National Textile Center

FY 2003 (Year 12) Continuing Project Proposal

Project No.

M01-CR02

Competency: Materials

Improving the Understanding and Acceptance of Personal Protective Equipment (PPE)

Project Team:

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Objective:

- Improve understanding of the complex interactions between pesticide chemicals and textile surfaces. Use the manipulation of the surface tension of the textile relative to the chemical challenge to develop a fabric with "idea" behavior of high protection and high air permeability for thermal comfort in hot, humid weather.
- Develop a model(s) using principal factor analysis to serve as the basis for recommendation of textile material selection and/or product development for full body coverage PPE when using existing and/or new pesticide products.
- Develop a matrix material for the textile structure that functions as a "smart" textiles with open pores in the dry state and swelling to "close" the pores when exposed to the chemical challenge (year 3 or 4 longer range).
- Explore using porous composite materials formed from a woven or knitted structure and a matrix that infiltrates only the structure of the textile in a way to engineer the size of the pores and the surface chemistry of the material (year 4 or 5 to show longer range directions)

Progress Statement:

We investigated the transfer of pesticides from contaminated work clothing to human skin with the goal of furthering our understanding of the role of non-barrier clothing in minimizing risk. Our objective was to study the use of synthetic membrane to evaluate the kinetics of pesticide transport from contaminated clothing through human skin. Rates of transport of pesticide through the test system with and without the presence of fabric were both diffusion-limited. The synthetic membrane system was an appropriate model for human skin in this situation. Starching applied to the fabric gave additional absorption and retention reducing pesticide transport through the fabric to the skin, and heavier weight fabric such as denim provided protection through absorption and retention of the pesticide limiting transfer to the skin.

The data followed a non-linear pattern with asymptotic, or limiting values (Figure 1). Data points with such behavior generally follow the equation of the form:

$$y = a\,(1 - e^{-bt}) + c$$

where the value of a+c represents the asymptotic value of the equation and t is time. The parameters a, b, and c were estimated using the statistical program SIGMAPLOT® (SPSS Inc. Chicago, IL).

Differences between the shirt-weight fabrics were observed for the bleached and mercerized versus carboxymethylated fabrics (Figure 1). Carboxymethylated fabrics showed penetration of pesticide higher than the synthetic membrane alone, while the bleached and mercerized fabrics showed lower penetration of pesticides. The denim fabric resulted in much greater reduction of pesticide penetration than the shirt-weight fabrics (Figure 2).

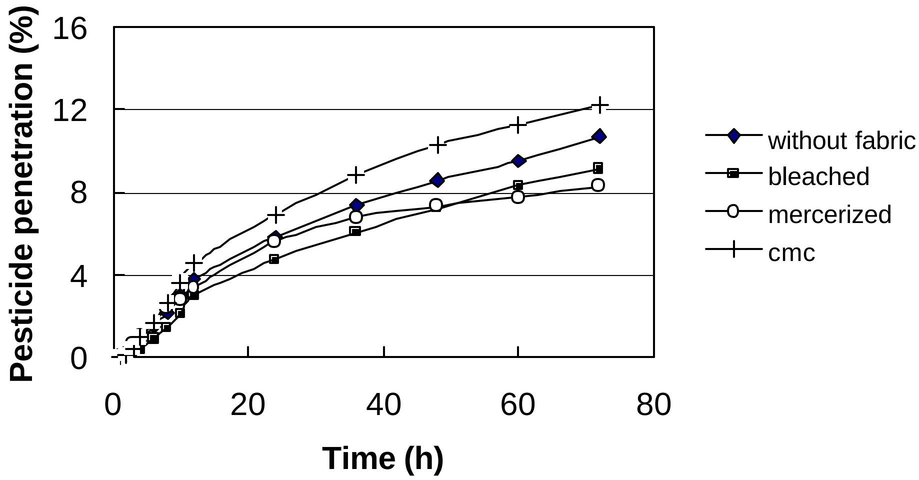

Figure 1 Transport of pesticide through synthetic membrane with and without shirt-weight fabric

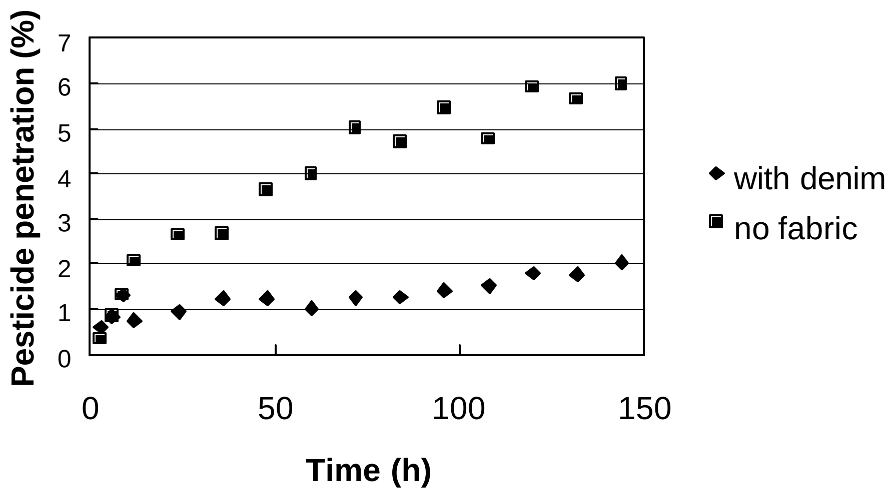

Figure 2 Transport through human skin with and without denim fabric

S. Kay Obendorf, Emília Csiszár, Dennis Maneefuangfoo, Judit Borsa, Kinetic Study of Transport of Pesticide from Contaminated Fabric Through a Model Skin, Archive of Environmental Contamination and Toxicology (submitted 9/02)

Next Year's Goals:

- We will continue efforts on woven fabrics performance modeling. Considerable data are required for this statistical model. We have made progress on these data collection but think that a broader viscosity range of the challenge liquid is required. Twist factor and cover factor will be considered as independent variables in the performance model. Fabrics and challenge liquids not used to develop the model will be used to test the model.
- Currently we are reviewing the literature and developing research ideas for developing a matrix material for the textile structure that functions as a "smart" textiles with open pores in the dry state and swelling to "close" the pores when exposed to the chemical challenge. In year three, we hope to try some preliminary ideas.

Approach:

Data that include physical characteristics of existing textile materials, e.g. fabric weight, thickness, air permeability, surface tension, will be used as the basis for the textile protection and comfort component of the model. Fabrics included are textile materials that a) represent materials typically used by pesticide applicators, b) have the potential to be used for protective clothing, and c) are commercially marketed for protective clothing. Scatter graphs of fabric weight, thickness, air permeability, etc. will be used to determine the fabric distribution including maximum and minimum limits. Additional materials will be included to fill the voids so that the fabrics are well represented. The first stage of our modeling effort with nonwoven fabrics is reported here. Following the work on nonwoven, the more complex woven structure will be evaluated and modeled. Fabric performance characteristics that define the protection and comfort properties of the textile materials are used for modeling. The laboratory analyses of the pesticide penetration and adsorption are conducted using gas chromatography using ASTM F213-01.

Representative pesticide formulations that characterize formulations and adjuvant combinations are used to measure pesticide penetration properties. Two commonly used pesticides – atrazine and pendimethalin- were selected. Atrazine, available as water dispersible granules, has a water solubility of 30 ppm. Pendimethaline (Prowl), an emulsibiable concentrate, is less soluble in water with 0.4 ppm at 20ºC. The full range of mixing that is specified on the labels by the manufacturer is used to provide a representative array of challenge liquids for the textile materials. These include various surfactant concentrations that vary surface tension and viscosity through the formation of micelles. Other pesticides and formulation will be used to evaluate modeling efforts and to check the prediction of the model.

Multivariant analyses are used to develop the model using parameters that impact fabric protection and moisture and heat transport (Figure 1and 2). The predictive model will be validated with laboratory methodology, using textile materials not included in the development of the model and a representative selection of pesticides and pesticide formulations.Information of the modeling effort will be used to attempt to identify a system with ideal behavior. This could open the possibility of engineering a PPE system that will provide chemical protection while reducing heat stress.

Modifications of polyurethane membranes with polyethylene glycol may offer the potential for developing a material in which the pores will change size and shape with exposure to moisture. Also, other hydrogels are under consideration as potential options.

1. Seungsin Lee, S. Kay Obendorf, A Statistical Model to Predict Pesticide Penetration through Nonwoven Chemical Protective Fabrics, Textile Research Journal, 71:1000-1009 (2001).

2. Matthew Dunn, Design and Permeability Analysis of Porous Textile Composites Formed by Surface Encapsulation, Surface Characteristics of Fiber and Textiles, Editors, Christopher M. Pastore and Paul Kiekens, Marcel Dekker, Inc., New York, NY, (2001) p. 249-283.

3. Ukpabi, P. and Obendorf, S.K., "Modified Polyurethane for Surgical Gown Applications", Performance of Protective Clothing: Issues and Priorities for the 21st Century: Seventh Volume, ASTM STP 1386, C. N. Nelson and N. W. Henry, Eds., American Society for Testing and Materials, West Conshohocken, PA, 2000, p 190-199.

Outreach to Industry:

These results will be shared with producers of fabrics for the PPE market and with those training pesticide applicators. Results will be published in the refereed literature. The paper on transport of pesticide from contaminated clothing fabric through skin is under review by Archive of Environmental Contamination and Toxicology for publication.

Based on collaborative interlaboratory work, ASTM F213-01 entitled "Standard Method for Measuring Repellency, Retention, and Penetration of Liquid Pesticide Formulation through Protective Clothing Materials" was approved as an ASTM standard in 2001. In addition, a test method draft was submitted to International Standards Organization for consideration as an ISO standard. It was approved as working draft ISO 22608. This year the draft was revised to include a simpler gravimetric method for analysis, as well as comments submitted by member countries as part of the ISO balloting process. The revised draft has been submitted for balloting as a standard.

New Resources Required:

The main resources needed are fabrics, chemicals, and personnel. In addition the laboratory needs a chromatographic columns/equipment and a laboratory oven for the analytical aspects of this work to facilitate the data collection by the extraction procedures required.