NIOSH Under the Microscope

Research Program Evaluation Follows NIOSH Values

Value Driven

The evaluation of research and development programs is problematic. Research activities are, by definition, innovative, creative, and risky. There must be tolerance for failure if new knowledge is to be found. In addition, research outputs must often go through many intermediate steps before they show their worth by generating measurable improvements in society.

Nevertheless, from 2005 to 2008, NIOSH underwent reviews of eight major research programs by the National Academies. The reviews were focused on the programs' relevance and impact. Each review lasted a year or more and involved extensive efforts by NIOSH program staff and the National Academies review committees.

Value Driven

NIOSH asked for these reviews as a way to live up to five of its stated values:

Relevance
Our programs are responsive to the occupational safety and health problems found in today's workplaces and the workplaces of tomorrow.

Quality
We use only the best science, the highest level of data quality, and the most transparent and independent peer review.

Partnership
We accomplish our mission in partnership with industry, workers, governments and scientific and professional communities, both nationally and internationally.

Performance
Our programs are results-oriented.

Accountability
Our programs are evaluated by how well they solve the occupational safety and health problems found in today's workplaces and the workplaces of tomorrow.

Evaluators/Framework

The Evaluators

NIOSH asked the National Academies to do the reviews because, as "science advisors to the Nation," their reviews are recognized for their independence and rigor. The program reviews were managed within the National Academies by the Institute of Medicine and the Division of Earth and Life Sciences. The National Academies recruited the top experts available for each review. Almost two hundred scientists participated in the reviews. All of them served without compensation and cleared a conflict of interest review.

The *Framework* for Reviews

Before the reviews started in 2005, the National Academies convened a committee of experts to write a framework of criteria for all program reviews. That framework advised the evaluation committees to examine program inputs, activities, outputs, and outcomes in order to assess the program's relevance to important safety and health needs in the workplace and its impact in improving safety and health. Evaluation committees were directed to assess emerging issues for the program, to make recommendations to the program and to score the program on its relevance and impact (two scores, each scaled one to five).

Review Process

The Review Process

Between 2005 and 2008, the National Academies recruited eight separate evaluation committees to review these programs:

Hearing Loss Research
Mining Research
Respiratory Disease Research
Agriculture, Forestry, and Fishing
Construction Research
Personal Protective Technology
Traumatic Injury Research
Health Hazard Evaluations

Staff of each program worked for approximately nine months prior to the formal start of its review to assemble evidence packages for the evaluation committee. The packages contained detailed information about program inputs, activities, outputs and outcomes. The data were organized by the goals of the program's strategic plans. Each evaluation committee met at least three times, and portions of at least two of those meetings were open to the public.

At the first meetings, NIOSH staff talked to the committees about the program's activities and accomplishments. At the second meetings, the evaluation committees heard testimony from program stakeholders. The final committee meetings were closed as the committees deliberated about their findings.

Once the evaluation committee had finished its report, it was reviewed by a second, independent group of experts. There was a separate report review committee for each review. The original evaluation committees had to respond to comments from the report review committee before the report was released.

Most reviews took a year or more between the first meeting of the committee and the release of the final report.

Program Outcomes

Mining

Mining program-developed software (called the Crewstation Analysis Program) is routinely used by MSHA's Approval and Certification Center in the approval process for mine lighting systems.

Mining program research on flammability of noise control materials in operator cabs led to MSHA's acceptance of the American Society for Testing and Materials (ASTM) E-162 Radiant Panel Test as a major criterion in the selection and use of these materials.

Agriculture, Fishing and Forestry

For more than 12 years, insurance companies' risk managers have used the NURSE Reports developed by an AFF program project to train farm workers, crew leaders, and managers in Department of Labor-mandated training. These reports are also used by university professors of agricultural education in their classrooms.

A Cornell University project, New York Agricultural Hazard Assessment Tool, demonstrated that farmers will voluntarily correct workplace hazards if it reduces workers' compensation costs. This program has been adopted by the State workers' compensation board.

Hearing Loss Prevention

EarTalk, a patented technology developed and patented by Hearing Loss researchers allows the user to talk and listen through microphones and receivers positioned under the hearing protection device, has been licensed to Cavcom Inc. for incorporation into a system that works with Motorola radios commonly used by police and firefighters.

According to a 2005 report by the Institute of Medicine on hearing loss and tinnitus in the military, recommendations from the 1998 NIOSH guidelines were used as the basis for the current DOD requirements for military hearing loss prevention programs.

Respiratory Diseases

As a result of the Respiratory Diseases Research Program initiated joint campaign on silicosis prevention, OSHA went on to develop a Special Emphasis Program to reduce occupational exposures to silica and eliminate the incidence of silicosis.

All U.S. manufacturers of TDI have committed to implement a protocol for worker health and environmental monitoring using the methods developed in collaboration with Respiratory Diseases Research Program scientists.

Personal Protective Technology

Program chemical, biological, radiological and nuclear (CBRN) respirator standards were among the first adopted by the Department of Homeland Security (DHS), which now uses these standards to award grants for the purchase of personal protective equipment. NIOSH CBRN respirators are used by the nation's first responders and first receivers.

In December 2008, the Permeation Calculator, which predicts the use time for chemical protective clothing, received a CDC Director's Innovation Award in the category of Research/Technology. This product is being incorporated in at least three ASTM standards.

The new ASTM F2668, *Standard Practice for Determining the Physiological Responses of the Wearer to Protective Clothing Ensembles* is based on PPT Program research and test methods. This is the first standard for physiological testing, and will enable uniform assessments to evaluate the physiological impact of PPE on workers.

Results

Evaluation Results

Program	Program Relevance	Program Impact
Hearing Loss Research	3	4
Mining Research	4	4
Agriculture, Forestry, and Fishing Research	4	3
Respiratory Disease Research	5	4
Personal Protective Technology	4	4
Traumatic Injury Research	4	4
Construction Research	5	4
Health Hazard Evaluations	4	4

Relevance score key:
3 = Research focuses on lesser priorities and is loosely connected to workplace protection.
4 = Research is in high-priority subject area and adequately connected to workplace protection.
5 = Research is in highest-priority subject areas and highly relevant to improvements in workplace protection.

Impact score key:
3 = Research program activities or outputs are going on and are likely to improve worker health and safety.
4 = Research program has made moderate contribution on the basis of end outcomes or well-accepted intermediate outcomes; research program generated important new knowledge and is engaged in transfer activities.

Types of Recommendations

	Agriculture Fishing & Forestry	Hearing Loss	Mining	Personal Protective Technology	Respiratory Diseases	Traumatic Injury Research	Construction	HHE
Administrative								
Leadership		X					X	
Provide/seek more resources							X	
Staff recruiting/develop OSH professionals		X	X					X
Partnerships and collaborations	X	X	X			X	X	X
Sustain Strategic Planning	X	X	X		X	X		X
Enhance Surveillance Activities	X	X	X		X	X		
Enhance Dissemination/Transfer/Diffusion Activities	X		X			X	X	
Enhance/Sustain Extramural Activities		X	X	X		X	X	
Program-specific								
Increase collaboration in specific research areas		X	X	X	X	X		
Improve service function				X				X
Expand scope of program				X		X		X
Continue service in public emergencies								X

Follow-up/Future Activities

Follow-up

Each evaluated program has written (or will write) a response to the National Academies review, stating which recommendations it intends to follow, and how it will do so. These implementation plans have been (will be) delivered to the NIOSH Board of Scientific Counselors (or the Mine Safety and Health Research Advisory Committee) for review and comment. Written response is an important part of making sure program evaluation efforts are carefully considered.

Future Activities

Reports from all eight programs will be available by this fall. NIOSH has already begun an analysis of the costs and benefits of conducting program evaluations using the National Academies. The National Academies is engaged in a similar exercise. This fall, the Framework Committee will reconvene to review the completed evaluations and to make recommendations for future reviews. NIOSH will decide on a path forward that will best fulfill its values and will best reinforce a culture of program evaluation within the Institute.

For More Information

http://www.cdc.gov/niosh/nas/
http://www.nas.edu/

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Personal Protective Equipment Use Data from the California Occupational Pesticide Illness Prevention Program

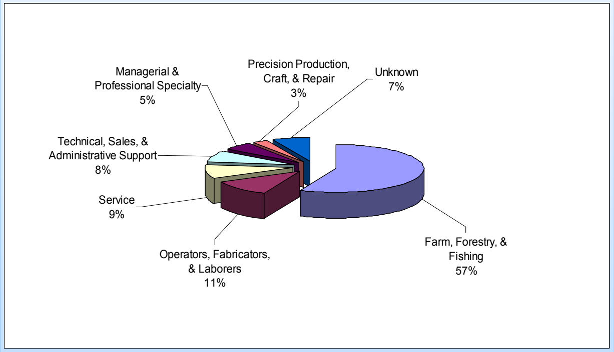
Lori Copan MPH, Rupali Das MD, MPH, John Beckman, Justine Weinberg MSEHS, CIH

CA Occupational Pesticide Illness

The Occupational Pesticide Illness Prevention Program (OPIPP) has worked to reduce work-related pesticide illness since 1998. OPIPP tracks information about acute **occupational pesticide illnesses (OPI)** statewide, investigates select incidents, and develops recommendations to prevent such illnesses from occurring again. OPIPP learns about pesticide illness cases from a variety of sources, most commonly from physicians, who are required to report any illnesses that they suspect may be related to work or to pesticides.

OPI was reported most commonly in agriculture: over half the cases were in this industrial sector. In addition, workers in many other industries also had OPI as shown in Figure 1,

Figure 1. Occupation of 1474 Workers with Acute Pesticide illness



Workers were engaged in a variety of activities on the job at the time they were exposed to pesticides (Table 1). Nearly two out of three workers were performing their "routine work" activities **that did not involve handling pesticides** at the time they became ill. Most workers who became ill while performing routine work (51%) were farm workers who were involved in such activities as weeding and handling crops. Almost one out of four workers became ill while applying pesticides.

Table 1. Activity at Time of Pesticide Exposure for 1474 Workers with OPI

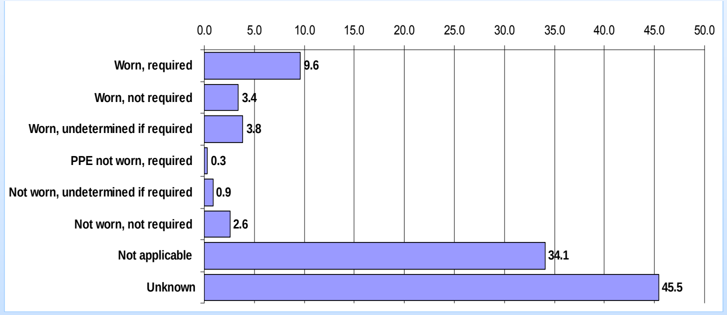
Activity at time of Exposure	Number of Workers (%)
Routine work (not application)*	900 (61.1%)
Applying pesticides	325 (22.1%)
Mixing/loading	71 (4.8%)
Transporting or disposing of pesticides	45 (3.1%)
Repairing or maintaining application equipment	17 (1.2%)
Any combination of above	20 (1.4%)
Emergency response	39 (2.7%)
Manufacturing or formulating pesticides	4 (0.3%)
Unknown	53 (3.6%)

Overall PPE Use in 1474 OPI Cases

Data on PPE use is not routinely collected through standardized instruments used by physicians to report occupational pesticide illness. As a result, we have PPE data on approximately 20% of cases.

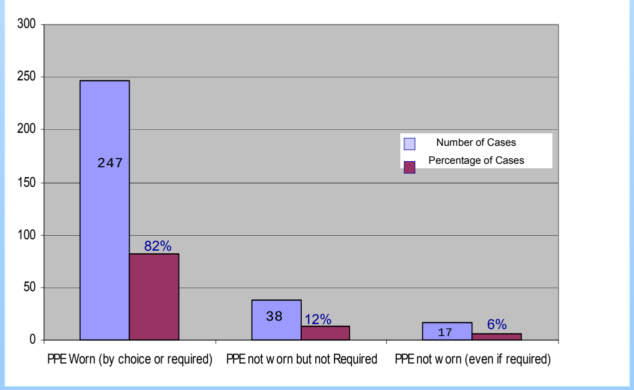
As shown in Figure 2, we lack information on almost half (45%) of the cases, while another 34% OPI cases occurred while conducting activities for which PPE is not expected to be worn (not applicable). Not applicable activities include incidents of workers becoming sick following pesticide treatment of their offices, and incidents where pesticides drift to an area where farmworkers are performing activities not requiring PPE.

Figure 2. Overall PPE Use by Percentage of 1474 OPI Cases



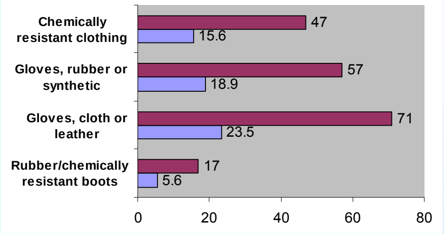
Among workers who wore PPE, either by choice or required, most of them (82%) became sick despite it's use. Only a small percentage (6%) did not wear PPE even if required, among that group PPE was required in only four cases. We do not have denominator data to assess the prevalence or incidence of illness among those who use PPE (properly or not).

Figure 3. Number and Percentage of PPE Use jn 302 cases

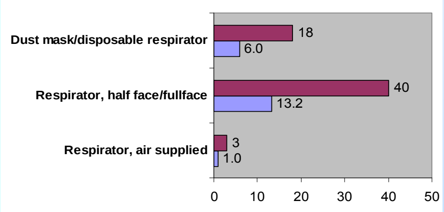


Specific PPE Use in 302 Cases

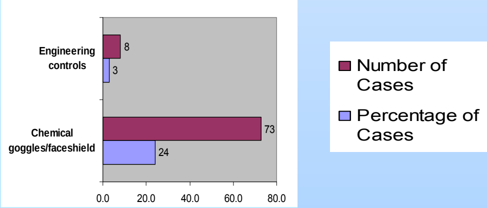
Type of Dermal PPE Used by Those Using PPE - Number and Percentage (N=302)



Type of Respiratory PPE Used by those Using PPE - Number and Percentage (N=302)



Goggles and Engineering Controls for those Using PPE - Number and Percentage (N=302)



Conclusions

Data on PPE use is not readily available through passive surveillance methods and obtaining such data is labor intensive. From the data we've been able to obtain, occupational pesticide illness is most common among workers where PPE use was not required or expected. Among cases where PPE use is documented, workers became ill despite its use, raising concern as to the adequacy of training, or if training is a factor that contributes to illness. The adequacy of PPE requirements as stated on the label and the additional controls, such as engineering controls is also unknown. Surveillance systems should be utilized to obtain PPE information – if such data were available we could assess the adequacy of control methods for workers potentially exposed to pesticides.

OPIPP participates in the national Sentinel Event Notification System for Occupational Risk (SENSOR), and is supported in part by the National Institute for Occupational Safety and Health (NIOSH) and the US Environmental Protection Agency (US EPA).

OHB Occupational Health Branch

Decontamination Strategies and Reusability of Chemical Protective Clothing

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Project Goals

- Develop suitable methods for chemical protective clothing (CPC) decontamination
- Develop evaluation methods for decontamination efficacy
- Develop guidelines for reusability of CPC
  - Decontamination, retirement, or disposal

Stakeholders

- CPC Users & Manufacturers
- AIHA
- ISEA
- OSHA
- Emergency responders
- ASTM

Partnerships

- ICS® Inc. Laboratories, Brunswick, OH
- University of California, Davis, CA

Background:

- Nondisposable CPC is too expensive to discard, e.g., Level A Hazmat Suit > $4,500; Viton Gloves > $100
- Repeated use of CPC without effective decontamination may result in secondary exposure and injury
- Cost of illness due to skin exposure was estimated to be $1 billion per year; more than $800 million of protective gloves sold in the US annually
- OSHA requires decontamination of CPC under two regulations, i.e., 29 CFR 1910.120 and 29 CFR 1910.132

Methods

- Tests: ASTM F 739-99a and ASTM D 412-98a
- CPC Materials: include 7 most commonly used materials for suit and glove: natural rubber, nitrile, PVC, neoprene, Tychem, butyl, and Viton
- Chemicals: include 12 chemicals listed in ASTM F 1001
- Decontamination Methods for Comparison:

  Heat Extraction: 100 ºC for 16 hours

  Water/detergent: Alcojet & an automatic dishwasher
- Self-decontamination: incorporate halamine functional groups in clothing material

Typical Results using Heat Extraction

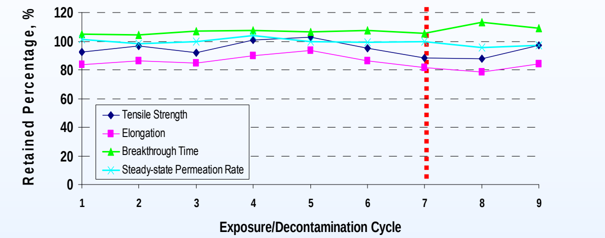

Fig 1. Reusability of nitrile gloves against acetone. After 7 exposure/heat extraction cycles, both chemical and physical properties retained ≥ 80% in order to maintain the highest performance level (i.e., Level 4) based on ANSI/ISEA 105 standard.

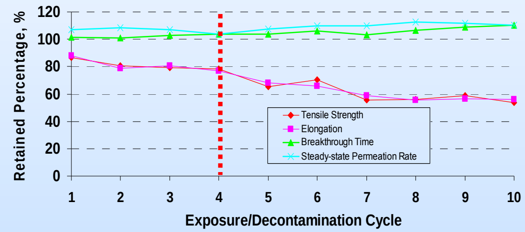

Fig 2. Reusability of neoprene gloves against acetone. Both chemical and physical properties retained ≥ 80% after 4 exposure/heat extraction cycles.

Conclusions

- Some CPC materials can be re-used multiple times after decontamination with a minimal loss of protective properties.
- Thermal decontamination removed residual chemicals more effectively than water/detergent decontamination for most of the selected material-chemical combinations. However, less material degradation was observed for the decontamination using water/detergent.
- Halamine structures can detoxify some carbamates and toxic chemicals, and halamine grafted fabrics can be employed as self-decontaminating materials.
- In evaluating decontamination and CPC reusability, both chemical resistance and material degradation should be carefully investigated.

Outputs

- Software
  - Developed “Permeation Calculator” computer program for automated and standardized analysis of chemical protective clothing permeation data. The computer program received the Bullard-Sherwood Research-to-Practice (r2p) Technology Award conferred by NIOSH in May 2008 and won the 2008 CDC Director's Innovation Award.
- Journal Publications

  - Gao, P, El-Ayouby N, and Wassell JT[2005]. Change in permeation parameters and the decontamination efficacy of three chemical protective gloves after repeated exposures to solvents and thermal decontaminations. *American Journal of Industrial Medicine*, 47(2):131-143.
  - Gao, P and Tomasovic B [2005]. Degradation of neoprene and nitrile chemical protective gloves after repeated acetone exposures and thermal decontaminations. *Journal of Occupational & Environmental Hygiene*, 2(11): 543-552.
  - Xin F, Gao P, Shibamoto T, Sun G [2006]. Pesticide detoxifying functions of N-halamine fabrics. *Archives of Environmental Contamination and Toxicology*, 51: 509-514.
  - Gao, P, Weise T, and Tomasovic B [2009]. Development of a computer program for permeation testing data analysis. *Journal of Occupational & Environmental Hygiene* (in press).

Outcomes

- Research findings incorporated into a guideline written by the AIHA Protective Clothing & Equipment Committee for decontamination of CPC and equipment.
- Research findings resulted in a new ASTM work item titled “Standard practice for permeation testing data analysis by use of a computer program”, which is being developed by the ASTM F23 committee.

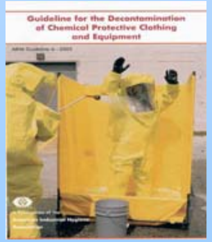

Fig 3. AIHA guideline for CPC and equipment decontamination

Fig 4. Permeation Calculator v2.4.1

http://www.cdc.gov/niosh/npptl/PermeationCalculator/permeationcalc.html

A Multi Domain Magnetic Passive Aerosol Sampler for Measuring Aerosol Particle Penetration Through Personal Protective Ensembles

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[1]NIOSH/NPPTL, Pittsburgh, PA, [2]EG&G Technical Services, Pittsburgh, PA

Background

- Current testing for particle penetration through protective ensembles is mainly based on active filtration principles, which may overestimate the particle penetration due to additional driving forces.
- New performance specifications for commercial protective ensembles require Man-In-Simulant Testing (MIST) to measure leakage at up to 40 body locations. Therefore, samplers should be small, thin, and light.

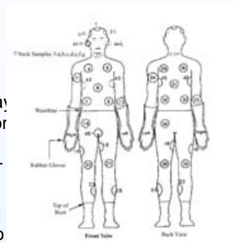


Fig 1. Sampler Locations During a MIST

- Conventional passive devices are not suitable for this application because of low collection efficiency resulting in an unacceptably long testing time.
- A magnetic passive aerosol sampler (MPAS) is expected to have a much higher collection efficiency than a conventional passive sampler to collect iron (II, III) oxide aerosol particles.

Goals of This Study

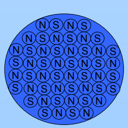
- Develop magnetic passive sampler prototypes that can be used for measuring particle penetration through protective clothing.
- Develop appropriate data processing procedures for evaluating magnetic passive samplers.
- Develop appropriate analytical methods for measuring the collection efficiency of magnetic passive samplers.

Methods and Materials

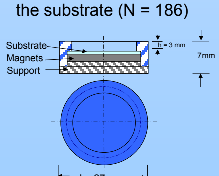
1). Development of a Multi Domain Magnetic Passive Aerosol Sampler (MPAS)

a. with a sampling substrate

b. 1 mm x 1 mm magnets under the substrate (N = 186)



c. magnets arranged with an alternative N & S pole pattern



d. dimension of the MPAS (drawing not to scale)

Fig 2. Prototype of the Multi Domain MPAS

2). Using Iron (II,III) Oxide as Challenge Aerosol Particles (80 nm – 5 µm)

- High magnetic susceptibility
- Low toxicity (OSHA PEL: 10 mg/m³)
- Spherical particles allowing accurate conversion from mass collected to particle number concentration

3). Generation of Iron (II, III) Oxide Aerosols

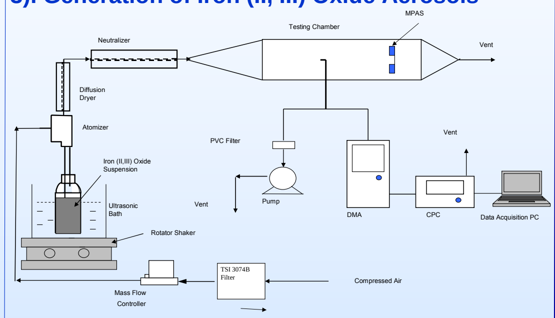


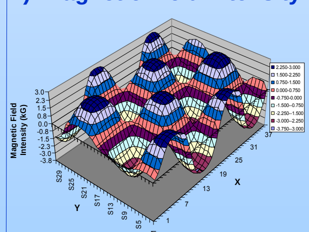
Fig 3. Particle Sampling Schematic

4). Quantitative Analyses of Iron (II,III) Oxide Particles Collected by the MPAS

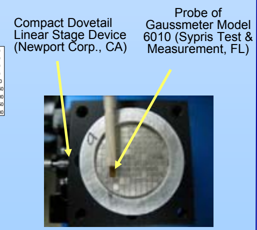
- Gravimetric Analysis using a microbalance
- Ferrozine (Fz) Colorimetric Method using a spectrophotometer
- Atomic Force Microscope (AFM) for low penetration

Results

1). Magnetic Field Intensity Measurement



a. Magnetic field intensity. Positive and negative values represent measurements from different poles.



b. Measurement setup

Fig 4. Magnetic Field Intensity Measured from a Representative Area Containing a Dozen Magnets by Using a Gaussmeter and a Compact Dovetail Linear Stage to Accurately Locate the Gaussmeter Probe.

2). Magnetic Field Intensity as a Function of Distance

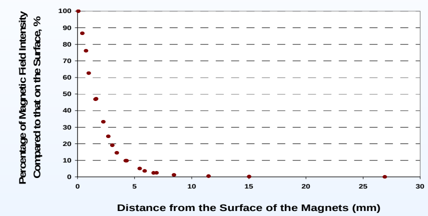


Fig. 5. Magnetic Field Intensity vs. the Distance from the Surface of the Multi Domain MPAS

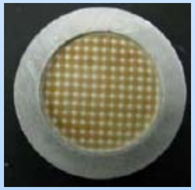
3). Comparison of Sampling Efficiencies

(a)Without magnet, half hour, 500X

(b) With magnet, half hour, 500X

Fig 6. Collection Efficiencies of Passive Aerosol Samplers With and Without Magnetic Force

4). Particle Deposition Pattern on the Sampler



a. Multi domain MPAS

b. Single domain MPAS

Fig 7. Comparison of Particle Deposition Patterns of Multi Domain with Single Domain MPAS

5). Iron (II, III) Oxide Particles Analyzed by Atomic Force Microscope

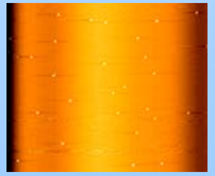


Fig 8. AFM Image of Iron (II, III) Oxide Particles Collected by the MPAS for Quantitative Analysis at Low Penetration

6). Effect of Exposure Time

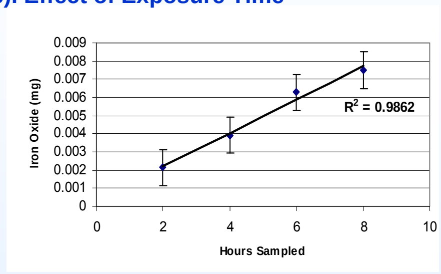


Fig 9. Particle Loading vs. Sampling Time

7). Comparison of Iron Oxide Measurements

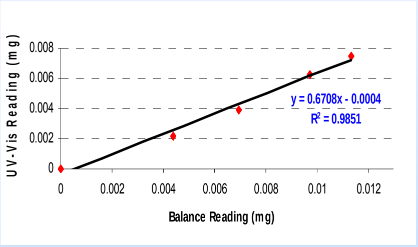


Fig 10. Colorimetric Method vs. Gravimetric Analysis (with a LOD of 1 µg)

Conclusions

- The MPAS prototypes are potentially suitable for MIST because they are small, thin, light, and the sampling efficiency is much higher than conventional passive samplers.
- Multi domain magnets are superior to the single domain magnet for fabricating passive aerosol samplers because the particle deposition pattern is more uniform than the single domain, and it allows magnetic force to disappear at the sampler opening thus avoiding any negative effects caused by possibly pulling particles from outside of the ensemble.
- While the microbalance or colorimetric method has a relatively low sensitivity for quantitative analysis, the use of AFM can determine particle penetration at very low values.
- The reusability of the MPAS, the high magnetic susceptibility and low toxicity of the simulant, and the sensitive and cheap colorimetric method would provide testing organizations and clothing ensemble manufacturers with an alternative method for MIST.

CDC Workplace Safety and Health
NIOSH
NPPTL Research to Practice through Partnerships

Nanoparticle Penetration Through Protective Clothing

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[1]NIOSH/NPPTL, Pittsburgh, PA, [2]EG&G Technical Services, Pittsburgh, PA

Project Goals

- The goals of this project are to
  - Develop a predictive model based on a wind-driven concept (Figure 1) coupled with single fiber theory to predict nanoparticle (<100 nm in size) penetration through clothing materials.
  - Investigate wind-driven nanoparticle penetration through protective clothing materials.

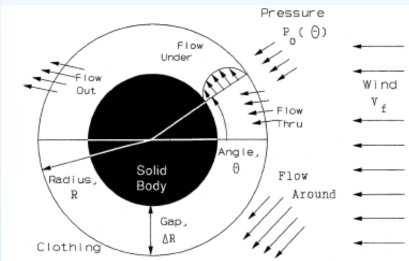


Figure 1. The cylindrical geometry adopted from Fedele [1992]

Stakeholders/Partnerships

- NIOSH Nanotechnology Research Center (NTRC)
- ASTM
- AIHA
- Protective clothing wearers
- Protective clothing manufacturers

Background

- Dermal exposure to nanoparticles is a growing concern for workers that handle these types of materials. Some studies suggest that nanoparticles could enter the body through the skin during occupational exposure.
- Current ensemble penetration testing is mainly based on a filtration approach using a pump to pull aerosols through clothing materials, which may overestimate particle penetration.
- Although particle penetration through respirator filter media has been successfully modeled using single fiber theory for decades, a comparable model for clothing materials does not exist.
- This is a one-year project funded by NIOSH NTRC.

Preliminary Models

For nanoparticles, diffusion dominates particle collection. Two preliminary models for nanoparticles have been developed. Model 1 includes diffusion and Model 2 includes diffusion plus enhanced collection due to the diffusion-interception interactions.

Model 1:

$$\ln P = \frac{4A\alpha t D^{B}}{\pi d_f^{(1+B)}\left(0.5\rho V_f^{2}\Gamma \frac{\cos\theta}{1+\beta^{2}}\right)^{B}}$$

Model 2:

$$E_{\Sigma} = Pe^{-B}\left[A + 1.24\left(\frac{r^{2/3}}{K_u^{1/2}}\right)\cdot\left(\frac{0.5\rho\Gamma d_f V_f^{2}\cos\theta}{D(1+\beta)}\right)^{-C}\right]$$

Relationship between E_{Σ} and lnP is shown below:

$$E_{\Sigma} = -\frac{\pi d_f}{4\alpha t}\ln P$$

where

P = particle penetration,
α = solidity of fabric,
d_f = fiber diameter,
ρ = density of air,
θ = wind direction,
K_u = Kuwabara hydrodynamic factor
Γ = air permeability of fabric
r = ratio of particle diameter to fiber diameter
A & B = constant, to be determined by empirical data

E_{Σ} = single fiber efficiency
t = thickness of the fabric
D = particle diffusion parameter
V_f = wind velocity
P_e = Peclet number

$\beta = \left(\frac{12\mu\Gamma R^{2}}{\Delta R^{3}}\right)^{0.5}$, where μ is the dynamic viscosity of air, and R is the radius of the cylinder in Figure 1.

Experimental Approaches

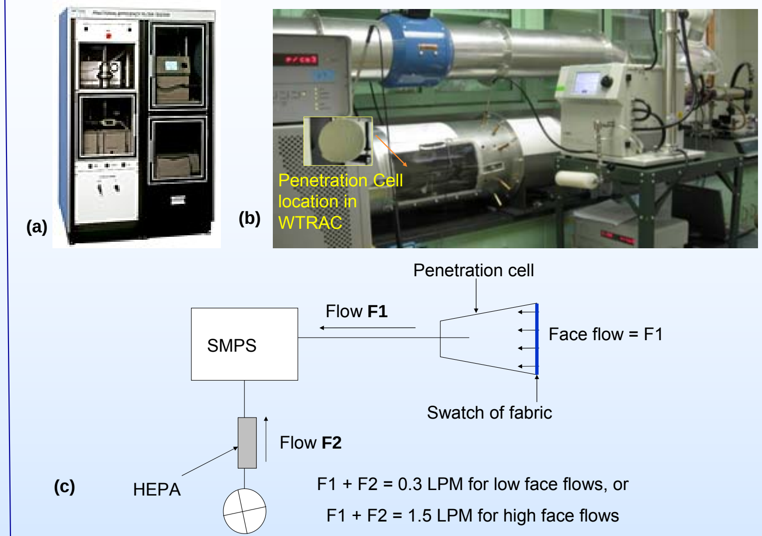


Figure 2. Experimental setup: (a) Approach 1 using a TSI Model 3160 automated tester; (b) Approach 2 using a 15-foot WTRAC that creates wind up to 8 miles/hr and (c) a particle penetration cell in the WTRAC. For Approach 2, paired scanning mobility particle sizers (SMPS) are used to measure particle concentrations inside and outside of the penetration cell. To eliminate any filtration effect, the flow rate of the SMPS that measures particle concentration inside the cell is adjusted to equal the effective wind-driven flow (F1).

Program Timelines in FY 2009

- **Q1:** Model development and improvement; select clothing materials; measure physical properties of the materials
- **Q2:** Conduct laboratory experiments; collect data
- **Q3:** Analyze data; refine and compare models
- **Q4:** Prepare manuscripts/presentations; translate research into practice

Expected Outputs

Manuscripts submitted to peer-reviewed journals describing:

- Particle penetration levels through various fabrics used in protective clothing ensembles
- Validation of a model based upon single fiber theory to predict nanoparticle penetration
- A bench-scale particular penetration test method based upon the wind-driven approach

CDC Workplace Safety and Health
NIOSH
NPPTL Research to Practice through Partnerships

FROM NANOPARTICLES TO NOVEL PROTECTIVE GARMENTS

C. Aikens; D. Karote; J. Langemeier; C. Leaym; J. Millette; S. Rajagopalan

NanoScale Corporation
1310 Research Park Drive
Manhattan, KS 66502
NanoScaleCorp.com

Our Approach

Highly reactive nanocrystalline metal oxide sorbents will be integrated with textile matrices to produce laminates that are suitable in the manufacturing of textiles for protection against toxic industrial chemicals (TICs) and chemical warfare agents (CWAs).

Specific Objectives

- Lightweight
- Air-permeable
- Comfortable
- Effective against liquids and vapors
- Engineered formulations for wide spectrum adsorption
- Destructive adsorption
- Increased and instantaneous protection
- Enable safe, effective, and comfortable operation by the wearer

Available Technology

- Air- permeable materials
- Semi-permeable materials
- Impermeable materials
- Selectively permeable materials

Key Features of Available Air-permeable Materials

- Permeable to air, liquids, vapors and aerosols
- Consist of woven shell fabric
- A layer of activated carbon impregnated foam or carbon loaded non-woven felt
- Liner fabric

Limitations of Carbons

- Partial protection by physical entrapment of toxins
- Preferential adsorption of water
- Increased temperature results in off-gassing of adsorbed toxins
- No effect on acid or alkaline gases

CARBON

Uniqueness of NanoActive® Materials

Extraordinary Chemical Reactivity

- High porosity
- Small crystallite sizes
- Large surface area
- Unique morphologies

Proven Safe by Independent Testing

- Pulmonary
- Ocular
- Oral
- Skin sensitization and irritation

NANO MATERIAL

Phase 1 Accomplishments

- Screened NanoActive materials and a carbon control for their reactivity against HCN, NH_3, Cl_2, $COCl_2$, and $(CH_3)_2SO_4$
- Materials based on Al, Ti, Zn, Mg, and Cu displayed varying affinity and adsorption for the hazardous chemicals
- Screened a variety of textile samples and impregnation procedures
- Two textile swatches were down-selected based on ASTM F739 permeation test outcome

Textile Swatch Containing NanoActive Aluminum Oxide Plus

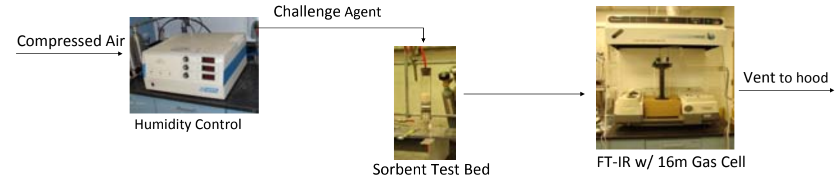
Specific Improvements Needed

- Eliminate shedding of the encapsulated sorbent
- Minimize variances in breakthrough time and permeated amount between swatches

Phase II Key Objectives

- Engineer formulations of nano materials to offer protection against a wider range of TICs and CWAs
- Produce granulated nano materials of increased hardness
- Obtain evidence for destructive adsorption
- Produce humidity resistant nano materials

Breakthrough Test Apparatus



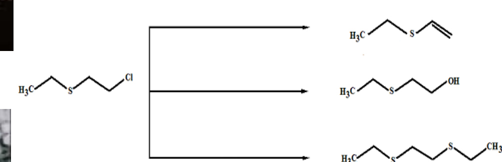
Results from 1st Round of Testing

Samples	Metal Oxide-1	Metal Oxide-2	Metal Oxide-3	Ball Pan Hardness (%)	*Average Breakthrough Time (minutes)*		
					NH_3	HCN	2-CEES
1	50	0	50	42	5.5	17	21
2	50	50	0	45	6.9	20	32
3	0	50	50	35	7.3	71	29
4	100	0	0	6.0	5.5	1.0	12
5	0	100	0	13	7.3	52	41
6	0	0	100	7.6	3.0	>180	3.0
7	33.3	33.3	33.3	44	6.5	49	28
8	16.7	16.7	66.7	47	5.5	54	19
9	16.7	66.7	16.7	19	7.3	25	24
10	66.7	16.7	16.7	47	5.0	12	23

Results from 2nd Round of Testing

Samples	Metal Oxide-3	Metal Oxide-4	*Average Breakthrough Time (minutes)*		
			NH_3	HCN	2-CEES
11	0	100	43	6.5	61
12	33	67	34	22	36
13	50	50	27	30	38
14	33	67	21	45	34

Likely Pathways for Destructive Adsorption



Post Analysis of 2-CEES Tested Formulations

Samples	Average Breakthrough Time (Minutes)	2-CEES	EVS	HEES	BEE
12	36	Present	Present	Present	Present
13	38				
14	34				

Permeation Tests Results

Sample	2-CEES Permeated, %		DMMP Permeated, %[a]	
	Dry	Humidified	Dry	Humidified
Control-no sorbent	12		5.3	
Unmodified sorbent	1.5	2.4	0.3	1.4
Modified B2	9.1	0.8	0.7	4.8
Modified B3	3.3	1.7	0.1	3.2
Modified B5	6.3	2.1	0.3	0.7

a – Additional peaks were observed.

Permeation Test Vessel

This work was supported by NIOSH Phase II SBIR Grant No. 2R44OH007963-02A2
SUB CONTRACTOR: Gentex Corporation, Carbondale, PA

Comparison of Physiological Measurements on Subjects Wearing Firefighter Ensembles: Standard Monitoring Equipment vs. a Wearable Plethysmographic Sensor Vest

Aitor Coca[1], Raymond J. Roberge[1], W. Jon Williams[1] , Douglas P. Landsittel[1], Jeffrey B. Powell[2], and Andrew Palmiero[2]
[1] NIOSH/NPPTL, Pittsburgh, PA, [2] EG&G Technical Services, Pittsburgh, PA

Introduction

• Firefighters experience tremendous physical stresses in the course of their firefighting duties, both metabolically and environmentally. The ability to monitor physiologic variables in real-time in these individuals can offer valuable information that could be used to address these stressors.

• New devices with wearable sensors are being developed that allow for real-time monitoring of several physiological variables. These devices use new technologies such as plethysmographic sensors incorporated into a vest as well as other sensors (i.e., skin temperature, ECG).

• Comparison of simultaneously-obtained physiological data from a wearable plethysmographic sensor vest and standard laboratory physiological monitoring equipment, on subjects wearing firefighting ensembles, could serve to verify the presumed accuracy of wearable plethysmographic sensor vests for possible application in future field tests of firefighter protective equipment.

• It was hypothesized that the data obtained from a wearable plethysmographic sensor vest would not be significantly different from the data obtained from the standard physiological monitoring equipment.

Methods

Figure 1. Subject during a GXT session using the Vmax 29 system and the LifeShirt

• Ten healthy subjects (eight men, two women), ranging in age from 21 – 39 years and having experience in the use of standard firefighter gear, participated in the study.

• All were nonsmokers and not taking medications. After providing informed consent, all subjects performed a maximal graded exercise test (GXT) wearing running clothes to obtain their VO_2max (Figure 1). On a separate day, subjects exercised for 20 min on a treadmill at 50% VO_2max, while wearing standard firefighter ensembles (Figure 2).

• For the purpose of this study, we decided to use a commercially available wearable plethysmograpic sensor vest known as the LifeShirt® (VivoMetrics, Ventura, CA) (Figure 3).

• Heart rate (HR), tidal volume (V_T), respiratory rate (RR), minute ventilation (V_E), skin temperature (Tsk), and oxygen saturation (SaO_2) were recorded concurrently by the LifeShirt, and standard laboratory physiological monitoring equipment (Vmax 29 system) for comparison. Data were averaged and stored every minute generating 20 data points for each subject.

• To evaluate the correlation and magnitude of differences between systems (i.e., Vmax 29 system, LifeShirt), we calculated bootstrap estimates, and corresponding 95% confidence intervals (CI) for the correlations and paired differences (Table 1).

• For this approach, a single time point was randomly selected from each subject (retaining both the Vmax 29 and LifeShirt measurements at that time point) and then used to calculate the correlation and paired differences (based one observation from each subject). This process is then repeatedly performed a total of 500 times, thus generating 500 correlations and paired differences

• This bootstrap approach was used in favor of a random effects repeated measures model for its ease of interpretation and lack of underlying assumptions about normality and specific within-subject correlation structures.

Figure 2. Subject during a comparison session, wearing standard firefighter ensemble over LifeShirt

Figure 3. LifeShirt system set up on a subject.

Results

• All subjects successfully completed the 20-minute duration of the comparison study.

• Significant correlations were observed for all the measurements by the two systems: HR (r=0.99), V_T (r=0.60), RR (r=0.98), V_E (r=0.88), Tsk (r=0.98), and SaO_2 (r=0.79).

• Figure 4 represents an individual example of the V_T measurements across the session. In this particular subject, differences between the two systems averaged 0.17 L (10.4% of V_T measured) and had a correlation (r=0.97). Figure 5 represents mean (SD) values across the session for V_T (n=10). Paired measurements showed very small differences on average, with a mean paired difference of only -0.03 L (or 1.92%).

• Figures 6 and 7 show the mean (SD) values across the session for RR and V_E , respectively. V_E demonstrated a significant correlation between systems (r=0.88); however, the paired differences was significantly different from zero, with a mean of -5.52 L/min (10.3% of V_E measured).

TABLE 1. Bootstrap estimates of the correlation and paired differences between the LifeShirt and standard laboratory monitoring equipment

	Correlations		Paired differences	
Physiological parameters	Mean (SD)	95% CI	Mean (SD)	95% CI
Heart Rate (beats/min)	0.99 (0.01)	[0.96, >0.99]	0.33 (0.93)	[-1.45, 1.67]
Tidal Volume (L)	0.60 (0.12)	[0.36, 0.78]	-0.03 (0.03)	[-0.09, 0.02]
Respiration Rate (breaths/min)	0.98 (0.02)	[0.93, 0.99]	-0.15 (0.38)	[-0.80, 0.46]
Minute Ventilation (L/min)	0.88 (0.03)	[0.82, 0.94]	-5.52 (0.92)	[-7.00, -4.08]
Skin Temperature (℃)	0.98 (0.03)	[0.93, 0.99]	0.03 (0.09)	[-0.11, 0.18]
Oxygen Saturation (%)	0.79 (0.11)	[0.58, 0.93]	0.81 (0.19)	[0.49, 1.13]

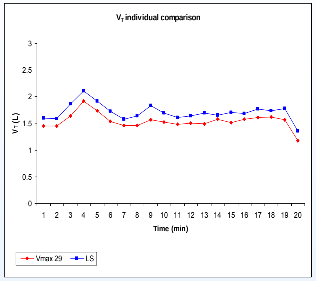


Figure 4. Individual subject dynamic of V_T as measured by both systems, LifeShirt (LS) and standard laboratory monitoring equipment (Vmax 29), during the 20 min comparison session.

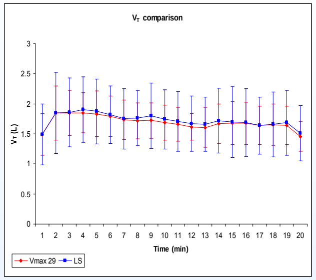


Figure 5. V_T mean (SD) for LifeShirt (LS) and standard laboratory monitoring equipment (Vmax 29) during the 20 min comparison session (n=10).

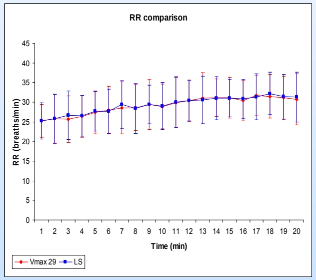


Figure 6. RR mean (SD) for LifeShirt (LS) and standard laboratory monitoring equipment (Vmax 29) during the 20 min comparison session (n=10).

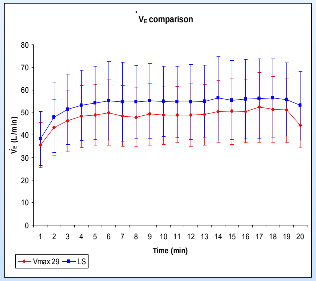


Figure 7. V_E mean (SD) for LifeShirt (LS) and standard laboratory monitoring equipment (Vmax 29) during the 20 min comparison session (n=10).

Conclusions

• Data from the wearable sensor vest is comparable to data captured from standard laboratory physiological monitoring equipment on subjects wearing standard firefighter ensembles while exercising at a moderate work rate.

• This study demonstrates the accuracy of the wearable sensor technology for these physiological parameters under the study specific conditions.

• The data obtained in this study are a preliminary assessment of the sensor vest under controlled lab conditions. Nevertheless, additional experiments to obtain LifeShirt data from firefighters in actual firefighting scenarios are warranted to determine its accuracy in field settings and its applicability for actual field studies of firefighters in traditional firefighting gear.

This research was performed while one of the authors (Aitor Coca) held a National Research Council Resident Research Associateship at the National Personal Protective Technology Laboratory (NPPTL).

Evaluation of Cooling Garments wearing a Prototype Firefighter Ensemble

Aitor Coca[1], Raymond Roberge[1], Jeffrey Powell[2], Andrew Palmeiro[2], and W. Jon Williams[1]
[1]NIOSH/NPPTL, Pittsburgh, PA, [2]EG&G Technical Services, Pittsburgh, PA

Introduction

• According to the National Fire Protection Association (NFPA), there are about one million firefighters in the U.S. Overexertion and heat stress are among the most common causes of firefighter injuries and deaths.

• The thermal stress faced by a firefighter results from a myriad of causes, including the environment, work, and their protective equipment. The protective qualities of a firefighter ensemble (FE) include a significant level of thermal insulation that serves to trap endogenously-generated heat from the high output of work required while on duty. In addition to wearing restrictive clothing, the firefighter must also carry the additional weight of a self-contained breathing apparatus (SCBA), communication equipment, and personal firefighting equipment. This additional equipment weighs as much as 21-22 kg, which further increases the wearer's thermal stress.

• This effort supports enhancing safety and work performance of firefighters by evaluating different cooling processes/strategies designed to reduce thermal stress, in order to identify the optimal system in regard to efficiency, weight, flexibility of movement, and subjective comfort.

Goal

The aim of this research was to assess five cooling strategies based on exploiting the conductive/convective mechanisms of body cooling. Our hypothesis was that any cooling (garments and/or ventilation) would provide a source of heat loss to the wearer by reducing core temperature and would allow to increase total exercise time.

Methods

• Six healthy subjects participated in this investigation. All were nonsmokers and not taking medications. Screening measures included a physical examination, and a maximal graded treadmill exercise test. The study protocol was approved by the NIOSH Human Subjects Review Board, and both oral and written consent were obtained from all subjects.

• This study used a prototype firefighter ensemble (PFE) designed to improve protection against chemical and biological hazards with the following additions (Figure 1):
  • vapor penetration-resistant front zipper closure on the jacket;
  • integrated hood with face piece gasket;
  • booties incorporated into the pants; magnetic gauntlet glove/sleeve interfaces;
  • re-routing of exhaled gases through a rubber hose from the SCBA respirator to the anterior right side of the jacket to enhance chemical/biological protection (through positive pressure effects preventing inward leakage) and cooling (through enhanced convection).

Figure 1. PFE new design features: booties, gloves, integrated hood, and hose.

• Each subject performed six sessions, five cooling sessions and one control session without cooling (CS). The five cooling sessions were conducted wearing various cooling strategies, as follows:

1) a shortened whole body cooling garment (SCG) (Fig. 2a);
2) SCG plus air ventilation (AV) from the PFE hose (SCG+AV);
3) a top cooling garment (TCG) (Fig. 2b);
4) TCG plus AV (TCG+AV);
5) only AV from the PFE hose (AV).

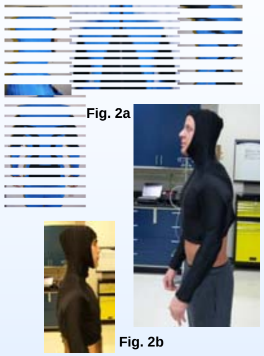


Figure 2. Cooling garments body surface covered details

• Each session consisted of 3 stages of 15 min exercise on a treadmill at 75% VO_2max with 10 min rest between stages while Tcore and heart rate (HR) were measured (Figure 3). Each session was completed in an environmental chamber operating at 35°C and 50% RH.

• Subjects were randomly assigned to sessions.

• Comparisons were made (Table 1) for the different cooling sessions and control at the end of the exercise using repeated measures analysis of variance (ANOVA) with each of the parameters (HR, Tcore, total exercise time).

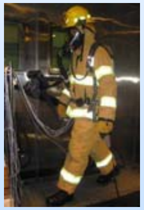


Figure 3. Subject during session

Results

• Results from this study showed that total exercise time for the CS was 13.4 and14.9 min shorter than SCG and SCG+AV ($p \leq 0.05$), respectively.

• Tcore and HR were lower for SCG and SCG+AV than for CS ($p \leq 0.05$). The other three conditions (TCG, TCG+AV, and only AV) were not significantly different from CS.

• Figure 4 shows an individual Tcore dynamic for the six sessions. It can be observed that time was longer for SCG and SCG+AV with a lower Tcore.

• Figure 5 focuses only on an individual Tcore dynamic for CS and SCG+AV. It can be observed how the cooling provided reduces Tcore during the rest time between exercise stages while Tcore continues increasing during rest for CS.

Table 1. Mean (SD) of HR, Tcore, and Total Exercise Time for the Different Sessions

Parameters (mean/SD) / Cooling used	CS	AV	TCG	TCG+AV	SCG	SCG+AV
Max. Heart Rate	180.8 (7.8)	179.2 (6.5)	179 (8.9)	178.8 (8.6)	171.7 (12.6)	172.7 (12.1)
Max. Core Temperature	38.29 (0.3)	38.07 (0.4)	38.25 (0.4)	38.17 (0.2)	38.01 (0.2)	37.95 (0.4)
Total Exercise Time	24.9 (2.8)	21.4 (2.7)	25.8 (4.3)	25.3 (3.9)	38.3 (8.3)	39.8 (4.6)

Disclaimer: The findings and conclusions in this poster have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

This research was performed while one of the authors (Aitor Coca) held a National Research Council Resident Research Associateship at the National Personal Protective Technology Laboratory (NPPTL).

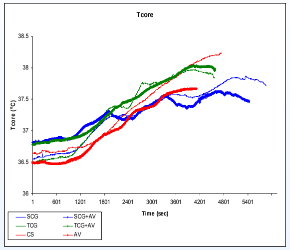


Figure 4.
Individual Tcore dynamic during the six sessions of the study.

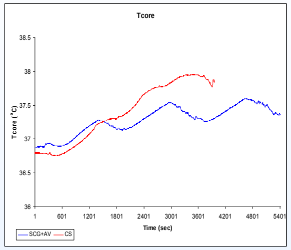


Figure 5.
Individual Tcore dynamic during CS and SCG+AV sessions.

Discussion

• To increase the protection against external chemical and biological hazards, the PFE incorporates new design features. While these features provide additional protection to the wearer, the prototype design further encapsulates the wearer such that essentially all routes of heat exchange between the body and the external environment are blocked. Use of cooling garments allows wearer to work longer and safer (lower Tcore) even in such encapsulated environment.

• Tcore indicated that the maximal internal temperature was lower ($p < 0.05$) while wearing the SCG or SCG+AV. A lower average Tcore with either the SCG or SCG+AV might reduce some of health and safety problems that firefighters encounter.

• HR also was lower during extended time for SCG and SCG+AV suggesting that the cardiovascular system was less affected by the heat and the strenuous exercise.

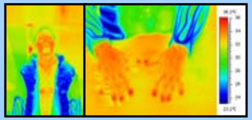
Conclusions

• The results of this research suggest that a shortened whole body cooling garment (SCG) with or without the additional ventilation system (AV) can be helpful to reduce thermal stress and the risk of heat-related injuries and it also prolongs the time that firefighters are able to exercise at a specific workload, thus increasing their work performance.

• Air ventilation (convective heat loss) through the hose seems to be a good addition to cooling garments to reduce core temperatures and decrease heat stress. However, the hose system used for convective heat loss does not show any improvement by itself and even decreases the total exercise time.

Future Work

• The use of thermal imaging could enhance this research by giving a whole body thermal topography to identify specific body areas needing improved cooling capacity.



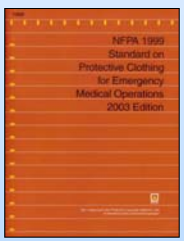
• Field studies could verify the improvement on work performance in real scenarios.

Improved Criteria for Emergency Medical Protective Clothing

Angie Shepherd, NIOSH/NPPTL, Pittsburgh, PA

Project Goals

- Establish design and performance criteria for protective clothing items including cleaning, work and examination gloves; single and multiple use garments; footwear covers; and eye/face protection that ensure an appropriate level of protection for emergency medical personnel.
- Conduct testing to support development of standards, test methods and criteria for the NFPA Technical Committee (TC) on Emergency Medical Operations Protective Clothing and Equipment for use in proposed standards including NFPA 1999, *Standard on Protective Clothing for Emergency Medical Operations.*
- Support the NFPA's development of head protection criteria, in addition to visibility and flammability requirements within NFPA 1999.



Stakeholders

- Firefighters/emergency responders
- Standards organizations (NFPA, ASTM)
- Manufacturers of materials and ensembles
- Certification organizations

Partnerships

- NFPA Technical Committee on Emergency Medical Services Protective Clothing and Equipment


Fig 1. Single Use Garment


Fig 2. Cleaning Glove


Fig 3. Eye/Face Protection Device

Background

- Footwear, footwear covers, work gloves, and cleaning gloves were added to the 2003 edition of NFPA 1999 to supplement the existing categories of examination gloves, garments, and eye/face protective devices. The 2003 edition did not include head protection requirements.
- There were no certifications of cleaning gloves or single use protective garments to the 2003 Ed. In addition, there was relatively little industry response to providing NFPA certified eye/face protection devices, work gloves, and footwear.

Example Results

Table 1. Cleaning Glove Test Data

Requirement	Criteria (2003 ed.)	Mfgr. A Nitrile 15 mil	Mfgr. B Nitrile 11 mil	Mfgr. A Neoprene 17 mil	Mfgr. B Neoprene 20 mil	Mfgr. B Nat. Rub. 20 mil
Ultimate tensile (MPa)	> 15	37	22	17	14	15
Ultimate elongation (%)	> 400	374	440	588	653	745
Puncture resistance (N)	> 20	17	32	15	13	9
Cut resistance (mm)	> 25	>50	>50	>50	>50	>50
Abrasion resistance (cycles)	>1000	>2000	>2000	>1000	>2000	>12000
Dexterity (%)	< 120%	205%	158%	210%	255%	230%
Protein level (ug/g)	< 50	NA	NA	NA	NA	FAIL

Results shaded in red indicate noncompliance with the 2003 edition criteria.
Results shaded in green indicate compliance with the 2003 edition criteria.

Table 2. Recommended Garment Criteria - NFPA 1999, 2008 Edition

Garment Item	Property	Test Methods	Multiple Use†	Single Use
Garment	Liquid integrity	ASTM F1359‡	No leakage	No leakage
Barrier layer	Biopenetration	ASTM F1671	Pass	Pass
Separable layer	Tensile strength (N)	ASTM D5034	≥ 135	≥ 50
	Burst strength (N)	ASTM D3787	≥ 222.5	≥ 66
	Puncture/tear (N)	ASTM D2582	≥ 25	Not recommended
	Tear resistance (N)	ASTM D5587* ASTM D5733**	≥ 36	≥ 17
Seams/ closures	Strength (N)	ASTM D751	≥ 135	≥ 50
Outer layer	Water absorption (%)	AATCC 42‡	≤ 30%	N/A
Composite	Total heat loss (W/m²)	ASTM F1868	≥ 450	≥ 450
Hardware	Corrosion resistance	ASTM B117	No corrosion	N/A
Labels	Durability	ASTM D4966	Remain legible	N/A

* Single use; ** Multiple use; † After 25 industrial launderings; ‡ Modified method
Criteria in red are revised or new recommendations for the 2008 Ed.

Project Conclusions

- Proposed criteria better match end user expectations and use practices, while permitting more flexibility in end user choices of appropriate PPE.
- Criteria for numerous product areas improved including: cleaning gloves, single-use and reusable garments, eye/face protection, head protection.

Project Outputs and Outcomes

- Results were incorporated into NFPA Public Comments which were used to create significant revisions to existing requirements and criteria for new PPE items for the 2008 edition of NFPA 1999 (Effective Date December 2007)
- Presentations at IAFF's 2007 Redmond Symposium, TSWG's 2007 PPE Conference, AIHce' 08
- Accepted presentation at FIERO Fire PPE Symposium, 2009

Risk Based Protective Clothing Material Permeation Criteria

Angie Shepherd[1], Heinz Ahlers[1], and Beth Tomasovic[2]

[1]NIOSH/NPPTL, Pittsburgh, PA, [2]EG&G Technical Services, Pittsburgh, PA

Objectives

- Determine permeation test end points for the evaluation of protective clothing material barrier performance against toxic industrial chemicals (TICs) resulting in new dermal exposure limits
- Develop detailed permeation procedures for new test end point criteria

Project Goals

- Evaluate potential skin permeation models
- Revise current test procedures to account for measurement of cumulative permeation
- Validate model and new permeation procedures through selected tests
- Work with ASTM to gain acceptance of new permeation test and NFPA for proposed criteria.

Stakeholders

- Firefighters / emergency responders
- Standards organizations (NFPA, ASTM)
- Ensemble manufacturers / material suppliers
- Test laboratories / certification organizations

Partnerships

Project activities are part of a multi-organizational project funded by TSWG and managed by International Personnel Protection, Inc.

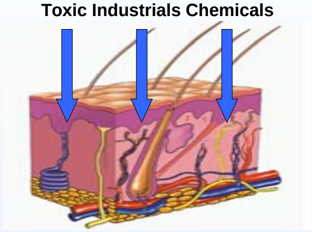


Fig 1. Skin Permeation Model

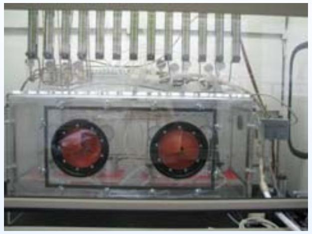


Fig 2. NIOSH Permeation Test Set-up

Background

- Current editions of several NFPA protective clothing standards contain CBRN requirements with permeation testing against both chemical warfare agents (CWAs) and toxic industrial chemicals (TICs).
- Cumulative permeation end points for CWAs are based on specific toxicity and skin effects, but TICs criteria are based on arbitrary breakthrough times that allow for relatively no permeation.

Proposed Target TICs

Acetone cyanohydrin $(CH_3)_2C(OH)CN$	Hydrazine $H_2N{=}NH_2$
Allyl alcohol $CH_2{=}CHCH_2OH$	Hydrogen fluoride HF
Cresol $CH_3(C_4H_6)OH$	Methyl isoamyl ketone $CH_3COCH_2CH_2CH(CH_3)_2$
Dichlorvos $(CH_3O)_2P(O)OCH{=}CCl_2$	Morpholine C_4H_9NO
Ethylene dibromide $C_2H_4Br_2$	Parathion $(C_2H_5O)_2P(S)OC_6H_4NO_2$
Ethyleneimine C_2H_5N	Sulfuric acid H_2SO_4

Disclaimer: The findings and conclusions in this poster have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

Significance

- The current approach does not account for specific toxicity and skin effects of TICs resulting in ensembles that may be over designed and create undue wearer stress.
- By determining toxicity-based test end points for TICs, the industry will be able to provide a wider range of NFPA certified products to the estimated 1.5 million first responders for use during CBRN incidents. The certified products may be eligible for the DHS grant program, which would further increase the availability to first responders.

Project Milestones and Timeline

Activity	Completion
Select target toxic industrial chemicals	Q1 2008
Analyze toxicity data / review models	Q2 2008
Set up new permeation test method	Q4 2008
Validate model / new permeation test	Q4 2009
Prepare report and recommendations to standards organizations	Q4 2009

Completed/Expected Project Outputs

- Presentation at AIHce '08
- Presentations at Navy-Marine PH Conference and AIHce '09 roundtable (Abstracts accepted)
- Model that predicts acceptable doses for selected TICs which could be expanded
- Final report with technical data including recommended criteria/test end points and methods for permeation testing for use by the NFPA Technical Committees and ASTM F23

Stored Thermal Energy in Fire Fighter Protective Garments

William E. Haskell and Angie M. Shepherd, NIOSH/NPPTL, Pittsburgh, PA

Project Goals

- To assist in the development of an apparatus and a procedure to measure the stored thermal energy (STE) in material composites
- To manage variability studies between test labs using the STE method and apparatus
- To provide input to the ASTM standard entitled "Standard Test Method for Measuring the Transmitted and Stored Energy of Firefighter Protective Clothing Material Systems"

Fig 1. Stored Thermal Energy Test Apparatus

Fig 2. Composite Sample with Reinforcement

Stakeholders

- Firefighters/emergency responders
- Standards organizations (SDOs)
  – NFPA, ASTM
- Manufacturers of materials and ensembles

Partnerships

Project activities are part of a multi-organizational project funded by NIOSH and a DHS Fire Grant (2008) through the NFPA Fire Protection Research Foundation

Fig 3. STE Burn Under Visibility Markings

Fig 4. Burns on Shoulder and Arm of Fire Fighter

Background

- Protective clothing or turnout gear is designed to insulate a fire fighter from the thermal environment. A series of protective layers and air gaps prevent the energy of the fire environment from being transferred to the fire fighter.
- Significant numbers of fire fighter burn injuries occur when thermal energy stored within the layers of the protective equipment are quickly transferred to the skin through compression of the layers.
- Current standards and testing methods do not adequately evaluate the risk caused by STE.

Project History

Phase 1	Phase 2	Phase 3	Phase 4
Development and refinement of test apparatus and procedure (NPPTL, NCSU) [Completed]	Testing of selected composites and work on the burn model (NPPTL, NCSU, NIST, NFPA) [Completed]	Inter-laboratory repeatability/ reproducibility studies and analysis (NPPTL, NCSU, Other Labs) [On-going]	Final report and dissemination to SDOs and stakeholders (NPPTL, NCSU, ASTM, NFPA) [On-going]

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Results

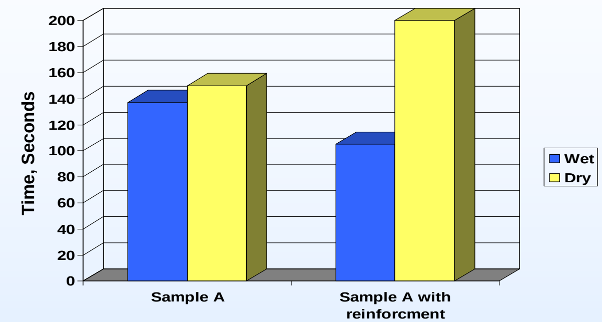

Fig 5. STE Test Results - Time to Second Degree Burn (Composites with and without reinforcement)

Project Timeline

Phase 3 Activity	Completion
Development of a Project Plan	Apr 2009
Set-Up of Experimental Capability at Selected Laboratories and Materials Procurement	Jun 2009
Testing of Additional Specimen Samples/ Combinations by Other Laboratories	Jul 2009
Phase 4 Activity	**Completion**
Complete Final Report	Dec 2009
Recommend Test Method and Criteria to Standards Organizations	Jan 2010

Completed Project Outputs

- ASTM Draft Standard, WK10531 - New Measuring the Transmitted and Stored Energy of Firefighter Protective Clothing Systems
- Phase 1 Final Report titled, "Development of a Test Method for Measuring Transmitted Heat and Stored Thermal Energy in Firefighter Turnouts"
- Phase 2 Final Report titled, "Thermal Capacity of Fire Fighter Protective Clothing." Available at: http://nfpa.org/assets/files/PDF/Research/PPE_Thermal_Energy.pdf