# Chemical and Physical Exposures in the Emerging US Green-Collar Workforce

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**Objective:** "Green collar" workers serve in occupations that directly improve environmental quality and sustainability. This study estimates and compares the prevalence of select physical and chemical exposures among green versus non-green U.S. workers. **Methods:** Data from the U.S. 2010 National Health Interview Survey (NHIS) Occupational Health Supplement were linked to the Occupational Information Network (O*NET) Database. We examined four main exposures: 1) vapors, gas, dust, fumes (VGDF); 2) secondhand tobacco smoke; 3) skin hazards; 4) outdoor work. **Results:** Green-collar workers were significantly more likely to report exposure to VGDF and outdoor work than nongreen-collar workers [adjusted odds ratio (AOR) = 1.25; 95% CI = 1.11 to 1.40; AOR = 1.44 (1.26 to 1.63), respectively]. Green-collar workers were less likely to be exposed to chemicals (AOR = 0.80; 0.69 to 0.92). **Conclusions:** Green-collar workers appear to be at a greater risk for select workplace exposures. As the green industry continues to grow, it is important to identify these occupational hazards in order to maximize worker health.

"Green"-collar workers are individuals employed in businesses whose services and work products directly improve environmental-friendliness and sustainability. Green-collar jobs are defined as those that involve the protection of wildlife or ecosystems, the decline of pollution and waste, and/or the reduction of energy usage and carbon emissions.[1,2] These jobs span across multiple industries, from the construction of energy efficient buildings and vehicles to the generation of renewable energy power (eg, biofuels development).[1,3] Despite increasing evidence linking climate change to human activity, jobs in environmentally friendly and sustainable industries did not garner significant political support in the US until 2007. The green-collar workforce is expected to expand significantly in the coming years with estimates of 40 million jobs in the renewable energy industries by 2030, a significant increase from the 8.5 million jobs in 2008.[4] This new found political and economic support contributed to the increased numbers of green-collar workers and focused attention on the potential occupational hazards and health conditions of this emerging workforce.[5–7]

Across occupational categories, occupational chemical and physical exposures have been associated with detrimental health consequences. For example, studies have shown that occupational exposures to vapor, dust, and smoke are associated with chronic and nonchronic dry cough and other respiratory symptoms.[8,9] Occupational vapor, dust, and smoke exposures have also been linked to complications, such as asthma and chronic obstructive pulmonary disease.[10] Chemical exposures in the workplace have been linked to adverse health effects such as respiratory (eg, stuffy nose and cough), ocular (eg, watery, itchy, or burning eyes), and dermal symptoms (eg, rash and itchy or burning skin).[11,12] Some occupational chemical exposures have also been linked to increased risk for cancer (eg, skin cancer, bladder cancer, and lung cancer).[13] Studies have also shown that occupational outdoor work is associated with increased sunlight exposure, which in turn has led to an increased risk of skin cancer.[14] Nevertheless, little is known of the specific chemical and physical workplace exposures associated with the emerging green-collar workforce.

This study uses nationally representative data to estimate and compare the prevalence of chemical and physical exposures in green versus nongreen-collar U.S. workers. Previous studies have shown that 40% of respondents of a similar occupational categorization reported exposure to vapors, gas, dust, or fumes.[15] Shopland et al[16] analyzed data from the national Current Population Survey (CPS), a survey administered by the Bureau of the Census for the Bureau of Labor Statistics, and found that the percentage of workers who reported a smoke-free workplace policy had increased from 46% in 1993 to 69% in 1999.[17,18]

The emerging green-collar workforce is likely not immune to traditional occupational hazards, and may be exposed to new evolving workplace harmful or protective health and safety factors. Due to advocacy in promoting environmental sustainability possibly extending to their workplaces, we would expect green-collar workers to have lower rates of vapors, gas, dust, or fumes, secondhand smoke exposures, and chemical exposures. As for work outdoor exposure, it is evident that a portion of the green-collar workforce is dedicated to wildlife preservation and the use of renewable energy resources and construction, which inherently involves more outdoor work than nongreen jobs for some green-collar workers.[1–3] Therefore, we hypothesized that green-collar workers would report lower rates of exposures to vapors, gas, dust, or fumes, secondhand tobacco smoke, and chemical exposures, but higher rates of work-related outdoor exposure relative to nongreen-collar workers.

## METHODS

### Data Sources

#### 2010 National Health Interview Survey (NHIS) Occupational Health Supplement

The National Health Interview Survey (NHIS) is a nationally representative survey that collects data on a wide range of health

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CC, KJM, AJCM, DJL, and LEF conceived the study, participated in its design, coordination, performed statistical analyses, and co-drafted the manuscript. WGL and KLA participated in the design of the study, performed statistical analysis, and helped with the manuscript draft. SLC, CAF, LAM, and MC read, revised, and approved the final manuscript.

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Institution and Ethics Approval and informed consent: This study was approved by the University of Miami Institutional Review Board (IRB #: 20120714).

The authors declare no conflict of interest.

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topics. The NHIS is the primary source of information on the health of the civilian noninstitutionalized population residing in the U.S since 1957. The cross-sectional household survey is administered annually by the National Center for Health Statistics (NCHS). The NHIS uses multistage, clustered, nonprobability sampling techniques. The 2010 NHIS Occupational Supplement provides unique national estimates of the prevalence of common workplace exposures and work-related health conditions. Information on individual job type, employment status, health status, medical conditions, health care utilization and access, and health-related behaviors was collected.[19] Adult NHIS respondents aged 18 years and older who reported being employed in the week before survey administration were included in the analyses.

### 2010 Occupational Information Network Online (O*NET), Version 19.0

The O*NET is an online occupational database sponsored by the U.S. Department of Labor that is periodically updated with new U.S. job title information. It contains information on over 900 standardized and occupation-specific descriptors over six domains, including 1) worker characteristics, 2) worker requirements, 3) experience requirements, 4) occupational requirements, 5) workforce characteristics, and 6) occupation-specific information. The O*NET labels each job with Standard Occupational Classification (SOC) codes, which is further classified into green-collar occupations based on the activities and technologies of the job requirements (eg, whether or not they provide green services or produce green goods).[20] If a job has at least one ''green'' task (eg, whether it provides green services or produces green goods), then it is categorized as a ''green collar'' job.

### NHIS and O*NET Linkage

Linking the publicly 2010 NHIS Occupational Supplement data with the green-collar classification in O*NET occurs through the Research Data Center (RDC) at the National Center for Health Statics. Although the NHIS publishes publicly a two-digit condensed occupational and industry code for each employed NHIS survey respondent, the two-digit public code limits the linkage between the NHIS survey data and the rich job titles and characteristics available in O*NET. After a formal peer-reviewed and secure application process at the RDC, our research team accessed and linked the four-digit occupational code variable (OCCUPN) in the NHIS (ie, digits 3 4 5 6) and the eight-digit O*NET SOC code (ie, 1 2 3 4 5 6. 7 8). On the basis of the digit coding and linkage, we created a new variable, ''Green Category,'' to label NHIS survey respondents as either a Green-collar or Nongreen-collar worker. In the case when the O*NET SOC code had a seventh and eighth digit ending in 0.00, this was considered an exact match with the NHIS data and labeled as green or nongreen. However, when the seventh and eighth digit had an extension beyond 0.00 (such as 0.01, 0.02, etc), we further investigated whether each of these detailed occupations were all green, all nongreen, or ''mixed-green'' collar workers. For example, if an O*NET broad occupational group had three different extensions of the seventh and eighth digit codes (eg, 0.01, 0.02, and 0.03) of which two were classified as green and one was classified as nongreen, then the NHIS occupational code was labeled as mixed-green to indicate that the parent job title had mixed jobs. The mixed-green collar workers ($n = 1005$; 6.8%) were excluded for this analysis.

## Dependent Variables

We examined four main outcome variables, reflecting self-reported chemical and physical agent occupational exposures: 1) vapors, gas, dust, or fumes; 2) secondhand tobacco smoke; 3) skin hazards; and 4) outdoor work. Vapors, gas, dust, or fume exposure was measured by the question: ''Please tell me if you are/were regularly exposed to vapors, gas, dust or fumes at work twice a week or more?'' Secondhand smoke exposure was measured by the question: ''During the past 12 months, were you regularly exposed to tobacco smoked from other people at work twice a week or more?'' Skin hazard was measured by the question: ''During the past 12 months, did you regularly handle or were you in skin contact with chemical products or substances at work twice a week or more?'' Outdoor work was measured by asking the respondent, ''During the past 12 months, did you regularly work outdoors twice a week or more?'' Each response was dichotomized (yes/no) by the NHIS.

## Independent Variables

The main independent variable was green-collar worker status (''green collar'' or ''non-green collar''). Self-reported socio-demographic, health characteristics, and job characteristic variables of the NHIS respondent were also included as predictors, including gender, race (white, black, or other), age, ethnicity (Hispanic or non-Hispanic), educational attainment (greater than high school, high school or GED, or less than high school), health insurance status (insured or uninsured), geographic region (Northeast, Midwest, South, West), body mass index (underweight, normal weight, overweight, obese), number of employees at the place of work (1 to 9, 10 to 24, 25 to 49, 50 to 99, 100 to 249, and 250+ employees), employment type (private, government employee, self-employed), and whether the workers had more than one job (yes/no).

## Statistical Analyses

Multivariable logistic regression analyses were performed for each of the four outcome variables to calculate unadjusted odds ratios (UORs), adjusted odds ratios (AORs), and 95% confidence intervals (95% CIs). Exposure status regression analyses were adjusted for smoking status, gender, age, ethnicity, education level, health insurance status, geographic region, body mass index, size of company, type of employment, and number of jobs. The university institutional review board approved the study protocol. The NHIS data collection involves a complex, multistage design with additional elements of oversampling, clustering, and stratification hence statistical analyses were conducted with SUDAAN 11 (Research Triangle Institute, Research Triangle Park, NC) to account for complex design of NHIS.

# RESULTS

## Descriptive Information

The socio-demographic and work-related characteristics of the total workforce, including green and nongreen-collar workers are listed in Table 1. There was a total of 14,805 workers in the study period of whom 2588 were classified as green collar (19%; US population estimate 24,614,939) and 12,217 nongreen collar (81%; US population estimate 106,628,031).

Green-collar workers were more likely to be male (76% vs 48% nongreen workers), white race (84% vs 82%), and be classified as overweight (40% vs 35%). Fewer green-collar workers reported functional limitations (13% vs 15%), or visual (6% vs 7%) impairments than nongreen-collar workers. The typical green-collar worker was employed in a private company (84% vs 72%), and worked primarily in that one green-collar job as opposed to having a second job (94% vs 91%).

The prevalence of chemical and physical exposures of green and nongreen-collar workers is displayed in Table 2. The prevalence of vapors, gas, dust, or fume exposure (32% vs 23%), secondhand smoke exposure (17% vs 14%), and working outdoors (34% vs 22%) was higher in green-collar workers than nongreen-collar workers. In contrast, the prevalence of chemical exposures was

 

**TABLE 1.** Socio-demographics and Work Characteristics of Green and Nongreen-collar Workers: The National Health Interview Survey, 2010 Occupational Supplement, and 2010 ONET Linkage[*,†]

| | Total Worker Population | | | Green Collar | | | Nongreen Collar | | |
|---|---|---|---|---|---|---|---|---|---|
| **Characteristics** | **US Estimated Population** | ***N*[‡]** | **Percent[§] [95% CI]** | **US Estimated Population** | ***n*[‡]** | **Percent[§] [95% CI]** | **US Estimated Population** | ***n*[‡]** | **Percent[§] [95% CI]** |
| Total | 131,296,970 | 14,805 | 100.0 | 24,614,939 | 2,588 | 18.7 (18.0–19.4) | 106,682,031 | 12,217 | 81.2 (80.5–81.9) |
| Gender | | | | | | | | | |
| Male | 69,814,890 | 7,306 | 53.1 (52.1–54.1) | 18,777,269 | 1,900 | 76.3 (74.5–78.0) | 51,037,621 | 5,406 | 47.8 (46.7–48.9) |
| Female | 61,482,080 | 7,499 | 46.8 (45.8–47.8) | 5,837,670 | 688 | 23.7 (21.9–25.4) | 55,644,410 | 6,811 | 52.1 (51–53.2) |
| Race | | | | | | | | | |
| White | 107,663,727 | 11,224 | 82 (81–82.9) | 20,600,991 | 2,018 | 83.7 (81.8–85.4) | 87,062,736 | 9,206 | 81.6 (80.7–82.5) |
| Black | 15,246,774 | 2,349 | 11.6 (10.8–12.3) | 2,621,791 | 365 | 10.6 (9.1–12.1) | 12,624,983 | 1,984 | 11.8 (11–12.5) |
| Other | 8,386,469 | 1,232 | 6.3 (5.8–6.9) | 1,392,157 | 205 | 5.7 (4.6–6.6) | 6,994,312 | 1,027 | 6.6 (5.9–7.1) |
| Age group | | | | | | | | | |
| 18–24 | 16,733,678 | 1,559 | 12.7 (11.9–13.5) | 2,260,000 | 210 | 9.2 (7.7–10.6) | 14,473,678 | 1,349 | 13.6 (12.6–14.4) |
| 25–64 | 109,210,100 | 12,552 | 83.1 (82.3–84) | 21,453,941 | 2,279 | 87.2 (85.4–88.8) | 87,756,159 | 10,273 | 82.3 (81.3–83.2) |
| 65+ | 5,353,192 | 694 | 4.0 (3.7–4.4) | 900,998 | 99 | 3.7 (2.8–4.4) | 4,452,194 | 595 | 4.1 (3.7–4.5) |
| Ethnicity | | | | | | | | | |
| Non-Hispanic | 112,465,426 | 11,865 | 85.6 (84.8–86.4) | 21,076,884 | 2,110 | 85.6 (84.1–87.1) | 91,388,542 | 9,755 | 85.7 (84.8–86.4) |
| Hispanic | 18,831,544 | 2,940 | 14.3 (13.5–15.1) | 3,538,055 | 478 | 14.4 (12.8–15.8) | 15,293,489 | 2,462 | 14.3 (13.5–15.1) |
| Educational level | | | | | | | | | |
| >HS | 85,961,694 | 9,479 | 65.6 (64.5–66.7) | 14,887,531 | 1,537 | 60.8 (58.2–63.2) | 71,074,163 | 7,942 | 66.8 (65.6–67.9) |
| HS | 32,367,120 | 3,574 | 24.7 (23.8–25.6) | 7,176,915 | 731 | 29.3 (27–31.5) | 25,190,205 | 2,843 | 23.7 (22.7–24.6) |
| <HS | 12,585,494 | 1,713 | 9.6 (9–10.2) | 2,440,156 | 310 | 10.0 (8.7–11.1) | 10,145,338 | 1,403 | 9.5 (8.8–10.2) |
| Health insurance | | | | | | | | | |
| Not insured | 22,946,866 | 2,899 | 17.5 (16.6–18.4) | 3,569,671 | 437 | 14.5 (12.9–16.2) | 19,377,195 | 2,462 | 18.2 (17.2–19.2) |
| Insured | 107,795,448 | 11,863 | 82.4 (81.5–83.3) | 20,934,477 | 2,142 | 85.4 (83.7–87) | 86,860,971 | 9,721 | 81.7 (80.7–82.7) |
| Regional location | | | | | | | | | |
| Northeast | 23,415,050 | 2,326 | 17.8 (16.7–18.9) | 4,458,522 | 407 | 18.1 (16.1–20.1) | 18,956,528 | 1,919 | 17.7 (16.6–18.9) |
| Midwest | 31,050,486 | 3,295 | 23.6 (22.4–24.8) | 5,971,088 | 608 | 24.2 (22.2–26.2) | 25,079,398 | 2,687 | 23.5 (22.2–24.7) |
| South | 46,202,248 | 5,456 | 35.1 (33.8–36.5) | 8,365,611 | 923 | 33.9 (31.8–36.1) | 37,836,637 | 4,533 | 35.4 (34–36.9) |
| West | 30,629,186 | 3,728 | 23.3 (22.1–24.5) | 5,819,718 | 650 | 23.6 (21.6–25.6) | 24,809,468 | 3,078 | 23.2 (21.9–24.5) |
| Use special equipment | | | | | | | | | |
| Yes | 2,262,315 | 247 | 1.7 (1.4–1.9) | 474,947 | 45 | 1.9 (1.3–2.5) | 1,787,368 | 202 | 1.6 (1.3–1.9) |
| No | 128,929,436 | 14,543 | 98.2 (98–98.5) | 24,128,685 | 2,542 | 98 (97.4–98.6) | 104,800,751 | 12,001 | 98.3 (98–98.6) |
| Any functional limitations | | | | | | | | | |
| Yes | 19,175,181 | 2,188 | 14.6 (13.9–15.2) | 3,262,315 | 332 | 13.2 (11.7–14.7) | 15,912,866 | 1,856 | 14.9 (14.1–15.6) |
| No | 112,121,789 | 12,617 | 85.3 (84.7–86) | 21,352,624 | 2,256 | 86.7 (85.2–88.2) | 90,769,165 | 10,361 | 85 (84.3–85.8) |
| Hearing impairment | | | | | | | | | |
| Yes | 15,220,235 | 1,585 | 11.5 (10.9–12.2) | 3,329,911 | 324 | 13.5 (11.9–15.1) | 11,890,324 | 1,261 | 11.1 (10.4–11.8) |
| No | 116,055,331 | 13,216 | 88.4 (87.7–89) | 21,285,028 | 2,264 | 86.4 (84.8–88) | 94,770,303 | 10,952 | 88.8 (88.1–89.5) |
| Visual impairment | | | | | | | | | |
| Yes | 8,700,869 | 1,030 | 6.6 (6.1–7.1) | 1,529,915 | 163 | 6.2 (5.1–7.3) | 7,170,954 | 867 | 6.7 (6.1–7.2) |
| No | 122,588,333 | 13,773 | 93.3 (92.8–93.8) | 23,085,024 | 2,425 | 93.7 (92.6–94.8) | 99,503,309 | 11,348 | 93.2 (92.7–93.8) |
| Body mass index | | | | | | | | | |
| Underweight | 1,747,585 | 205 | 1.3 (1.1–1.6) | 184,376 | 21 | 0.7 (0.3–1.1) | 1,563,209 | 184 | 1.5 (1.2–1.7) |
| Normal weight | 44,199,496 | 4,969 | 34.8 (33.8–35.8) | 6,925,364 | 733 | 28.7 (26.6–30.8) | 37,274,132 | 4,236 | 36.2 (35–37.3) |
| Overweight | 45,907,356 | 5,200 | 36.1 (35.1–37.1) | 9,630,198 | 1,026 | 39.9 (37.7–42.2) | 36,277,158 | 4,174 | 35.2 (34.1–36.3) |
| Obese | 35,129,657 | 3,923 | 27.6 (26.7–28.5) | 7,335,945 | 739 | 30.4 (28.2–32.6) | 27,793,712 | 3,184 | 27 (26–28) |
| Employees at work | | | | | | | | | |
| 1–9 employees | 32,784,032 | 3,735 | 25.8 (24.9–26.7) | 5,311,894 | 570 | 22 (20–24) | 27,472,138 | 3,165 | 26.7 (25.7–27.7) |
| 10–24 employees | 18,550,259 | 2,064 | 14.6 (13.8–15.4) | 3,324,045 | 348 | 13.8 (12.1–15.5) | 15,226,214 | 1,716 | 14.8 (14–15.6) |
| 25–49 employees | 14,989,208 | 1,631 | 11.8 (11.1–12.5) | 2,956,846 | 296 | 12.2 (10.5–14) | 12,032,362 | 1,335 | 11.7 (10.9–12.4) |
| 50–99 employees | 13,537,794 | 1,505 | 10.6 (10–11.3) | 2,381,265 | 257 | 9.8 (8.5–11.2) | 11,156,529 | 1,248 | 10.8 (10.1–11.6) |
| 100–249 employees | 15,888,297 | 1,812 | 12.5 (11.8–13.1) | 3,595,234 | 377 | 14.9 (13.3–16.5) | 12,293,063 | 1,435 | 11.9 (11.2–12.6) |
| 250+ employees | 31,017,765 | 3,528 | 24.4 (23.5–25.4) | 6,502,470 | 686 | 27 (25–28.9) | 24,515,295 | 2,842 | 23.8 (22.8–24.9) |
| Employment type | | | | | | | | | |
| Private | 97,249,605 | 10,977 | 74.4 (73.5–75.3) | 20,623,010 | 2,157 | 83.8 (82.1–85.6) | 76,626,595 | 8,820 | 72.2 (71.2–73.2) |
| Government | 21,721,619 | 2,466 | 16.6 (15.8–17.4) | 2,088,164 | 229 | 8.4 (7.1–9.8) | 19,633,455 | 2,237 | 18.5 (17.6–19.3) |
| Self-employed | 11,684,404 | 1,285 | 8.9 (8.3–9.5) | 1,870,619 | 196 | 7.6 (6.4–8.7) | 9,813,785 | 1,089 | 9.2 (8.5–9.9) |
| Incorporated Corp. | | | | | | | | | |
| Yes | 3,203,863 | 330 | 27.5 (24.6–30.4) | 720,097 | 67 | 38.4 (31.2–45.7) | 2,483,766 | 263 | 25.4 (22.4–28.4) |
| No | 8,411,963 | 947 | 72.4 (69.5–75.3) | 1,150,522 | 129 | 61.5 (54.2–68.7) | 7,261,441 | 818 | 74.5 (71.5–77.5) |
| More than one job | | | | | | | | | |
| Yes | 11,312,689 | 1,282 | 8.6 (8–9.2) | 1,443,380 | 168 | 5.8 (4.8–6.8) | 9,869,309 | 1,114 | 9.2 (8.6–9.9) |
| No | 119,775,083 | 13,501 | 91.3 (90.7–91.9) | 23,162,291 | 2,418 | 94.1 (93.1–95.1) | 96,612,792 | 11,083 | 90.7 (90–91.3) |
| Smoker | | | | | | | | | |
| Current | 2,783,095 | 2,818 | 19.2 (18.4–20.0) | 557,846 | 540 | 20.5 (18.6–22.4) | 2,225,250 | 2,278 | 18.9 (18.0–19.8) |
| Former | 2,790,580 | 2,705 | 19.2 (18.5–20.0) | 594,847 | 535 | 21.9 (20.0–23.7) | 2,195,733 | 2,170 | 18.6 (17.8–19.5) |

(*Continued on next page*)

**TABLE 1.** (*Continued*)

| Characteristics | Total Worker Population | | | Green Collar | | | Nongreen Collar | | |
|---|---|---|---|---|---|---|---|---|---|
| | US Estimated Population | $N^{\ddagger}$ | Percent[§] [95% CI] | US Estimated Population | $n^{\ddagger}$ | Percent[§] [95% CI] | US Estimated Population | $n^{\ddagger}$ | Percent[§] [95% CI] |
| Never | 8,925,572 | 9,190 | 61.6 (60.6–62.5) | 1,568,056 | 1,495 | 57.6 (55.5–59.8) | 7,357,516 | 7,695 | 62.5 (61.4–63.5) |

95% CI, 95% confidence interval.
*Green jobs are characterized as having at least one ''green'' task.
†The estimates from this table are based on questions from the National Health Interview Survey; Mixed workers have been excluded.
‡Sample size from the National Health Interview Survey for the year 2010.
§Percent (prevalence) estimated from the National Health Interview Survey for the year 2010.

reportedly lower in green-collar workers than that of nongreen-collar workers (19% vs 21%).

## Logistic Regression Analyses

In the univariate logistic regression analyses, green-collar workers were significantly more likely to be exposed to vapors, gas, dust, or fumes exposure (UOR, UOR = 1.65; 95% CI = 1.47 to 1.85), secondhand smoke exposure (1.27; 95% CI = 1.11 to 1.47), and work outdoors (1.82; 95% CI = 1.62 to 2.04). Green-collar workers were less likely to be exposed to chemicals (0.89; 95% CI: 0.78 to 1.03), although this finding was not statistically significant.

The multivariable logistic regression analyses for chemical and physical exposures of green and nongreen-collar workers are summarized in Table 3. In the multivariate logistic regression, green-collar workers were significantly more likely to be exposed to vapors, gas, dust, or fume exposure and working outdoors relative to nongreen-collar workers (AOR = 1.25; 95% CI = 1.11 to 1.40 and 1.44; 95% CI = 1.26 to 1.63, respectively). However, green-collar works were less likely to be exposed to chemicals and skin hazards (0.80; 95% CI = 0.69 to 0.92). There was not a statistically significant difference in secondhand smoke exposure between green and nongreen workers (1.06; 95% CI = 0.90 to 1.24).

# DISCUSSION

To our knowledge, this is the first study to describe the potential chemical and physical occupational exposures within the emerging U.S. green-collar workforce using the uniquely linked 2010 NHIS and O*NET data. Studies have shown that occupational chemical and physical exposures can lead to adverse health outcomes. Our data show that there is a significant difference in self-reported chemical and physical exposures between green and nongreen workers. Green-collar workers have a greater prevalence in vapors, gas, dust, or fume exposure, secondhand smoke exposure, and outdoor work exposure, whereas nongreen workers report a higher prevalence of chemical exposure.

Contrary to our hypothesis, green-collar workers have higher rates of vapors, gas, dust, or fume exposures than nongreen workers. Occupational vapor exposure can lead to adverse health outcomes such as idiopathic pulmonary fibrosis, asthma, and other respiratory symptoms.[8,21] These results are unexpected given the green industry's general image to focus on work with nonhazardous materials.[22] Further research is necessary to characterize the vapor exposures in order to determine potential health and wellbeing effects and to develop intervention strategies to reduce workplace exposures.

Although not significant in our multivariable models (1.06; 0.90 to 1.24), green-collar workers may have higher rates of secondhand tobacco smoke exposure than nongreen workers (32% vs 24%). Secondhand smoke exposure has been linked to lung cancer, cardiovascular disease, and cerebrovascular disease.[23–25] Studies have used secondhand smoke serum markers such as cotinine to further quantify the degree of workplace secondhand smoke exposure.[26] Although the result is unexpected, it is important to note that having a green industry is not necessarily synonymous with a ''green'' or healthy workplace environment. This may help to explain the discrepancy between the expected hypothesis and the results.

As we hypothesized, occupational outdoor exposure rates were higher among green-collar workers than nongreen-collar workers (1.44; 95% CI = 1.26 to 1.63) after adjusting for other sociodemographic and work characteristics. Among all exposures, the greatest difference between green and nongreen workers was the number of workers reporting outdoor work exposure. Increased outdoor exposure may be attributable to the environmentally friendly and eco-friendly services provided by the green industry such as installation of solar panels or wind turbines. Outdoor work exposure has been linked to increased rates of skin cancer.[14,27] Variables such as duration of outdoor exposure and use of sun

**TABLE 2.** Prevalence of Occupational Exposures* Among Green and Nongreen-collar Workers: The National Health Interview Survey, 2010 Occupational Supplement, and 2010 ONET Linkage†

| Characteristics | Total Worker Population | | | Green Collar | | | Nongreen Collar | | |
|---|---|---|---|---|---|---|---|---|---|
| | US Estimated Population | $N^{*}$ | Percent‡ [95% CI] | US Estimated Population | $n^{*}$ | Percent‡ [95% CI] | US Estimated Population | $n^{*}$ | Percent‡ [95% CI] |
| Vapor exposure | 31,989,790 | 3,536 | 24.4 (23.6–25.3) | 7,975,809 | 846 | 32.4 (30.4–34.5) | 24,013,981 | 2,690 | 22.6 (21.6–23.5) |
| Secondhand smoke exposure | 18,834,642 | 2,102 | 14.3 (13.5–15.1) | 4,172,504 | 446 | 16.9 (15.2–18.6) | 14,662,138 | 1,656 | 13.7 (12.9–14.6) |
| Chemical exposure | 26,683,550 | 2,876 | 20.3 (19.5–21.1) | 4,599,107 | 468 | 18.7 (16.9–20.4) | 22,084,443 | 2,408 | 20.7 (19.8–21.6) |
| Work outdoors | 31,396,888 | 3,419 | 23.9 (23.0–24.8) | 8,268,994 | 885 | 33.6 (31.4–35.7) | 23,127,894 | 2,534 | 21.7 (20.7–22.6) |

95% CI, 95% confidence interval.
*Sample size from the National Health Interview Survey for the year 2010.
†The estimates from this table are based on questions from the National Health Interview Survey that asked respondents ''Please tell me if you [fill 2: are/were] regularly exposed to vapors, gas, dust, or fumes at work twice a week or more?''
‡Percent (prevalence) estimated from the National Health Interview Survey for the year 2010.

**TABLE 3.** Multivariable Logistic Regression Analyses Predicting Occupational Exposures in Green versus Nongreen-Collar Workers: The National Health Interview Survey, 2010 Occupational Supplement, and 2010 O*NET Linkage

| Independent Variable | Vapor Exposure ($n = 13,678$) AOR (95% CI) | Secondhand Smoke Exposure ($n = 13,688$) AOR (95% CI) | Chemical Exposure ($n = 13,686$) AOR (95% CI) | Work Outdoors ($n = 13,691$) AOR (95% CI) |
|---|---|---|---|---|
| Green Collar (Ref = Nongreen) | | | | |
| Green | 1.25 (1.11–1.40)* | 1.06 (0.90–1.24) | 0.80 (0.69–0.92)* | 1.44 (1.26–1.63)* |
| Smoker (Ref = Never) | | | | |
| Current | 1.78 (1.57–2.03)* | 5.03 (4.39–5.77)* | 1.54 (1.34–1.76)* | 1.39 (1.22–1.59)* |
| Former | 1.51 (1.34–1.72)* | 1.39 (1.18–1.65)* | 1.22 (1.05–1.41)* | 1.13 (1.00–1.28)* |
| Gender (Ref = Female) | | | | |
| Male | 2.38 (2.15–2.64)* | 1.97 (1.74–2.23)* | 1.37 (1.24–1.51)* | 4.66 (4.14–5.25)* |
| Race (Ref = White) | | | | |
| Black | 1.08 (0.92–1.26) | 1.41 (1.19–1.67)* | 0.79 (0.67–0.93)* | 1.03 (0.86–1.24) |
| Other | 0.63 (0.52–0.78)* | 0.94 (0.72–1.22) | 0.68 (0.53–0.86)* | 0.45 (0.36–0.58)* |
| Age (Ref = 18–24) | | | | |
| 25–64 | 1.15 (0.96–1.39) | 0.58 (0.47–0.71)* | 0.80 (0.67–0.96)* | 1.10 (0.91–1.33) |
| 65+ | 0.69 (0.51–0.94)* | 0.31 (0.20–0.46)* | 0.35 (0.24–0.50)* | 0.97 (0.72–1.30) |
| Ethnicity (Ref = Non-Hispanic) | | | | |
| Hispanic | 0.9 (0.76–1.07) | 0.87 (0.71–1.07) | 0.89 (0.76–1.04) | 0.99 (0.85–1.17) |
| Education (Ref = HS+) | | | | |
| High school/GED | 1.98 (1.76–2.23)* | 1.49 (1.28–1.72)* | 1.52 (1.34–1.73)* | 1.83 (1.60–2.09)* |
| Less than high school | 2.12 (1.79–2.52)* | 1.43 (1.17–1.76)* | 1.46 (1.21–1.76)* | 2.21 (1.85–2.64)* |
| Health insurance status (Ref = No) | | | | |
| Yes | 0.92 (0.80–1.05) | 0.68 (0.58–0.8)* | 0.75 (0.66–0.85)* | 0.85 (0.74–0.98)* |
| Geographic region (Ref = Northeast) | | | | |
| Midwest | 1.20 (1.03–1.40)* | 1.18 (0.96–1.45) | 1.27 (1.09–1.49)* | 1.02 (0.84–1.23) |
| South | 1.14 (1.00–1.32)* | 1.47 (1.21–1.78)* | 1.12 (0.96–1.30) | 1.29 (1.08–1.53)* |
| West | 1.16 (0.98–1.38) | 1.21 (0.96–1.51) | 1.04 (0.88–1.24) | 1.42 (1.19–1.69)* |
| Body mass index (Ref = Normal) | | | | |
| Underweight | 0.92 (0.56–1.50) | 1.09 (0.65–1.81) | 1.26 (0.79–2.00) | 0.79 (0.47–1.32) |
| Overweight | 1.17 (1.02–1.33)* | 1.20 (1.02–1.42)* | 1.11 (0.97–1.27) | 1.08 (0.95–1.23) |
| Obese | 1.31 (1.14–1.50)* | 1.37 (1.17–1.60)* | 1.22 (1.05–1.42)* | 1.16 (1.01–1.34)* |
| Size of company (Ref = 250+ employees) | | | | |
| 1–9 employees | 1.09 (0.94–1.27) | 0.89 (0.73–1.09) | 1.14 (0.97–1.34) | 2.51 (2.11–2.99)* |
| 10–24 employees | 0.99 (0.83–1.17) | 1.08 (0.89–1.30) | 1.09 (0.91–1.30) | 2.03 (1.70–2.42)* |
| 25–49 employees | 1.12 (0.94–1.34) | 1.03 (0.81–1.30) | 1.16 (0.97–1.38) | 1.85 (1.53–2.24)* |
| 50–99 employees | 0.97 (0.79–1.18) | 1.17 (0.94–1.44) | 0.97 (0.79–1.18) | 1.44 (1.16–1.78)* |
| 100–249 employees | 1.00 (0.84–1.19) | 0.95 (0.76–1.18) | 0.83 (0.69–1.01) | 1.32 (1.10–1.60)* |
| Type of employment (Ref = Government employee) | | | | |
| Private employee | 1.00 (0.87–1.14) | 1.13 (0.93–1.38) | 1.15 (0.97–1.35) | 0.46 (0.40–0.54) |
| Self-employed | 1.22 (0.98–1.53) | 0.97 (0.70–1.34) | 1.39 (1.10–1.76)* | 0.80 (0.63–1.02) |
| More than one job (Ref = No) | | | | |
| Yes | 1.10 (0.91–1.34) | 1.20 (0.97–1.49) | 1.31 (1.08–1.59) | 1.31 (1.10–1.56)* |

95% CI, 95% confidence interval; AOR, adjusted odds ratio.
*Statistically significant ($P < 0.05$).

protection are needed to further characterize outdoor work exposure in the green and nongreen workforces.

In contrast to the vapors, gas, dust, or fumes, secondhand smoke, and outdoor exposure rates, nongreen-collar workers had higher rates of chemical exposure than green-collar workers. The lower rates of chemical exposure among green-collar workers may relate to the workforce's commitment to sustainability and eco-friendliness—nonhazardous, ecofriendly alternatives to chemicals may replace chemicals typically used in nongreen occupations. Studies have shown that green-collar workers have lower rates of occupational dermatologic disease, which may account for the lower rates of chemical exposure for green-collar workers seen in this study.[5] However, as it cannot be assumed that ''green'' chemicals are necessarily less toxic to humans, future studies should better identify the chemical exposures such as the types of chemical, duration of exposure, and frequency of exposure.[28,29]

This study is not without limitations. The use of cross-sectional and self-reported data in the NHIS may limit the classification of the exposure or job characteristic given that quantitative or validated individual assessments of the occupational exposures or workplace job tasks/activities are not available in the NHIS.[20] The estimates generated by self-reporting survey data can be biased due to the varying subjective assessments performed by the participants. The reasons include low self-confidence, self-biasing, and memory recall. Nonetheless, self-reported data provide a relatively inexpensive and rapid approach to collect exposure data. The O*NET exposure data are ecological, suggesting that interpretations of these data may be prone to the ecological fallacy.

In addition, we may be overestimating the true prevalence of green-collar workers employed in the U.S. workforce using the NHIS data. Although the U.S. economy and workforce expands and contracts throughout the study period, there may be variations in the number of individuals truly employed in green-collar occupations. For example, the construction industry has seen an increase in the number of workers and projects in recent years following the global financial crisis; green and sustainable building maybe increasing the number of green-collar related construction jobs. Nonetheless, the BLS used a different sampling frame (ie, business and government establishments

within 325 industries). Furthermore, the BLS measurement of ''Green Goods and Services'' was different (ie, consisted of the percentage of the establishment's revenue related to sale of green goods and services), while the O*NET uses a different mechanism to categorize green and nongreen occupations, not industries.

To highlight this importance, we undertook a post-hoc analysis of our univariate logistic regression results, varying the prevalence of green workers in our 2-by-2 exposure–outcome tables to examine the potential influence of misclassification bias. We varied the prevalence from 18% of green-collar workers, obtained in our study, down to 6.5%, the prevalence rate noted in the BLS report, and examined the impact this had on odds ratio estimates. Results for two of the outcome measures (vapors, gas, dust, or fumes; and outdoor work) had odds ratio estimates similar to the one listed in Table 2 (1.71 to 1.75 and 2.00 to 2.11, respectively). However, odds ratio estimates for secondhand smoke and chemical exposures were variable across the range of green-collar prevalence estimates (0.52 to 1.33 and 0.12 to 1.39), respectively. These post-hoc findings highlight the importance of developing a uniform definition of green-collar work that can be used both for estimating the size of the workforce and to conduct surveillance on this growing workforce.

Despite these limitations, this preliminary analysis estimating the chemical and physical exposures of green-collar workers has several strengths, including the large and nationally representative sample of NHIS adult participants, with a snapshot of all U.S. civilian workers. Using uniquely linked and publicly available (NHIS and O*NET data) for the first time provided a classification scheme of green and nongreen-collar occupations of the U.S. workforce. Lastly, the time period that NHIS Occupational Health Supplement assessed novel self-reported measures on specific workplace physical and chemical exposures not available in other state- or national-level U.S. surveillance systems.

This study documents preliminary findings that the emerging green-collar workforce self-reported significantly different chemical and physical occupational exposure rates compared to nongreen workers. Green-collar workers showed higher prevalence of vapor, gas, dust, or fume exposure, secondhand smoke exposure, and outdoor work exposure than nongreen-collar workers. Previous studies have shown that these occupational exposures can be detrimental to worker health. Worker health is directly tied to worker productivity, and these chemical and physical exposures may pose a threat to green-collar worker health.[30] Although exposure rates differ between green and nongreen workers, variables such as exposure duration, frequency, and chemical composition are needed to better understand the differences in occupational exposure rates between the two workforces.

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