

**The Western Center for Agricultural Health and Safety  
NIOSH/CDC U54 OH007550  
Close Our Report (2011-2016)**

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Project start date: September 30, 2011

Project end date: September 29, 2016

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## ***Abstract***

Western agriculture is the most intensive and productive in the world but differs in many ways from the rest of the country. The overall goal of the Western Center for Agricultural Health and Safety (WCAHS) at UC Davis is to improve the health and safety of farmers, farm family members, and hired farmworkers and their families in western agriculture. UC Davis is uniquely situated to address these issues because of the co-locations of its Schools of Medicine and Veterinary Medicine and the College of Agricultural and Environmental Sciences and College of Engineering. UC Davis is a land grant and a research university located in the heart of the California's Central Valley. The multidisciplinary expertise of the Center faculty enables varied, largely field-oriented research projects, outreach and interventions. During this cycle, the Outreach program provided leadership in innovative efforts to improve the health of immigrant farmworkers. Areas of focus included creating bilingual/bicultural health and safety programs and materials for immigrant farmworkers, exploring the link between respiratory disease and exposures in Western farming environments, and engineering better ergonomic solutions to reduce acute and cumulative trauma injuries. A major effort in this cycle was to understand and develop effective interventions to prevent heat-related illness among agricultural workers. Another study evaluated exposures and respiratory disease in new laying-hen facilities. We continued our efforts to design better-engineered solutions to counter the musculoskeletal stresses of labor-intensive agriculture and to transfer this improved technology to the workplace. We also characterized respiratory toxicants in Western agriculture. Newer and more efficient pesticide bioassays were developed and linked to exposure studies of agricultural workers. The Center disseminated research findings and news about its activities through traditional and new forms of media. The comprehensive evaluation program assessed Center projects and activities for their success and effectiveness with stakeholders.

## **Section I**

### **Overall Center**

PI: Marc Schenker, MD, MPH

#### **SIGNIFICANCE AND KEY FINDINGS:**

The Western Center for Agricultural Health and Safety (WCAHS), based at the University of California, Davis (UC Davis), is a comprehensive, multidisciplinary program dedicated to the understanding and prevention of illness and injury in western agriculture. The overall goal is to improve the health and safety of farmers, farmworkers and their families and communities, with particular consideration of those issues unique to western agriculture. WCAHS aims to be a leader in this field by partnering with diverse stakeholders, conducting innovative multidisciplinary research, providing education that links to established health education networks, and demonstrating effective outreach and translation of all Center activities.

WCAHS, with its many landmark achievements, has established itself as a regional and international center of excellence for agricultural health and safety. This past funding cycle, WCAHS had impressive outputs and products, including:

- Over 100 publications based on research findings;
- Over 180 research presentations;
- 200 outreach events reaching nearly 10,000 people in the western agricultural community;
- 72 features of WCAHS research in the media;
- 17 grants totaling over \$25 million in additional funding

WCAHS funding from NIOSH has led to a return on investment of \$9:1 for the total Center funding during the 2011 to 2016 grant period, with other grants coming from NSF, NIH, NIOSH, and private foundations. The Center supported the training of 27 individuals, including 21 graduate students and 6 postdoctoral scholars in the field of agricultural health and safety. Additionally, WCAHS continued to support new investigators interested in the field and applicable and exploratory research projects through the pilot and seed grant program.

Below are various overall Center accomplishments by category for WCAHS research during the 2011-2016 grant period.

#### **TRANSLATION OF FINDINGS:**

- **Policy / Regulations**

##### ***Heat Illness Prevention Campaign – WCAHS efforts shaped policy and legislation within the State of California***

Together with policymakers, advocates, farmworker unions, and workers, WCAHS contributed to a multilevel transformation of California's heat illness prevention requirements (California Code of Regulations, Title 8, § 3395). New preventive measures are now required when the temperature equals or exceeds 95° F, including observing employees for signs and symptoms of heat illness, supervising new employees, reminding all workers to drink water throughout their shift, and requiring a 10 minute cool-down rest for every 2 hours of work and at the end of a 8 or 10 hour shift.

WCAHS Outreach Core staff conducted a series of workshops throughout California to assist farm managers, owners and/or staff in charge of workplace safety to develop effective heat illness prevention programs to comply with the new Cal/OSHA standard. Over 190 participants—field-level supervisors—received direct assistance in drafting their Heat Illness Prevention Program and for conducting effective tailgate trainings, including practicing their presentation skills using adult-education methods. Participants were provided with take-home materials in English, Spanish, Punjabi, and Hmong, depending on language of choice. Physiological and qualitative data collected in Project 5 has been used to develop heat illness risk estimates for farmworkers and improve on old physiological data that were derived from intense, short term work periods (e.g. firefighters, athletes, military personnel), and to understand and overcome behavioral and cultural barriers to effective prevention of heat stress illness.

***WCAHS advocated for policy initiatives to improve agricultural health regulations***

A policy paper, “Improving the health of agricultural workers and their families across America: Current status and policy recommendations,” was released in 2015 by WCAHS investigators, Drs. Schenker and McCurdy along with public health expert, Dr. Don Villarejo and WCAHS manager, Heather Riden. The paper was presented at the University of California Center in Sacramento. More than 85 people attended (including the California Governor’s Deputy Legislative Secretary) to hear the paper’s 11 specific policy recommendations, such as improving public health infrastructure, increasing the numbers of health workers, and promoting greater agricultural safety and health education.

- **Guidelines or Best Practices Adopted**

***WCAHS engineers designed a safer ladder***

WCAHS engineers designed a safer ladder based on optimally spaced rungs and ladder angle to reduce joint stress and falls in agricultural orchard work. Safer ladder standards were developed through theoretical modeling, laboratory testing and validation, and subsequent testing and validation in the field (Project 6). Two California ladder manufacturers made the newly designed orchard ladder with 11 inch spaced rungs as an option to the traditional 12 inch spaced rungs.

***WCAHS improved comprehensive surveillance of the agricultural health and safety system***

WCAHS researchers (Project 2) used large national datasets (e.g. NAWS) and econometrics in agricultural injury research to find more valid estimates of the number and types of agriculture-related injuries and illness. Analysis of data from the Bureau of Labor Statistics' Survey of Occupational Injury and Illness (BLS-SOII) revealed that the US government undercounted the number of injuries and illnesses on farms by nearly 80%. This research was highly featured by the media, including National Public Radio.

Final estimates of participation in the federal Women, Infants and Children (WIC) program by authorized and unauthorized farmworker households from the National Agricultural Workers Survey were determined. Unauthorized households were found to participate at almost the same rate as authorized households. In addition, unauthorized households with 2+ children were more likely to participate than authorized households.

- **Research Methods or Procedures Used Beyond WCAHS**

### ***WCAHS methods to measure air pollution used by other agencies***

Methodology developed from research on agriculturally derived airborne particulate matter (Project 1) is being implemented in other studies with colleagues for research supported by the California Air Resources Board (CARB) and the Electric Power Research Institute (EPRI). The methodology was published and made available to other researchers in the journal *Atmospheric Environment*.

### ***Immunoassays for pesticide exposure available for use in human and animal studies***

WCAHS has helped further refine the technique of using antibodies to rapidly detect exposure to chemicals (in our case herbicides and pesticides) with immunoassays that can be taken into the field to determine pesticide applicator exposures (Project 4). The methodology is applicable to a wide range of other chemicals and scientific fields, and details have been published in numerous scientific journals.

- **Outreach to Agricultural Community Through Education and Training**

#### ***Safety videos made available on U.S. Agricultural Safety and Health Centers YouTube channel***

WCAHS helped implement the Ag Center YouTube Channel in partnership with the other 9 NIOSH funded centers. Over 60 videos were made available for extension agents/educators, agricultural science teachers, producers/owners/operators, first responders, agricultural families, and anyone else interested in agricultural safety and health. The WCAHS Outreach and Education Specialist reviewed submitted Spanish-language videos. Two popular WCAHS videos focus on pulmonary health and were made in collaboration with Drs. Kent Pinkerton and Keith Bein (Project 1). The videos explain how particulate matter is collected, analyzed, affects human health, and contributes to the development of asthma. Preventative measures to reduce the risk of asthma are discussed as well.

#### ***Workplace injury and illness prevention program guide developed***

WCAHS Outreach staff helped develop the “Taking Action for Safety and Health – a Guide to Developing Your Workplace Injury and Illness Prevention Program in Agriculture,” available in English and Spanish. This outreach project was part of the Worker Occupational Safety & Health Training & Educational Program (WOSHTEP) jointly funded by the Commission on Health and Safety and Workers’ Compensation. Multiple trainings on how to use the guide were given as well.

**RESEARCH OUTCOMES/IMPACTS:** See specific research reports and output lists.

## **Section II**

### **Administration and Planning Core**

PI: Marc Schenker, MD, MPH

#### **ABSTRACT:**

The Western Center for Agricultural Health and Safety (WCHAS) Administrative and Planning Core, consisting of the Center Director, Associate Director and Center Manager, provided general oversight and management of the Center. The objectives of the Core were to: (1) coordinate and facilitate sharing of cross- disciplinary expertise and promote interactions between program investigators; (2) manage the Steering Committee and External Advisory Board and develop strategic plans for addressing agricultural health and safety concerns; (3) provide accounting and human resources support for all projects; (4) maintain the data sharing website; (5) promote training and education of all program participants; (6) provide administrative support to the Pilot/Feasibility Projects and Emerging Issues Program, Outreach Program, and Evaluation Program; (7) serve as a liaison to NIOSH, campus administration, other campus units, and other Centers; (8) generate timely progress reports and contractually obligated information for NIOSH/CDC; and (9) nurture new research and outreach projects and support for agricultural health and safety.

Center Communication was coordinated by the Administrative and Planning Core through efforts led by the Center Director and Manager. Center goals included promoting two-way communication between the WCAHS and populations served. This included organizing and staffing meetings and presentations of WCAHS investigators and of community and stakeholder groups. These meetings served the functions of information seeking, dissemination of findings and education/translation efforts.

All meetings of the Steering Committee and External Advisory Board were coordinated and staffed by the administrative unit. The Steering Committee consisted of representatives from the Center investigators, UC Davis Schools of Medicine, Veterinary Medicine, Agriculture and Environmental Sciences and Engineering; UC Berkeley School of Public Health; CalEPA; and a graduate student representative. The External Advisory Board consisted of 11 members bringing broad-based expertise in agricultural practices relevant to the Center activities. The EAB consisted of stakeholders representing farmers, farmworkers, government and non-government agencies, commodity groups and industry representatives in California, Arizona and Nevada.

#### **SPECIFIC AIMS:**

Specific Aim #1: Coordinate and facilitate sharing of cross-disciplinary expertise and promote interactions between program investigators;

Specific Aim #2: Manage the Steering Committee and External Advisory Board in their efforts to develop strategic plans for evolving agricultural health and safety concerns;

Specific Aim #3: Provide accounting and human resources support for all projects;

Specific Aim #4: Maintain the data sharing web site and organize data from all projects for incorporation into the web site;

Specific Aim #5: Promote training and education of all program participants, especially young researchers;

Specific Aim #6: Provide administrative support to the WCAHS Pilot/Feasibility Projects and Emerging Issues Program, the Outreach Program, and the Evaluation Program;

Specific Aim #7: Serve as a liaison to NIOSH, campus administration, other campus units, and other Centers;

Specific Aim #8: Generate timely progress reports and contractually-obligated information for NIOSH/CDC; and

Specific Aim #9: Nurture new research and outreach projects and support for agricultural health and safety.

## **METHODS:**

The Center Director was responsible for the overall organization and coordination of the WCAHS. Decisions regarding budgets, experimental design, and research progress were made collectively by the Steering Committee (described below) at monthly meetings. The Center Manager and other administrative support personnel assisted the Center Director and the Steering Committee in their duties. The project leaders were responsible for day-to-day operations within their projects, on which they reported to the Center Director and the Steering Committee on a regular basis. An External Advisory Board (EAB; described below) made recommendations for the future direction of the Center as a whole and interactions with stakeholders. Meetings of all Center investigators were held twice a year, or more often as needed.

### Advisory Committees

- **Steering Committee** — Members of the UC Davis School of Medicine, School of Veterinary Medicine, College of Agricultural and Environmental Sciences, College of Engineering, UC Berkeley School of Public Health and the California Department of Pesticide Regulation served on the Steering Committee. The Steering Committee consisted of investigators representing the focus areas within WCAHS, including the Administrative and Planning Core, Pilot/Feasibility Projects and Emerging Issues Program, Research Core, Intervention/Prevention Core, Education/Translation Core, Outreach Program, Evaluation Program, as well as additional advisory members to expand the cross-disciplinary nature of the committee. The breadth of expertise and academic affiliations provided a valuable foundation for Center decision-making. Their responsibilities included monitoring progress by periodic assessment of evaluation measures generated by the Evaluation Program, integrating cross-disciplinary expertise through a series of internal (monthly meetings, annual retreat for strategic planning) and external meetings (seminars, training, educational efforts, and community engagement) to assure that programmatic objectives were on target. These efforts also allowed for rapid identification of emerging issues in agricultural health and safety that were addressed in strategic planning efforts so that WCAHS stayed at the forefront of innovation for agricultural health and safety.
- **External Advisory Board (EAB)** — The EAB, seating representatives from the western region, consisted of a selected group of leaders and advocates in and for WCAHS agricultural health and safety. The EAB membership provides broad-based expertise and diversity in agricultural practices relevant to the Center activities. As WCAHS moved into a new cycle of funding, membership was re-evaluated on a routine basis during the Strategic Planning meetings to identify potential new members so as to expand the cross-disciplinary expertise of the advisory group.

The EAB served the dual purpose of providing feedback, guidance and advice to the Center on the recognized needs of stakeholders in agricultural health and safety, and communicating activities from the Center to various stakeholders, both at the regional and national level. At meetings held one to two times a year, the EAB provided an independent

assessment of the progress of the Center and made recommendations for future Center directional needs as a whole. The EAB met annually with the Steering Committee and other major stakeholders in a strategic planning retreat to further enhance the collaborative nature of WCAHS efforts (see description above for the Steering Committee). The EAB also provided valuable linkages with important stakeholders and served a vital role in helping us expand the sphere of influence of our best practices models and leverage additional resources related to WCAHS efforts.

Interactions with other University of California Units — The WCAHS administration and investigators have close affiliations and working relationships with funded centers and programs on the UC Davis campus, other university campuses, government or quasi-government agencies, non-governmental organizations (NGO), community organizations, and agricultural industries and commodity groups. These interactions enhanced the Center's programs and effectiveness.

Interactions of WCAHS with Community and Governmental Organizations — The WCAHS has had long and substantial interactions with several California state agencies, including the Departments of Health Services, Industrial Relations, Food and Agriculture, Cal OSHA, California Office of Environmental Health Hazard Assessment, and the California Environmental Protection Agency. Each of these agencies were involved with the Center by providing representatives to advisory committees, speakers for seminars and conferences, research collaborators, and policy forums for communication of Center and state activities. Our partnerships and collaborations with growers and large farm management companies provided invaluable opportunities to conduct complex field studies, engaging not only Center investigators but also graduate students.

Agricultural Health Policy Initiatives – The Administrative and Planning Core was actively involved in policy initiatives to effect changes identified or supported by the WCAHS with regard to improving health and safety in Western Agriculture. For example, WCAHS helped organize and sponsor an international conference *'Migrant Labor and Global Health'* which included a panel specifically on vulnerable workers such as farmworkers. Dr. John Howard was a keynote speaker. The Center continues to work toward translational policy solutions to improve health and safety of all constituencies in agriculture.

Monthly WCAHS Seminar Series – WCAHS hosted a monthly seminar during the academic year. The seminar series invited diverse, distinguished guest lecturers to speak on a variety of topics relevant to agricultural health and safety.

Annual WCAHS Strategic Planning Retreats – WCAHS convened formative meetings to bring together the Steering Committee, EAB, WCAHS investigators, and other key stakeholders to promote collaboration and communication, re-evaluate Center progress, and develop/refine the strategic plan for the coming year(s). The goals were to share Center activities, network, explore new areas of agricultural health and safety appropriate for WCAHS efforts, develop mechanisms to expand stakeholder involvement in Center activities, and identify emerging agricultural health concerns. The retreats were also opportunities for pilot project progress to be presented to the advisory boards. The WCAHS Administrative and Planning Core personnel played a key role in all aspects of planning these highly successful opportunities for broadening the collaborative environment and impact of the Center's efforts.

## **ACTIVITIES:**

The Administrative and Planning Core facilitated cross-disciplinary collaborations, business operations, retreats, communications, meetings, and the infrastructure to promote interactions among the cores, programs and projects of the Center.

### **Coordinated Annual Strategic Planning Retreats**

Each fall, the Center held WCAHS External Advisory Board and Steering Committee Strategic Advancement Planning retreats, which served to help identify new areas of research and outreach. As an example, interpreters from Natividad Medical Foundation's Indigenous Interpreting+ (<http://interpretnmf.com/>) attended the 2014 annual retreat to describe the importance of ensuring community services are accessible and useful for farmworkers speaking indigenous languages. Interpreters explained that in some regions of California over 50% of people migrating from Mexico speak indigenous languages, such as Mixteco, Zapoteco and Triqui. Many of these indigenous language speakers speak little to no Spanish. The retreat brought together California Department of Pesticide Regulation (DPR) Director, Brian Leahy, the Indigenous Interpreting+ Director Victor Sosa and Natividad Medical Foundation President Linda Ford to talk about the challenges of alerting indigenous speakers to pesticide and other agricultural hazards when many of the safety signs are in Spanish. DPR is working to translate its safety materials into indigenous languages and WCAHS outreach is working with Natividad Medical Foundation to add content to their programs on agricultural health and safety. Graduate students receiving pilot funding also had the opportunity to report their findings at both retreats and in the WCAHS monthly seminar series. These meetings were instrumental in providing communication among all WCAHS investigators and members of the Steering and External Advisory Board members as well as attendees of the seminar series.

In addition, the retreats provided WCAHS investigators with a chance to hear from stakeholders. Patty Rominger, safety and compliance officer for Rominger Brothers Farms in Winters, CA, gave a real world explanation of the company's process in meeting California's heat illness prevention measures. This included building a 24-person shade structure, providing personal umbrellas, and giving daily weather reports and advice to workers, many of whom were long-time farmworkers, about how to change their behavior in the heat. Initially, there was resistance to the new rules, but with time and persistence, Patty reported that the workers "get it" and appreciate her safety concerns.

### **Participated in National and International Conferences and other scientific presentations**

The Administrative and Planning Core facilitated travel of WCAHS investigators and staff to multiple national and international meetings. Below are just a few examples.

#### *Binational Health Week Conferences*

Each year, Dr. Schenker served on the program planning committee, presented research findings, and conducted workshops for the Binational Health Week Conference, which is one of the largest mobilization efforts of government agencies, community-based organizations, and volunteers in the Americas to serve Latino populations living in the U.S. and Canada. This conference is held in the San Francisco Bay Area of California, and is attended by ~200 participants from the US and Mexico.

#### *International Society for Agricultural Safety and Health (ISASH)*

ISASH is the largest annual gathering of professionals dedicated to agricultural safety and health, providing national and international leadership in preventing agricultural injuries and illness to the ag community. WCAHS staff attended this annual conference and provided a

perspective on WCAHS programs and research. In 2012, WCAHS Outreach Specialist, Teresa Andrews, co-presented “Chemicals in Rural Areas” (English and Spanish educational package) with Shari Burgus, Education and Outreach Director at Farm Safety for Just Kids.

#### *Other Scientific Presentations*

WCAHS investigators and staff regularly presented results of Center research and other efforts at a variety of invited lectures, grand rounds, special symposia and other forums. For example, Center Director Marc Schenker lectured on agricultural health and safety throughout the US as well as in Europe and Africa.

#### **Hosted Monthly Seminar Series**

WCAHS hosted informative and educational seminars monthly during the academic year. This was a chance for the general public, students, investigators, and stakeholders to become educated on a wide range of topics, including agricultural health and safety issues, outreach, agricultural workforce employment and demographics, agricultural education, and specialized sessions on agricultural related science (e.g., Valley Fever and farm work, AgrAbility services for disabled farmers, social media communications for stakeholders). The talks were advertised on the website, list serves, print ads, and through general campus strategic communications and were well attended by a diverse audience.

#### **Administered Center Research Projects and Pilot Projects**

During this past funding cycle, the Administration and Planning Core successfully administered the funds and reporting requirements of the research projects and pilot projects. These projects generated numerous publications and media features and often involved the hiring of multiple personnel at all levels and lengths of employment. The Administration and Planning Core was responsible for communicating and problem solving with all project leaders and selecting pilot projects.

#### **Acted as a Liaison with NIOSH and Other Ag Centers**

The Administration and Planning Core acted as the main conduit of information between the Center and NIOSH and the other Ag Centers. The manager of the Center within the Administration and Planning Core was available in person and by telephone on a daily basis to facilitate communication and coordination of news and planning with NIOSH and all 10 NIOSH funded Agricultural Centers across the nation. Activities included participation of the Director, Associate Director and Manager in the monthly Director’s calls, as well as facilitating efforts to communicate to state and federal officials of the benefits of the work accomplished not only by our Center, but by all the NIOSH funded Centers across the nation. An important function of the Administration and Planning Core over the past cycle was the coordination of materials and impact statements for annual visits to Senators and Congress representatives in Washington DC.

#### **Facilitated Communications**

WCAHS has always been strongly committed to publicizing Center findings and educational material via traditional and new means of communication. The Administration and Planning Core oversaw all communications efforts, including print, electronic, and social media.

**COMMULATIVE ENROLLMENT TABLE: N/A**

## **Outreach Core**

PI: Stephen McCurdy, MD, MPH

### **ABSTRACT:**

The WCAHS Outreach Program Core is a key component of the Western Center for Agricultural Health and Safety and its mission to improve occupational health and safety in Western agriculture. Responsible for promoting communication and dialog within the WCAHS and with external partners, the Outreach Program Core expanded its activities during the 2011-2016 funding cycle. Highlights include conducting nearly 200 events serving nearly 10,000 persons. Events included 82 presentations serving 6,832 persons on topics such as heat illness prevention, injury-and-illness-prevention programs (IIPPs), pesticide safety, dairy safety, and others; informational tabling nearly 1000 persons; and conducting training of trainer (TOT) courses serving 541 persons. In addition, the Outreach Core was active in development of educational materials supporting our training programs and agricultural health and safety in general; participation and co-sponsorship of conferences with numerous partner organizations; and a robust media program spanning traditional print to modern social media platforms. Many of our activities and communications channels are available in English and Spanish, befitting WCAHS's engagement with the farm worker community, which is predominantly Hispanic. The Outreach Program has always been an "early adopter" of modern media to amplify our outreach efforts. In addition to our quarterly newsletter (available in print and electronic format) and monthly seminars, we have an active listserv, Facebook page, and Twitter account. All of these serve to expand the breadth of our reach and nurture partnerships with important stakeholders in the agricultural community, which is key to our success. Partnerships facilitate the flow of information between the researcher and the agricultural community and speed adoption of important findings and best practices.

### **SPECIFIC AIMS:**

The WCAHS Outreach Program works to establish two-way communication between and among Center investigators and stakeholders in the agricultural community, particularly in the western states, but also reaching communities nationwide. This two-way communication serves to focus and improve the quality of Center research and promotes the transfer of research findings into the agricultural community.

**Specific Aim #1: Promote communication among and between WCAHS investigators.** We have organized several forums and activities to promote communication among and between WCAHS investigators including monthly public seminars and periodic meetings between Outreach Program staff and WCAHS investigators to address their outreach needs.

**Specific Aim # 2: Promote communication between WCAHS investigators and other agricultural health and safety centers.** We coordinate regional and national meetings of the NIOSH Agricultural Health and Safety Centers and are engaged in inter-Center activities, including the Evaluators, Coordinators, and Outreach (ECO) work group.

**Specific Aim # 3: Develop and sustain partnership between WCAHS and key stakeholders in the agricultural community, and promote dissemination of research findings and best practices to that community.** The agricultural community includes but is not limited to farmers, farmworkers, policy makers, local and state representatives, *promotores* (lay community members trained as leaders and sources of information regarding occupational health), and nonprofit agencies.

## METHODS:

The Outreach Program Core mission is achieved through the following means:

<b>WCAHS Outreach Core Communications Tools</b>	
<b>Communication Medium or Channel</b>	<b>Examples and Comment</b>
<i>In-person</i>	
Conferences and symposia	Monthly WCAHS seminar featuring speakers from academia and the broad agricultural community; open also to the general public. Participation and co-sponsorship of symposia with partner organizations.
Training sessions	Train-the-trainer sessions for farm supervisors on how to protect against heat illness
Focus groups	Farm worker focus groups to assess their health and safety concerns and identify effective channels of communication.
<i>Traditional print media</i>	
WCAHS Quarterly Newsletter (also available online)	Circulation among academia; legislative, policy and regulatory personnel; agricultural employers; insurers; community-based organizations
Articles in lay publications	E.g., local newspapers and newsletters within the agricultural industry
Published training materials	Available through our website for national dissemination
Pocket cards	Helpful as handouts for participants at health and safety trainings; available through our website for national dissemination
Articles in peer-reviewed scientific journals	Important venue for scientific researchers, providing source of quality-controlled (through peer review) research results and policy recommendations.
<i>Television and Radio</i>	
Interviews and news stories	Television news casts (English and Spanish) <i>Radio Bilingüe</i> Spanish-language radio
<i>Digital media</i>	
WCAHS web page ( <a href="https://aghealth.ucdavis.edu/">https://aghealth.ucdavis.edu/</a> )	The WCAHS webpage is the main portal for information regarding WCAHS activities and includes links to important sources of agricultural safety and health information.
Electronic distribution mailing list	WCAHS communicates with stakeholders via a mailing list of over 750 individuals. Information about WCAHS research findings, trainings, and seminars are published.
WCAHS blog ( <a href="https://aghealth.ucdavis.edu/blog">https://aghealth.ucdavis.edu/blog</a> )	The WCAHS Agricultural Health and Safety blog is updated monthly with information regarding important agricultural health and safety issues. Suggestions for topics come from readers and participants in WCAHS activities.
Twitter (@AgHealthUCD)	WCAHS maintains an active Twitter feed with information on agricultural health and safety and related news.
Facebook (@AgHealthUCD and @SaludAgUCD)	WCAHS maintains an English and Spanish Facebook page with daily updates. WCAHS participates in AFF center-wide social media campaigns.

WCAHS Outreach Core Communications Tools	
Communication Medium or Channel	Examples and Comment
Wikipedia	Identify important topics and provide text for Wikipedia in English and Spanish, as a way to increase general public awareness about our research findings and increase traffic to our science based social media sites.
YouTube (Western Center for Agricultural Health and Safety)	Source of up-to-date and topical health & safety information. (Current offerings address health & safety around cattle and are available in English and Spanish. We plan to expand offerings significantly in the upcoming funding cycle.) We also contribute to the US Agricultural Health and Safety Center's library of health & safety videos.

### FINDINGS:

Over the 2011-2016 funding cycle, WCAHS continued its leadership role in agricultural health and safety education, technology transfer, and training. Below is a summary of our activities.

	2011		2012		2013		2014		2015		2016		Total	
	# E*	# R*	# E	# R	# E	# R	# E	# R	# E	# R	# E	# R	# E	# R
<b>Presentations</b>	15	1137	28	2749	7	1004	18	1086	13	786	1	70	82	6832
<b>Workshops</b>	5	279	0	0	4	104	6	96	2	240	0	0	17	719
<b>24-hr WOSHTEP Training</b>	0	0	0	0	3	32	0	0	0	0	6	50	9	82
<b>Information table</b>	4	900	0	0	0	0	0	0	0	0	2	92	6	992
<b>Collaboration Meetings</b>	2	80	2	50	5	11	10	9	0	0	0	0	19	150
<b>Technical Assistant</b>	0	0	3	0	0	0	1	4	0	0	0	0	4	4
<b>Attended Conference</b>	1	0	0	0	3	20	2	0	4	0	0	0	10	20
<b>Health Fair</b>	0	0	0	0	0	0	1	350	0	0	0	0	1	350
<b>TOT Trainings</b>	7	165	11	176	0	0	3	30	3	34	0	0	30	541
<b>Trainings</b>	0	0	0	0	0	0	0	0	2	56	7	186	9	242
<b>Total</b>	34	2561	44	2975	22	1171	41	1575	24	1116	16	398	187	9932

\* E = Events; R = Reached

### Highlights:

The WCAHS Outreach Program Core conducted nearly 200 outreach events, reaching nearly 10,000 people from the broad western agricultural community, including farm workers, farmers, agricultural industry representatives, and regulatory and policy personnel.

- **Presentations:** Outreach provided 82 presentations to 6832 people. Two of the most effective presentation venues are the **Consulate General of Mexico in Sacramento, CA and hosting the monthly WCAHS seminars.**
- **Workshops:** Outreach held 17 workshops with 719 attendees. Main topics include heat illness prevention, pesticide safety, and general agricultural health and safety.
- **Training-of-Trainers:** Outreach presented 30 training-of-trainers sessions, reaching 541 people. A significant training program was established with the **UC Statewide Integrated Pest Management (IPM) Program.** In collaboration with this program we created materials to assist those in charge of conducting pesticide-safety sessions for farm workers. The materials include step-by-step guides and educational materials for supervisors to assist them in conducting brief 15-to-20-minute tailgate sessions on California's required training topics regarding pesticide safety.
- **Collaborations:** While WCAHS participates in many partnerships, a major ongoing outreach effort is **between WCAHS and other Agricultural Health and Safety Centers.**

Ms. Teresa Andrews, WCAHS Education and Outreach Specialist, attends regular meetings of the Evaluators, Coordinators, and Outreach (ECO) Group comprising over 50 outreach personnel from each of the NIOSH-sponsored Agricultural Health and Safety Centers across the U.S. The ECO group works closely with CDC/NIOSH to promote health and safety in the Agriculture, Forestry, and Fishing industry group that the Agricultural Health and Safety Centers are meant to serve. Within ECO, the following work groups have been established:

- **Evaluation Work Group** - Develops best practices for collecting, analyzing, and reporting Ag Center data
- **Awareness Work Group** – Promotes safety campaigns through two nationally recognized events, including National Agriculture Day (3/15/2016; <http://www.agday.org>) and National Farm Safety & Health Week (9/20-26/2015; <http://www.necasag.org>)
- **National Ag Safety Database Work Group** – Acts as online clearinghouse (<http://nasdonline.org>) of safety education materials
- **YouTube Channel Work Group** - Advances health and safety education in the Agriculture, Forestry, and Fishing industry sector with a peer-reviewed YouTube channel.

WCAHS Education and Outreach Specialist Teresa Andrews contributes to the ECO Work Group activities through leadership and review of submitted Spanish-language videos and translation of flyers used to promote health and safety in agriculture.

**Collaboration with community organizations: Local farm employers and nonprofit agencies:** Early in 2015, a group of Yolo County farmers requested our assistance in organizing a conference for Latina farmworker women. We helped with general logistics and identifying Spanish-speaking presenters for topics of interest as previously suggested by the workers. Working with the farmers and a local non-profit agency (**Rural Innovations in Social Economics, Inc. (RISE)**), we participated the ¡Que Viva la Vida! (Up with Life!) Conference in Esparto, California, in March 2015. Forty farmworker women attended, all of whom were paid by their employers for the day. Participants not only learned about the

covered topics (domestic violence, nutrition, self-esteem, immigration law, and the importance of college education for children), but also about local public resources.

***Collaboration with community organizations: Natividad Medical Foundation (NMF):*** Natividad Medical Center in Salinas, California, is the largest hospital serving an area with a great number of agricultural workers. Most of these workers are foreign-born, and many speak only an indigenous language, complicating provision of care. Accordingly, NMF started an interpreter program that now is a leader in its kind in the nation, offering interpretation services in 15 indigenous languages. We have arranged with NMF leadership to train their interpreters on occupational health and safety issues, as well as to use their services when conducting training to groups that speak indigenous languages, such as Triqui, Mixteco, and others.

- **Media:** Outreach made major use of both traditional and new media communications, in English and in Spanish, reaching several hundred radio listeners and social media viewers.

**CONCLUSIONS:** The WCAHS Outreach Program Core has actively promoted communication and dialog within the Center, among the national group of Agricultural Health and Safety Centers, and with partner organizations representing governmental regulatory agencies, employers, farmworkers, and advocacy groups.

**OUTPUTS/OUTCOMES:** As described above under Findings.

**COMMULATIVE ENROLLMENT TABLE:** N/A

## **Research Core**

PI: Fadi Fathallah, PhD

The following pages contain reports for Research Projects 1-6 and the Pilot/Feasibility Projects and Emerging Issues Program.

### ***Project 1: Effects of California agricultural particulate matter in a murine intranasal sensitization model of allergic airway inflammation***

PI: Kent Pinkerton, PhD

**ABSTRACT:** The Sacramento and San Joaquin Valleys of California are some of the most productive agricultural lands in the United States. However, they are also home to millions of people with the highest particulate matter (PM) pollution in the country and have been consistently designated by the Environmental Protection Agency (EPA) to be in non-attainment for fine PM  $\leq 2.5\mu\text{m}$  in diameter (PM<sub>2.5</sub>). The goal of the proposed research has been to enhance our knowledge of the relationship between agricultural PM, alone and relative to other PM sources and source mixtures, and adverse health effects; thereby, establishing better approaches to managing exposure risks and regulating air quality in rural, agricultural and urban regions of the Sacramento and San Joaquin Valleys. The following hypothesis was tested: size-segregated, activity-oriented agricultural PM, PM emitted from urban and residential sources and the background PM mixture differentially influence the degree of allergic reaction. A novel approach to collecting ambient, size-segregated PM was implemented to provide both single pollutant (e.g., single source) and multi-pollutant (e.g., source mixture) PM samples for subsequent toxicological studies. This approach allowed insight into the relative toxicity of different PM sources and source combinations; i.e., some sources or source combinations were more toxic than others. A murine intranasal sensitization model of allergic airway inflammation and PM collected from various agricultural, rural and urban sites in the Sacramento and San Joaquin regions of California were used. These studies have provided unique key information to demonstrate the diverse nature of particle size and chemical composition to influence the allergic response in the mouse.

**BACKGROUND:** California's Central Valley is the agricultural center of the state with a current population of approximately 6 million people. This burgeoning population faces tremendous growth pressure in future years as cities in the Sacramento and San Joaquin Valleys expand to accommodate the demand for affordable housing. Currently, the Central Valley has some of the highest particle pollution in the U.S. but is unique compared to other highly polluted cities, such as those on the east coast, in that agricultural activities are a major contributor to these high PM concentrations. As the population expands, a larger number of people will be exposed to higher concentrations of agricultural related emissions, both separate from and in addition to urban and residential PM sources, photochemically processed PM and long-range transport sources.

Although there is a huge literature establishing the epidemiological association between ambient PM and health effects, which has motivated much of toxicological research, that work does not indicate which sources of PM are responsible for the health effects. Similarly, there is a huge literature on the toxicity of (a) ambient PM mixtures in various urban and residential settings that are not associated with specific emissions sources and (b) select source emissions without ambient processing or multi-source effects. The toxicological literature on ambient PM resulting directly from agricultural activities, however, and how this compares with the toxicity of

more heavily studied urban and residential sources, as well as background and photochemically processed mixtures of these sources, is essentially non-existent.

The significance of this research is that it seeks to identify these important health issues so that the appropriate and most effective air quality regulation and exposure risk management strategies can be implemented to ultimately improve and protect the health of the agricultural, suburban and urban populations comprising California's Central Valley.

#### **SPECIFIC AIMS STUDIED:**

- 1) Exposure to size-segregated, activity-oriented agricultural PM, PM emitted from urban and residential sources and the background PM mixture differentially influence the degree of allergic airway inflammation using a murine intranasal sensitization model and PM collected from various agricultural, rural and urban sites in the Central Valley of California.
- 2) Examine dose-metrics for intranasal aspiration of agricultural ultrafine ( $D_p < 0.17 \mu\text{m}$ ) and fine ( $0.17 < D_p < 2.5 \mu\text{m}$ ) PM to determine if instilled mass, particle number, surface area, or pro-oxidant potential elicit an increase in the allergic inflammatory response in a dose-dependent manner.
- 3) Conduct educational outreach to the agricultural and surrounding communities about how and what types of PM exposure can affect health, methods to reduce exposure, and the importance of considering PM exposure risks when having a preexisting respiratory/allergic condition or being predisposed to such a condition.

#### **METHODS USED:**

The health effects associated with exposure to agricultural, rural and urban PM sources and source mixtures during the sensitization phase of the pulmonary allergic response were assessed using a murine intranasal sensitization model of allergic airway inflammation.

Animals were sensitized via intranasal aspirations of ovalbumin with or without particles on days 2, 4 and 6. Following a period of rest, animals were challenged with 1% aerosolized ovalbumin for 1 hour on days 11-13 and necropsied on day 14. Bronchoalveolar lavage and tissues were collected. The primary endpoints of cellular airway inflammation, immunoglobulin production, Th2 cytokine production, goblet cell hyperplasia and mucous production were assayed to determine the extent and degree of allergic airway inflammation.

Agricultural, urban and residential sources of PM, as well as various mixtures of these sources, were collected from 5 different locations in the Central Valley of California, including Parlier (agricultural), Tulare (agricultural), Sacramento (urban/residential) and Fresno (agricultural-urban interface), as well as at different times of day and seasons.

Particles were collected using 10 ChemVol impactor-based samplers housed in a mobile research trailer. Particle size fractions collected included: ultrafine ( $< 0.1 \mu\text{m}$ ), submicron fine ( $< 1.0 \mu\text{m}$ ), supermicron fine ( $< 2.5 \mu\text{m}$ ) and coarse ( $< 10 \mu\text{m}$ ). Particles were generally sampled in a 2-3 hours sampling window of time. Collected size-segregated ambient PM samples were extracted from the filters to be used for animal dosing.

The particles were analyzed for bulk-phase physical and chemical characterization, such as mass, water-soluble inorganic ions, speciated organic compounds, trace elements, metals, and

elemental and organic carbon. In addition to bulk-phase analyses of filter samples, real-time data taken during particle collection was analyzed for various meteorological variables; i.e., wind speed and direction, temperature and relative humidity. Filter samples were also analyzed for endotoxin.

### **FINDINGS (most recent highlights):**

- Vehicular emissions, the regional background PM mixture of Fresno, CA – which is dominated by agricultural emissions – and residential and commercial cooking emissions were found to significantly cause inflammatory responses depending on PM size and the season. Fresno is a large Central Valley city surrounded by agriculture and having high air pollution. Bein KJ, Zhao Y, Wexler AS. Retrospective source attribution for source-oriented sampling. *Atmospheric Environment* 2015 Oct;119:228-239.
- For the first time, source-oriented PM collected from the atmosphere representing rural, agricultural and urban sources were placed onto 38 source/size substrates. Mice were exposed via oropharyngeal aspiration to equivalent mass doses [50 µg] of two size fractions: ultrafine (UF;  $D_p < 0.17\mu\text{m}$ ) and submicron fine (SMF;  $0.17 < D_p < 1\mu\text{m}$ ) during summer and winter seasons. At 24 hours post-exposure, cellular and biochemical indicators of pulmonary inflammation were evaluated in the bronchoalveolar lavage (BAL) fluid. These experiments demonstrated vehicles, regional background, and cooking sources elicited significant inflammatory responses that were dependent on size and season. However, many sources of PM elicited no response. *Atmospheric Environment* 2015 Oct;119:228-239
- Methods development of the murine model of allergic sensitization extensively used PM samples collected from agricultural, rural and urban areas of the Central Valley. A paper describing the details of how the model can be applied to examine the allergic inflammatory response was published. Castañeda AR, Pinkerton KE. 2016. Investigating the Effects of Particulate Matter on House Dust Mite and Ovalbumin Allergic Airway Inflammation in Mice. *Current Protocols in Toxicology*. 68:18.18.1-18.18.18.
- Studies in the laboratory have confirmed that PM administered during the sensitization period to ovalbumin, and not during challenge, significantly increase airway inflammation compared to ovalbumin-alone sensitization/challenge. Total cells, macrophages, and eosinophils recovered in bronchoalveolar lavage were significantly elevated. Histopathological assessment also demonstrated significant inflammation with exposure to PM over only ovalbumin/ovalbumin treatment. IgE and TNF $\alpha$  levels were found to be significantly elevated. Heme oxygenase-1 positive alveolar macrophages, a signal of oxidative stress, were also significantly elevated compared to only exposure to ovalbumin. Castañeda AR, Bein KJ, Smiley-Jewell S, Pinkerton KE. 2017. Fine particulate matter (PM<sub>2.5</sub>) enhances allergic sensitization in BALB/c mice. *J Toxicol Environ Health A*. 80(4):197-207.
- We are pursuing evidence that suggests AhR activation by PAHs in PM promotes Th17-immune responses, which drive the allergic immune response.

### **CONCLUSIONS:**

NIOSH support of research through Project 1 of WCAHS during this cycle has encompassed the development and implementation of multiple technologies, techniques and approaches to

specifically address the issues around inhaled particles with implications towards particle size, shape and composition in the agricultural setting and consequent effects on the respiratory tract. This study furthered of knowledge concerning:

- Characterization of aerosolized particles
- Health implications of diverse particles depositing in the respiratory tract and consequent implications in vascular health
- Particle influence on infectious susceptibility
- Interaction of environmental organisms, allergic sensitization and particle influence to augment the asthmatic state.
- Individual particle sources eliciting different toxicity profiles supporting the need for source-specific emissions control strategies.
- Fine particulate matter enhancing the allergic inflammatory response in the lung through mechanisms of increased oxidative stress.

## OUTPUTS / OUTCOMES

### Publications (showing 15 out of a total of 42)

1. Amy K. Madl, Stephen V. Teague, Yongquan Qu, Daniel Masiel, James E. Evans, Ting Guo, and Kent E. Pinkerton "Aerosolization System for Experimental Inhalation Studies of Carbon-Based Nanomaterials," Publisher: Taylor & Francis Informa Ltd Registered in England, 06 October 2011, At: 15:07
2. Herr CE, Ghosh R, Dostal M, Skokanova V, Ashwood P, Lipsett M, Joad JP, Pinkerton KE, Yap PS, Frost JD, Sram R, Hertz-Picciotol. Exposure to air pollution in critical prenatal time windows and IgE levels in newborns. *Pediatr Allergy Immunol*, 2011; 22(1 pt 1): 75-84.
3. Plummer LE, Ham WH, Kleeman MJ, Wexler AE, Pinkerton KE. Influences of Season and Location on Pulmonary Response to California's San Joaquin Valley Airborne Particulate Matter, *Journal of Toxicology and Environmental Health*, 2012; 75:253-271.
4. Chan, J. K., Vogel, C. F., Baek, J., Kodani, S. D., Uppal, R. S., Bein, K. J., ... & Van Winkle, L. S. Combustion derived ultrafine particles induce cytochrome P-450 expression in specific lung compartments in the developing neonatal and adult rat. *American Journal of Physiology-Lung Cellular and Molecular Physiology*, 2013; 304(10), L665-L677.
5. Carosino CM, Bein KJ, Plummer LE, AR, Castañeda, Zhao YJ, Wexler AS, Pinkerton KE. Allergic Airway Inflammation is Differentially Exacerbated by Daytime and Nighttime Ultrafine and Submicron Fine Ambient Particles: Heme Oxygenase-1 as an Indicator of PM-mediated Allergic Inflammation. *J Toxicol Environ Health A*.
6. Hopkins LE, Patchin ES, Chiu PL, Brandenberger C, Smiley-Jewell S, Pinkerton KE. Nose-to-brain transport of aerosolised quantum dots following acute exposure. *Nanotoxicology*. 2014 Dec;8(8):885-93. PubMed Central PMCID: PMC3992067.
7. Wang X, Ji Z, Chang CH, Zhang H, Wang M, Liao YP, Lin S, Meng H, Li R, Sun B, Winkle LV, Pinkerton KE, Zink JI, Xia T, Nel AE. Use of coated silver nanoparticles to understand the relationship of particle dissolution and bioavailability to cell and lung toxicological potential. *Small*. 2014 Jan 29;10(2):385-98. doi: 10.1002/smll.201301597. PubMed Central PMCID: PMC4001734.

8. Anderson DS, Patchin ES, Silva RM, Uyeminami DL, Sharmah A, Guo T, Das GK, Brown JM, Shannahan J, Gordon T, Chen LC, Pinkerton KE, Van Winkle LS. Influence of Particle Size on Persistence and Clearance of Aerosolized Silver Nanoparticles in the Rat Lung. *Toxicol Sci.* 2015 Apr;144(2):366-81.
9. Carosino CM, Bein KJ, Plummer LE, Castañeda AR, Zhao Y, Wexler AS, Pinkerton KE. 2015. Allergic airway inflammation is differentially exacerbated by daytime and nighttime ultrafine and submicron fine ambient particles: heme oxygenase-1 as an indicator of PM-mediated allergic inflammation. *J Toxicol Environ Health A.* 78(4):254-66. PubMed PMID: 25679046.
10. Linderholm, AL, Franzi LM, Bein KJ, Pinkerton KE, Last JA. A quantitative comparison of administration of coarse PM intranasally and intratracheally in the house. *Integrative Pharmacology, Toxicology and Genotoxicology*, 2015, 1(1):2-7.
11. Plummer LE, Carosino CM, Bein KJ, Zhao Y, Willits N, Smiley-Jewell S, Wexler AS, Pinkerton KE. 2015. Pulmonary inflammatory effects of source-oriented particulate matter from California's San Joaquin Valley. *Atmospheric Environment*. In press (October 2015, volume 119).
12. Calvo-Lorenzo, M. S., Hulbert, L. E., Fowler, A. L., Louie, A., Gershwin, L. J., Pinkerton, K. E., ... & Mitloehner, F. M. (2016). Wooden hutch space allowance influences male Holstein calf health, performance, daily lying time, and respiratory immunity. *Journal of dairy science*, 99(6), 4678-4692.
13. Castañeda, A. R., & Pinkerton, K. E. (2016). Investigating the effects of particulate matter on house dust mite and ovalbumin allergic airway inflammation in mice. *Current protocols in toxicology*, 18-18.
14. Belafsky, P. C., Peake, J., Smiley- Jewell, S. M., Verma, S. P., Dworkin- Valenti, J., & Pinkerton, K. E. (2016). Soot and house dust mite allergen cause eosinophilic laryngitis in an animal model. *The Laryngoscope*, 126(1), 108-112.
15. Plummer, L. E., Carosino, C. M., Bein, K. J., Zhao, Y., Willits, N., Smiley-Jewell, S., ... & Pinkerton, K. E. (2015). Pulmonary inflammatory effects of source-oriented particulate matter from California's San Joaquin Valley. *Atmospheric Environment*, 119, 174-181.

**Grants** (showing 2 out of a total of 5)

1. 1U01 OH010839-01, NIOSH. Coccidioidomycosis Among California Hispanic Farm Workers, McCurdy (PI), Project Period: 09/01/2014 – 08/31/2017
2. P30, ES023513, UC Davis Environmental Health Sciences Core Center (EHC), (NIH/NIEHS) Hertz-Picciotto (PI), Pinkerton, Deputy Director, 2015/05/05-2020/03/31

**Media Coverage** (showing 2 out of a total of 11)

1. News Article: "Air Pollution Linked to Significant Decrease in Life Expectancy" July 10, 2013, *Scientific American*. <http://www.scientificamerican.com/article/air-pollution-linked-to-health/>
2. Radio: "Drought Creates Extra Burden for Allergy Sufferers" Capital Public Radio. <http://www.capradio.org/articles/2014/03/03/drought-creates-extra-burden-for-allergy-sufferers/>

**Presentations** (showing 4 out of a total of 44)

1. LE Plummer, CM Carosino, KJ Bein, Y Zhao, AS Wexler, KE Pinkerton. Toxicity of day/night urban San Joaquin Valley particulate matter is size and season dependent. *Society of Toxicology*, San Francisco, CA, March 2012.
2. "Dose response to Sacramento particulate matter", Van Winkle, L.S., Anderson, D.S., Pinkerton, K.E., et al., 2013 *Society of Toxicology Annual Meeting*, San Antonio, TX, March 10-14

3. "Occupational health and accident prevention in farmworkers," Binational Promotoras Conference. Oakland, CA. September 9, 2014.
4. "Health effects of Central Valley particulate matter" California Air Resources Board Seminar, May 27, 2017, Sacramento, CA

**COMMULATIVE ENROLLMENT TABLE:** N/A

## ***Project 2: Using large national datasets (NAWS) and econometrics in agricultural injury research***

PI: J. Paul Leigh, PhD

**ABSTRACT:** Large, reliable, national data sets specifically designed to provide information on the safety and health of farm owners, their children, farm managers and workers have existed for more than 20 years and are projected to collect data for future years. Two of these are the National Agricultural Workers Survey and the Children's Agricultural Injury Survey. Both appear to be underutilized. There are also large national data sets focused on occupational injuries and illnesses across all industries, medical costs, and general health for all persons in the U.S. that have information on persons working in agriculture. The overall goal of this project was to demonstrate how these data sets, combined with straightforward econometric techniques, can be used to address significant questions facing agricultural stakeholders including health professionals, researchers, farmers, policy makers, unions and trade groups.

**BACKGROUND:** In 2009, the U.S. General Accounting Office (GAO) released a report addressing the significant undercount within the Survey of Occupational Injuries and Illnesses (BLS-SOII) in all industries combined. That report led to improvements in the OSHA Administration's methods of auditing by, for example, including worker interviews and better informing employers of recordkeeping techniques. However, data on the agricultural industry was sparse. This is unfortunate because the undercount is thought to be greater in agriculture than any other industry. An understanding of characteristics of people, jobs, injuries and illnesses both currently and over time would enhance our ability to efficiently target resources for prevention in agriculture.

Farm owners, managers, and especially workers are groups that are known to have poor access to health insurance coverage. But the extent of the disparity in access is under debate, in part, because there have only been a few studies on the topic. The proposed research analyzed nationally representative data on insurance coverage and medical care utilization. Studies on the costs of occupational injury and illness within agriculture, despite their size, have not kept pace with those done for other industries. Thus, estimates of current and future costs for occupational injuries and illnesses within agriculture across states were calculated in this project.

### **SPECIFIC AIMS:**

- 1) Test hypotheses about the government undercount of non-fatal injuries and time-trends for injuries, as well as assess differences across injury and demographic groups. Data will be drawn from the Bureau of Labor Statistics' Survey of Occupational Injury and Illness (BLS-SOII).
- 2) Assess predictors of which groups of farm workers are covered by insurance, access medical care, report barriers to care, work for contractors and work excessive hours. Data will be drawn from the National Agricultural Workers Survey (NAWS).

3) Estimate disparities and time-trends in disparities between agriculture and all other industries for insurance coverage and physical functioning of persons employed in those industries using the Medical Expenditure Panel Survey (MEPS) and the Health and Retirement Survey (HRS).

4) Estimate current and forecast future costs for occupational injuries and illnesses within agriculture across states.

5) Use the Childhood Agricultural Interview Survey (CAIS) and the National Health Interview Survey (NHIS) to test hypotheses and assess differences across groups.

**METHODS:** Linear regression was used for studies on low wages, Medicaid use, WIC and SNAP participation. Instrumental variables were used in the study on wages and smoking. Attributable risk proportions models were used in the study on the undercount of injuries in agriculture and the study on forecasting autism costs. The difference-in-differences technique was used for the study on nursing injuries.

#### **FINDINGS:**

- Final estimates of participation in the federal Supplemental Nutrition Assistance Program (SNAP), or food stamps program were produced. We found that undocumented households participate at roughly one-third rate as citizens documented households. We also found that undocumented households were far more likely than documented households to increase their participation rate as more children were added to the family.
- Final estimates for participation in Medicaid by authorized and unauthorized households were produced. We found that unauthorized households participate at about half the rate of authorized households and that, again, the unauthorized were more likely to increase their participation with greater numbers of children in the household.
- Final estimates of participation in the federal Women, Infants and Children (WIC) program by authorized and unauthorized farm worker households from the NAWS. We found that unauthorized households participate at almost the same rate as authorized households. We also found that unauthorized households with 2+ children were more likely to participate than authorized households.
- In the study on food stamps, we found that the 2008 financial crisis almost doubled SNAP-participation by agriculture households (6.5% in 2003-2007 vs. 11.3% in 2008-2012). The increasing SNAP-participation was found for citizen, documented and undocumented immigrant households. We found low participation among documented (OR=0.67, 95%CI:0.56-0.8) and undocumented immigrants (OR=0.63, 95%CI:0.54-0.74) compared to citizens. Low odds ratios (OR=0.70, 95%CI: 0.55-0.89) were found for Hispanic-citizens as compared with non-Hispanic white-citizens.
- Paper on low wages points out that the history of occupational medicine has been characterized by ever-widening recognition of hazards from fires to asbestos to job strain. I argue for broadening the recognition further to include low wages, hazards that are pervasive and expanding. Psychosocial and economic hypothesis involve self-esteem, job satisfaction, social rank, deprivation, patience and the ability to purchase health-producing goods and services. Empirical studies rely on large, typically national, data sets and statistical models that use either Instrumental Variables or Natural Experiments and also account for other family income. I draw implications for private firms' pay structures, laws governing minimum wages and labor unions, and high school graduation rates.

- Paper on smoking and wages analyzes nationally representative US data are drawn from the 1999-2009 waves of the Panel Study of Income Dynamics. Our sample is restricted to employed persons, age 25 to 65 who state that they had once been or currently are smokers and includes quitters and backsliders. We use Logit models with random effects, fixed effects, and instrumental variables. We find that low wages are associated with more smoking in both random effects and fixed effects Logit models; the instrumental variable models yield mixed results. In the preferred fixed effects model, a 50% increase in the wage is associated with a 3.65 percentage point decrease in the prevalence of smoking. We further examine sub-samples and find that increasing wages have negative effects on recidivism in the fixed effects and random effects models.

## **CONCLUSIONS:**

In the study on food stamps, our results may help inform the debate surrounding the effects of the financial crisis on SNAP-participation and on differences in participation among citizens, immigrants, Hispanics and non-Hispanics, the latter suggesting ethnic farmworker disparities in SNAP-participation.

Articles on minimum wage and low wages, in general, make the case that low wages ought to be considered job hazards, on par with job strain.

In the study on smoking, the preponderance of evidence suggests that wages are risk factors for smoking prevalence among employed persons who have smoked at some time in their lives.

## **OUTPUTS / OUTCOMES**

### **Publications**

1. Leigh JP, Du J. 2012 Are low wages risk factors for hypertension? *European Journal of Public Health*. 22(6):854-9.
2. Leigh JP, Marcin JP. Workers' compensation benefits and shifting costs for occupational injury and illness. *Journal of Occupational and Environmental Medicine*. 2012 Apr; 54(4):445-50.
3. Leigh JP, Du J, McCurdy SA. 2014. An estimate of the U.S. government's undercount of nonfatal occupational injuries and illnesses in agriculture. *Ann Epidemiol*. 24(4):2549.
4. Leigh JP, Markis CA, Iosif A-M, Romano PS. 2015 California's nurse-to-patient ratio law and occupational injury. *International Archives of Occupational and Environmental Health*. 57(3):329-333.
5. Chung, Y.-K., & Leigh, J. P. (2014). Medicaid Use by Documented and Undocumented Farm Workers. *Journal of Occupational and Environmental Medicine* 57(3):329-333.
6. Du J., Leigh JP, 2015 Effects of wages on smoking decisions of current and past smokers. *Annals of Epidemiology*, 25(8): 575-582.
7. Leigh JP, Medel-Herrero A. 2015. Participation in the Women, Infants and Children (WIC) Program as Reported by Documented and Undocumented Farm Worker Adults in the Households. *Journal of Agromedicine*, 20(4):409-418.
8. Leigh, J. P. (2016). Could Raising the Minimum Wage Improve the Public's Health?. *American Journal of Public Health*, 106(8), 1355.
9. Leigh, J. P., & De Vogli, R. (2016). Low wages as occupational health hazards. *Journal of Occupational and Environmental Health*. 58(5):444-447.
10. Leigh, J. P., Grosse, S. D., Cassady, D., Melnikow, J., & Hertz-Picciotto, I. (2016). Spending by California's Department of Developmental Services for persons with autism across demographic and expenditure categories. *PloS one*, 11(3), e0151970.

11. Leigh, J. P., & Du, J. (2015). Brief report: Forecasting the economic burden of autism in 2015 and 2025 in the United States. *Journal of autism and developmental disorders*, 45(12), 4135-4139.
12. Medel-Herrero A, Leigh JP. 2017. Changing SNAP-Participation Trends among Farmworker Households in the U.S., 2003-2012. *Journal of Immigrant and Minority Health*, in press

### **Media Coverage (Showing 16 out of a total of 33)**

1. News Article: "Fast Food's Biggest Customer: Not the Poor, But the Middle Class" November 7, 2011. Time.  
<http://healthland.time.com/2011/11/07/fast-foods-biggest-customers-not-the-poor-but-the-middle-class/>
2. News Article: "People eat more fast-food as income rises" (<https://www.upi.com/People-eat-more-fast-food-as-income-rises/39271320383932/>)
3. News Article: "Cost of Job-Related Illnesses Exceeds Costs of All Cancers, Diabetes and Strokes" January, 17, 2012. EHS Today.  
<http://ehstoday.com/safety/management/skyrocketing-cost-occupational-injuries-0117>
4. News Article: "Happy Labor Day. Here's the Best Reporting on Worker Safety" August 31, 2012. Pro Publica.  
<http://www.propublica.org/article/happy-labor-day-heres-the-best-reporting-on-worker-safety>
5. News Article: "Is your job killing you?" January 13, 2013. Fox News.  
<http://www.foxnews.com/health/2013/01/11/is-your-job-is-killing/>
6. News article on low wages and high blood pressure garnered some media attention from: the San Diego UnionTribune, Women's Health, Men's Health, Environmental Health and Safety magazine (EHS Today), Consumer Affairs, and numerous European publications including the British Psychological Society Newsletter, UK's Daily Mail, and Irish Health.
7. News Article: Injuries On The Farm Happen Much More Often Than We're Told, NPR (May 2014)
8. News Article: " 77 percent of U.S. ag injuries, illnesses unreported: Study" May 2, 2014. Iowa Farmer Today.  
[http://www.iowafarmertoday.com/news/crop/percent-of-u-s-ag-injuries-illnesses-unreported-study/article\\_a0753bb0-d138-11e3-9639-001a4bcf887a.html](http://www.iowafarmertoday.com/news/crop/percent-of-u-s-ag-injuries-illnesses-unreported-study/article_a0753bb0-d138-11e3-9639-001a4bcf887a.html)
9. Blog post, "Higher Nurse-to-Patient Ratio Law Improves Nurse Injury Rates by One-Third", [http://blogs.cdc.gov/niosh-science-blog/2015/05/May\\_6\\_2015](http://blogs.cdc.gov/niosh-science-blog/2015/05/May_6_2015), 2015.
10. News Article: "'I lost a hand. I didn't lose a hook': Inside the crippling decline of workers' compensation" March 6, 2015, Salon.  
[http://www.salon.com/2015/03/06/i\\_lost\\_a\\_hand\\_i\\_didnt\\_lose\\_a\\_hook\\_inside\\_the\\_painful\\_decline\\_of\\_workers\\_compensation\\_partner/](http://www.salon.com/2015/03/06/i_lost_a_hand_i_didnt_lose_a_hook_inside_the_painful_decline_of_workers_compensation_partner/)
11. News article: "Injured Workers Suffer As 'Reforms' Limit Workers' Compensation ..."New Hampshire Public Radio-Mar 4, 2015 and many other NPR stations.  
<http://nhpr.org/post/injured-workers-suffer-reforms-limit-workers-compensation-benefits>
12. News article: "The Demolition of Workers' Comp: ProPublica/NPR Report", ClaimsJournal.com-Mar 10, 2015  
<http://www.claimsjournal.com/news/national/2015/03/09/262195.htm>
13. News article: The Myth That Links Poor Families to Fast Food (September 21, 2015)  
<https://www.theatlantic.com/national/archive/2015/09/cdc-fast-food-poor-families-american/406447/>
14. News article: Raising worker pay reduces smoking (August 7, 2015)  
<http://fortune.com/2015/08/07/minimum-wages-smoking/>
15. News article: Saving lives with the minimum wage: A different way to think about ...Salon-Aug 3, 2016

16. News article: Sorry, Breitbart: immigrant farmworkers are much less likely to use ... The New Food Economy-Jun 22, 2017

### **Presentations**

1. "Use of Medicaid by documented and undocumented farm worker households." Graduate epidemiology course. UC Davis. January 13, 2014.
2. "Medical costs for underserved populations." Dr. Kruse's course on health care to underserved populations. January 28, 2014.
3. "Cost of occupational injuries on farms." UC Davis Health Services Seminar.
4. "An estimate of the US government's undercount of occupational injuries on farms." UC Davis Health Services Seminar. UC Davis. September 24, 2014
5. "California's nurse-to-patient ratio law and occupational injury" presented to the Wednesday noon seminar for the Center for Healthcare Policy and Research, UC Davis, April 22, 2015

**COMMULATIVE ENROLLMENT TABLE:** N/A

### ***Project 3: Impacts on new caging laws in California on worker health & safety in layer hen facilities***

PI Jerold Last, PhD

**ABSTRACT:** In 2008, California voters passed Proposition 2, which requires that egg-laying hens be confined only in ways that allow these animals to lie down, stand up, fully extend their limbs, and turn around freely. The large quantity of concentrated animal waste produced in such facilities, which currently are envisioned not to have automated waste removal capabilities, raises important issues with regard to worker health and safety. This project compared the toxicity of PM collected from battery, enriched, and free-range (indoor) facilities in mice to determine the potential impact of changes in animal housing on the workers in otherwise similar egg production facilities. These studies demonstrated equivalent toxicity on an equal mass basis for particulate matter (PM) collected in layer hen barns with conventional (battery) or enriched caging, or with free-range confinement indoors. Thus, conventional PM monitoring of indoor air to ensure compliance with OSHA standards should be protective of worker health in any of these types of facilities. However, PM concentrations in free-range barns were much higher than in conventional or enriched facilities, so additional precautions will be required to ensure adherence with OSHA standards in these types of facilities.

**BACKGROUND:** In 2008, more than 8 million California voters passed Proposition 2, which requires that egg-laying hens be confined only in ways that allow these animals to lie down, stand up, fully extend their limbs and turn around freely. The large quantity of concentrated animal waste produced in such facilities raises important issues with regard to worker health and safety. Proposition 2 effectively bans the use of conventional battery cages, which generally include a fully automated conveyer belt system directly under the cages for manure removal. Thus, the egg production industry in California has to adjust to a new set of rules, which require the use of either larger cages (not currently designed for automated manure removal systems) or systems that allow laying hens to range freely over floors of enclosed facilities. The impact of these changes on worker health and safety received no consideration in Proposition 2.

If laying hens range freely within enclosed barns in conformity with Proposition 2, bedding material (e.g., rice hulls) must be used on the floors. Manure, urine, feathers, and other materials produced by the laying hens becomes mixed with the bedding material, which becomes a major source of indoor particulate and gaseous air pollution as it dries, creating a

new source of exposure to toxic materials that presently does not exist for these workers. Bird feces contains uric acid, which is rapidly converted by ubiquitous microorganisms to ammonia (NH<sub>3</sub>), the major noxious gas associated with poultry operations. Ammonia can react with indoor air pollutants to form secondary particulate matter (salts, aerosols) that may be toxic when inhaled.

The emphasis in this project was upon risk assessment (toxicological studies of PM in the barns) within the framework of a before-and-after caging modification study design. We hypothesized that Proposition 2–compliant facilities (especially of the free-range type) would preferentially employ strategies that would increase the levels of particulate matter (PM) pollution in the barns (especially enhanced use of bedding materials on barn floors), and this would be a major source of increased exposure of workers to bioaerosol components and allergens.

**SPECIFIC AIMS:**

1) Quantitatively monitor gaseous and particulate pollutants over several seasons in conventional (battery cage) and Proposition 2–compliant layer hen barns of similar capacity.

2) Quantitatively determine the toxicity and inflammatory activity induced in lungs of mice by instillation of size-fractionated coarse and fine PM.

3) Test workers for allergic sensitization by analyzing blood samples, pulmonary function and physical examination data, and job descriptive data from egg production workers.

4) Develop and implement a new worker health education component to inform workers, owners and managers about the impact of specific emissions on human health and ways to minimize these impacts.

**NOTE:** We were unable to perform several of the proposed experiments due to factors beyond our control (factors keyed to the original Specific Aims):

1) Quantitatively monitor gaseous and particulate pollutants over several seasons in conventional (battery cage) and Proposition 2–compliant layer hen barns of similar capacity.

These studies were performed by collaborators and published independently of my research group. The key results have been included and the relevant publications have been cited in the published paper summarizing our results (Franzi et al., 2017).

2) Quantitatively determine the toxicity and inflammatory activity induced in lungs of mice by instillation of size-fractionated coarse and fine PM.

These studies were performed (and are reported herein) using total suspended particles eluted from air sampling filters, the only PM source made available to us by our collaborators.

3) Test workers for allergic sensitization by analyzing blood samples, pulmonary function and physical examination data, and job descriptive data from egg production workers.

This aim proved impossible to do as the egg production workers at the facility studied (and apparently throughout the industry) move from one type of barn to another through the course of a day's work and are, therefore, not uniquely only exposed to any specific type of layer hen caging.

4) Develop and implement a new worker health education component to inform workers, owners and managers about the impact of specific emissions on human health and ways to minimize these impacts.

The results of our research have been broadly disseminated by publication in the peer-reviewed, open, scientific literature.

**Due to the nature of the collaborations established to accomplish our aims, the specific aims were changed to:**

1. Quantitatively determine the toxicity and inflammatory activity induced in lungs of mice by instillation of PM collected from all three types of layer hen caging.

We succeeded in this goal, as described below.

**METHODS:** Total suspended particulates were collected and mice were exposed under laboratory conditions to each source of particles.

BALB/c mice were intratracheally instilled with known dose(s) of collected particulate matter (PM) to determine the toxicity and inflammatory activity from PM exposure. Inflammatory effects of coarse and fine particulate matter were quantified by lung lavage determination of total and differential cell counts (e.g., neutrophils, macrophages, etc.). Toxicological responses were determined by histopathology of fixed lung sections, immunohistochemistry, and measurement of markers of oxidative stress in the lung lavage fluid.

**FINDINGS:**

- Toxicological studies in mice demonstrate equivalent toxicity on an equal mass basis for particulate matter (PM) collected in layer hen barns with conventional (battery) or enriched caging, or with free-range confinement (indoors).
- However, PM concentrations in free-range barns were much higher than in conventional or enriched facilities, so additional precautions will be required to ensure adherence with OSHA standards in these types of facilities.

**CONCLUSIONS:**

- Conventional PM monitoring of indoor air to ensure compliance with OSHA standards should be able protection of worker health in any of these types of facilities.

**OUTPUTS / OUTCOMES**

**Publications**

1. Franzi LM, Bratt JM, Williams KM, **Last JA**. Why is Particulate Matter Produced by Wildfires Toxic To Lung Macrophages? Toxicology and Applied Pharmacology. 2011, 257(2):182-188. PMID: 21945489

2. Linderholm AL, Franzi LM, Bein KJ, Kent E Pinkerton KE, **Last JA**. A quantitative comparison of intranasal and intratracheal administration of coarse PM in the mouse. *Integrative Pharmacology, Toxicology and Genotoxicology*, 2015, 1(1):2-7.
3. Williams KM, Franzi LM, **Last JA**. Cell-Specific Oxidative Stress and Cytotoxicity after Wildfire Coarse Particulate Matter Instillation into Mouse Lung. *Toxicology and Applied Pharmacology*, 2013, 266:48-55. PMID: 23142465
4. Franzi LM, Linderholm AL, Rabowsky M, **Last JA**. Lung toxicity in mice of airborne particulate matter from a modern layer hen facility containing Proposition 2-compliant animal caging. *Toxicology and Industrial Health*. 2017, *Toxicol Ind Health*. Mar;33(3):211-221. PMID: 26939833

#### **Grants**

1. T32, HL070013-(36-40), NIH, Co-Investigator, Training in Comparative Lung Biology and Medicine, Reen Wu (Principal Investigator), 07/01/2011-06/30/2012
2. D43, 5D43TW005718-10, FIC/NIEHS, International Training Program in Environmental Toxicology and Public Health, 03/01/2011-02/27/2013

#### **Media Coverage**

1. Especialistas extranjeros arriban a Moquegua para informar resultados de analisis de agua en Pasto Grande (Revista Ilo al Dia---Peru)
2. News Article: "UC Davis experts: Wildfires" August 26, 2013. UC Davis News [http://news.ucdavis.edu/search/news\\_detail.lasso?id=10703](http://news.ucdavis.edu/search/news_detail.lasso?id=10703)

**COMMULATIVE ENROLLMENT TABLE: N/A**

### ***Project 4: Rapid assays for human and environmental exposure assessment***

PI: Bruce D. Hammock, PhD

**ABSTRACT:** The translational goal of this project was to develop improved tools for the detection of pesticides in farmworkers and landscape workers, and apply these tools to determine exposure levels. To accomplish this goal, new immunoassays for pesticides used heavily in western states were generated, particularly for the herbicides 2,4-dichlorophenoxybenzoic acid (2,4-D), glyphosate, and paraquat and the insecticides chlorantraniloprole and the class of pyrethroids. These assays complement the over 50 immunoassays for environmental and human contaminants already developed in the laboratory. New immunochemical and sensor technologies to develop improved detection systems for use in the field were implemented. These techniques included a phage displayed peptide based replacement for synthetic haptens, a trivalent phage amplified immunoassay or PHAIA, use of novel camelid antibodies, and the use of novel lanthanide nanoparticles. All of these technologies make field detection faster, more sensitive, robust and cheaper. Quantifying exposures and the education component of the project were completed using a field study with

three distinct populations: farmworkers from the Central Valley of California, landscape gardeners in central California, and bird chasers from Kauai, Hawaii. Nanobodies represent a revolutionary new reagent for immunoassays and will make high throughput lab monitoring of pesticides and worker exposure as well as field assays faster, more sensitive and cheaper.

**BACKGROUND:** When used properly, pesticides are considered safe, yet pesticide exposure ranks among the greatest health concerns of farmers and farmworkers, as well as the general public. The farmworker population may have greater risks both through their occupational exposure and exposures associated with living in an agricultural area, often in substandard housing. In addition, individuals who engage in home landscaping and gardening services may also have higher pesticide exposure.

To assess exposures, studies must be conducted that often yield a large number of samples for analysis, or require on-site analysis. The cost of analyzing large sample sets can be high and field portable tests are not available or of sufficient sensitivity and ruggedness, thus limiting the scope of most exposure studies. Immunoassays are characterized by their speed, sensitivity, throughput and low cost, which is underscored by their long history of use in clinical analysis and diagnosis. The assays are also adaptable to field portable formats for measuring pesticides, hormones, food toxins and viruses and bacteria.

The purpose of this project was to portable, easy-to-use, sensitive and rugged on-site tests for pesticide exposure. This project explored three novel technologies — phage displayed peptides, single domain recombinant heavy chain antibodies (sdAbs) derived from camelids, and gold coated magnetic luminescent nanoparticles — to improve laboratory and field portable immunoassays.

If workers are able to get a better understanding of the relationship between activities and resulting pesticide exposures through use of a rapid on-site assay method (before and after pesticide application), they may be more likely to do self-protective behaviors. It may also motivate them to obtain additional pesticide education.

**SPECIFIC AIMS:**

- 1) Develop, validate and implement new immunoassays for heavily used and emerging pesticides.
- 2) Develop and implement new technologies resulting in immunoassays for human pesticide exposure of improved sensitivity, speed, portability and reproducibility.
- 3) Quantify exposure in workers who apply pesticides, using field-testing techniques and by analyzing samples in the laboratory.
- 4) Determine the effectiveness of using field-testing techniques to improve pesticide education.

**METHODS:** The project explored developing portable immunoassays with three novel technologies — phage displayed peptides, single domain recombinant heavy chain antibodies (sdAbs) derived from camelids, and gold coated magnetic luminescent nanoparticles. Assays were developed to detect urinary metabolites indicative of pesticide exposure, such as from glyphosate herbicide and synthetic plant growth regulator trinexapac-ethyl.

Once the assays were developed, participant groups were recruited for the study: landscape workers and agricultural workers from the Central Valley of California, and a small population in Hawaii. Landscape workers often have little formal training in pesticide safety, and exposures among this group are largely unknown. Agricultural workers are exposed to larger amounts of pesticides but generally have some level of training. The seed corn industry in Hawaii employs agricultural workers that typically sit in lawn chairs, and under beach umbrellas in newly planted seed cornfields to prevent birds from consuming the seeds. Thus, bird chasers are exposed in the field to pesticides.

Pesticide exposure was monitored through both a dermal wipe and metabolite/parent compound levels in the urine of participants, providing information on the temporal variability in exposure levels. Two samples were collected prior to pesticide training and two after.

Participants were interviewed by field staff about exposure to pesticides prior to receiving exposure results. They were then given their exposure data. Information based on the activities they completed that day was discussed to help them reduce future pesticide exposure.

#### **FINDINGS:**

- The project has developed highly sensitive urine assays for herbicide, 2,4-D, and pesticide, fipronil, both having a limit of detection of approximately 0.1 ng/mL.
- Urine was collected from 33 individuals who worked in farm, landscape, and greenhouse settings in California. A significant difference in urinary detection of glyphosate herbicide was found between those who reported applying the pesticide versus those who did not. Thus, participants learned they needed to take greater precaution when applying herbicides.
- Golf course workers applying the synthetic plant growth regulator trinexapac-ethyl in Hawaii were found to have detectable levels of the chemical on their head, chest, back, upper arms, thighs, shins and hands following application. Again, participants learned they needed to take greater precaution and use better techniques to lower their exposure risk.

**CONCLUSIONS:** Historically, to assess pesticide exposures, studies must be conducted that often yield a large number of samples for analysis, or require on-site analysis. The cost of analyzing large sample sets can be high and sufficient sensitivity is a concern. Immunoassays, as developed through this project, are valuable laboratory and portable field tests for monitoring worker exposure and insuring safe handling of pesticides. The technology makes field detection faster, more sensitive and cheaper, thus helping to make worker safety more attainable. In addition, the assays developed through this project add to the number and variety of immunoassays that can be utilized by researchers for both human and environmental exposure assessment. They contribute to the body of knowledge that provides guidance to educators to inform the participant population about pesticide use and how to avoid or minimize exposures. This information informs regulators to develop or modify pesticide use in occupational settings.

#### **OUTPUTS / OUTCOMES**

**Publications** (Showing 15 out of a total of 39)

1. Ahn, K.C., H-J. Kim, M.R. McCoy, S.J. Gee and B.D. Hammock. 2011. Immunoassays and biosensors for monitoring environmental and human exposure to pyrethroid insecticides. *J. Agric. Food Chem.* 59(7):2792-2802. PMID: PMC3070843
2. Kim, Y.A., E.H. Lee, K.O. Kim, Y.T. Lee, B.D. Hammock and H.S. Lee. 2011. Competitive immunochromatographic assay for the detection of the organophosphorus pesticide chlorpyrifos. *Anal. Chim. Acta* 693(1-2):106-113. PMID: PMC3927651
3. B.D. Hammock. 2012. Isolation of alpaca anti-hapten heavy chain single domain antibodies for development of sensitive immunoassay. *Anal Chem.* 84(2):1165-71.
4. B.D. Hammock, M.B. Schenker. 2013. Pyrethroids in house dust from the homes of farm worker families in the MICASA study. *Env. Int.* 61C:57-63.
5. Kim, H.J., M. McCoy, Z. Majkova, J. Dechant, S.J. Gee, S. Tabares-da Rosa, G.G. Gonzalez-Sapienza and B.D. Hammock. 2012. Isolation of alpaca anti-hapten heavy chain single domain antibodies for development of sensitive immunoassay. *Anal Chem.* 84(2):1165-71. PMID: PMC3264785
6. Hammock. 2012. An enzyme-linked immunosorbent assay for detecting 3-phenoxybenzoic acid in plasma and its application to farmers and consumers. *Anal. Meth.* 4:3772-3778 (2012).
7. Hammock. 2013. Determination of the pyrethroid insecticide metabolite 3-PBA in plasma and urine samples from farmer and consumer groups in northern Thailand. *J. Environ Sci Health B.* 49:15-22.
8. Trunnelle, K., D.H. Bennett, D.J. Tancredi, S.J. Gee, M.T. Stoecklin-Marais, T.E. Hennessy-Burt, B.D. Hammock, M. B. Schenker. 2013. Pyrethroids in house dust from the homes of farm worker families in the MICASA study. *Env. Int.*
9. Hua X, Yin W, Wang H, Wang Y, Kim HJ, Gee SJ, Wang M, Liu F, Hammock BD. Development of phage immuno-loop-mediated isothermal amplification assays for organo phosphorus pesticides in agro-products. *Anal Chem.* 2014;86:8441-8447. PMID: PMC4139188.
10. Trunnelle KJ, Bennett DH, Ahn KC, Schenker MB, Tancredi DJ, Gee SJ, Stoecklin-Marais MT, Hammock BD. Concentrations of the urinary pyrethroid metabolite 3-phenoxybenzoic acid in farm worker families in the MICASA study. *Environ Res.* 2014 May;131:153-9. doi: 10.1016/j.envres.2014.03.003. Epub 2014 Apr 11. PubMed PMID: 24721133
11. Wang J, Bever CR, Majkova Z, Dechant JE, Yang J, Gee SJ, Xu T, Hammock BD. Heterologous antigen selection of camelid heavy chain single domain antibodies against tetrabromobisphenol A. *Anal Chem.* 2014 Jul 28. [Epub ahead of print] PubMed PMID: 25068372.
12. Vasylieva N, Ahn KC, Barnych B, Gee SJ, Hammock BD. 2015. Development of an immunoassay for the detection of the phenylpyrazole insecticide fipronil. *Environ. Sci. Technol.* 49:10038-10047. PMID: 26196357

13. Wang J, Majkova Z, Bever CRS, Yang J, Gee SJ, J. Li, T. Xu, Hammock BD. 2015. One-step immunoassay for tetrabromobisphenol A using a camelid single domain antibody-alkaline phosphatase fusion protein. *Anal Chem.* 87(9):4741-48. PMID:PMC4476793

14. Rossotti, M. A., Pirez, M., Gonzalez-Techera, A., Cui, Y., Bever, C. S., Lee, K. S., Hammock, B. D.,... & González-Sapienza, G. (2015). Method for sorting and pairwise selection of nanobodies for the development of highly sensitive sandwich immunoassays. *Analytical chemistry*, 87(23), 11907-11914..

15. Hua, X., Zhou, L., Feng, L., Ding, Y., Shi, H., Wang, L., Hammock, B. D.,... & Wang, M. (2015). Competitive and noncompetitive phage immunoassays for the determination of benzothiostrubin. *Analytica chimica acta*, 890, 150-156.

## **Grants**

N/A

## **Media Coverage**

1. News Article: "Headaches, Heart Disease, Stroke; Can Aspirin Prevent Cancer, Too?" July 15, 2013. KQED. <http://blogs.kqed.org/stateofhealth/2013/07/15/headaches-heart-disease-stroke-can-aspirin-prevent-cancer-too/>

2. News Article: Dispute aired over Sacramento County spraying of West Nile-targeting pesticide, (July 22, 2014) Sacramento Bee, <http://www.sacbee.com/news/local/health-and-medicine/article2604501.html>

3. News Article: "Worst Outbreak Ever of West Nile Virus in California" <http://www.allgov.com/usa/ca/news/controversies/worst-outbreak-ever-of-west-nile-virus-in-california-140905?news=854168>

## **Presentations**

1. March 17, 2013. "Immunoassay for Human/Environmental Exposure Assessment" presented at the Pittsburgh Analytical Conference (PittCon 2013) Philadelphia, PA.

2. Sep 20, 2014. Participated at the Fiesta Educativa- a community health fair organized by a local group in Sacramento to educate farm workers about pesticide exposure and recruit them to participate in an exposure study.

3. Jan 31, 2015. Location: UC Davis. Event: Women of Color Academic Summit hosted by Women's Resources and Research Center. Title: Pesticide exposure to landscape and agricultural workers in the Napa, Davis, and Sacramento areas.

4. February 4, 2015. Location: Woodland, CA. Event: Spray Safe hosted by Yolo County Farm Bureau.

5. February 18, 2015. Location: UC Davis. Event: Agricultural and Environmental Chemistry Graduate Group Winter Colloquium.

COMMULATIVE ENROLLMENT TABLE: N/A

***Project 5: Reducing the risk of heat-related illness (HRI) in western agricultural workers***

PI: Marc Schenker, MD, MPH

**ABSTRACT:** Although the major environmental and personal risk factors for heat-related illness (HRI) are known and California regulations have been enacted to protect workers, deaths and significant numbers of HRI continue to occur, particularly in agriculture. There continue to be many uncertainties surrounding factors that place workers at risk for HRI and employers' ability to utilize risk reduction strategies for worker protection. Missing from most occupational studies on factors contributing to HRI are considerations of the metabolic heat load from working in diverse agricultural environments, and the socio-cultural factors affecting the mostly immigrant workers' work practices/behaviors. Without thorough understanding of these aspects, effective strategies to reduce agricultural HRI are diminished. This multidisciplinary research project brought together investigators from medicine, epidemiology, public health, physiology, anthropology and community outreach/education uniquely positioned to address HRI in agricultural populations. The goal of this project was to obtain physiologic data on internal body temperature as it relates to work practices and geography, external heat and internal metabolic loading, including accounting for work type and personal factors. Using an innovative approach, we obtained critical information on worker knowledge, work practices and social-cultural issues that impact individual decisions with regard to HRI prevention. The information was used to develop protective strategies to be translated and broadcast through WCAHS' outreach and education programs.

**BACKGROUND:** Although the major environmental and personal risk factors for worker HRI are known and California regulations have been enacted to protect workers, deaths and significant numbers of HRI continue to occur, particularly in agriculture. Factors related to high morbidity and mortality rates in farmworkers due to heat exposure are varied, but include the exemption of agriculture from some regulatory oversight resulting in reduced enforcement, immigration status of workers, and the basic need for economic survival experienced by low-wage farmworkers.

California agricultural laborers can significantly elevate their metabolic heat load while working during peak summer heat. Because of the body's need to sweat profusely to increase evaporation and dissipate high heat loads, workers may become transiently dehydrated. This combination puts these individuals at increased risk of developing heat stress and hyperthermia. Meanwhile, peak summer heat coincides with peak harvest season, and the pressure to collect perishable produce counteracts the natural tendency to rest and seek shade.

For heat-stress interventions targeted to farm laborers to be successful, it is critical to obtain a better understanding of workers' knowledge and the diverse factors that prevent them from protecting their health and lives. Therefore, the goal of this project was to obtain data on broad community experiences of HRI, including farmworker, farmer and other involved stakeholder perspectives. Key informant interviews and guided conversations in focus groups allowed community participants to discuss their actual experiences in a relaxed manner. At the same time, this qualitative data generated hypotheses and identified potential solutions. The collected

information was used to answer questions concerning work practices and cultural issues that impact a worker's decisions with regard to heat illness prevention. On-farm barriers to the adoption of heat illness protective strategies were also identified.

**SPECIFIC AIMS:**

1. Increase understanding of the physiological responses to increased environmental heat and physical exertion among farmworkers through the analyses of personal characteristics, monitors and sensors, and use the protocols developed to generate and validate risk models.
2. Examine socio-cultural perspectives of HRI using focus groups and key interviews, and identify barriers to adoption of prevention strategies and potential solutions acceptable to all parties.
3. Assess normal practices of farmworkers that impact HRI risk using epidemiological techniques.
4. Increase awareness of HRI as a credible personal risk to farmworkers, and translate project findings into HRI prevention strategies throughout the western states. (See Outputs/Products)

**METHODS:** The external and internal heat loads to which agricultural workers in the California Central Valley are exposed during the summer work season and the effects these have on the risk of developing hyperthermia were assessed. The California Heat Illness Prevention Study (CHIPS) recruited workers from multiple work settings to span the broad range of thermoregulatory challenges that Central Valley work environments pose — from low-growing row crops to orchards with a canopy. Labor-intensive crops were targeted. Each participant contributed physiological data over the course of one work day. The measures included core body temperature from an ingested sensor, heart rate, activity counts from an accelerometer, and hydration from change in weight and in blood osmolality across the shift. Other measurements included ambient temperature and subjective assessments from questionnaires conducted by bi-lingual and bi-cultural student interviewers (Spanish speaking, Latino culture). Qualitative data on broad community experiences with HRI, including farmworker, farmer and other involved stakeholders, were obtained from targeted interviews and focus groups. Participants were asked to identify perceptions of risk related to HRI, barriers to HRI prevention, and work practices/habits/cultures that may play a part in moderating the risk.

Combining these qualitative and quantitative findings, outreach personnel created focused educational materials and applied training techniques to address the risk factors for HRI identified by research. A tool kit including basic physiology, requirements and practical solutions was created for employers.

**FINDINGS:** The center grant funded 320 farmworker assessments of risk of HRI; we received a supplemental grant (R-01OH010243) that allowed an enrollment of 367 extra workers, wider geographical recruitment and additional physiological and socio-behavioral assessments.

SA 1: Physiological aims: Generalizability of the sample. We compared the demographics of our farmworkers to the latest National Agricultural Worker Survey (NAWS) random sampling of crop workers in California. Although CHIPS conducted a convenience sampling of farms and their workers, the demographics did not vary significantly from the NAWS. The mean age of a farmworker was 39 years, 34% were female, and the sample was overwhelmingly Latino, with lower educational experience.

Risk of HRI. We used the ACGIH definitions of HRI risk for elevated body temperature and dehydration: a core body temperature of  $\geq 38.5^{\circ}\text{C}$ , or a sustained heart rate of  $180 - [\text{age in years}] \text{ bpm}$  for  $\geq 5$  minutes. For dehydration: a decrease in weight over a day of  $\geq 1.5\%$ .

Eight percent of the participants experienced elevated body temperature, and 18% of the workers were stressed, according to the heart rate criterion; 3.5% were categorized by both measures of heat strain. Despite  $< 2\%$  being classed as dehydrated at the start of their shift, 11.8% became dehydrated compared to their starting weight. Using the NHANES classification of activity levels (inactive, sedentary, light, moderate, vigorous), we determined that the mean farmworker activity level was only in the light category.

In a multiple variable linear regression model, we used the maximum of a 3-minute moving mean core body temperature as the outcome. Only dehydration and work activity were significantly associated with core body temperature. Included in the model, but not associated significantly with body temperature were the ambient maximal temperature, gender, clothing, age and shift length.

In a multivariable logistic regression model, the odds of experiencing a core temperature  $\geq 101^{\circ}\text{F}$  ( $38.33^{\circ}\text{C}$ ) was significantly increased for irrigation workers OR (95% CI) 2.37 (1.07 – 5.15). In a separate model with activity level rather than task, a dose-response was seen for increasing time in the moderate / vigorous activity level with  $\geq 90$  minutes registering an OR (95%CI) of 6.57 (2.45 – 10.8). Both models included age, gender and ambient temperature. Acute kidney injury (AKI) was assessed in the summer of 2014. Twelve percent of workers suffered AKI as defined by changes in serum creatinine. The risk of AKI was independently associated with heat strain (core temperature and heart rate) and whether the worker was paid by the piece.

SA 2: Socio-cultural perspectives on the risk of HRI from employers and employees: Focus groups (12) and key interviews (50) were conducted from 2013 to 2016 by the California Institute for Rural Studies (CIRS). We found that water consumption, which is promoted by California regulations, is not the drink of choice (energy giving beverages are preferred). There are cultural beliefs that counteract drinking cold water when hot. Although workers prefer piece rate to maximize earnings, the incentive undercuts self-protective measures such as reducing work intensity or taking a rest, even if workers experience HRI symptoms. Women are more likely to identify early stages of HRI symptoms, and there is a difference between the sexes in risk perception, work rate and motivation. Most workers prefer interactive, cooperative learning styles for the mandatory HRI prevention training, including audio and video rather than printed materials and text. As most workers have not received more than a 6th grade education, training should be targeted with lower literacy in mind. Management style is very important and influences the ability of workers to make wise safety decisions. In particular the foreman/woman's attitude and level of enthusiasm when promoting or advocating breaks for rest, shade or drinking affect the behavior of their supervisees. A complex interaction of pay structures, employer relations and the perception of workers' control over their work environment affect their willingness to adhere to training messages.

SA 3: Knowledge of risk factors and safe hydration practices were found to be low in both the CHIPS and the MICASA cohort studies although nearly 100% said they had received HRI prevention training. Less than 38% of CHIPS participants knew they should drink 3 or more cups of water per hour in the heat, and under 30% knew that in general it takes a person 2-14 days to acclimate to hot weather. Although 97% of CHIPS participants believed they drank enough to be safe over the work day, 73% felt thirsty to extremely thirsty at work. Only 43% had any concern about HRI at work, but at least 65% pushed themselves relatively frequently to work faster to keep up with coworkers.

## **CONCLUSIONS:**

In our convenience sample of farms throughout California, we assessed a generalizable population of Latino farm workers. It is possible that we were more likely to access farms with good labor practices, but we have no way to judge this.

We determined the main physiological risk factors for increased core body temperature (heat strain,  $\geq 38.5$  °C) were dehydration (loss  $\geq 1.5\%$  body weight) and protracted periods of moderate to vigorous activity. This would describe the work of irrigators and some harvesting categories when working on a piece rate. Neither gender, age or maximum environmental temperature appears to significantly increase the risk of HRI. Similarly, risk of AKI was independently associated with heat strain and piece rate work. Approximately 17% of participants exhibited sufficiently elevated core body temperature and/or dehydration to put them at risk of HRI symptoms. Although both employer and employee benefit economically from piece rate incentives, they are a contributor to the risk of HRI in agricultural work.

Workers are not learning or remembering and practicing safe HRI prevention methods, and in general do not see themselves at risk of HRI even if they have had previous symptoms of HRI. Current HRI prevention training is not achieving the aim of reducing the risk of HRI to negligible levels. New methods are needed to engage the workers actively as participants in their own education. Educators must acknowledge the high rate of illiteracy and de-emphasize printed materials, which use text and passive reading as the primary method of informing the worker. Materials must also address cultural biases against cold water and have different emphases for men and women. The employer also needs to be engaged in HRI prevention and ensure their supervisors are supportive of worker protections and advocate breaks for drinking and rest.

## **OUTPUT /OUTCOMES:**

SA 4 (Improved HRI prevention training) was designed to implement the findings and conclusions of the integrated study.

New, more interactive heat illness prevention trainings for Californian farm workers were created, specifically to encourage workers to maintain their hydration, critical to both kidney health and to keep core body temperature under control (within 1 °C of normal body temperature). These trainings have been piloted at a variety of farms and positively evaluated by follow-up discussions after a few months to assess retention and application. Information from these in-field trainings are contained in the below outputs.

A new train-the-trainer program was developed using the integrated information from focus groups, the physiological study, and key interviews. This program was created to increase capacity of the HRI prevention trainings, multiplying the audience on average by 20 for every supervisor/*majordomo* attending the half-day program.

- Each attendee learned the necessary information, regulations and requirements of the Cal-OSHA standard and how to create a heat illness prevention plan as part of their required farm or company's illness and injury prevention plan.
- A PowerPoint presentation was developed for this training session where, through group and individual activities, the attendees learned how to train their supervisees, including how to make that training memorable and participatory. They discussed how to evaluate whether their workers understood and retained the messages, how to reinforce the themes throughout the summer, and further encourage workers to practice safety in the heat.
- Each attendee received a workbook with the exercises, information and contacts for the WCAHS heat illness prevention team and where to find further resources, such as videos and other materials.

These materials and trainings were piloted in the Central Valley of California with 38 supervisors participating. The contents are still under revision and will be published in Spanish and English on the WCAHS web site. WCAHS outreach delivered 11 trainings of HRI prevention in 2014-2016 (including at pesticide training workshops) throughout California, reaching over 170 supervisors and workers. The study was also publicized on National Public Radio – KVPR Central Valley on October 13, 2015. Study findings, presentations and relevant heat illness prevention information can be found in Spanish and English at: <http://chips.ucdavis.edu/index.php>

#### **Papers published:**

1. Stoecklin-Marois MT, Hennessy-Burt T, Mitchell D, Schneker MB “Heat-related illness knowledge and practices among California hired farm workers in the MICASA study.” *Industrial Health*. 2013; 51: 47-55.
2. Courville, MD, Wadsworth G, Schenker MB. “We just have to continue working”: Farmworker self-care and heat-related illness. *J Agriculture, Food Systems and Community Development*. <http://dx.doi.org/10.5304/jafscd.2016.062.014> pp. 143–164 Published online March 2, 2016
3. Moyce S, Joseph J, Tancredi D, Mitchell D, Schenker MB. “Cumulative Incidence of Acute Kidney Injury in California’s Agricultural Workers”. *J. Occupational and Environmental Medicine* . 2016; 58 (4): 391-7.
4. Moyce S, Mitchell D, Armitage T, Tancredi D, Joseph J, Schenker MB. “Heat Strain, Volume Depletion and Acute Kidney Injury in California Agricultural Workers”. *Occupational and Environmental Medicine* Jun 2017, 74 (6) 402-409;
5. <sup>1</sup>Mitchell D, Castro J, Armitage T, Vega-Arroyo A, Moyce S, Tancredi D, Bennett D, Jones J, Kjellstrom T, Schenker MB. “Recruitment, Methods, and Descriptive Results of a Physiologic Assessment of Latino Farmworkers: the California Heat Illness Prevention Study (CHIPS). *J. Occupational and Environmental Medicine*. 2017; 59 (7): 649-58.

#### **Selected Posters and Talks:**

1. “Climate Change and Occupational Heat Stress”. Schenker, MB. UC Berkeley Guest speaker Class on Global Health. April 30, 2015.
2. “Cumulative Incidence of Acute Kidney Injury in California’s Agricultural Workers”. International Workshop on Mesoamerican Nephropathy, San Jose, Costa Rica, November 18-20, 2015.
3. “Risk of Dehydration: California Latino Farmworkers’ Knowledge and Actions Taken to Prevent Dehydration” Schenker MB. EPICOH September 5-8, 2016, Barcelona.
4. “Heat Strain, Volume Depletion and Kidney function in California’s Agricultural Workers”. Moyce S. EPICOH September 5-8, 2016, Barcelona
5. “Risk of HRI in California Latino Farmworkers: Quantitative and Qualitative Findings”. Schenker MB. PNASH Webinar May 25, 2017.
6. “HRI: Gender Differences in Hydration Practices and Risk in Latino Farmworkers (CHIPS)”. Schenker MB. EPICOH 2017, Edinburgh August 28-31st.
7. <sup>2</sup> “Heat Related Illness in Latino Agricultural workers: Core Body Temperature and Work Task” Javier Castro, EPICOH 2017, Edinburgh August 28-31st.

**COMMULATIVE ENROLLMENT TABLE:** See next page

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<sup>1</sup> Manuscript won an International Society for Agricultural Safety and Health award June 28, 2017.

<sup>2</sup> Poster won the Best poster by an early career researcher, EPICOH 2017 Conference.

## Cumulative Inclusion Enrollment Report

This report format should NOT be used for collecting data from study participants.

**Study Title:** Reducing the risk of heat-related illness in western agricultural workers Project 5

5U54OH007550

**Comments:** Includes all enrollments - years 2012, 2014, 2015

Racial Categories	Ethnic Categories									Total
	Not Hispanic or Latino			Hispanic or Latino			Unknown/Not Reported Ethnicity			
	Female	Male	Unknown/Not Reported	Female	Male	Unknown/Not Reported	Female	Male	Unknown/Not Reported	
American Indian/Alaska Native				5	12					17
Asian										0
Native Hawaiian or Other Pacific Islander										0
Black or African American										0
White				83	220					303
More Than One Race										0
Unknown or Not Reported										0
<b>Total</b>	0	0	0	88	232	0	0	0	0	320

## ***Project 6: Effects of ladder rung spacing on agricultural workers***

PI: Fadi Fathallah, PhD

**ABSTRACT:** The main goal of the proposed research was to develop an alternative ladder or set of ladders designed to better suit the anthropometry of specific worker populations, with the ultimate objective of reducing the number of falls from ladders in orchards. With a research design focused on optimum rung spacing, an improved orchard ladder is expected to reduce worker force exertions, fatigue, and self-reported pain, as well as a potential increase in worker stability during climbing activities or unexpected ladder movement or foot slippage. This research found that reduced spacing between rungs of orchard ladders is preferred. No human subjects in this study selected the standard 12-inch spacing when provided a choice among identically new ladders with the standard 12-inch and non-standard 11.5, 11, 10.5, and 10 inch spacing. One half of the subjects chose the 11-inch design as preferred, and one quarter chose the 10.5-inch design. Heart rate data and Borg Rating of Perceived Exertion data were consistent with this finding favoring a shorter spacing design. The trials included positioning the ladder at standard and shallower angles. The subjects also preferred the shallower angles, and this was consistent with the heart rate and perceived exertion data. Two California manufacturers made the non-standard primary orchard (or tripod) ladders using the Special Purpose ladder exemption, with one creating new model numbers for the products. One commercial grower purchased a number of the ladders with shorter rungs. Although a biomechanical model derived optimum spacing for an alternative ladder to the standard design was not conclusive, the data suggest that a single ladder alternative with 11-inch rung spacing would be preferable to many workers in the industry. This could be particularly helpful to the aging agricultural workforce and also to the general industry, landscaper, and home do-it-yourself communities.

**BACKGROUND:** The annual rate of injury due to falls from ladders is alarming in both occupational and non-occupational settings across all age groups. In California, there are about 600,000 acres in tree fruit orchard production with a labor force of about 50,000 workers. According to data made available by a major California worker's compensation insurance carrier, falls in orchard work constitute among the highest number of claims and represent the largest percentage of total claims cost.

Although previous work on ladder rung spacing has been done for over nearly three decades, a review of the literature suggests that the lack of a successful alternative spacing may be due to those studies' arguably extreme dimensional differences that essentially are self-defeating. When taking into account that the standard rung spacing is twelve inches, those studies' alternative spacing of 8 inches, 14 inches, or 15 inches represents too large a differential that was perhaps selected in the interest of ensuring a response difference. Ergonomics work often relies on modest adjustments to tools and equipment to improve fit with the worker.

### **SPECIFIC AIMS:**

- 1) Develop a biomechanical simulation model that predicts optimum ladder rung spacing based on individual and workplace characteristics, including worker anthropometry, posture and motion, muscle force generating capacity, harvest container, and tree characteristics.
- 2) Conduct a lab-based study to validate and refine the biomechanical model using motion capture technology, lumbar motion tracking instrumentation, electromyography, and heart-rate based metabolic measures.

3) Conduct a season-long field trial to perform additional model validation, using comprehensive demographic, anthropometric, posture and motion data, and worker adoptability and health outcome measures.

NOTE: We were unable to meet the timing window for the hourly harvest workers that we planned to work with. Because the ladders with shorter spacing are heavier due to one or more extra rungs, the ladders would have faced a much steeper adoptability threshold in a piece rate environment in other crops, especially where the ladders are taller than the 10-foot style we were working with in hourly harvest commodities, such as peaches and nectarines. Ongoing graduate student efforts in the ladders area will continue the predictive model and field work based on closer scrutiny of the lab study data.

4) Obtain regulatory variances or standards revisions that will lead manufacturers to build and market ladders with shorter rungs and growers to use alternative ladders for their operations, with the applications likely spreading to the general industry and homeowner products.

#### **METHODS:**

The project used data from existing anthropometric literature and basic anthropometry derived from a pilot study as inputs to the AnyBody Modeling System software package to calculate joint forces, moments and angles for different postures with different ladder rung spacing.

The data collection included practice climbing all five ladders at the three different angles before data collection to help the subjects orient their motor and coordination capabilities. The actual instrumented data collection included five ascent/descent of five rungs on each of the five ladders (12, 11.5, 11, 10.5, and 10 inch spacing), each at a three different angles (72, 68, and 64 degrees), with adequate sit/stand rest in between each of the 15 trials. The resting period allowed heart rate to recover, and the researchers to reconfigure the ladder and/or angle for the next trial. The angles included the ladder design angle, a typical shallower in-field use angle, and an even slightly shallower typical in-field use angle. The ladders were secured to a calibrated base that allowed for the different angles to be established quickly and precisely. The subjects each had a random sequence of rung spacing and ladder angle. Besides the instrumented data collection, the subjects provided a Borg Rating of Perceived Exertion (RPE) for each ladder. After instrumented data collection, and subsequent de-instrumentation including usually a bathroom break, each subject was asked to try the ladders in a comparison alignment from shortest to standard rung spacing and various angles. The subject was asked to rank the top three rung spacing/ladder angle combinations.

Subject-specific anthropometry was entered into the predictive model. Outputs were compared to lab study electromyography.

#### **FINDINGS:**

The laboratory study collected heart rate, electromyography, perceived rating of exertion, 3D kinematics, anthropometric measures, and ladder design ranking data from twelve subjects (9 male, 3 female) who each participated in a 3-hour data collection protocol. The subjects were in healthy condition, ranging in age from 19 to 56 (mean 29, median 26), and who indicated they climbed ladders at work or at home somewhat regularly. No subject selected the standard 12-inch ladder at any angle, one selected the 11-1/2 inch ladder among their top three, one half selected the 11-inch spacing at the middle angle as their top choice, and one quarter selected the 10-1/2 inch design. These results are consistent with earlier pilot work in the field during

actual harvest, in terms of strong interest in a ladder with shorter rungs, and the 11-inch spacing being particularly attractive.

The electromyography and motion data showed trends favoring shorter rung spacing, however, they did not provide conclusive guidance for an optimum spacing. The anthropometric data also did not provide conclusive guidance for an optimum spacing. Using various factors to help narrow the model's recommended spacing, we saw confounding factors that could not be resolved to a reasonable point for a single alternative spacing. Ultimately, the decision was made to perform the lab study using a standard ladder and four others with incrementally shorter spacing. The standard ladder has a 12-inch spacing, and the alternative spacings were 11-1/2 inches, 11 inches, 10-1/2 inches, and 10 inches. One of the major ladder manufacturers was willing to custom fabricate these as official products for us to use in any of our work.

The all-subjects all-trials average increase in heart rate was the lowest for the 10-1/2 inch spacing at 64 and 68 degree angles (Figure 1a).

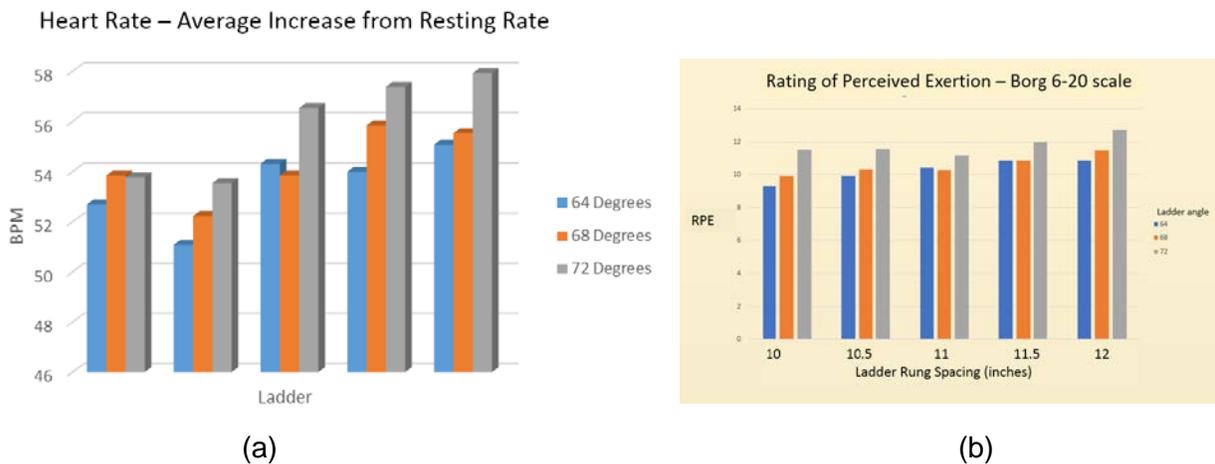


Figure 1. Heart rate increase (a) and RPE (b) for each ladder and angle combination.

The all-subjects all-trials average RPE (Figure 1b) was consistent with the preference rankings. The chart below indicates the high levels for the 72 degree orientation and for the 12-inch ladder. There is a drop-off for the 11-inch spacing even for the 72 angle. The 11-inch spacings level is lowest for any of the ladders at the 72 degree angle

Figure 2 summarizes the preferred ladder rung spacing and ladder angle orientation by the 12 subjects. None of the subjects preferred the standard 12-inch ladder, and only one preferred the 11-1/2 inch design. Six preferred the 11-inch, three preferred the 10-1/2 inch, and two preferred the 10 inch design. No subject chose the standard 72 degree ladder angle as preferred, indicating that not only ladder rung spacing but also ladder angle is an opportunity for improvement.

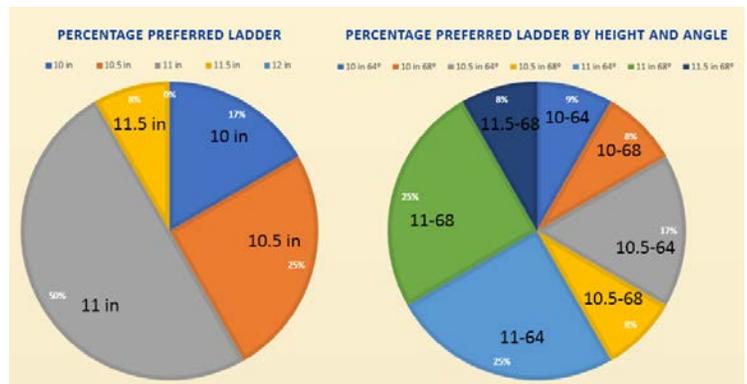


Figure 2. Subject preferred ladder (right) and ladder/angle combination (left)

Although we were not able to pursue regulatory variances at this time for general industry/home stepladders (typical four-legged style), the interest and follow through of the major orchard ladder manufacturers using the Special Purpose regulatory designation was successful, including sale of shorter rung space ladders to a grower who learned about the work at one of our California Ag Leadership Foundation Fellows presentations. Although the current project was unable to determine a single alternative rung spacing, this is an important direction of research and potential impact especially for our aging work force.

Based on the orchard ladder research by our group, including this study on ladder rung spacing, California's two manufacturers of orchard ladders, Stokes Ladders and Strathmore Ladder, made ladders with shorter rungs with full company decals, and Strathmore added product model numbers for the special rung spacings. The two companies supply most of the industry in California, with a third competitor being Tallman Ladder from State of Washington. Stokes Ladders are commonly found in Tractor Supply Company stores, a major farm supply chain. These ladders are also used by landscape industry.

We have previously and plan to continue to reach out to the American Ladder Institute, which is the secretariat for the ANSI standard on ladders. This includes potential collaboration on an orchard ladder module to join their existing training modules and to promote this research's findings in an effort to modify existing ladder standards currently set at 12 inches spacing.

### **CONCLUSIONS:**

Portable tripod ladders, also known as orchard ladders, utilize the same standard rung spacing of 12 inches as do all portable ladders including four-legged stepladders and various extension ladders. The 12 inch standard goes back to the beginning of the American National Standards Institute ladder standard where the spacing was specified as "one foot." Two of the main California tripod ladder manufacturers are willing to manufacturer custom spaced ladders using the Special Purpose Ladder exemption, including full company decals and in one case new model numbers. Although predicting the optimum rung spacing based on a person's anthropometry was unsuccessful in this project, none of the subjects preferred the standard 12-inch rung spacing at any angle. We conclude that shorter rung spacing and shallower angles for orchard ladders would be well received by workers. Furthermore, the 11-inch design would be most appropriate because one half of the projects subjects preferred it, and almost the entire other half preferred even shorter spacing. The 11-inch design, especially in the typical 10-foot height for stonefruit, results in only one additional rung, which minimizes the ladder weight increase. The project's findings also suggest that there would be interest in general industry step ladders with shorter rung spacing and a shallower angle.

### **OUTPUTS / OUTCOMES**

#### **Publications**

1. Duraj, V., Hunter, T., Fathallah, F. (2017). Adoptability of Orchard Ladders with Short Rung Spacing. Proceedings of the XXIXth Annual International Occupational Ergonomics and Safety Conference; International Society for Occupational Ergonomics and Safety, Seattle, WA, June 1-2, 2017.
2. Duraj, V., Fathallah, F., Miles, J., Meyers, J., Guzman, D., and Hunter, T. (2015). Orchard Ladders with Shorter Rung Spacing for Stone Fruit Harvest. Proceedings of the 19th International Ergonomics Triennial Congress. Melbourne, Australia.
3. Fathallah, F., Duraj, V. (2017). Small changes make big differences: The role of ergonomics in agriculture. American Society of Agricultural and Biological Engineers

(ASABE), Resource Magazine Special Issue, November-December 2017

### **Media Coverage**

1. Magazine Article: "What You Need to Know About Orchard Ergonomics" Growing – Produce for Profit. January 13, 2017. <https://www.growingmagazine.com/fruits/orchard-ergonomics-guide/>

### **Presentations**

1. Agricultural Safety and Health Council of America, AgSHARP Certificate Course presentation. Hands-on five-ladder interactive presentation/demonstration, including attendees from throughout California but also from Washington State orchard industry. Monterrey, CA. July 2017.
2. UC Center for Occupational and Environmental Health's Summer Internship Program (Project overview and ladder demonstrations; August 2017 and August 2016).
3. 2016 Advancing Pain Relief Symposium. Presentation on "Interventions to Reduce Musculoskeletal Pain and Discomfort among California Farmworkers." Sacramento, CA, November, 2016.
4. NIOSH Southern California Education and Research Center's Ergonomics Symposium "Updates in Ergonomics: Demonstrating Economic Value." Presentation on Ergonomic interventions in California agriculture (includes this project findings). UCLA, February, 2016.
5. Project overview for researchers from Tokyo University of Agriculture and Technology (March 2014).
6. California Ag Leadership Foundation Fellows tours of Heidrick Western Center for Agricultural Equipment at UC Davis, demonstration of intervention examples of UC Agricultural Ergonomics Research Center based at WCAE, including alternative ladders. (January 2013, May 2013, December 2013, and December 2015)
7. July 2013 Annual International Meeting of the American Society of Agricultural and Biological Engineers (ASABE). "A Preliminary Evaluation of the Effects of Orchard Ladder Rung Spacing on Workers' Health and Safety."

**COMMULATIVE ENROLLMENT TABLE:** See next page

## Cumulative Inclusion Enrollment Report

This report format should NOT be used for collecting data from study participants.

**Study Title:** Western Center for Agricultural Health & Safety at UC Davis

**Comments:** SCHENKER, MARC B./Fathallah- AG CENTER Project 6- U54OH007550

Racial Categories	Ethnic Categories									Total
	Not Hispanic or Latino			Hispanic or Latino			Unknown/Not Reported Ethnicity			
	Female	Male	Unknown/ Not Reported	Female	Male	Unknown/ Not Reported	Female	Male	Unknown/ Not Reported	
American Indian/ Alaska Native										0
Asian		2								2
Native Hawaiian or Other Pacific Islander										0
Black or African American										0
White	1	3								4
More Than One Race										0
Unknown or Not Reported				2	4					6
<b>Total</b>	1	5	0	2	4	0	0	0	0	12

## ***Pilot/Feasibility Projects and Emerging Issues Program***

PI: Fadi Fathallah, PhD

**ABSTRACT:** The overarching goal of the WCAHS Pilot/Feasibility Projects and Emerging Issues (PFP/EI) Program was to encourage the development of creative research, prevention/intervention, translational, and outreach projects while nurturing researchers — particularly early-stage researchers — interested in agricultural health. The program also addressed new developments in agricultural health and safety otherwise not addressed in the five-year competitive renewal of the Center.

**BACKGROUND:** An important goal of the WCAHS is to nurture and train the next generation of agricultural health and safety researchers who will be the new leaders of academic institutions, government agencies, and outreach organizations. By supporting Pilot Projects, providing a mentoring, increasing access to conferences and research retreats, and fostering new collaborations, the PFP/EI Program provided students, fellows, junior and senior faculty with the opportunities and interactions necessary to develop innovative new research projects.

A primary issue for future success of agricultural health and safety–related research is the development of the next generation of investigators who can apply new paradigms, ideas, technologies, and synergies to the assessment of exposure risks, development of intervention/prevention strategies, and engagement of community stakeholders. Much work remains to explore strategies to mitigate exposure to hazards in the agricultural workplace, and to devise and test new methods to promote safety among this vital worker population.

### **SPECIFIC AIMS:**

- 1) Support short-term research and outreach projects addressing agricultural health and safety needs.
- 2) Support projects with a high likelihood of leading to further funding from extramural sources.
- 3) Support projects with a high likelihood of leading to further funding from extramural sources.
- 4) Provide support for new and innovative directions in agricultural health and safety.
- 5) Provide funding opportunities for graduate student research.

**METHODS:** The PFP/EI Program disseminated an annual call for proposals to attract innovative, high-risk research focused on addressing under-investigated research questions and/or the unmet needs of target populations. Each proposal underwent an independent scientific review for merit, specific aims, and likelihood of success. Recommendations were made to the Steering Committee and Center Director for final decisions regarding funding.

**FINDINGS:** See individual PFP/IE projects

**CONCLUSIONS:** See individual PFP/IE projects

**OUTPUTS / OUTCOMES:** See individual PFP/IE projects

**COMMULATIVE ENROLLMENT TABLE:** N/A

# PROJECTS

## 2012-2013

### **1. Immune-mediated mechanisms of agricultural particle-induced lung inflammation and injury**

Alexa Pham, PhD Candidate, UC Davis

Background: Occupational dust exposure among California farmers has been associated with respiratory symptoms, and epidemiological studies have suggested altered innate immunity in farmers and immunological consequences with organic dust exposure to agricultural PM. The goal of this project was to characterize the mechanisms by which agricultural particulate matter (PM) causes lung injury that is further exacerbated by endotoxin, an allergen commonly found in agricultural settings.

Methods: Rats were exposed to ambient coarse (2.5-10  $\mu\text{m}$ ) particles collected from agricultural settings located in the California Central Valley and / or endotoxin.

Findings: The results show that agricultural derived PM and/or endotoxin exposure contributed to lung injury characterized by enhanced cellular infiltration, increased cytokines and cellular stress.

Conclusion: Agricultural derived PM and endotoxin may have major impacts on the pulmonary health of California's farmworkers exposed to these compounds.

### **2. Development and field evaluation of summer garments for California agricultural workers**

Gang Sun/UC Davis and Uwe Reischel/Boise State, Idaho

Background: Agricultural workers are often exposed to high temperatures while working outside that put them at risk for developing heat-related illness. Clothing may help reduce this risk. The purpose of this project was to test if increasing the permeability of fabric improves heat loss and if certain fabrics block solar radiation, thereby reducing radiation heat gain.

Methods: Different types of fabrics were measured and analyzed for air permeability, porosity, water vapor transmission, heat loss, and thermal insulation.

Findings: It was determined that the risk of heat-related illness can be reduced by wearing clothing that is loose, light in weight and color, and highly air permeable.

Conclusion: Choice of clothing (light color and weight, air permeable) can minimize internal heat gain and offer better moisture management than dark, heavy, thick clothes, especially layers.

### **3. Respirator training module for pesticide handlers and applicators**

Joyce Strand, PI, and Lisa Blecker, MS, from the University of California Statewide Integrated Pest Management Program

Background: Pesticide applicators and handlers need to know when they are required to wear a respirator, how to wear and maintain the respirator, identify the different types of respirators and determine which type is appropriate for the situation, understand the fit test requirements, and properly clean, store, and replace respirators and respirator parts.

Methods: Design a hands-on respirator training module for California pesticide applicators and handlers.

Result: A 2-hour module in English and Spanish was developed and will be used across the state. Lisa Blecker has been asked to be on a team that will develop a national respirator presentation module for use by other Pesticide Safety Education Programs across the country. The UC IPM team is seeking extramural funding to expand the respirator training module and create other modules on pesticide health effects, mixing and loading, decontamination, and personal protective equipment.

## **2013-2014**

### **1. Assessment of Arizona agriculture health data**

Philip Harber, Professor, University of Arizona, Tucson

Background: Challenging aspects comprise the outsourcing of workers compensation data to a private entity, non-inclusion of industry/occupation on discharge records, and difficulty in precisely estimating cross-border workers. Findings can be integrated in a comprehensive analysis describing the health status of the agricultural industry and suggest approaches to surveillance and, ultimately, prevention. The purpose of this study was to develop an overview of agricultural health in Arizona, which has several unique aspects, including diverse animal and crop work, a significant proportion of workers are difficult to identify, and considerable bidirectional travel across the Arizona-Mexico border.

Methods: Hospital discharge and death certificate databases were accessed from the Arizona Department of Health Services. A computer system was created to extract information from large databases. The software served as an intermediary, doing trial runs to determine if specified queries lead to any unacceptable level of granularity. Data collection was done using markers, such as E codes, diagnoses (ICD-9 or 10), and similar sources. Because the hospital discharge database did not include occupation or industry, the significance of rates for agriculture were indirectly imputed by comparing disease/injury rates per adult population size in comparison to the significance of the agricultural sector within county.

Results: Rather than focus on a single perspective, multiple information sources were explored. Technical databases included an extensive set of analyses of the Arizona Hospital Discharge Database, which contains information about 19 million emergency department and hospital records. Toxic exposures, such as pesticides, have been identified. In addition, we explored using pesticide incident data from the Poison Control Centers.

### **2. Valley Fever: the farmworker perspective**

Carol Sipan, Professor, UC Merced

Background: Valley Fever disease has dramatically increased in the western US, including areas of prime agricultural production, yet little is known about the ecology of the fungus or if farmworkers are at higher risk of infection. The goal of this project was to determine if farmworkers are at increased risk for contracting Valley Fever.

Methods: Forty persons with a history of Valley Fever acquired while employed in outdoor agricultural work were interviewed using a mixed methods approach at the lung nodule clinic operated by UCSF-Fresno. The study focuses on quality of life issues.

Results: The initial work on this pilot study led to a funded U01 (OH010839-01, PI McCurdy) on the epidemiology of coccidioidomycosis. The grant aims to survey CA Hispanic farm workers for knowledge, attitudes, beliefs, and behaviors regarding coccidioidomycosis; identify work-related risk factors; and sample respirable dust for *Coccidioides* species. Thus, the work from this small grant was rolled over into the U01 that is still in progress.

### **3. Developing the next generation of ag safety and health leaders**

Benjamin Swan, Assistant Professor, Cal-Poly San Luis Obispo

Background: Providing a skilled workforce for the California agriculture industry that is safety and health conscious is a goal for all agricultural educators as they train and prepare their students for employment.

Methods: This study looked specifically at secondary agriculture teachers in the San Joaquin Region to see what extent they were trained to teach safety and health topics and to what extent they train their students in those same safety and health topics. Safety and health topics were within the following areas: Overall Agricultural Safety & Health, Farm Buildings, Crop Storage, Chemical Storage, Tractor Safety, Equipment and Machinery, and Livestock Facilities.

Findings: The seven areas (listed above) were comprised of 97 items, and 26 items surfaced as needing immediate attention. It was also noted that the lowest trained area was in communicating in Spanish, which applied to all of the safety and health topics. This will be a focus area as this pilot project moves forward and eventually to the state and region.

Conclusion: Teachers are interested in improving their training and would attend a multi-day training: teachers indicated they would prefer June and/or July in the Fresno, Hanford, and/or Visalia area(s) in half-day to 2 full day increments. In general, the teachers feel their administrator will strongly support their participation in the training. The course will be designed to offer teachers professional development credit.

Output: Swan, B. G. (2015). Determining Teachers' Agricultural Safety & Health Level of Instructional Practices. AAAE (American Association for Agricultural Education) National Agricultural Education Research Conference Proceedings, 194-197.

### **4. Evaluating inhalation exposure of biochar particulate matter and bound contaminants from agricultural associated dust**

Sanjai Parikh, Assistant Professor, UC Davis

Background: The purpose of this project was to assess the occupational hazards associated with biochar particulate matter (PM) inhalation by farm workers and local residents.

Methods: Simulated dust generation experiments were conducted to evaluate the potential for transfer of toxic chemicals from biochar to humans via a series of chemical and biological analysis of collected dust fractions. The trials were designed to examine effect of 1) soil texture; 2) biochar types; and 3) biochar application rate using silt loam and sandy loam soils and various biochars (900° C walnut shell; 500, 700, 900° C pine wood) at 1, 2, and 5% biochar application rates with varied moisture contents.

Findings: We found that soil texture is the key factor in dust particle size distribution, with fine textured soils producing finer dust than coarser soils. In contrast, biochar type, biochar application rate and irrigation rate, do not have a big influence on the dust size. Increasing the irrigation amount was found to lead to larger dust size percent, indicating that aggregates could have been formed. It was determined that soils amended by biochars can reduce PM<sub>10</sub> emission, and this phenomenon becomes obvious when irrigation is intense, indicating formation of aggregates. Soils amended by high biochar application rate (5% biochar) at low irrigation rate generated the most dust, posing the most potential hazards among all the treatments.

Conclusion: Results from this study demonstrate that guidelines for the management of biochar amended agricultural fields can be established through recommendations of irrigation practices based on soil texture, with only minor considerations for the specific biochars used.

## **2014-2015**

### **1. Assessing clothing as a preventative method for heat illness in California's agricultural workers** (Note: funding for this project began in 2013)

Deborah Bennett, Professor, Alondra Vega, PhD Candidate, Uwe Reischl, Professor, UC Davis and Boise State University, Idaho

Background: Global climate change is increasing, posing a threat to heat-related illnesses in outdoor occupations, such as agricultural laborers. A heat illness preventative measure is understanding how to best dress when working outside in high temperatures.

Specific aims:

- 1) Determine the optimal clothing scheme for agricultural laborers when working in varying conditions of extreme heat.
- 2) Validate Dr. Budimir Mijovic's methods in agricultural laborers working in the fields.
- 3) Determine the effects of wearing multiple layers of clothing when working in varying conditions of extreme heat.

Methods: A mannequin was equipped with 6 different scenarios of garments and heated with infrared light to measure total heat loading and heat insulation from the clothes.

Findings:

Garment Set	Description	Total Heat Loading (Watts)
Control	Nude	63.3
<b>1</b>	<b>Boxer shorts + black t-shirt (100% polyester) + denim jeans</b>	<b>113.3</b>
2	Boxer shorts + white t-shirt (100% cotton) + short sleeve shirt + denim jeans	140.0
3	Boxer shorts + white t-shirt (100% cotton) + long sleeve shirt + denim jeans	146.6
4	Boxer shorts + white t-shirt (100% cotton) + short sleeve shirt + 100% cotton pants	133.3
5	Boxer shorts + white t-shirt (100% cotton) + long sleeve shirt + 100% cotton pants	146.6
6	Boxer shorts + basketball shorts + white t-shirt (100% cotton) + short sleeve shirt + sweatpants	136.6

Conclusion: Based on the results of the total heat loading, it is recommended that agricultural workers wear only one layer of clothing (garment set 1). These results can be used to design educational programs for farm workers about selecting proper protective clothing to minimize heat stress in the field.

## 2. National Hmong American Farmers conference

Fresno, CA

Background: WCAHS helped sponsor the 2015 National Hmong American Farmers conference held in Fresno, CA. This is an annual event that brings useful information to the farmers, especially small growers, on economic, regulatory and other agricultural related issues.

Methods: WCAHS Education and Outreach Specialist Teresa Andrews presented a session (with an interpreter) on government agencies that protect worker rights. A Cal/OSHA consultation person (Eugene Glendenning, Regional Manager) was there also. Forty people attended the session. Ms. Andrews also had an information table with heat illness prevention materials, and approximately 200 people received posters or flyers created by Cal/OSHA for their heat campaign.

Results: WCAHS has established successful outreach relationship with Chukou Thao, the executive director of the National Hmong American Farmers, and the conference was a success.

## 3. ¡Que Viva la Vida! conference

Esparto, CA

Background: WCAHS sponsored the *¡Que Viva la Vida!* conference in Esparto, CA on Saturday, March 21, 2015. The goal of the conference was to address the women's' physical, emotional, and spiritual well-being while providing them with necessary advice to improve their overall lifestyle.

Methods / Results: Approximately 20 farm worker Latino women attended the conference. WCAHS Education and Outreach Specialist Teresa Andrews as well as other presenters in attendance emphasized to the women the tremendous importance of working towards and maintaining good health in order to better provide for their family. The first presentation featured

information about physical health and nutrition, such as a healthy and balanced meal. The second presentation dealt with domestic violence - what it looks like and the negative impact it has on families, specifically children. Afternoon presentations included talks on residency or citizenship, deportation, obtaining a driver license, college-level education and financial aid and scholarships.

#### **4. The effects of agricultural particles on pulmonary allergic responses: a focus on dendritic cells** (Note: funding for this project began in 2013)

Alejandro Castañeda, PhD Candidate, UC Davis

Background: The San Joaquin Valley has one of the highest incidences of asthma in the country, a phenomenon that is related to the high levels of ambient particulate matter generated through anthropogenic processes such as agriculture farming and vehicular transportation emissions. The purpose of this study is to understand how agricultural particulate matter exacerbates asthma through the use of an animal model. Specifically, through the use of in-vitro cell culture systems we are interested in addressing the molecular mechanisms through which agricultural particles enhance the activation of immune cells that involved in asthma.

Specific aims:

- 1) Validate an animal model in which agricultural particulate matter exacerbates the pulmonary allergic immune response in house dust mite.
- 2) Analyze dendritic antigen presenting cell (APC) activation markers upregulated by agricultural particulate matter.
- 3) Assess the mechanisms of APC activation by particulate matter.

Methods: Eight-week-old BALB/c mice were exposed to PBS, Sacramento ambient particulate matter (PM, 2.5 $\mu$ m), house dust mite (HDM), or HDM+PM (n=4 for all groups). Lung tissue, bronchoalveolar lavage (BAL) and plasma were analyzed for extent of inflammation. Gene expression was analyzed by quantitative polymerase chain reaction using lung homogenate. To assess APC activation by PM, the human U937-monocyte cell line was used to generate macrophages. Macrophages were treated with 10 $\mu$ g, 50 $\mu$ g, or 100 $\mu$ g of PM as well as ovalbumin (OVA) and OVA+PM to assess their activation and extent of pro-inflammatory gene expression

Findings: Administration of PM during allergen sensitization to HDM lead to a significant increase in airway inflammation as assessed through BAL total cells, compared to mice treated with HDM only. Histopathological analysis of lung tissue supported these findings. Gene expression analysis of the lung indicated that pro-inflammatory markers IL-6, TNF $\alpha$ , CXCL5, and CYP1A1 were elevated in HDM and HDM+PM groups. Additionally, the APC/dendritic cell markers CD80, CD86, MHC Class II, and CD11c were also elevated in HDM and HDM+PM treatment groups. Cell culture experiments demonstrated that macrophage cells treated with increasing levels of PM produced a dose-response curve in relation to the markers: TNF $\alpha$ , CXCL3, IL-6, IL-1b, HO-1, and CYP1A1. Cells treated with both OVA+PM showed synergistic increases in the pro-inflammatory markers CXCL3 and IL-1b.

Conclusion: Our findings suggest agricultural particulate matter enhances the inflammatory response to allergens in the lung by significantly enhancing the influx of immune cells that enter the lung.

Output: Carosino CM, Bein KJ, Plummer LE, Castañeda AR, Zhao Y, Wexler AS, Pinkerton KE. 2015. Allergic airway inflammation is differentially exacerbated by daytime and nighttime ultrafine and submicron fine ambient particles: heme oxygenase-1 as an indicator of PM-mediated allergic inflammation. *J Toxicol Environ Health A*. 78(4):254-66. doi: 10.1080/15287394.2014.959627. PMID:25679046

## **2015-2016**

### **1. Biosolarization is a fumigation alternative for controlling soil pests**

Christopher Simmons, PhD, Assistant Professor, UC Davis

Background: Biosolarization involves using passive solar heating and induced soil microbial activity synergistically to create pesticidal conditions in the soil. To better characterize the potential for biosolarization to displace fumigation, we are studying the efficacy of biosolarization in managing two major pests, puncture vine and root knot nematode.

Methods: Volatile emissions from soil are quantified during biosolarization, which can impact both process efficacy and worker exposure. Conventional methodologies are adapted for measuring weed seed and nematode mortality to enable detection of pest inactivation during biosolarization. Atmospheric sampling near biosolarized and fumigated fields is conducted to measure emission of volatile compounds during both biosolarization and conventional fumigation with chloropicrin and 1,3-dichloropropene. These data are used to assess the composition of biosolarization emissions and compare their toxicity to the emissions stemming from conventional fumigation.

Progress to date: Dissecting and compound microscopes were used to observe and photograph weed seeds and nematodes, respectively, during viability assays. Stocks of puncture vine seeds were obtained and baseline viability is being tested using both germination and tetrazolium staining assays. A nematode viability assay is being developed in our laboratory, which involves saturating samples of infested soils with water within a funnel, collecting the viable nematodes that migrate out the bottom of the funnel, and counting viable nematodes via light microscopy in a compound microscope. For both pests, positive (i.e., known viable pests) and negative controls (heat-sterilized pests) are being used to confirm that the assays are working correctly. A gas sampling device has been acquired to capture volatile compounds.

### **2. Examining primary exposure risks of zoonotic enteric pathogens occurring in large commercial dairies within California**

Robert Atwill, Professor, Western Center for Food Safety, UC Davis

Background: The study targets four major zoonotic enteric bacterial pathogens that are endemic in dairy cattle populations and are distributed throughout the dairy environment, posing a constant threat to human and animal health. While previous studies have investigated the prevalence of one or more pathogens in dairy cattle populations, few have been designed to

simultaneously quantify these specific pathogens while investigating exposure risks in the dairy worker population. This project establishes and optimizes laboratory protocols designed to simultaneously quantify *Escherichia coli* O157, *Salmonella* spp., and *Listeria monocytogenes* in dairy cattle feces using a real-time molecular method (qPCR). An additional goal is to develop a novel protocol to quantify *Campylobacter jejuni* in dairy cattle feces.

Methods / Progress to date: Two working dairies from the California Central Valley were enrolled in the study. Fecal samples were collected during routine health screen visits directly from the rectum of up to 20 individual adult animals on August 29, 2016, and September 12, 2016, in accordance with standard veterinary practices. The samples were screened for the presence of *E. coli* O157, *Salmonella* spp., *L. monocytogenes*, and *C. jejuni*. To evaluate the specificity and sensitivity of the proposed methods, different fecal sources (cow feces from different dairies) were inoculated with the four types of bacteria. This allowed evaluation of how well the assay works when cows are being raised under different management practices (i.e., dietary supplements). These trials allow any necessary adjustments be made to the methods.

Output: This project was just expanded into a new 4 year research project of the Western Center for Agricultural Health and Safety.

### **3. Exploring the role of depression as a moderator of a workplace obesity intervention for Latino immigrant farmworkers**

Jessie Pintor, PhD, Post-doc, UC Davis

Background: Latino immigrant farmworkers experience high rates of both obesity and depressive symptoms; over 70% of are overweight or obese, and 20% to 50% report symptoms that could indicate depression. The purpose of this project was to explore how depressive symptoms moderate the effect of a workplace obesity intervention for Latino immigrant farmworkers.

Methods: Secondary data from a randomized, controlled pilot intervention, *Pasos Saludables*, whose objective was to reduce obesity within an immigrant farmworker population was used. The primary outcome was change in BMI; BMI was assessed pre-randomization and at 12-14 weeks follow-up. Risk of depression at baseline was assessed with the CES-D 10; scores of 10 or higher may indicate clinical depression.

Findings: Treatment effect within groups stratified by depression risk, adjusting for age, gender, education, and baseline BMI was compared. Over one quarter (27.3%) of participants scored 10 or higher on the baseline CESD-10. Overall, compared to the control, intervention participants saw a 0.57 reduction in BMI ( $p < .01$ ); among females, BMI was reduced by 0.63 ( $p < .01$ ). For those with no indication of depression at baseline, the intervention group reduced their BMI by 0.62 on average, compared to controls ( $p < .01$ ). The reduction observed within the group at risk for depression was not statistically significant from controls (0.45 reduction compared to controls,  $p = .141$ ). Among women, a larger treatment effect was observed for those with no risk of depression at baseline, while again no significant effect was detected for those with baseline risk of depression: 0.72 BMI reduction for no depression ( $p < .01$ ) vs. 0.42 reduction for baseline depression ( $p = .233$ ).

Conclusion: The study provides preliminary evidence that the experience of depression may keep Latino immigrant farmworkers from benefiting fully from a successful workplace obesity

prevention intervention. The findings suggest that obesity and mental health need to be jointly addressed. Efforts to mitigate the structural factors that contribute to depression among farmworkers, as well as efforts to increase access to mental health services and/or coping education, could improve both mental and physical health.

#### **4. Heat exposure, dehydration, and kidney function in California's agricultural workers**

(Note: funding for this project began in 2013)

Sally Moyce, PhD Candidate, UC Davis

**Background:** During California's summer harvest, agricultural workers are at risk for heat related illness. The body's response to increased workload in extreme temperatures is to create evaporative cooling through sweating. This mechanism may cause transient volume depletion, resulting in decreased blood flow to the kidneys and potentially acute kidney injury. Understanding the magnitude of occupational heat-related kidney dysfunction in agricultural workers is important to inform early detection measures and to plan occupational interventions for its prevention.

**Methods:** Seed grant funds were used to fund a field staff worker to collect data on kidney function and diabetes in California's agricultural workers. Data was collected from 149 male participants working in conditions of high ambient temperatures throughout the Central Valley. Changes in serum creatinine, urinary micro-albumin levels, and hemoglobin A1c were measured.

**Findings:** In a sample of 295 agricultural workers, acute kidney injury was found in nearly 12% of the workers after a single day of work in the fields. Diabetes was associated with 4.18 times the odds of acute kidney injury (95% confidence interval 1.12-15.56).

**Conclusion:** The cumulative incidence of acute kidney injury after a single day of agricultural work is alarming due to the increased risk of long-term kidney damage and mortality. The association with volume depletion suggests that acute kidney injury may be prevented with proper rehydration during a work shift.

**Outputs:** Moyce S, Joseph J, Tancredi D, Mitchell D, Schenker MB. Cumulative incidence of acute kidney injury in California's agricultural workers. *J Occup Environ Med* 2016 Apr;58(4):391-7.

Moyce S, Mitchell D, Armitage T, Tancredi D, Joseph J, Schenker M. Heat strain, volume depletion and kidney function in California agricultural workers. *Occup Environ Med*. 2017 Jun;74(6):402-409.

#### **5. Impact of California drought on community health: The water quality side**

Swee Teh, Adjunct Professor, UC Davis

**Background:** Drought is affecting groundwater/surface water exchange, and pollutants may inadvertently be concentrated in well water resulting in decreased drinking water quality. Rural agricultural areas have been found to suffer from unsafe tap water. Therefore, it is important to assess and monitor water quality regularly, especially in areas that have agricultural runoff and

are dependent on well water. This project samples water quality from the California Central Valley, where some rural towns suffer from unsafe water.

**Methods:** Specific sampling sites were selected in conjunction with a Community Stakeholders' Advisory Committee meeting at UC Merced on May 27, 2016. Following the meeting, we met at the Community Water Center, which advocates that all communities should have access to safe, clean, and affordable water, in Sacramento on July 11, 2016, to confirm and schedule water sample collection. Water sampling was conducted at a private well located in Porterville, CA on August 11 and 22. A well-established fish model (Japanese Medaka) was used to determine water quality; larval fish (7 days old) were exposed for 4 days and juvenile fish (30 days old) were exposed for 7 days to the collected water on August 25 and the exposures were terminated on August 29 and Sept 1 2016, respectively. Larval fish were preserved for microarray analysis. Ten juvenile fish per replicate (for 3 replicates) were sampled at the end of exposure for RNA-sequencing, and the remainder of the fish was raised in tanks with clean water for 1 month. These fish will be sampled for histopathological analysis on Sept 30, 2016.

**Progress to date:** The Aug 11, 2016, water sample was used to measure general parameters of water quality. Since all the evaluated parameters were within the range of the recommended levels for fish, no water dilution was performed. The Aug 22, 2016, water samples were collected in brown glass jars and shipped refrigerated at ~4 °C to UC Davis. No obvious signs of acute toxicity (changes in swimming pattern and behavior, and mortality) were observed during both the 4 day larvae and the 7 day juvenile exposures. Fish samples collected from those experiments will be analyzed for endocrine disruption and carcinogenesis by microarray, RNA-sequencing and histopathology.

## **6. Investigating the links between chemical exposures and toxicological responses for air pollutants using a novel aerosol mass spectrometry method**

Qi Zhang, PhD, Professor, UC Davis

**Background:** The connections between the chemical properties of particulate matter (PM) and adverse health effects, such as cardiopulmonary disease, remain poorly understood due to the enormous chemical complexity of PM. The goal of this project was to identify both sources and key chemical components of PM that are potentially responsible for toxicological responses through detailed analysis of ambient PM samples. A secondary goal was to develop analytical techniques to identify markers for inflammation in a non-selective, top-down approach using a High-Resolution Time-of-Flight Aerosol Mass Spectrometer (AMS).

**Methods:** In this study, PM<sub>2.5</sub> (particles with diameters less than 2.5 micrometer) samples collected during winter from the City of Sacramento located in the Central Valley of California (CA) and the City of Taiyuan in northern China were analyzed for chemical composition and toxicological responses. Both locations experience high levels of air pollution and have diverse sources of PM enabling highly complex and chemically different aerosol compositions to be compared.

**Findings:** Notable compositional differences were observed between the CA and China samples, including organic contribution to total PM mass, average degree of oxidation of the organic compounds, metal content, and distinct tracer ions, indicating different sources of the PM. The CA PM had a greater organic contribution, higher levels of oxidized organics, and high concentrations of copper whereas the China PM had a greater contribution of inorganics,

especially from sulfate, more reduced organics, and higher concentrations of alkaline metals. Analysis indicated that the CA PM was influenced by biomass burning emissions whereas coal combustion compounds were more abundant in the China PM.

Conclusion: Toxicological analysis demonstrated significantly different biological responses between the two samples, with higher inflammatory responses resulting from exposure to the CA PM on an equal mass basis. CA PM appears to be more toxic than China PM due to a greater degree of oxygenation of the organics and a higher concentration of copper. This study highlights the importance of considering chemical composition when assessing PM toxicity and provides evidence for targeted emission abatement and source-specific regulations in order to improve human health and air quality.

Output: Sun X, Wei H, Young DE, Bein KJ, Smiley-Jewell SM, Zhang Q, Fulgar CCB, Castañeda AR, Pham AK, Li W, Pinkerton KE. Differential pulmonary effects of wintertime California and China particulate matter in healthy young mice. *Toxicol Lett.* 2017 Aug 15;278:1-8

## **7. Joint funding for agricultural health and safety projects in developing countries**

Blum Center for Developing Economies, UC Davis (Note: funding began in 2014)

Background: The Western Center for Agricultural Health and Safety (WCAHS) partnered with the UC Davis Blum Center for Developing Economies to help impoverished communities around the world improve their agricultural health and safety.

Methods: WCAHS and the Blum Center jointly funded six UC Davis undergraduate students and eight UC Davis graduate students to conduct agricultural health and safety related projects both in the U.S. and abroad in conjunction with a local non-profit or agency.

Results: Hands-on opportunities allowed undergraduate and graduate students to gain fieldwork experience in establishing change to problems that they are passionate about solving. The students, faculty and outside organizations affiliated with these projects aim to further the WCAHS' and the Blum Center's mission of assistance and aid domestically and abroad. This is an excellent opportunity to train the next generation of leaders through experiential learning in agricultural health and safety.

## **8. Online certificate program for promotores on agricultural health and accident prevention** (Note: funding began in 2014)

Health Initiative of the Americas (HIA), UC Berkeley

Background: The overall goal of this project is to build a healthier and better-informed agricultural worker community in the U.S. by reducing occupational health and safety issues and promoting healthy lifestyles among Hispanic agricultural workers and their families. The strategy to achieve this goal is to create, pilot, and launch an online certificate program on Agricultural Health and Accident Prevention for *promotores*. The certificate program will be the first in the nation focused on the occupational health and safety of agricultural workers. The long-term goal is to institutionalize this online certificate nationwide so community health outreach workers are better prepared to assist Latinos who work in agriculture.

Methods: A minimum of 300 *promotores* working directly with the vulnerable Latino population in the area of agricultural health and accident prevention in the context of migration will be trained. HIA worked with the Autonomous University of Zacatecas (UAZ) and the Carlos Slim Foundation, and with two independent consultants with expertise in *promotora* training curricula.

Results: Six modules were created for the online certificate program. In June 2016, HIA held a pilot study at UC Berkeley where seven *promotoras* tested parts of each module and then participated in a focus group immediately following the pilot. They completed a 12-question evaluation survey and offered suggestions regarding reading and comprehension level of the modules and the presentation of the information. A consultant analyzed the observations and modified the program to address the common themes.

Conclusion: The final version was provided to the UAZ partners for translation into the online platform. The first module was uploaded, and Mexican and U.S. researchers and the consultant are currently evaluating the quality. Pilot testing of the platform will inform the other five modules.

## **9. Sexual harassment and Latino immigrant farmworkers**

Kim Prado, Graduate Student, UC Davis

Background: Workplace sexual harassment is an unwelcome fact of life for women working in the fields and food processing plants across the US. The farm work environment offers isolated venues, e.g., distant orchards, outbuildings, and other settings, where perpetrators can bring their victims under pretense of work responsibilities and remain unobserved. Fear of potential repercussions – social stigma, adverse employment consequences, and deportation - often ensures silence. Previous research efforts have focused on experience of women farm workers without exploring attitudes and beliefs among men, who are in almost all cases the perpetrators. As a result, we lack important epidemiologic information regarding sexual harassment in the agricultural workplace, limiting our ability to develop and target effective prevention programs. The purpose of this project is to characterize attitudes, beliefs, and experience relevant to workplace sexual harassment among men and women farm workers in California and Mexico to inform subsequent development of effective educational materials and policy recommendations for agricultural employees, employers, and governmental agencies.

Methods: Attitudes, perspectives, beliefs, and experiences regarding sexual harassment in the agricultural workplace will be investigated through farmworker focus groups (n=20, 10 men 10 women), farmworker surveys (n=100, 50 men and 50 women), and employer questionnaires (n=10-15). A second team of investigators under the leadership of our co-Principal Investigator Dra. María Elena Rivera Heredia will duplicate focus group and survey efforts separately at the University of San Nicolás de Hidalgo in Michoacán, Mexico.

Findings: Prominent themes in both male and female focus groups included barriers to reporting for victims, an increased response to the issue in recent years by some employers, and the observation that both men and women may perpetrate and suffer sexual harassment. While comparing focus group discussions between men and women, we found that none of the men had known of sexual harassment cases in their workplaces, whereas eight women did; none of the men believed “men inevitably notice women in a sexual way,” whereas all women did; all men strongly felt that the industry labeled and generalized them as sexual harassers. Both

groups of farmworkers offered suggestions for prevention of sexual harassment. These included gender-segregated crews, a dress code, and frequent education on sexual harassment for supervisors, crew leaders, workers, and transporters. Comparing focus groups in CA to focus groups in Mexico revealed that both groups of men agreed women should be encouraged to report; both women's groups mentioned people believe that women "provoke" sexual harassment; the line between innocent expressions of interest versus sexual harassment differs between CA and Michoacán men, specifically, CA men were more insistent about the need to avoid certain non-work related conversation topics (such as inquiring about single or partnered status) at work.

Conclusion: Focus group data show that perspectives of sexual harassment in the agricultural industry vary by sex and work location. Surveys and employer questionnaires will be conducted next.

## ***Evaluation Core***

PI: Julie Rainwater, PhD

### **ABSTRACT:**

The WCAHS evaluation component has served the WCAHS program by assessing the impact of WCAHS research, outreach, and the Center overall. The Evaluation team has worked with WCAHS investigators to gather outputs and outcomes and report the impact of the Center. Evaluation has been critical for improving the quality and relevance of WCAHS.

### **BACKGROUND:**

The Evaluation Core of the WCAHS has identified objectives, principal measures/indicators, and data sources to determine the effectiveness and impact of the Center and its programs and projects. This has been done by identifying specific factors that have facilitated and/or hindered progress toward achieving WCAHS' goals and objectives. The Evaluation program findings have been utilized to improve research, education, and outreach of the WCAHS.

### **SPECIFIC AIMS:**

- 1) Tracking: Identify the objectives, principal measures/indicators, and data sources for the Center and its programs.
- 2) Evaluation: Provide an assessment of the effectiveness and impact of the WCAHS by identifying specific factors facilitating and/or hindering progress toward WCAHS goals and objectives.
- 3) Collaboration: Integrate evaluation functions into improvements in research, education, and outreach of the WCAHS.

### **METHODS:**

Evaluation utilizes a logic model approach along with evaluation questions, standards, and data for each component of the Center to insure progress toward WCAHS objectives. WCAHS evaluation practices and findings have been shared to develop and disseminate best practices for evaluating NIOSH Agricultural Health and Safety Centers.

## **FINDINGS (By Specific Aim)**

### **Specific Aim 1: Tracking**

The evaluation team has tracked activities, outputs, and outcomes of Center projects. Publications and grants that are potentially associated with each project were routinely recorded based on lookups in SCOPUS and NIH Reporter. Data on non-NIH grants, honors and awards, accomplishments, scientific products, media coverage, presentations, success stories, and individuals supported were collected by the evaluation team from annual progress reports, WCAHS newsletters, personal communication, and online searches. Final outputs and outcomes approved by WCAHS investigators were entered into a database management system for WCAHS utilizing FileMaker Pro software.

The WCAHS has an impressive set of research outputs and products: WCAHS projects have produced 150 publications, 181 presentations, and 71 features of WCAHS research in the media. Projects have garnered 17 subsequent grants totaling over \$25 million in additional funding, which represents a return on investment of \$9:1 for the total Center funding during the 2011 to 2015 grant period (see details below). The Center supported 27 individuals, including 21 graduate students and 6 postdoctoral scholars in addition to the new investigators and research projects supported through the pilot and seed grant program.

### **Specific Aim 2: Evaluation.**

The Evaluation team worked closely with WCAHS leadership to comprehensively evaluate the Center and address areas of excellence or concern. Quality improvement has been achieved through regular meetings with the Center Director, Steering Committee, Outreach team, and WCAHS administration. The Evaluation team held annual meetings with WCAHS project investigators to review program-specific logic models. The logic models served the following purposes: 1) articulate the “theory of change” underlying their program activities, 2) identify and update outcome measures and data sources, and 3) ensure that outcomes and impacts are aligned with NIOSH Agricultural Safety and Health Centers program objectives and relevant NORA Strategic Goals.

**Stakeholder Feedback** Each grant year, the Evaluation team has distributed a survey to WCAHS stakeholders. The survey asked stakeholders to rate the value of their interaction with WCAHS, WCAHS products, and the center overall, as well as suggestions for future direction and improvements. The survey also measured respondents’ perceptions of the Center’s influence on their understanding of agricultural health and safety issues. Results of the Stakeholders’ Survey were presented at each offering of the Annual Retreat by Evaluation Director Dr. Julie Rainwater. Over the five year period, the Stakeholder Survey has shown a high degree of satisfaction and support for Center activities. Stakeholders posed a number of new research questions that were ultimately integrated into Center activities, such as the impact of climate change and night work on worker health and safety.

**Return on Investment** The WCAHS Evaluation team conducted a return on investment analysis based on funded projects, support for outreach activities, and seed/pilot grants. The WCAHS return on investment overall was \$9:1 for the 2011-2016 grant period. The table below shows a detailed account of each source type in the return on investment formula:

## Return on Investment, 2011-2015\*

	Total WCAHS Investment/ Funding Received	Subsequent Grants Obtained <sup>†</sup>	Total Funding from Subsequent Grants	ROI
<b>WCAHS Research Projects (2011-2015)</b>				
<b>Particulate Matter - Airways</b> (PI: Kent Pinkerton)	416,250	4	5,042,981	<b>\$12:1</b>
<b>Econometrics in Agricultural Injury</b> (PI: Paul Leigh)	310,290	0	0	<b>\$0:1</b>
<b>California Hen Caging Laws</b> (PI: Jerold Last)	449,441	2	2,340,670	<b>\$5:1</b>
<b>Immunoassays</b> (PIs: Bruce Hammock/Shirley Gee)	585,461	6	12,304,310	<b>\$21:1</b>
<b>Heat Illness</b> (PI: Marc Schenker)	486,052	4	4,782,302	<b>\$10:1</b>
<b>Orchard Ladder Spacing</b> (PI: Fadi Fathallah)	250,450	1	720,000	<b>\$3:1</b>
<b>Projects Total</b>	<b>2,497,944</b>	<b>17</b>	<b>25,190,263</b>	<b>\$10:1</b>
<b>Outreach (2011-2015)</b>				
<b>Outreach Activities</b>	165,000	2	172,000	<b>\$1:1</b>
<b>Seed/Pilot Projects (2011-2015)</b>				
<b>Seed/Pilot Grants</b>	336,614	1	312,500	<b>\$1:1</b>
<b>Overall Total</b>	<b>2,999,558</b>	<b>20</b>	<b>26,499,763</b>	<b>\$9:1</b>

\*ROI analysis conducted in October 2015

### Specific Aim 3: Collaboration

**Collaboration with Ag Center Evaluators** As a member of the NIOSH AFF initiative-wide evaluation workgroup, Evaluators, Coordinators, and Outreach personnel (ECO), the WCAHS Evaluation Core played a leading role in producing several cross-center products, such as the National Agriculture Safety Database (NASD), YouTube channel, and a repository of compelling outcomes from the NIOSH Ag Centers. Each of the 10 NIOSH Ag Centers contributed documents to the repository available through a Dropbox website. These documents were filed and indexed by center and by research topic. The repository provides evaluators from all participating Ag Centers with access to cross-center program information, best practices, and relevant statistics and research for agricultural health and safety. Using data in the repository, the WCAHS Evaluation program created a WCAHS-specific fact sheet that includes information on the impact and importance of the Center's work.

**Collaboration with Ag Center Directors** The WCAHS Evaluation Director has attended the NIOSH Center Directors' Meetings (October 2013, Aurora, CO and March 2015 Cincinnati, OH). During the 2013 meeting, the Evaluation Director gave a presentation entitled, "Center Evaluation, Measurement, and Metrics - Agricultural Health and Safety." The presentation described the rigorous and professional approach that the NIOSH Agricultural Safety and Health Centers have taken in evaluating themselves, offering a potential model for demonstrating effectiveness of occupational safety and health interventions and research. During the 2015 Directors' meeting, Dr. Rainwater shared the recommendations of the ECO group on evaluation pertaining to the NIOSH/NORA AFF logic model and discussed ways the ECO group can help to focus on intermediate outcomes that are aligned with NIOSH reporting platforms. Dr. Rainwater also presented several models of how activities and success stories are currently captured at various centers.

## CONCLUSIONS:

The WCAHS has been successful in fulfilling its mission to improve the health and safety of farmers, farmworkers, and their families in Western agriculture. The WCAHS research projects have led to impactful outputs and outcomes. Additionally, the Center has had an impressive return on investment on funded activities and continues to advance research in agricultural health and safety.

## OUTPUTS / OUTCOMES:

### *Evaluation Core*

Several products related to the center evaluation have been created. In 2012, a presentation on “Program Theory-Driven Evaluation” was delivered by Dr. Julie Rainwater, as well as a presentation on the “Success Case Method” by the Associate Evaluation Director, Dr. Stuart Henderson at the HICAHS and UMASH meeting. A report on WCAHS related research, the PASOS Saludables project, was completed by the evaluation team in 2013. A poster presenting WCAHS’ significant accomplishments in promoting agricultural health and a presentation on Center Evaluation, Measurement, and Metric- Agricultural Health and Safety and safety was presented at the NIOSH Ag Center/ERC Directors’ Meeting October 2013 in Aurora, CO. A report describing the results of the Stakeholders’ Survey was distributed at the WCAHS Annual Retreat in 2013 and 2014.

### *WCAHS Overall*

The following table provides a summary of outputs documented by the Evaluation Core from the 2011-2016 grant period. Please refer to individual project reports for the list of outputs.

#### **WCAHS Selected Project Outputs, 2011-2016**

Project	Publications	New Grants	Presentations		Media Coverage	Educational Materials	Honors/Awards	Individuals Supported	
			Scientific	Community				Graduate Students	Postdocs
<b>Particulate Matter - Airways</b> (PI: Kent Pinkerton)	42	4	40	4	12	1	0	7	3
<b>Econometrics Agricultural Injury</b> (PI: Paul Leigh)	11	0	3	2	32	0	0	0	0
<b>California Hen Caging Laws</b> (PI: Jerold Last)	7	2	0	0	3	2	1	1	1
<b>Immunoassays</b> (PIs: Bruce Hammock/ Shirley Gee)	37	5	5	6	9	0	0	2	0
<b>Heat Illness</b> (PI: Marc Schenker)	45	7	115	4	8	4	1	9	2
<b>Orchard Ladder Spacing</b> (PI: Fadi Fathallah)	8	1	1	1	7	1	0	2	0
<b>Total</b>	<b>150</b>	<b>19</b>	<b>164</b>	<b>17</b>	<b>71</b>	<b>8</b>	<b>2</b>	<b>21</b>	<b>6</b>

Outreach has also been a significant contributor to the center’s successful achievement of its goal to improve the health and safety of agricultural workers and their families and communities. During the 2011 to 2015 grant period, WCAHS outreach conducted 187 events that reached 9,617 individuals. These outreach activities and materials were delivered to diverse audiences in multiple languages.

Below are selected outcomes by category for WCAHS research during the 2011-2016 grant period:

Outcome	Description
<b>Policy/regulations/standards</b>	<ul style="list-style-type: none"> <li>• Together with policymakers, advocates, farmworker unions, and workers, WCAHS contributed to a multilevel transformation of California's heat illness prevention requirements. New preventive measures are now required when temperatures reach 95 degrees, including observing employees, supervising new employees, and reminding all workers to drink water throughout their shift.</li> </ul>
<b>Guidelines or best practices adopted</b>	<ul style="list-style-type: none"> <li>• WCAHS engineers are developing a safer ladder with rungs spaced optimally to reduce joint stress. Safer ladder standards have been developed.</li> <li>• WCAHS ladder safety research results will encourage ladder manufacturers to offer add an alternative orchard ladder in addition to their existing standard orchard ladders.</li> <li>• In-field demonstrations of ergonomic solutions that reduce acute and cumulative trauma injuries, specifically due to lifting, stooping, and squatting.</li> <li>• WCAHS develops rapid immunoassays to test for pesticide exposure in the field and in farmworkers' homes. Center researchers are also conducting an environmental exposure assessment to help policymakers and the public understand the significance of pesticide exposure on the job.</li> <li>• WCAHS research has produced more valid estimates of the number and types of agriculture-related injuries and illness to improve comprehensive surveillance of the agricultural health and safety system.</li> </ul>
<b>Research methods or procedures used beyond center project</b>	<ul style="list-style-type: none"> <li>• Methodology developed from research on airborne particulate matter is being implemented in other studies with colleagues for research supported by the California Air Resources Board (CARB) and the Electric Power Research Institute (EPRI).</li> <li>• Methodologies developed from WCAHS research on heat-related illness utilized by Dr. Kenneth Culp of the University of Iowa for a grant proposal submission.</li> <li>• Immunoassays for pesticide exposure available for use in human and animal studies developed at WCAHS.</li> <li>• WCAHS ladder safety research is developing scientific biomechanical computer models with subsequent lab and field studies to identify the bases for the strong worker adoptability in the previous Community Partners for Healthy Farming Interventions study.</li> </ul>
<b>Technology (pilot or market-ready)</b>	<ul style="list-style-type: none"> <li>• Trials of ladder rung spacing research using custom ladders in California stone fruit orchards users report decreased knee and back discomfort, and improved stability.</li> <li>• Collaborative robot ("co-bot") developed at WCAHS designed to help agricultural worker with strawberry picking. The co-bot will assist in worker productivity and safety.</li> </ul>
<b>Use of education and training products*</b>	<ul style="list-style-type: none"> <li>• Workers in California's dairies, who face respiratory health problems due to high levels of particulate matter in their work environment, have benefited from WCAHS educational products to limit workers' exposure. These include Spanish-language posters, a Dairy Safety Training Guide, a targeted report to San Joaquin dairymen, and a dedicated webpage: <a href="http://cal.dehri.ucdavis.edu">cal.dehri.ucdavis.edu</a></li> <li>• Hundreds of farmworkers and their families receive health assessments and information through annual health fairs in Central Valley farming communities (MICASA)</li> <li>• Webinar workshop on Fall Prevention for Agricultural workers provided through AgriSafe.</li> <li>• Presentation to The Sacramento Chapter (400 members) of the American Society of Safety Engineers on agricultural ergonomics and safety.</li> <li>• A YouTube channel was developed for the U.S. Agricultural Safety and Health Centers. Over 60 videos are available for extension agents/educators, agricultural science teachers, producers/owners/operators, first responders, agricultural families, and anyone else interested in agricultural safety and health.</li> <li>• The Western Agriculture Health and Safety Blog was developed to improve understanding and prevent illness and injury in western agriculture to increase the number of youth that we reach.</li> <li>• WCAHS co-sponsors the Bionational Promotores Conference with the Health Initiative of the Americans (HIA). WCAHS is training promotores/as to deliver occupational safety and health messages to farmworkers.</li> <li>• WCAHS staff conducted a series of workshops throughout California to assist farm managers, owners or staff in charge of safety to develop effective Heat Illness Prevention programs to comply with the CalOSHA standard (California Code of Regulations, Title 8, § 3395).</li> </ul>
<b>Exposure Reduction</b>	<ul style="list-style-type: none"> <li>• WCAHS research has led to the potential to reduce heat-related illness (HRI) and create improved HRI prevention strategies for both the employers and employees on farms.</li> </ul>