg. laundry).

From the various sources of information, two designs were formulated and presented to the lawn care company. A one-piece design was initially accepted and experimentation with features designed to solve problems such as ease of arm extension followed. The design was later rejected by the lawn care company officials because they felt that the lawn care specialists would not accept a one-piece garment for aesthetic reasons because it resembled a typical protective coverall garment. The second two-piece design was then modified to incorporate what was learned in experimenting with the first design.

Body measurements were taken, patterns were drafted, and the protective garments and gloves were constructed for each member of the sample. After fitting, the garments were adjusted and packaged for each individual along with the gloves, boots, underwear, socks, and hats. Refer to chapter four for a full description of the development of the design.

Selection of the Sample

Since human participants were involved, the approval of appropriate committees involving research with human participants was sought and attained at both Michigan State University and The Dow Chemical Company. The sample consisted of six lawn care specialists employed by the TruGreen Corporation from two branch offices in the greater Detroit, Michigan area. The potential participants were identified intially by using employment records which identified experienced applicators.

An orientation meeting was held for the experienced personnel at this office. The researchers presented information pertaining to the nature and importance of the research project, and an overview of the procedures and what the participants involvement would be. Volunteers were assured that they were under no obligation to participate. From this group, four men volunteered to participate. Participants gave their informed consent and body measurements were then taken of these four volunteers.

Since six male participants were needed, two potential lawn care specialists with prior experience were identified by management at another branch office. The research project was explained to them and they were given the opportunity to abstain from the research project without further consequences. Both consented to participate, gave their informed consent, and had body measurements taken.

A second orientation session for the six volunteers was held three days prior to data collection. Further instructions pertaining to procedures and participant responsibilities in data collection were given. The volunteers were also fitted for their protective uniforms and need for alterations noted.

Description of the Measures

Chemical lab testing of the various body fluids can provide definite quantification of organophosphate absorption (Petersdorf, et al., 1983).

In order to measure the absorption, as opposed to exposure, two types of biomonitoring were employed. First, absorption was measured by plasma and erythrocyte cholinesterase levels, and second, by the urinary excretion of 3,5,6-trichloro-2-pyridinol, the principle metabolite of chorpyrifos.

Biomonitoring devices:

Cholinesterase (ChE) is a critical enzyme in the nervous system of the human body (Baron, 1976) and is affected by organophosphates. The measurement of plasma and red blood cell cholinesterase levels is an indicator of organophosphate exposure. However, several factors may interfere with its sensitivity. First, is the wide range of variance that is normal in individuals and second, the lapse time that occurs in normal cholinesterase depression because the compound (or its metabolites) can bind to the protein in the blood or tissue (Goodman, Gilman, 1965) or can be excreted before a measurable effect occurs. Other changes in cholinesterase levels may also occur after exposure that are coincidental and unrelated to exposure (Jager, 1976).

The measurement of 3,5,6-trichloro-2-pyridinol (3,5,6-TCP) quantifies the absorption of chlorpyrifos, the active ingredient in Dursban , into the body and can be used as a measure under actual conditions (Nolan, et al., 1984). It is unlikely that chlorpyrifos will build up on repeated exposure (Nolan, 1985). In order to control for any incomplete urine collections, 3,5,6 TCP has been normalized by the output of creatinine in this study. See Appendix A for description of 3,5,6-TCP and creatinine measurement.

In order to quantify plasma and red blood cell cholinesterase levels, blood samples were taken by venipuncture. This is a measure that is commonly used in the supervision of lawn care workers for organophosphate exposure (Baron, 1976). Blood samples were taken prior to exposure at the start of the spray season, which is normal procedure, in order to establish a baseline for the study and to account for the wide variation between individuals (Dreisbach, 1980). During the two week study, six samples were drawn.

For the five days each week of the study, participants collected 24-hour urine voidings. Each days sample extended from the first collection immediately following the first voiding to the end of the first voiding on the following day. The voidings that were analyzed included the day before the organophosphate spraying, the day of the spraying, and the three days following the spray days on each of the two weeks. Volumes were recorded for each sample and an aliquot of each of the 24-hour urine samples was taken and stored under refrigeration, while the remainder was discarded. The urine and blood samples were scheduled as shown in Table 2 (see Appendix B for daily instructions to participants).

DAY	EVENTS
FRIDAY	BLOOD SPECIMEN FOR ChE
SATURDAY	----------------
SUNDAY	24 HR URINE COLLECTION
MONDAY	BLOOD SPECIMEN FOR ChE
	24 HR URINE COLLECTION
	SPRAY CHOLRPYRIFOS
TUESDAY	BLOOD SPECIMEN FOR ChE
	24 HR URINE COLLECTION
WEDNESDAY	24 HR URINE COLLECTION
THURSDAY	24 HR URINE COLLECTION
FRIDAY	STOP COLLECTING URINE

Table 2.--Schedule of blood and urine collections (R.J. Nolan, 2/19/1985).

Wearer evaluation of the garment:

In order to obtain responses to the protective clothing, participants were asked to fill out a questionnaire at the end of the day in which they wore the protective garments (see Appendix C). The questionnaire asked the participants to rate fit, mobility, comfort, and the appearance of the shirt and pants and the mobility and comfort of the gloves.

Structure of the Study

The structure of the study included two test spray days during a two week period. On these two test days, participants sprayed Dursban®. Dursban® and other organophosphates were not sprayed during the week prior to the study and during the study weeks. Dursban® was sprayed only on the test days however, regular spraying continued with primarily fertilizer and herbicides being sprayed.

On the first spray day, three of the participants wore protective clothing and three wore the regular uniform. On the second spray day, the clothing treatment was reversed. In this way, the participants acted as their own control and changes in temperature, humidity, and wind speed and direction on the two test days would not be confounded with one clothing treatment. A request was also made for similar work schedules (eg. route lengths) for the two test spray days.

The participants were each given labeled bags on the day that they wore the protective clothing which contained the protective, pre-laundered undershirt, shorts, and socks, boots, and gloves. Cotton gloves were worn for the first hour of spraying for other research purposes and new polyvinyl chloride gloves were worn for the remainder of the day. The participants were given a second bag to put the protective uniform in at the end of the day. They were allowed to keep the underwear and boots. The boots were worn again on the second test day. On the day the subjects wore the regular uniform, they were given new,

pre-laundered uniforms, shorts, and socks. The participants were not issued new gloves to be worn with the regular uniform because it had not been anticipated that gloves would be worn as part of the regular uniform. participants wore their usual work gloves.

Researchers at Michigan State University placed identification numbers on the urine samples and The Dow Chemical Company ran the urine analysis blind using the Jaffe reaction method (Teitz, 1976) for creatinine and the procedure described by Nolan, et al. (1984) for 3,5,6-TCP.

In analyzing the results, it was assumed that the sample was composed of healthy individuals who sprayed pesticides during 75% of the spray day, or at least six hours out of an eight hour day.

A frequency tally of questonnaire responses was completed, and a Wilcoxon matched-pairs signed ranks statistical test was run on the chlorpyrifos absorption data.

CHAPTER FOUR

FINDINGS AND ANALYSIS

This study involved the development and testing of a protective garment. The amount of chlorpyrifos absorbed into the bodies of a sample of lawn care specialists spraying an organophosphate insecticide was compared when the subjects wore the protective and regular uniform.

This chapter has been organized into two major sections. The first section addresses objectives one through four concerning the development of the protective garment and the analysis of the questionnaire administered to the subjects. The second section addresses objective five and the results of the biomonitoring.

Objective One

Objective number one was to identify, evaluate, and select pesticide protective fabrics and finishes from those available, based on past fabric penetration and decontamination research literature (see chapter two).

Although research literature supports the use of several fabric structures for protection (eg. Saran ®-coated Tyvek ®), there was resistance to using them, for practical reasons, by the lawn care company representatives. Of primary concern was the image of danger some of these fabrics may portray as they are sometimes associated with sterile environments. Second, was the concern of thermal comfort, since some of

these fabrics blocked not only pesticide penetration, but air flow, which would be uncomfortable for summer work, and third, cost concerns from disposables that would require continual replacement.

Originally, 100% woven cotton was the chosen fabric for the protective uniform because it would offer thermal comfort, it would absorb the pesticide rather than allowing it to wick through, and in appearance, was considered to be a more conventional fabric. However, it was necessary for the fabric to be available in company colors since the study was under actual work conditions and recognition of the employees is important to sales for the company. The researchers searched for an adequate weight 100% cotton woven and knit however, they had difficulties finding it under the time constraints of the study. The researchers attempted to dye the neutral 100% cotton fabrics but were unsuccessful in producing the company colors. The researchers and company representatives were also concerned that 100% cotton could not be adapted as a uniform because of the need to iron it after laundering.

The shirt body and sleeves of the protective garment were constructed in a white 50/50 cotton/polyester single jersey knit. The cotton-polyester blend, which was the same blend used in the regular uniform shirt, offered ease of care and after repeated wearings, still looked acceptable. This was an important consideration to the company involved since each worker was responsible for the laundry of their uniform. The research literature suggested that for woven fabric, the greater percentage of cotton there is in a blend, the more insecticide will be absorbed by the fabric and thus not be available for human absorption (Finley, 1969). Therefore a higher level of polyester may promote the insecticide to wick through and also be warm to wear.

However, the 50/50 cotton/polyester knit was used in an area of minimal deposition. The knit solved many mobility needs as the fabric can stretch with the wearer. The white color is in keeping with company colors of green and white, and may be subjectively perceived as being cooler to wear and perhaps may actually be cooler to wear due to reflection.

A microporous film laminate which consisted of 3.2 ounce nylon, polytetraflouraethylene, and nylon tricot, was used for protection in areas of high deposition and absorption such as the lower leg and lower abdomen area. Goretex® is twenty-five times more protective than cotton chambray (Orlando, et al., 1981).

A flourocarbon spray treatment (Scotchgard®) was also used in areas of high deposition and absorption to resist liquid absorption by the fabric. A commercial application of flourocarbon was considered but the researchers were unable to secure it in the alloted time. The areas which were given the finish included parts of the shirt and the entire pants. Each received three flourocarbon treatments.

Objective Two

Objective two was to explore and evaluate garment design alternatives, based on protection, mobility, thermal comfort, and aesthetic criteria.

Protection and mobility:

Design ideas were generated through a number of sources. Initially, Slocum and Shern's (1986) deposition study, the first phase of the overall project, provided necessary information on the parts of the body needing the greatest protection. This field study, which involved the spraying of blue dye by lawn care specialists and later extraction and spectrophotometric analysis of the dye deposited on the garments, showed the greatest deposition to be on the lower legs, both front and back. The palm of the hands also received a great amount of dye. Other areas of the body showed minimal deposition. However, since the study did not include unreeling the hose from the truck, which is a normal procedure and carried out at each spray location, the estimate of dye deposition was conservative. Absorption for specific anatomic regions was quantified by Maibach, et al.(1971) through an analysis of urinary excretion. He found relatively high absorption rates in several anatomic regions, especially in the lower abdomen area (see Table 1.).

The deposition field study was also videotaped for later observation. Body motions of the lawn care specialists during spraying were observed. From these observations, specific movement criteria were developed. It was evident that the design needed to allow for movement of the shoulder and arm. The way in which the applicators held the hose also was observed. Generally the hose was pulled over the shoulder when unreeling from the truck and around the waist and down the arm when spraying. Although reeling and unreeling was not included in the deposition study, observations of the researchers encouraged extra protection in the shoulder, waist, or arm since the hose was contaminated when pulled through the grass. Pay gave employees incentive to work quickly resulting in long strides and wide arm swings which influences both mobility and protection needs.

Design ideas were also generated by reviewing past research literature in protective clothing for pesticide applicators. Although the protection and ease of motion aspects were important, other aspects and consequences were important including thermal comfort and expectations of the corporation involved (see chapter two).

Thermal comfort and aesthetics:

Thermal comfort was a major area of concern since the job required physical exertion in the summer. If the prototype were adapted it could be used in the South as well as the Mid-West. Since the garment was designed for a specific lawn care company, approval of the corporation involved regarding presentation of corporate image was necessary.

Design ideation:

From these various sources of information, conceptualization and clarification of the problem was accomplished. Ideas were then generated, based on the specific needs of the user by reviewing what was available for protection in similar types of problems. Work clothes and uniform catalogs were reviewed and note was taken as to the finishes being used (eg. new and improved finishes), average prices, manufacturers, availability, specific design features (eg. for movement and protection), and fiber contents. Fiber and fabric sources were explored further and a number of distributors were contacted for information concerning availability, wearability, and specific protective features. A summary of findings pertaining to available fabrics is reported in chapter two.

After reviewing available information and making contacts for further information, two specific ensembles were developed. One, a two-piece sportswear design that would offer minimal protection, but more than the currently worn uniform (see Figure 6.). It was designed

Short sleeved polo style shirt with

work weight twill pants

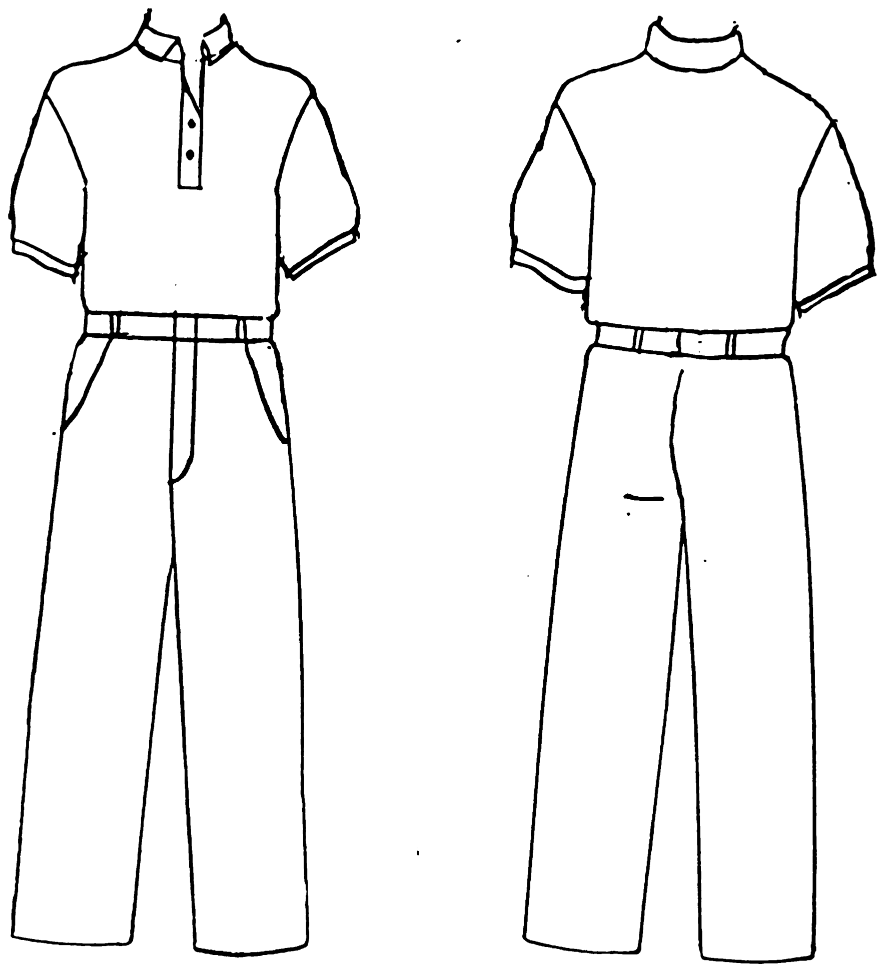


Figure 6.--Typical uniform of lawn care specialists.

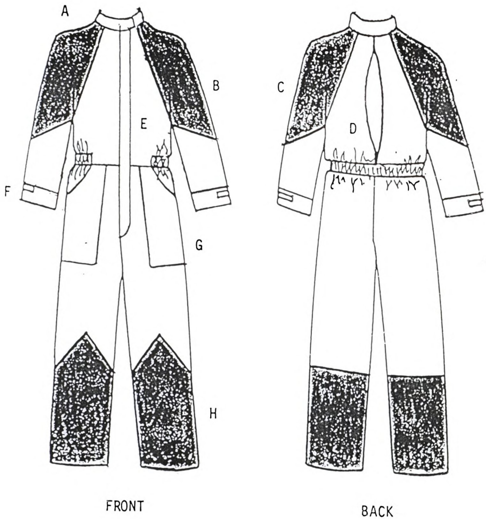
with optional disposable chaps. The second design was a one-piece design in the form of coveralls and similar to the sketches seen in Branson (1982) and many of the work clothes catalogs.

One-Piece design:

The intent of the one-piece design was to offer as much protection as possible without appearing overly conspicuous to the customer. The company representatives were in favor of the one-piece garment because it not only covered more of the body than the regular uniform and provided a unique look for the lawn care workers from the typical uniform worn in the area. This uniform was initially accepted for use in the study by the company officials supporting the project.

Specific design features of the one-piece garment included a high stand-up collar with a synthetic mesh liner to wick body moisture, raglan sleeves for added shoulder movement, upper arm and lower leg inserts of a microporous film laminate for added protection in the areas of high deposition with the benefit of breathability, a covered zipper to protect the closures from mist infiltration, cuffs with hook and mesh type closures, large abdominal pockets lined with the microporous laminate, an inner mesh panel to wick moisture from the back, and a back action pleat for extra movement across the shoulder blades, as illustrated in Figure 7.

The coveralls were originally constructed from 100% cotton twill with the microporous laminate simulated in cotton. A male student from the Horticulture Department at the university, who had previous experience in lawn care application, wore the prototype and simulated typical movements of the job for the research group. He also sat in the uniform and wore it during his daily activities for a three hour period.



A. High woven stand-up collar lined with knit

B. Raglan sleeves for added mobility

C. Upper arm inserts of microporous film laminate

D. Back action pleat

E. Covered zipper

F. Long sleeves with cuffs

G. Abdominal pocket inserts of microporous laminate

H. Lower leg inserts of microporous laminate

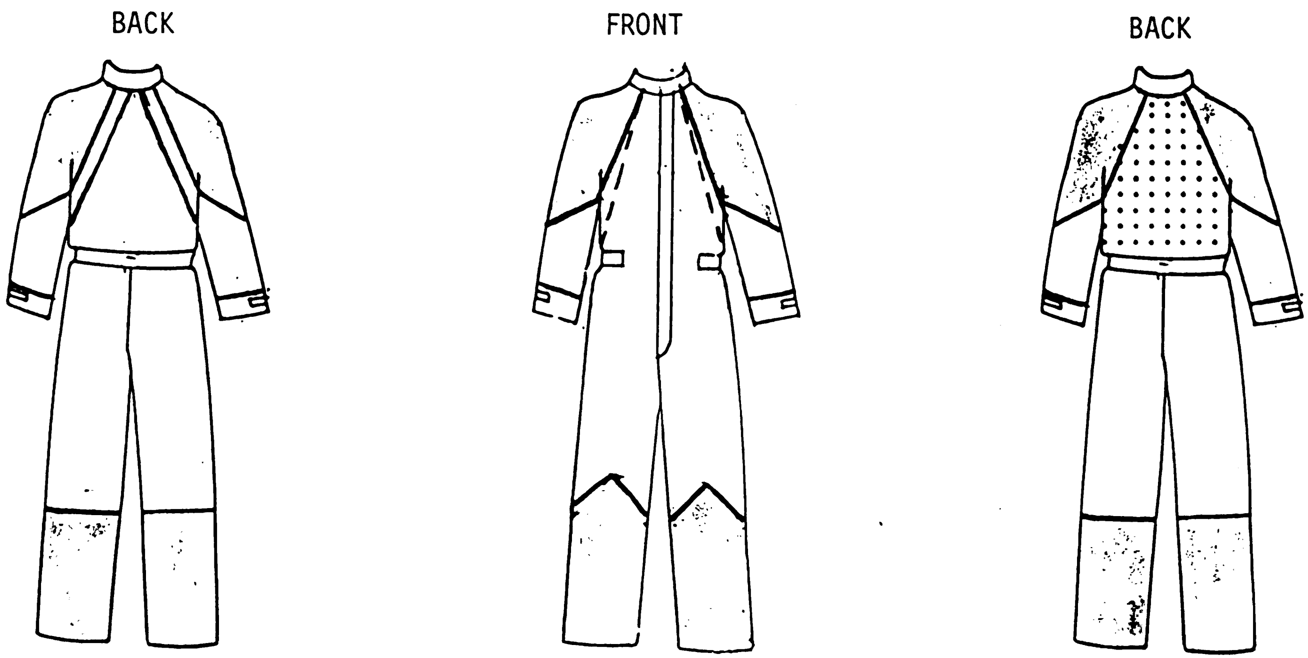
Figure 7.--One-piece protective garment.

The student was personally satisfied with the aesthetic and protective features of the garment however both he and the research group observed several problems in the design. First, the neckline was too small and needed to be enlarged for comfort. The back action pleat was not functioning as intended but instead was pulling out of place. Finally, problems were observed in the amount of ease that was allowed for reaching of the arms along with design features intended for movement purposes. Alternatives were intiated and constructed in an attempt to solve the problem of inadequate ease for reaching and swinging of the arms. See figures 8. and 9. for sketches of alternatives explored.

<u>Upper arm and lower leg alternatives:</u>

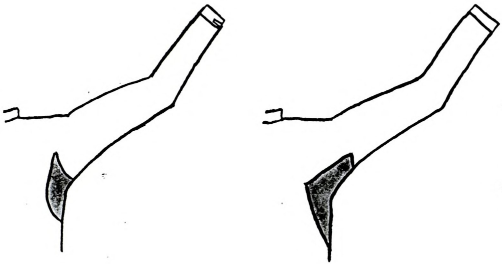
Many oberservations were made in analyzing the alternative prototypes by the researchers and a panel of undergraduate students involved in the study. First, it was observed that the more ease that was allowed in the raglan sleeve, the less length was left for reaching. In order to counteract this, the uniform would require a no-fit style if the raglan sleeves were to be kept in the one-piece design. Since this was not desirable to the lawn care company intended for, set-in sleeves were explored. It was observed that when the woven sleeves were attached to a mesh knit panel or to the knit back, the functionality of the stretch knit was diminished. Knit underarm gussets increased reaching overhead, but did not increase shoulder movement. These alternatives were constructed and a panel of undergraduate students wore them, simulating work movements, and evaluated them as a group.

At the same time, the researchers began to investigate upper arm and lower leg alternatives to increase protection in these areas. These included disposable and semi-disposable fabric inserts such as spunbonded

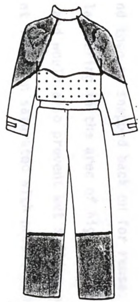


1. Moving the back action pleat to both raglan sleeve lines.
2. Adding extra ease to the armscye by dropping it lower.
3. Constructing the entire back in a stretch knit fabric.

Figure 8.--Alternative upper body designs.



1. Adding knit underarm gussets in various sizes and shapes.



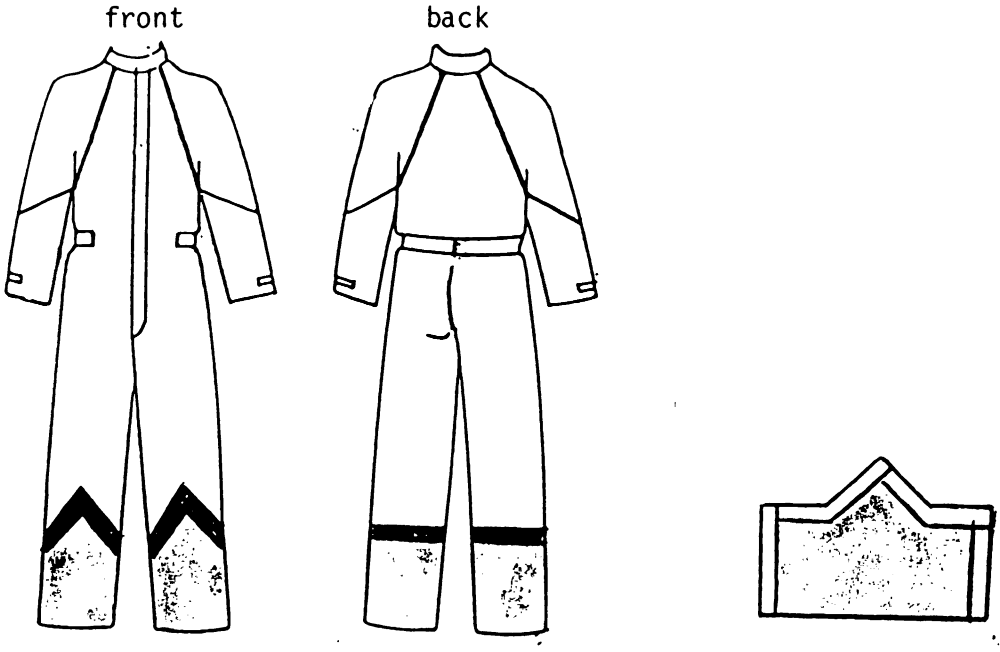
2. Changing the raglan sleeve line with a knit mesh panel in the upper back with a loose woven overhanging panel.

Figure 9.--Additional upper body designs.

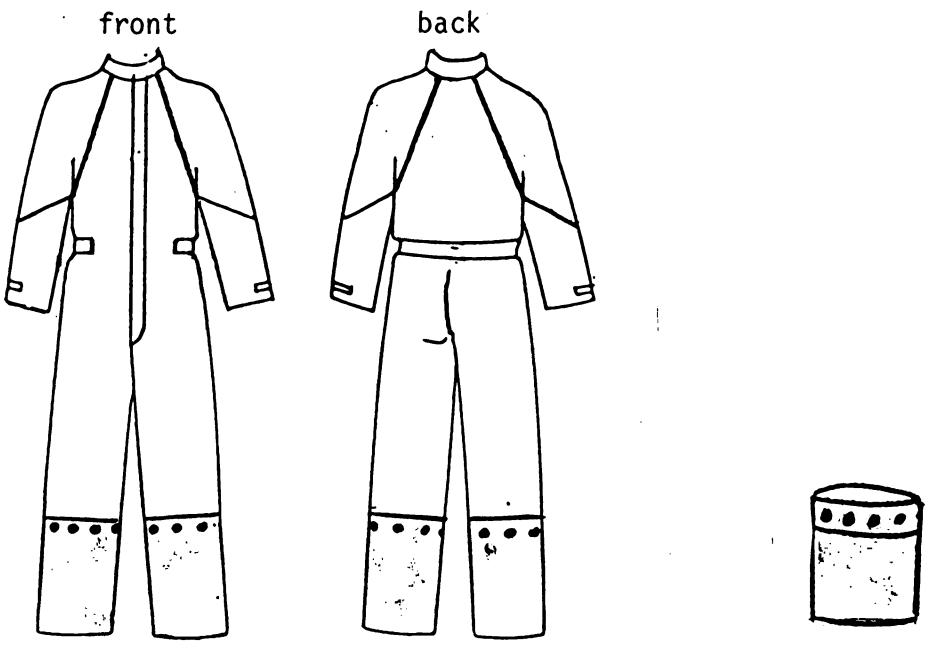
olefin (SBO) products and vinyl coated nylon detachable pieces. One design alternative was to snap vinyl coated nylon pieces on in these two areas. The inserts could be removed and hosed off at the end of the work day, and then be snapped back on for reuse. This would solve the problem of laundering in the area of high deposition with the rest of the garment and would also prevent wet soiling, especially in the lower leg area that is often saturated with pesticide when spraying. Another alternative was to use a disposable fabric such as Saran®-coated SBO that would be attached with a disposable polypropylene hook and mesh closure. The inserts could simply be discarded after every spray day. See Figure 10. for sketches of these alternatives. Experimentation was then done concerning thread size, seam construction, and seam sealing for these fabrics.

Design ideas also were discussed concerning SBO gaitors or chaps as a disposable alternative to lower leg attachments (see Figure 11.). Spunbonded olefin and other disposable fabrics were also discussed as a full garment fabric. Problems with this, however, included problems with ease and fit. The garment, if constructed of a no-give disposable (due to the fabric's form of construction involving extrusion of the synthetic "dope" into a thin, nonporous film or sheet), would have to be oversized or constructed as a partial garment in order to compensate for the lack of elasticity in the fabric structure. A partial garment of SBO was designed that would cover the legs and abdomen, but not the arms, in order to allow for air flow and body cooling.

The researchers met again with company representatives and presented a constructed prototype of the one-piece garment with permanent lower leg inserts and pants with removable vinyl coated nylon



1. Disposable SBO inserts with disposable polypropylene hook and mesh fasteners.



2. Removable vinyl-coated nylon lower leg inserts with snap fasteners.

Figure 10.--Alternative lower leg designs.

A. Rolled hood stand-up collar

B. Covered zipper placket

C. Dropped armscye and shoulder line

D. Knit sleeves

E. Woven yoke

F. Twill work weight pants

G. Disposable SBO chaps

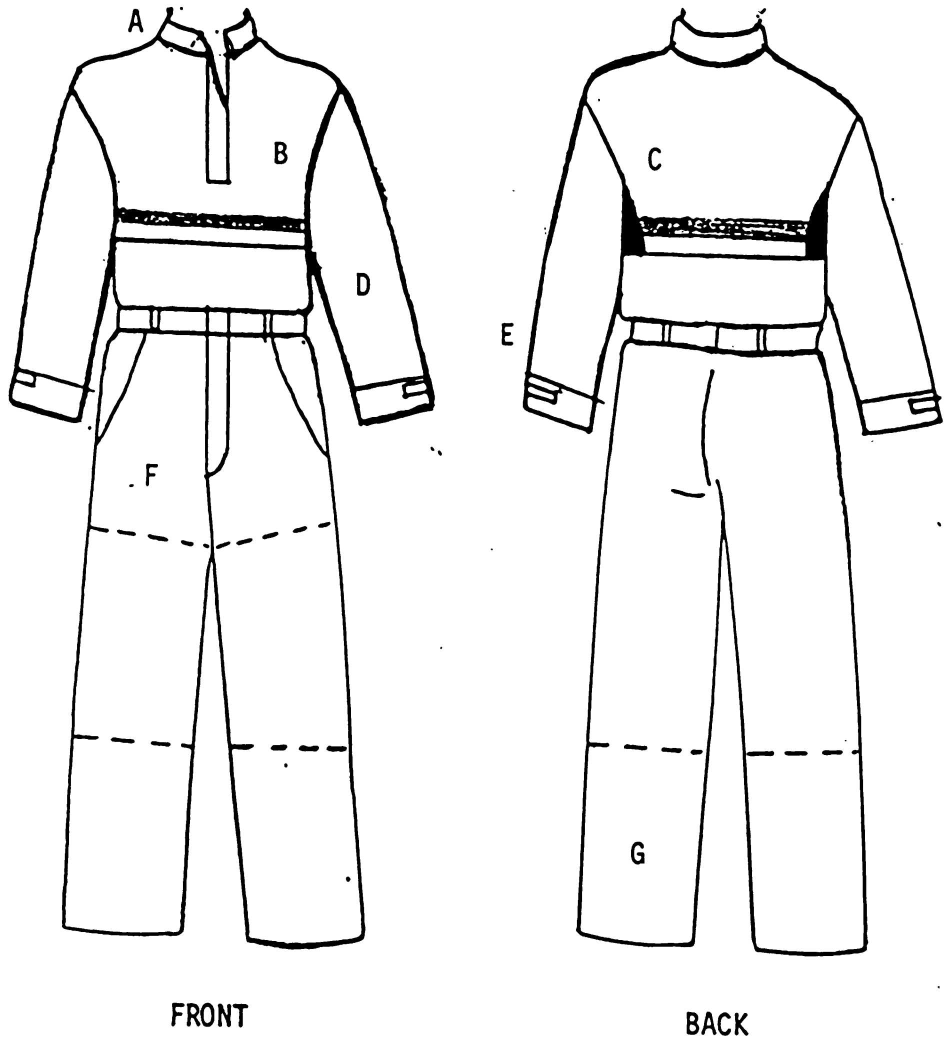
Figure 11.--Twp-piece design with chaps.

leg attachments along with sketches of upper body and lower leg alternatives, and the disposable garment alternatives. The lawn care company representatives felt that the detachable inserts would not be used by the lawn care specialists after time, and that the disposable pieces would not be replaced. They also did not feel that the disposable partial or full garments would be accepted by the wearers. In addition, the disposable garment would be more conspicuous than a garment of conventional fabrics, and this was undesirable. The company involved desired a garment that looked as "normal" as possible in order to not convey a message of danger to their customers. At this time, the lawn care industry chose to reject the one-piece garment along with any disposable or removable alternatives. It was agreed that the researcher would return to the two-piece design initially presented and strive for a more conventional looking garment for the lawn care specialists.

Two-piece design:

An attempt was made to inconspicuously increase protection as much as possible by incorporating more protective features into the two-piece design. With the two-piece design, many of the high reaching problems were solved as the top half of the garment was no longer attached at the waistline. It also eliminated several fitting problems, mainly in length. It also solved a laundering problem in that the lower half of the garment that had high deposition would not be laundered with the top half of the garment which had minimal deposition. This could help to reduce deposition in laundering. Some of the features of the initial shirt prototype were retained including the high collar, front placket, and long sleeves with cuffs (see Figure 12.).

An extended shoulder yoke, attached only at the neckline and the



A. High woven stand-up collar lined with knit

B. Woven yoke overlay attached only at the neckline

C. Underarm stretch knit mesh gusset

D. Shirt body and sleeves of stretch knit

E. Long sleeves with cuffs

F. Abdominal pocket lining of microporous laminate

G. Lower leg lining of microporous laminate

Figure 12.--Two-piece protective uniform used in this study.

front placket, offered added protection in the area of potential mist fall and against the contaminated hose when pulled over the shoulder. Since it was attached only at the neckline, the knit body of the shirt was not stabilized. The shoulder seam was covered with a stripe that offered a sportier look and also protected from infiltration from the contaminated hose through the seamline. Mesh underarm gussets provided ventilation and extra mobility. The yoke overlay was constructed from a heavy green 50/50 cotton/polyester 7-8 ounce twill, was treated with three flourocarbon treatments to resist pesticide pick-up, and featured a design stripe.

The shirt had long sleeves with cuffs constructed from the same fabric as the yoke overlay. They also had three flourocarbon treatments. The intention of the researchers was to discourage the subjects from rolling up their sleeves in warmer weather. The extra weight of the cuffs made it difficult for the light weight knit to support them when rolled up. The woven cuffs also offered added protection at the interface of the glove and sleeve.

The shirt also had a high woven collar that was lined with the knit fabric for comfort. The collar was also treated with a flourocarbon finish for added protection as the contaminated hose is often pulled up over the shoulder and against the neck when reeling and unreeling the hose from the truck.

The pants in the protective ensemble were the same as those worn in the regular uniform ensemble. They were of green 50/50 cotton/polyester work weight twill. The pants were a major concern since the area of highest deposition was found on the lower legs and the lower abdomen was an area of high ease in absorption. Because of this, protective

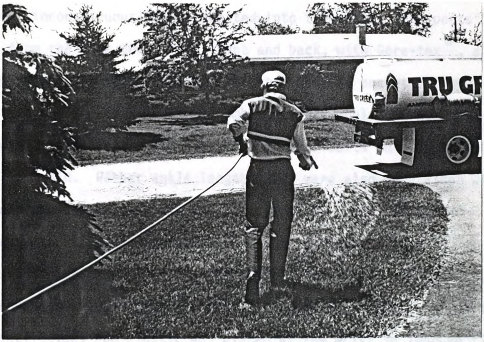


Figure 13.--Participant spraying lawn in the protective garment.

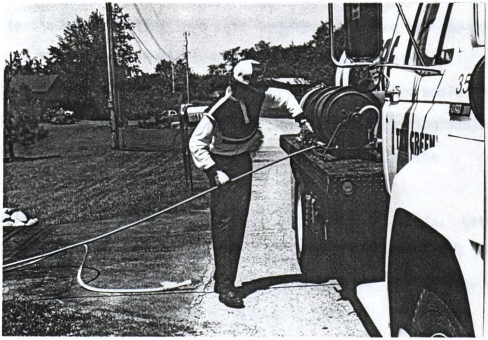


Figure 14.--Participant reeling hose in the protective garment.

features were inconspicuously incorporated into the pants. The pants were lined from the knee down, both front and back, with Gore-tex®, a microporous film laminate, as were the front abdominal pockets.

Nylon belts were added to the ensemble as they would not hold the insecticide and remain contaminated as the leather belts worn in the regular uniform did. Rubber ankle length boots were also worn along with new, prelaundered cotton t-shirts and jockey shorts. New company baseball hats and PVC gloves were worn. PVC is a material that is commonly used for protective wear however, it can be very warm to wear. For this reason, mesh panel inserts were incorporated into the top of the hand for ventilation, and elastic was placed at the wrist to improve fit.

Objective Three

Objective three was to illustrate designs and present them to company officials.

After many sketches were evaluated and discussed, two designs were presented to the participating lawn care company, including the one-piece coveralls and the two-piece design with chaps. It was originally proposed that two protective garments and the regular uniform would be tested. The cost of data analysis and the difficulty of getting subjects to participate for a longer period necessitated only testing one protective garment.

Initially, the one piece garment was accepted for the study. Later it was rejected and the original two-piece garment was modified and presented to company officials. This clothing system was accepted by the lawn care company involved for use in the study.

Objective Four

After body measurements were taken and patterns were drafted, six sets of the ensemble were constructed by the researchers and a group of undergraduate students in an assembly line fashion. The gloves were purchased, and the mesh inserts and elastic were added. Under wear and boots were purchased. Refer to Figure 8. for an illustration of the protective ensemble.

Questionnaire responses

When the participants were finished spraying at the end of the day they were wearing the protective uniform, they were asked to complete a questionnaire shown in the Appendix C. This questionnaire was completed and returned by five of the six participants. Although the questionnaire was not analyzed statistically, a frequency tally gave insight to the participant perceptions of the garment by the wearers.

The first three groups of questions addressed the participants evaluation of fit, mobility, comfort, and appearance of the pants and shirt and the fit and thermal comfort of the gloves. Participants rated their responses on a five point scale, one indicating a high score, five indicating a low score.

Response totals for the pants are shown in Table 3. The overall average of individual scores for the pants was 2.7. Ratings for fit, mobility, and appearance of the pants were consistant with the averages ranging from 2.2 to 2.6 and the standard deviation .3 to .7. There was greater deviation from the average for comfort (1.3), however, with the average rating being 3.6 indicating participants were less satisfied with comfort.

factors \ participants	1	2	3	4	5	x	s.d
fit	3	2	3	2	3	2.6	.3
mobility	2	2	3	3	2	2.4	.3
appearance	2	2	3	3	1	2.2	.3
comfort	3	2	5	4	4	3.6	1.3
x	2.5	2	3.5	3	2.5	2.7	.65
s.d.	.33	0	1	.66	1.66	.39	.76

Table 3.--Participant rating of protective pants.

The shirts received a slightly higher overall rating than the pants with an average rating of 2.05. Again, the scores for fit, mobility, and appearance were higher and more consistent than those for comfort. Comfort was rated lower by the wearers. Response totals for the shirt are shown in Table 4.

factors \ participant	1	2	3	4	5	x	s.d.
fit	1	3	1	1	2	1.6	.8
mobility	1	3	1	2	2	1.8	.7
appearance	2	3	2	1	1	1.8	.7
comfort	2	3	2	4	4	3	1.0
x	2.5	3	1.5	2	2.25	2.05	.8
s.d.	.33	0	.33	2	1.58	.41	.2

Table 4.-- Participant rating of protective shirt.

The overall average rating of individual scores for the gloves was 2.7. Gloves were rated for fit and comfort. The scores were consistent. Scores are shown in Table 5.

factors \ participant	1	2	3	4	5	x	s.d.
fit	2	4	3	2	2	2.6	.8
comfort	3	3	4	2	2	2.8	.7
x	2.5	3.5	3.5	2	2	2.7	.75
s.d.	.5	.5	.5	0	0	.1	.025

Table 5.--Participant rating of gloves.

Participants also were asked to respond to two questions concerning protection and appearance. When asked whether they felt the protective uniforms would offer better protection than the regular uniform, all five responded that they did feel that the garment would provide better protection. One participant, however, qualified this by adding an exception for the gloves. Participants also were asked what kind of image the protective garments would project to their customers. Four out of five felt that the protective garment ensemble would project a positive image while one participant felt that the garment would cause the customer to worry.

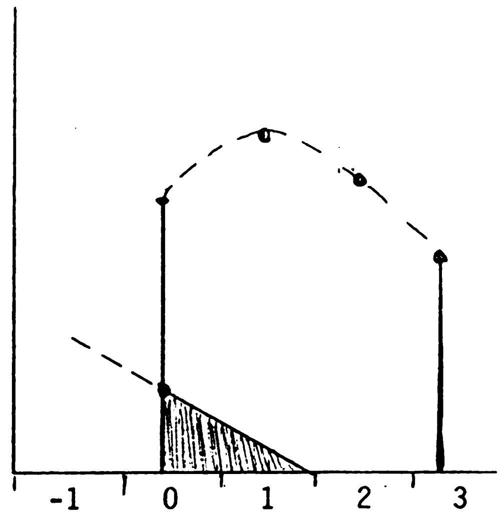
Objective Five

Objective five was to measure the effectiveness of the protective garment in reducing the amount of chlopyrifos absorbed when spraying on a typical work day in comparison to the regular uniform. In order to do this, two biomonitoring measures were planned: the measurement of plasma and erythrocyte cholinesterase levels and the urinary excretion of creatinine and 3,5,6-trichloro-2-pyridinol. However, for some reason, one set of data were lost. Data was not used because it was incomplete and those that were available did not show any change in cholinesterase levels. Based on the 3,5,6-TCP data, it is reasonable that a change in plasma and erythrocyte cholinesterase levels would not be apparent.

As described in Appendix A, 3,5,6-TCP is the principle metabolite of chlorpyrifos. An average of seventy percent of 3,5,6-TCP is excreted with a one-half life of twenty-seven hours with a volume distribution of 181 ± 18 ml/kg (Nolan, et al., 1984).

Creatinine is excreted at a constant rate and the urinary 3,5,6-TCP was normalized for incomplete collection by dividing the concentrate of 3,5,6-TCP in the urine by the concentration of creatinine in that specimen.

In order to determine the micrograms of 3,5,6-TCP excreted, an adjustment was made so that the time period before the spray day would not be included in the event that organophosphates had been absorbed previously and remained in the system. The amount of 3,5,6-TCP excreted for the day before the spray day (-1), shown by the shaded triangle in Figure 9., was subtracted from days 0 to day 3. This is under the assumption that 3,5,6-TCP is excreted at first-rate order Kc=0.619 for day -1 and that the area under the curve (Figure 15.) =amount/Kc.



$Ab = A_1 e^{-K_e t} = A_1 e^{-0.619} = 0.538 A_1$

Area of shaded triangle= Ab/Ke=0.729A

Figure 15.--Adjustment of cumulative urinary excretion of 3,5,6 TCP for the day preceeding the spray day (From Nolan, 1985).

Comparisons of the micrograms of 3,5,6-TCP excreted on the spray day that the participants were wearing the protective clothing and the day that they were not were made. A comparison of the micrograms excreted standardized on the basis of creatinine for both days is shown in Table 6.

VOLUNTEER	PROTECTIVE CLOTHING	NORMAL CLOTHING	DIFFERENCE	% REDUCTION
1	46.7	101.4	54.7	53
2	91.2	148.6	57.4	37
3	87.2	103.9	16.7	16
4	38.4	61.3	22.9	37
5	26.6	58.5	31.9	54
6	40.2	41.6	- 1.4	-.03

Table 6.--Micrograms of 3,5,6-TCP excreted when protective clothing and normal clothing were worn.

Looking at the amount of micrograms of 3,5,6-TCP excreted, it is easy to see the varying amounts of absorption between individuals. One factor that plays a part in these differences between volunteers is worker attitude. Some lawn care specialists are much more meticulous than others when spraying. Since the lawn care specialists have a set number of lawns to spray in a day, many times they are hurried, and therefore less careful with the chemicals. Another variable is the variation of human response to chemicals. Thirdly, is the varying amounts of gallons sprayed during a single day.

In this data, five of the six participants had a reduction in micrograms of 3,5,6-TCP excreted on the test day that they were wearing the protective clothing. The increased excretion for participant six while wearing protective clothing may have been due to his physiological response to chemicals. It may also have been influenced by the fact that he wore the protective clothing the second day and the boots he had been issued on the first test day split after the first hour of work. He also sprayed slightly more insecticide on the day he wore protective clothing

Because the micrograms of 3,5,6-TCP excreted differed between individuals, a consideration of the gallons sprayed was added. In order to adjust for the difference in gallons sprayed by the individual on the two spray days, the micrograms of 3,5,6-TCP excreted were divided by the number of gallons sprayed for that day. This gives the micrograms excreted per gallon sprayed for the protective clothing and normal uniform for each participant. These porportions (see Table 8.) were then ranked for use in the Wilcoxon matched-pairs signed rank test.

The Wilcoxon matched-pairs signed ranks test was performed on the data. This test ranks the size or magnitude of the difference between pairs and also the direction of the differences within a pair. In order to accomplish this, the difference between each pair is ranked, without regard to whether it is positive or negative (eg. -1 is treated as 1). The positive or negative sign is then affixed after ranking. T then equals the smaller sum of like-signed ranks and can be accepted or rejected at the set significance level.

The nonparametric Wilcoxon test was used because the sample was small and diverse in that the standard deviation was large in comparison to the mean.

The results of the Wilcoxon matched-pairs signed ranks test indicated a reduction in 3,5,6-TCP excreted when the protective clothing was worn in comparison to the regular uniform at less than the .025 alpha level.

	PROTECTIVE CLOTHING			NORMAL UNIFORM		
VOLUNTEER	gallons sprayed	micrograms excreted	porportion	gallons sprayed	micrograms excreted	porportion
1	750	46.7	.062	1000	101.4	.101
2	825	91.2	.111	532	148.6	.279
3	960	87.2	.091	920	103.9	.113
4	750	38.4	.051	680	61.3	.090
5	408	26.6	.065	450	58.5	.130
6	650	41.6	.064	600	40.2	.067

Table 7.--Micrograms 3,5,6-TCP excreted per gallons sprayed.

CHAPTER FIVE

SUMMARY

This study, which was a part of a larger project, involved the development and construction of a protective garment for lawn care specialists, and the evaluation of the effectiveness of the particular protective garment in comparison to the regular uniform on reducing chlorpyrifos absorption.

The protective uniform was developed after reviewing a number of sources of information including dye deposition data, a videotape of phase one of the study and research literature dealing with fibers, yarns, fabric constructions, and finishes and their effectiveness as barriers to pesticide penetration. Design criteria, which included pesticide protection, thermal comfort, mobility, and aesthetics, were established based on these sources, and experimentation with fabric and design combinations followed. Designs were periodically reviewed with the lawn care company until mutual satisfaction was achieved.

The protective garment used in this study was a two-piece design. The two-piece design allowed the bottom, with its heavier concentration of the pesticide, to be laundered separately from the top.

The shirt body and sleeves were constructed in a 50/50 cotton/polyester knit fabric to allow for movement of the arm and shoulder. The shirt featured a high roll collar for protection against contact with the hose and a yoke overlay of heavy cotton/polyester twill, attached only at the neckline and placket, which eliminated shoulder seams and added protection when pulling the hose over the shoulder. A stretch mesh underarm gusset was inserted for movement and cooling. The shirt had long sleeves and woven cuffs.

The pants, which were constructed from 50/50 cotton/polyester work weight twill, were lined from the knee down and in the lower abdomen area with a microporous laminate fabric. The pants received three flourocarbon treatments, as did the shirt yoke, collar, and cuffs.

The sample consisted of six experienced lawn care specialists in the greater Detroit area, who sprayed chlorpyrifos on the two test days. On the first test day, three subjects wore the protective uniform and three wore the regular uniform. On the next test day, the clothing was reversed so that each participant acted as their own control. The test days involved regular work activities however, chlorpyrifos was sprayed only on the two test days and not for three working days before the test day.

During the two week study, participants collected urine samples for the day before the spray days, the spray days, and the three days following the spray days. The urine samples were analyzed for the amount of 3,5,6-trichloro-2-pyridinol excretion, the principle metabolite of chlorpyrifos, and for creatinine excretion, which was used to standardize 3,5,6-TCP excretion.

Plasma and erythrocyte samples also were analyzed. Samples were drawn at the start of the spray season, the Friday before the spray days (Monday), and the day following the spray days. The blood samples were taken in order to measure any change in cholinesterase, an enzyme affected by organophosphate absorption. Due to an error in timing the analysis data were not used.

The participants were given new, pre-laundered clothing including the uniform, undershirt, shorts, and socks. New boots and company caps were issued on the first test day and were worn again on the second test day. Gloves were issued to be worn with the protective uniform ensemble.

Responses to the questionnaire subjectively rated the protective uniform as slightly above average in fit, mobility, and appearance, and average or below average in comfort. The findings of this study indicate that clothing can be effective in reducing the amount of chlorpyrifos absorbed into the human body when protective clothing is worn.

DISCUSSION

This study is different from much of the past pesticide protective clothing research in that it considers bodily absorption of pesticides rather than pesticide penetration into clothing materials. It also deals with a clothing ensemble rather than the evaluation of particular fabrics (eg. permeation rates) or design elements, but is similar in that it adds to the mounting evidence that clothing can reduce bodily pesticide absorption (Davies, et al., 1982).

This research contributes to our existing knowledge of pesticide protection by building on research dealing with component parts of an ensemble (eg. fabric) and viewing the clothing system as a whole. It also emphasizes the need to draw from all of the sub components of the two environments in the human ecosystem model (p. 8) in order to establish design criteria.

When reviewing the clothing ensemble as a whole, elements which are not as important when viewing the component parts of a design become important. For example, the appearance of the clothing ensemble. In the case of the lawn care specialist, the problem of protection from organophosphate insecticides is complicated by the fact that lawn specialists are highly visible professionals involved in both lawn care and sales. Their appearance is thought to be important to sales. Thermal comfort for warm summer weather and the ability of the garment to allow mobility are also important in a clothing ensemble.

Working directly with company officials, it became evident that at times they had different priorities or criteria for the protective ensemble. Their criteria were sometimes more practical than those held by the researchers. For example, the lawn care company was concerned with how the garment would be perceived by their customers, how the lawn care specialists would react to wearing the garments and how they may attempt to change them (eg. rolling up sleeves), and future costs to employees or the corporation.

A challenge of this functional design problem was to adequately protect the wearer while maintaining thermal comfort, mobility, and aesthetics. In the greater Detroit area, the typical lawn care specialists' uniform consists of workweight twill pants and a short sleeve polo style shirt in the colors of the respective company. Most employees find this ensemble to be lightweight and comfortable. Upon introducing features such as long sleeves, however, sprayers may immediately evaluate the garment as being warm to wear. In the questionnaire given to the participants, four out of the five participants answering the questions wrote in that the shirts were too hot even though the air temperature on the first spray day was low. The extended yoke overlay of a heavy woven fabric, the long sleeves, and the high collar may have been the contributing factors to this. All three of these features were added for protection. However, since this was a subjective assessment and was not a measured objectively, we are not sure whether the protective garment was much warmer or whether it was only only perceived to be.

Three out of the five responding commented that the pants were too hot and one wrote in that the pants caused chaffing of the legs. The lawn care company involved in the study wanted the microporous laminate to be placed on the inside, as a liner, because the color the researchers were able to obtain in the limited time available did not match the pants when it was used as an inset. The additional layer probably added to warmth and stiffness.

The overall design tested was a compromise that met each of the criteria to a degree and established that a different uniform could reduce the amount of pesticide absorbed. Further research could establish whether a mere comfortable outfit or less costly one would afford equal protection.

Limitations:

1. This study was limited to six lawn care specialists who had at least one year of prior experience in the lawn care industry. Because of the limited sample size and the variation on human response to chemicals, conclusions should be limited to this sample.

2. The complexity of human physiology and the interaction of uncontrolled variables in regard to biomonitoring makes it difficult to precisely quantify chlorpyrifos absorption. Estimates were based on a

kinetic model of excretion and excretion of the principle metabolite, 3,5,6-trichloro-2-pyridinol.

3. This study was limited to one prototype which involved a particular design and specific fabric selections. Because of this, conclusions can be made in regard to this ensemble only, without any substitutions or changes. Because of this, it is not possible to make conclusions concerning specific design or fabric features (eg. the yoke overlay) in regard to thermal comfort, mobility, or protection, but only as a whole ensemble.

4. There was an uncontrolled variance in the regular uniform due to participants choosing their own gloves to wear with the regular uniform in this study. The extent to which these gloves may have been contaminated is not known. From observations of the lawn care specialists before the participants volunteered, it appeared that most did not wear gloves. However, the participants that volunteered for the study did wear gloves with the regular uniform. This may relate to the possibility that the most interested volunteered to be participants.

Recommendations:

As research in the area of pesticide protection increases, indepth studies into fabric and design features of specific items of clothing that contribute to pesticide protection should be considered.

In past research literature dealing with pesticide protection, protective boots or other footwear has been studied some, but many questions remain such as how to decontaminate the boots or how much residue build-up in boots is absorbed over time. For lawn care specialists, this is an area of concern since the sprayer continually walks through the contaminated grass, with the hose pointed downward spraying towards the feet.

Although permeation of glove materials has been studied, the effect of wearing or not wearing gloves has not been studied with respect to the effect on absorption. In this study, an uncontrolled variable of the regular uniform was caused by individual choice to wear gloves and the kind of gloves to wear. Gloves do protect the skin from direct contact with the chemicals initially, but the effect of each particular glove on absorption, or even how much pesticide comes in contact with the gloves or hands is not known. Repeated studies, with and without gloves may provide an answer to the question of the effect of gloves in bodily absorption.

Continued research in the area of pesticide protective clothing is important in order to synthesize the information pertaining to specific elements of fabrics and designs. Research that addresses pesticide bodily absorption gives additional meaning to the pesticide barrier and/or penetration and laundry research.

Further studies using biomonitoring to measure bodily absorption will help to build on these previous studies. Because of the number of design features possible and fabrics available, combinations of fabrics and designs are innumerable. For instance, shirts with and without the yoke overlay or even with or without the flourocarbon finish could be compared. Design and fabric combinations should be compared with each other for their effectiveness as protection against pesticides, and also for thermal comfort, mobility, and their acceptance aesthetically.

APPENDICES

APPENDIX A

APPENDIX A

Plasma and erythrocyte cholinesterase levels:

Cholinesterase levels can be detected before any signs of toxicity occur (Nolan, et al., 1984). Organophosphates, upon entering the body, act as anticholinesterases by reducing the cholinesterase levels of red blood cells and plasma (Dreisbach, 1980). A.R. Main (1984) describes the anticholinesterase activities as follows:

> "In this capacity they act as nerve poisens by inhibiting cholinesterases (ChE's) essential to the operation of certain vital nerves. Such nerves employ acetylcholine as their transmitter substance and are referred to as cholinergic neurons to distinguish them from nerves using different transmitters. The acetylcholine tansmits nerve impulses by transfusion across the 20nm synaptic gap separating the nerve from the muscle or gland it controls or from another nerve. The assigned function of the essential ChE is to catalyze the hydrolysis of acetylcholine in the synaptic gap. The products of this hydrolysis are 100,000 times less effective as transmitters than is acetylcholine. Thus the ChE acts to control transmission of nerve impulses by modulating the concentration of acetylchloine in the synaptic gap, particularly in the region of the post synaptic gap membrane where ChE's and cholinoreceptors appear to be principally located. When ChE is inhibited by organophosphate...compounds, the acetylcholine accumulates and its concentration remains at levels which are continously to operate as signals. The cholinoreceptors are then saturated with acetylcholine, making the nerve system inoperative" (p. 351).

Urinary excretion of creatinine and 3,5,6-trichloro-2-pyridinol:

After absorption, organophosphates are metabolized and excreted almost entirely in the urine (Goodman, Gilman, 1965). Matthews describes the metabolic breakdown as follows:

> "...most important in terms of detoxication and excretion, organophosphate insecticides are degraded by phosphatases which hydrolyze the phospherous from the larger organic portion of the molecule and to a lesser extent by phosphatases which dealkylate the phosphorous portion of the molecule. Thus, the products of these enzymatic degradations, dialkyl phosphates

> and various conjugates are generally molecules smaller and more polar than the parent compounds and excreted primarily in the urine" (p. 335).

Creatinine is formed by the removal of water from creatinine phosphate, generally in the muscle mass of the body. This formulation is irreversible. Creatinine can be found not only in the muscle, however, but in all of the bodily secretions including blood and urine (Fabiny, Ertingshausen, 1971). The excretion of creatinine in the urine is known to be generally constant in a given individual (Harper, 1969) thus creatinine excretion is a surrogate for time and is effective as a normalizer.

Some controversy exists concerning variables involved in the creatinine excretion, especially the consumption of meat in the diet and physical exercise. Bleirer and Schedl (1961) describe the relationship of meat in the diet to creatinine excretion as the following:

> "In general, rates of addition of creatine to loss of creatinine from the precursor pool depend on the dietary intake and synthesis of creatinine and the conversions of phosphoryl creatine and creatinine. Meat in a usual diet can appreciably expand the pool because of the slow turnovers of the precursors. Thus, 24-hour urinary creatinine contains a component from that day's turnover of stored creatinine ingested previously" (p. 945).

In a more recent study, Patterson (1967), in a reinvestigation of the constancy of the 24-hour excretion of creatinine, found little variance in the excretion with varying diets. He also found that physical exercise appeared to increase creatinine output only slightly.

APPENDIX B

APPENDIX B

INSTRUCTIONS GIVEN VOLUNTEERS

FRIDAY:
1) Have blood specimen drawn
2) No exposure to chlorpyrifos or other OP

SATURDAY:
1) No exposure to chlorpyrifos or other OP.

SUNDAY:
1) Discard urine from first voiding in morning
2) Collect all urine voided over next 24 hours.
3) No exposure to chlorpyrifos or other OP.

MONDAY:
1) Place urine from first voiding in Sunday's container.
2) Collect all urine voided over next 24 hours.
3) Turn Sunday's urine specimen in when you come to work.
4) Have second blood specimen drawn.
5) Spray chlorpyrifos; No exposure to other OP.

TUESDAY:
1) Place urine from first voiding in Monday's container.
2) Collect all urine voided over next 24 hours.
3) Turn Monday's urine specimen in when you come to work.
4) Have last blood specimen drawn.
5) No exposure to chlorpyrifos; May spray other OP.

WEDNESDAY:
1) Place urine from first voiding in Tuesday's container.
2) Collect all urine voided over next 24 hours.
3) Turn in Tuesday's urine specimen when you come to work.
4) No exposure to chlorpyrifos; May spray other OP.

THURSDAY:
1) Place urine from first voiding in Wednesday's container.
2) Collect all urine voided over next 24 hours.
3) Turn in Wednesday's urine specimen when you come to work.
4) No exposure to chlorpyrifos; May spray other OP.

FRIDAY:
1) Place urine from first voiding in Thursday's container.
2) Stop collecting urine.
3) Turn in Thursday's urine specimen when you come to work.

COLLECTION OF URINE: It is important to collect all urine voided over the entire 24 hour period. Each collection should start immediately following the first voiding and end with the first voiding on the next morning. Record, directly on the container label, the time each container actually began and ended, and the approximate time interval representing any urine that was lost. You will be given two containers for each day's urine. As a matter of convenience we suggest that you place no more than about 16 hours of urine in any container.
If you have any questions, please contact your supervisor or Richard J. Nolan. Work phone 517-636-2182.

Observation Record: Protective Clothing Study

Observer______________________________________ Date___________________

Observing____________________________ Time day began___________________
Temperature__________________________ Time day ended___________________

Wind conditions:
Still ______
Steady______
Gusty ______

Sun conditions:
Clear ______
Partly cloudy______
Overcast ______

Temperature:______

Number of Applications done this day______

General description of terrain for the day. Were there any unusual features (hilly, rocky, etc.)?

Did you notice the sprayer having any problems with the clothing (pulling at the shoulders, tight in the shoulders, pants too long, etc.)?

Did the pants look like they fit?

Did the shirt look like it fit?

Exposure observations:
Include direction of applicator's travel in relation to wind direction, the way the hose is handled, nozzle drip, hose breakage, truck problems, body movement of the sprayer, and other circumstances that occured during the day.

APPENDIX C

APPENDIX C

QUESTIONNAIRE

Name:____ Date_____________
Time day began___________________ Time day ended_______________
Number of sq. ft. sprayed today______ Time showered after work________
Approximate number of gallons sprayed______

Were there any unusual events in today's work (eg. broken hoses, problems with truck, etc.)?

Please answer the following questions by circling the number of your responses for each question.

	Very Good	Good	Average	Poor	Very Poor
How was the fit of the pants?	1	2	3	4	5
How easily could you move in them?	1	2	3	4	5
How would you rate their appearance?	1	2	3	4	5
How comfortable were the pants?	1	2	3	4	5

Do you have any comments to make about the pants?

How was the fit of the shirt?	1	2	3	4	5
How easily could you move in it?	1	2	3	4	5
How would you rate its appearance?	1	2	3	4	5
How comfortable was the shirt?	1	2	3	4	5

Do you have any comments to make about the shirt?

How was the fit of the gloves?	1	2	3	4	5
Was the temperature comfortable?	1	2	3	4	5

Do you have any comments to make about the gloves?

Do you feel these garments will offer better protection than the regular uniform when spraying pesticides?

What kind of image do you think these garments will project to your customers?

APPENDIX D

Dursban® is the registered tradmark of The Dow Chemical Company.

Tyvek® is a registered tradmark of DuPont.

Saranex® is a registered tradmark of The Dow Chemical Company.

Gore-tex® is a registered trademark of W.L. Gore and Associates, Inc.

Scotchgard® is a registered trademark of the 3M Company.

APPENDIX D

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