The Agricultural Health Study

https://aghealth.nih.gov

The Agricultural Health Study (AHS) is funded by NIEHS and NCI. The study has benefitted from longstanding collaboration with the US EPA. NIOSH previously participated. A multi-agency Executive Committee provides overall cohort leadership.

AHS Executive Committee

NIEHS
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Overview

The Agricultural Health Study (AHS) is an ongoing prospective study of cancer and other health outcomes in a cohort of licensed pesticide applicators and their spouses from Iowa and North Carolina, and commercial applicators from Iowa. The study has generated or contributed to over 300 peer-reviewed publications to date, representing the work of investigators and collaborators from numerous intramural and extramural institutions. Add-on or nested studies of specific outcomes or exposures have enriched the cohort. As the cohort ages, the value of continued follow-up is manifest through new research on chronic diseases and conditions that increase markedly with age.

Figure 1 provides an overview of major data collection efforts to date. The study enrolled over 89,000 participants between 1993 and 1997 (Phase 1). Since enrollment, the cohort has been actively followed, including four cohort-wide surveys (Phases 2 to 5). Phases 4 and 5 (which began in 2019 and is scheduled to be completed in late 2021) focused primarily on non-cancer health outcomes and were carried out by NIEHS. At the first follow-up, buccal cells and diet history questionnaires were also collected. The cohort is passively followed for mortality and cancer incidence through linkage to vital statistics, state cancer registries, and other databases (below). Linkage to the US Renal Data System (for end-stage renal disease) and Medicare claims data facilitate studies of non-cancer health outcomes.

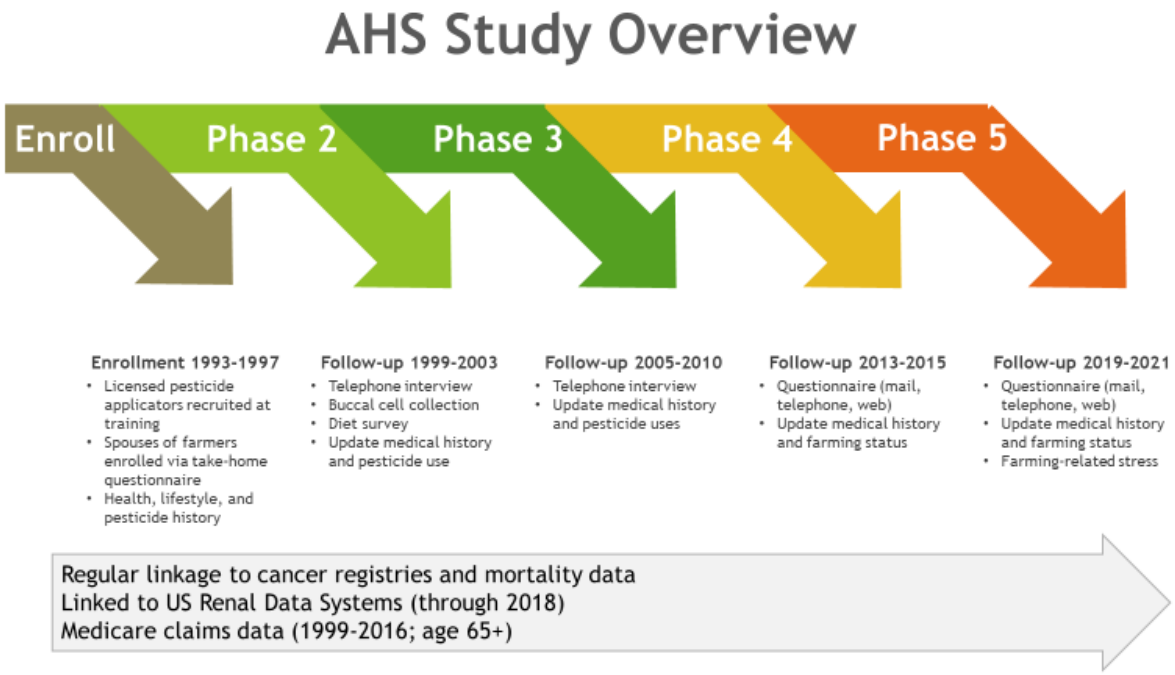

Figure 1. Enrollment and follow-up of AHS study participants

Population

The AHS cohort consists of licensed private pesticide applicators (mainly farmers) and their spouses from Iowa and North Carolina (NC) and commercial pesticide applicators in Iowa, enrolled in 1993 - 1997. Pesticide applicators were recruited when they came to pesticide training classes to obtain or renew a license to apply restricted-use pesticides. Spouses of private applicators were recruited via questionnaires brought home by the applicator or, occasionally, through direct outreach using information provided by the applicator at enrollment. Over 80% of the licensed private pesticide applicators enrolled, along with 75% of the spouses of the married private applicators. The response rate for the commercial applicators was lower (47%). A total of 89,655 individuals enrolled in the AHS (52,394 private applicators; 32,345 spouses; and 4,916 commercial pesticide applicators).

Table 1 shows selected demographic and farming characteristics of the cohort at enrollment. The average age of private applicators and their spouses was 47 years, with commercial applicators about 9 years younger. Two thirds of cohort participants were from Iowa. Most licensed applicators reported personally mixing or applying pesticides (99% of private applicators, 92% of licensed commercial applicators), as did nearly half (56%) of the spouses.

Even with the inclusion of NC, which had been selected because of a tradition of farming in the African American community, less than 3% of the cohort reported their race as something other than White. To address the limited representation of minoritized racial groups in the study, a sub-cohort of 1,198 African American/Black current and former farmers (66% female) were recruited through churches in eastern NC (1995-96). Participants in the add-on study were older than the main cohort and most were not licensed pesticide applicators. Because of key differences in participant characteristics and in pesticide information that could be collected from

former farmers and those not licensed to use restricted pesticides, this sample was not included in active follow-up, except for a small number (N=9) who also enrolled in the main cohort.

Table 1. Characteristics of the Agricultural Health Study Cohort at Enrollment

		Private Applicators (N=52,394)		Commercial Applicators (N=4,916)		Spouses (N=32,345)	
Age (years)	mean, SD	47.1	13.3	38	11.5	46.9	12.1
		N	%*	N	%*	N	%*
Gender							
	Male	51,036	97	4,712	96	219	1
	Female	1,358	3	204	4	32,126	99
Self-reported race							
	White	49,762	97	4,855	99	30,921	98
	Other	1,514	3	26	1	552	2
State							
	Iowa	31,876	61	4,916	100	21,771	67
	North Carolina	20,518	39	0	.	10,574	33
Education							
	≤High School	29,285	59	2,197	46	12,917	46
	>High School	20,708	41	2,557	54	15,177	54
Smoking status							
	Never smoked	26,937	53	2,312	48	21,997	72
	Past smoker	15,514	31	1,245	26	5,324	17
	Current smoker	8,047	16	1,282	26	3,179	10
Mix or apply pesticides							
	Ever (since age 18)	50,620	99	4,475	92	17,628	56
	Years mixed or applied						
	1 year or less	1,614	3	849	10	15,018	56
	2-10 years	13,040	26	2,147	47	6,096	22
	11-20 years	15,987	33	1,071	23	3,079	11
	21+ years	18,166	37	534	11	2,786	10

*Percentages based on the N responding to the question

Cohort Follow-up

Active follow-up of the main cohort has included four contacts to date (three completed phases and one underway). Phase 2 (1999-2003) updated pesticide use and health histories and included the collection of buccal cells and a diet history. Eligibility for the Phase 3 (2005-10) follow-up was limited to participants who had completed at least one prior cohort activity besides the enrollment questionnaire (i.e., applicator take-home or Phase 2). Thus, 8,000 applicators were excluded. Commercial applicators were also dropped from active follow-up. Participants

eligible for Phase 3 were also considered eligible for Phases 4 (2013-15) and 5 (2019-present), regardless of participation in Phase 3. Phase 4 added proxy respondents for deceased or incapacitated participants. The number of participants and response among eligible participants are shown in Table 2. Approximately 4% of the cohort has formally refused further contact and one person has requested the full removal of their records.

Table 2: AHS Cohort-wide Data Collection and Response

	Enrolled	Follow-up questionnaires							
	Phase 1 1993-97	Phase 2 1999-2003		Phase 3 2005-2010		Phase 4 2013-15		Phase 5 2019-21	
	N	N	(%)	N	(%)	N	(%)	N	(%)
Private Applicators	52,395	33,457	69	24,171	60	24,145	60	17,491	48
Spouses	32,347	23,796	76	19,959	66	18,186	61	13,428	48
Commercial Applicators	4,916	2,885	59	NA	NA	NA	NA	NA	NA
Total	89,658	60,138		42,052		42,331		30,919	

Percentages shown are among those eligible for follow-up.
NA: Commercial applicators were not interviewed after Phase 2.

All participants who enrolled in the study (including the main cohort and the African American sub-cohort), are followed for cancer incidence and mortality through regular linkages to assess cancer incidence and mortality (currently through 2018). The cohort also has been linked twice to the United States Renal Data System to identify cases of end stage renal disease (through 2018). Participants in the main cohort over age 65 were linked to Medicare administrative healthcare data (1999-2016) to identify or confirm diagnoses based on claims for inpatient and outpatient care and filled prescription medications.

Subsets of the cohort have been invited to participate in add-on studies (see below) that often included the collection of biological or environmental samples. NIEHS has specifically led or sponsored (with extramural grantees) studies of Parkinson's disease, dementia, asthma, and neurobehavioral function. Self-reported non-cancer conditions of interest (Parkinson's disease, thyroid disease, macular degeneration, rheumatoid arthritis, and systemic lupus erythematosus) have been validated through additional participant screening and medical records review.

Data Collection

Copies of all questionnaires (enrollment to Phase 5) questionnaires are available on the AHS website (https://aghealth.nih.gov/collaboration/questionnaires.html).

At enrollment self-administered questionnaires collected detailed information on lifetime pesticide use, demographics, and medical history. Applicators were asked to complete two questionnaires - one that was filled out at a pesticide training/licensing location and one to be filled out at home and mailed back. While over 80% of licensed private applicators enrolled in

the study by completing the on-site form, only 44% returned the second (take-home) questionnaire. Some details of medical history and covariates (e.g., BMI), other farming tasks and occupational exposures were only obtained in the take-home questionnaire, as was information on the frequency and duration of use of some pesticides (mostly of historical interest) for which only ever-use was ascertained on the on-site enrollment questionnaire. Married private applicators (mostly farmers) also took home a questionnaire for their spouses, of whom 75% completed the questionnaire by mail (81%) or telephone to enroll. Spouses provided information on their own use of pesticides, though in less detail than the applicators. They also provided demographic, lifestyle, and health information as well as information on off-farm exposures. Women who enrolled (both spouses and female applicators) were also asked to complete a Female and Family Health questionnaire that obtained reproductive histories and information about children; 60% of female participants completed this questionnaire.

The ***Phase 2*** follow-up questionnaires were administered using computer assisted telephone interviews, and collected detailed information on current pesticide use practices, potential confounders, and medical history. Exposure questions were similar for applicators and spouses. Health questionnaires varied slightly by sex and age. Those who completed the Phase 2 interview were asked to complete and return by mail a self-administered food frequency questionnaire (the NCI Diet History Questionnaire with added items on cooking practices); approximately 37% of applicators and 49% of spouses completed the diet questionnaire. At Phase 2, participants were also asked to collect buccal cell samples for DNA, and samples were returned by 38% of applicators and 46% of spouses. Buccal cell samples continued to be collected for some specific cancers (and other outcomes such as Parkinson's disease as part of validation efforts) during follow-up.

Phase 3 also employed a computer-assisted telephone interview to collect updated information on pesticide use practices, potential confounders, and health. A common instrument was used for all participants (applicators and spouses) to allow better integration of data for combined analyses, while women received additional questions on reproductive histories.

Phase 4 follow-up focused on health changes, updating farming status and important covariates such as smoking and family history of disease. Data collection included paper, telephone, and a pilot web version of the questionnaire. Next-of-kin provided proxy interviews (8%) for participants who were previously known or discovered to be incapacitated or deceased, to recover crucial data on health status.

The ongoing ***Phase 5*** follow-up started in 2019 and is expected to be completed at the end of 2021. Data collection includes web-based, paper, and telephone options. This phase focuses on updating health conditions, farming status, and covariate data. Special topics include pain and medication use, farming-related and other stressful life event, social support, and perceived stress. By Sept, 2021, 30,919 participants completed Phase 5 (48% of the eligible sample).

Exposure Assessment

The detailed assessment of pesticide exposures is a unique feature of the AHS. Pesticide exposure metrics have been created by integrating self-reported use information with expert judgment on exposure intensity based on application methods and use of personal protective equipment. Because they buy and apply the pesticides themselves, farmers and other licensed applicators are more likely to provide accurate information about pesticide exposure than other pesticide-exposed individuals (e.g., farmworkers).

At **enrollment**, applicators provided information on duration (years) and frequency (days per year) of use for of 50 common pesticides, which were used to calculate lifetime days of use for each of the 50 pesticides. Applicators also reported their pesticide mixing habits, application methods, use of personal protective equipment, and whether they repaired their pesticide equipment. This information was used to assign exposure intensity weights, so individuals most likely to experience personal pesticide exposures (e.g., those who did not use personal protective equipment) had their lifetime exposure days weighted more heavily than those who applied pesticides with lower exposure possibility. This algorithm has been validated in field studies conducted by EPA and NIOSH. Spouses were asked about ever mixing or applying pesticides generally, including the duration (years) and frequency (days per year) of use, ever use of 50 common pesticides, and about non-specific household pesticide treatment practices.

In the **follow-up phases**, pesticide questions were open-ended, which made it possible to characterize changes in pesticide use practices over time. Applicators and spouses were asked the same questions on pesticide use since enrollment. In Phase 2, 6,585 pesticide names were reported corresponding to 1,878 unique standard names, which in turn were associated with 403 unique active ingredients. Pesticides classified by their active ingredients were used to assign pesticide exposure in Phases 2 and 3. For applicators, this information is combined with data from enrollment to calculate lifetime days of exposure to a pesticide active ingredient. For those who did not complete the Phase 2 follow-up interview, exposure information has been imputed. Similarly, Phase 2 data have also been used to impute missing data from the baseline take-home questionnaire.

Pesticide exposures in spouses, who are less likely to report occupational use of pesticides, have been recently addressed through the development of an algorithm estimating lifetime use based on take-home (applicator), residential use, and agricultural drift.

In Phases 4 and 5, questions included an update of farming status and use of agricultural pesticides, generally, while the Phase 5 questionnaire asks about high pesticide exposure events and the specific chemical involved in the most recent incident.

In addition to pesticide information, data on other agricultural and occupational exposures and activities were collected, including various types of field work and use of different types of fertilizer. Information on specific crops and livestock raised was collected and updated throughout all follow-up phases. At enrollment (in the take home questionnaire) and in Phase 3, non-farm occupational histories were collected from both applicators and spouses. In Phases 4 and 5, work histories off the farm are updated. Enrollment data on longest off-farm job has been classified using standardized industry and occupation coding, and several occupational exposures were queried.

Outcome Ascertainment

Information on cancer and causes of death is routinely obtained by linkage to state cancer registries, state vital statistics, and the National Death Index. Other passive follow-up includes linkage to identify cases of end-stage kidney disease through the U.S. Renal Data System, and for participants ages 65 and older linkage to Medicare administrative healthcare data (1999 through 2016; N=46,689 – 98% of eligible participants).

Non-cancer outcomes (e.g. cardiovascular, neurological, kidney, endocrine, autoimmune, and reproductive outcomes) are typically ascertained based on participant self-report of a doctor's diagnosis. Questionnaires include information on age at onset, and sometimes symptoms or

other disease characteristics which help to confirm (or refute) the self-reported information. In Phase 3, extensive data on respiratory and allergic conditions were collected. The Phase 4 follow-up extended the collection of data on incidence of many of the same outcomes and added more questions on symptoms or conditions related to aging, including potential pre-motor signs of Parkinson's disease. Phase 5 follow-up continues to update health conditions and symptoms, with an added focus on and stress-related outcomes including symptoms of perceived stress and depression, unintentional injuries, chronic pain and pain medication use.

Biological Specimens

Biological specimens were collected from study participants in Phase 2, and in focused add-on studies. Individuals who completed the Phase 2 telephone interview were asked to provide a buccal cell sample using a rinse-and-spit kit. Both the cells and the supernatant were stored for future analyses. Approximately 40% of the cohort provided a buccal specimen. In addition to this cohort-wide collection, several add-on studies have collected either blood or saliva samples as a source of DNA. NCI has collected additional buccal cell samples from NHL as well as prostate, breast, and lung cancer cases diagnosed since enrollment, and blood specimens on the Biomarkers of Exposure and Effects in Agriculture study. NIEHS has collected biological specimens for DNA and other measures from Parkinson's disease cases and controls and participants in the neurobehavioral testing study, as well as saliva samples for DNA from age-related macular degeneration and ALS cases. Blood and urine samples were also collected in the AHS Lung Health Study. To date, the AHS has source material for DNA for ~35,000 participants including from buccal cell collection and specimens from the add-on studies.

Add-on Studies

The AHS executive committee encourages the use of add-on studies to leverage the cohort for new research. Studies have been carried out by both intramural and extramural investigators. Studies involving NIEHS investigators in leadership or key collaborative roles include:

Farming and Movement Evaluation Study
PI: Caroline Tanner, The Parkinson's Institute
NIEHS Collaborators: Freya Kamel, Jane Hoppin, Dale Sandler, David Umbach

The Farming and Movement Evaluation (FAME) study is a case-control study of Parkinson's Disease nested within the AHS. Home visits were conducted to perform structured neurologic examinations, draw blood, and collect dust. Movement disorder specialists confirmed the PD cases; 115 confirmed PD cases and 383 controls were included in this study which was funded by an R01 grant to Dr. Tanner, supplemented with Epidemiology Branch funds.

Neurobehavioral Testing Study
PI: Fred Gerr, University of Iowa
NIEHS Collaborators: Jane Hoppin, Freya Kamel, Dale Sandler

This study, funded through an R01 grant to Dr. Gerr, was designed to assess the impact of chronic organophosphate pesticide exposure on neurobehavioral function. Neurobehavioral testing was conducted on 701 farmers in the AHS from November 2006 to March 2008. Participants were selected based on lifetime use of organophosphate insecticides; individuals with the most use were oversampled to enrich the sample for higher exposures. At the time of testing, a questionnaire was administered, and blood was drawn for genetic and other analyses.

Agricultural Lung Health Study
PI: Stephanie London
NIEHS Collaborators: Jane Hoppin (now NC State University), Christine Parks, Dale Sandler, David Umbach

The Agricultural Lung Health Study is a case-control study of current (as of Phase 3) asthma in the AHS. Cases were identified based on responses to the Phase 3 follow-up interview; controls were selected from those who completed the Phase 3 interview and did not report respiratory conditions. At home visits, lung function tests were conducted, height and weight were measured, and biological and environmental samples were collected, along with questionnaire data on early life factors and other exposures. Field work began in February 2009 and was completed in September 2013 with a sample size of 3301. This study was funded through the American Recovery and Reinvestment Act of 2009.

Biomarkers of Exposure and Effect in Agriculture
PI: Johnathan Hoffman, NCI
NIEHS Collaborators: Dale Sandler, Christine Parks

The Biomarkers of Exposure and Effect in Agriculture study was designed to facilitate molecular epidemiologic research to address etiologic questions on the relationship of pesticides with cancer and other health outcomes. The study sample includes male applicators over age 50 who completed AHS questionnaires in Phases 1 to 3. Field work began in 2010 and enrollment of a sample of ~1680 AHS applicators is complete. Data collected in home visits included an interview on recent agricultural exposures and health status, and blood, urine, and house dust specimens (since 2013). Additionally, BEEA enrollment included 211 demographically similar male non-applicator controls identified using state voter rolls in Iowa and North Carolina.

AHS Memory and Aging (AHS-MA)
PI: Brenda Plassman, Duke University
NIEHS Collaborators: Dale Sandler, Christine Parks, Freya Kamel, Honglei Chen (now Michigan State University)

The AHS Memory and Aging study is focused on understanding risk factors for the development of symptoms of cognitive decline and Alzheimer's disease in the AHS. The study sample included living male AHS participants (private applicators) ages 70 and older who completed questionnaires in Phases 3 and 4. Data were first collected on cognitive status using a validated telephone questionnaire, starting in 2015 and completed in early 2017 with a total of 2622 enrolled. Those with suspected dementia based on screening were evaluated through 294 in-person visits and 100 proxy phone interviews. Blood was collected on 281 participants for DNA analyses and to evaluate levels of selected organochlorines and biomarkers of effect.

AHS Pesticides and Sense of Smell (PASS)
PI: Honglei Chen, Michigan State University
NIEHS Collaborators: Dale Sandler, Christine Parks

The AHS – Pesticides and Sense of Smell (PASS) Study aims to investigate whether chronic and acute high-level pesticide exposures are associated with olfactory impairment in farmers, as an indicator of potential prodromal neurodegeneration. Eligible participants included AHS farmers who reported a poor sense of smell at the AHS Phase 4 survey and a random sample of those who reported normal olfaction. From March 2020 through July 2021, 2535 participants were enrolled and completed a mailed kit for assessment of sense of smell. A subset (~600

ages 60-79) has been selected for a clinical assessment of neurodegeneration via video telemedicine, starting Fall 2021.

Study Governance

The AHS is a collaboration including partners from NCI, NIEHS, EPA. Cohort maintenance and passive follow-up is funded jointly by the NIEHS and the NCI, managed through a contract with Westat, Inc. The Phase 4 and 5 follow-up interviews, focused on non-cancer health endpoints of interest to the NIEHS EB, is funded by NIEHS and managed through its support contract with SSS, Inc.

The AHS Executive Committee makes joint decisions on the study, and reviews and approves data requests, add-on studies and manuscripts prior to submission. Development of outside proposals and collaboration is encouraged; information on collaboration and other study policies can be found on the AHS website (www.aghealth.org). Executive Committee members serve as liaisons to outside investigators working with AHS data or who wish to contact AHS participants for add-on studies. The AHS uses a project management website (www.aghealthstars.com) to track data requests, add-on studies and manuscripts arising from these projects. An interagency exposure assessment working group coordinates the development and interpretation of exposure metrics for the study. The study also has an outside advisory group consisting of scientists, community representatives, and state farm agency representatives.

AHS Collaborators

NIEHS Collaborators

Donna Baird	Epidemiology Branch
Freya Kamel	Epidemiology Branch (retired March 2017)
Stephanie London	Epidemiology Branch
David Umbach	Biostatistics and Computational Biology Branch

NIEHS Fellows and Trainees (current position)

Brittney Baumert	Post Baccalaureate Fellow (PhD candidate, Emory)
John Beard	Postdoctoral Fellow (NIOSH/CDC/DHHS)
Megan Carnes	Postdoctoral Fellow (OmniSoft)
Melissa Furlong	Special Volunteer (UNC doctoral student; now at Univ. Arizona)
Ameena Hester	Scholar's Connect Fellow (UNC undergraduate student)
John House	Postdoctoral Fellow IIDL (NC State University)
Jill Lebov	UNC Doctoral Student (Research Triangle Institute)
Martha Montgomery	Post-Baccalaureate Fellow (MD Wake Forest University, now at CDC, Columbus, OH
Jessica Rinsky	Summers of Discovery Student (UNC Doctoral Student)
Tina Saldana	Postdoctoral Fellow (Social and Scientific Systems, Inc.)
Anne Starling	Special Volunteer (University of North Carolina)
Srishti Shrestha	Postdoctoral Fellow (currently University of Mississippi)
Emily Werder	Postdoctoral Fellow
Jenna Waggoner	ASPH Fellow (Social and Scientific Systems, Inc.)

Outside Collaborators

Michael Alavanja	Hood College (formerly NCI; retired)
Gabriella Andreotti	National Cancer Institute

Laura Beane Freeman	National Cancer Institute
Aaron Blair	National Cancer Institute (retired)
Matthew Bonner	SUNY, Buffalo
Honglei Chen	Michigan State University (formerly NIEHS)
Karen Costenbader	Harvard Medical School
Meghan Davis	Johns Hopkins University
Nicole Deziel	Yale University
Lawrence Engel	University of North Carolina, Chapel Hill
Frederick Gerr	University of Iowa
Samuel Goldman	The Parkinson's Institute
Whitney Goldner	University of Nebraska Medical Center
Paul Henneberger	NIOSH
Cynthia Hines	NIOSH (retired)
Jonathan Hofmann	National Cancer Institute
Jane Hoppin	North Carolina State University (formerly NIEHS)
James Kestner	NIOSH
Ellen Kirrane	EPA
Stella Koutros	National Cancer Institute
Charles Lynch	University of Iowa
Michele Marcus	Emory University
Brenda Plassman	Duke University Medical Center
Paul Romitti	University of Iowa
Jennifer Rusiecki	Uniformed Sciences University
Caroline Tanner	University of California, San Francisco
Kent Thomas	EPA
Peter Thorne	University of Iowa
Scott Weichenthal	Health Canada

Publications

Since its inception in 1993, over 300 papers from the AHS have appeared in the peer-reviewed scientific literature. A complete list of publications since 1993 can be found at Publications | Agricultural Health Study (nih.gov). NIEHS investigators collaborate on papers related to cancer and lead research on non-cancer health effects. Research by NIEHS investigators since 2017 focused on Parkinson's disease, neurologic symptoms (dream enacting behaviors, olfactory impairment), thyroid disease, systemic autoimmune diseases (rheumatoid arthritis, systemic lupus erythematosus, Sjögren's syndrome), autoimmunity (antinuclear antibodies), infections, respiratory and allergic conditions, shingles, and mortality (overall, cause specific, permethrin).

NIEHS Authored or Coauthored AHS Publications Since 2017

2021 (through August 2021)

1. Parks, C.G., Hofmann, J.N., Beane Freeman, L.E., Sandler, D.P. Agricultural Pesticides and Shingles Risk in a Prospective Cohort of Licensed Pesticide Applicators. Environmental health perspectives. 129(7):77005. Epub 2021 July 29.
2. Goldberg, M., Ciesielski Jones, A. J., McGrath, J. A., Barker-Cummings C, Cousins, D.S., Kipling, L. M., Meadows, J. W., Kesner, J. S., Marcus, M., Monteilh, C. and Sandler, D. P. Urinary and salivary endocrine measurements to complement Tanner staging in studies of pubertal development. PLoS One; 16(5): e0251598. Epub 2021 May 14.

3. Fix, J., Annesi-Maesano, I., Baldi, I., Boulanger, M., Cheng, S., Cortes, S., Dalphin, J.C., Dalvie, M.A., Degano, B., Douwes, J., Eduard, W., Elholm, G., Ferreccio, C., Harding, A.H., Jeebhay, M., Kelly, K.M., Kromhout, H., MacFarlane, E., Maesano, C.N., Mitchell, D.C., Mwanga, H., Naidoo, S., Negatu, B., Ngajilo, D., Nordby, K.C., Parks, C.G., Schenker, M.B., Shin, A., Sisgaard, T., Sim, M., Soumagne, T., Thorne, P., Yoo, K.Y., Hoppin, J.A. (2021). Gender differences in respiratory health outcomes among farming cohorts around the globe: findings from the AGRICOH consortium. J Agromedicine, 26(2):97-108. Epub 2020 Mar 17.

4. Hofmann, J.N., Beane Freeman, L.E., Murata, K., Andreotti, G., Shearer, J.J., Thoren, K., Ramanathan, L., Parks, C.G., Koutros, S., Lerro, C.C., Liu, D., Rothman, N., Lynch, C.F., Graubard, B.I., Sandler, D.P., Alavanja, M.C., Landgren, O. (2021). Lifetime Pesticide Use and Monoclonal Gammopathy of Undetermined Significance in a Prospective Cohort of Male Farmers. Environ Health Perspect., 129(1):17003. Epub 2021 Jan 6.

5. Lerro, C.C., Beane Freeman, L.E., DellaValle, C.T., Andreotti, G., Hofmann, J.N., Koutros, S., Parks, C.G., Shrestha, S., Alavanja, M.C.R., Blair, A., Lubin, J.H., Sandler, D.P., Ward, M.H. (2021). Pesticide exposure and incident thyroid cancer among male pesticide applicators in agricultural health study. Environ Int., 146:106187. Epub 2020 Oct 27.

6. Shearer, J.J., Sandler, D.P., Andreotti, G., Murata, K., Shrestha, S., Parks, C.G., Liu, D., Alavanja, M.C., Landgren, O., Beane Freeman, L.E., Hofmann, J.N. (2021). Pesticide Use and Kidney Function Among Farmers in the Biomarkers of Exposure and Effect in Agriculture Study. Environ Res., 199:111276. Epub 2021 May 11.

7. Shrestha, S., Parks, C.G., Richards-Barber, M., Chen, H., Sandler, D.P. (2021). Parkinson's disease case ascertainment in a large prospective cohort. PLoS One, 16(5). Epub 2021 May 19.

8. Shrestha, S., Umbach, D.M., Beane Freeman, L.E., Koutros, S., Alavanja, M.C.R., Blair, A., Chen, H., Sandler, D.P. (2021). Occupational pesticide use and self-reported olfactory impairment in US farmers. Occup Environ Med. 78:179-191. Epub 2020 Oct 23.

9. Sikdar, S., Wyss, A.B., Lee, M.K., Hoang, T.T., Richards, M., Beane Freeman, L.E., Parks, C., Thorne, P.S., Hankinson, J.L., Umbach, D.M., Motsinger-Reif, A., London, S.J. (2021). Interaction between Genetic Risk Scores for reduced pulmonary function and smoking, asthma and endotoxin. Thorax. Epub 2021 May 7.

2020

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