CLOSE OUT REPORT
November 30, 2014

1R21OH009831-03

Green Cleaning: Exposure Characterization and Adoption Process Among Custodians

September 1, 2009 to August 31, 2014

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List of Terms and Abbreviations

CBPR - Community-based participatory research

CEUI - Connecticut Employees Union Independent - Service Employees International Union (CEUI) Local 511

CFR – Code of Federal Regulations

ConnectiCOSH - The Connecticut Council of Occupational Safety and Health (ConnectiCOSH) is a non-profit statewide organization which helps unions, individuals and communities obtain healthier and safer working conditions.

CSHC - Coalition for a Safe and Healthy Connecticut, community-based group that promotes safer alternatives to toxic chemicals.

EH&S – Environmental Health & Safety

EPP – Environmentally Preferable Products

GM - Geometric mean

GS - Green Seal

GSD – Geometric standard deviation

HSPH - Harvard School of Public Health

IFRA - International Fragrance Association

LEP – Limited English Proficiency

LOQ – Limit of Quantitation

MSDS – Material Safety Data Sheets

NHANES – National Health and Nutrition Examination Survey

NIOSH - National Institute of Occupational Safety and Health

OR – Odds ratio

PPE – Personal Protective Equipment

SARA – Superfund Amendments and Reauthorization Act

SGAM - Small Group Activity Method

SDS - Safety data sheets

TTT - Train-the-Trainer

UCHC –University of Connecticut Health Center

<u>Phthalate Abbreviations</u>

DEP - diethyl phthalate

DMP - dimethyl phthalate

DBP - dibutyl phthalate

BBP - butyl benzyl phthalate

DEHP - bis 2-ethylhexyl phthalate

MEP - monoethyl phthalate

MMP - monomethyl phthalate

MBP - monobutyl phthalate

MBzP - mono-benzyl phthalate

MEHP - mono(2-ethylhexyl) phthalate

Abstract

Green Cleaning: Exposure Characterization and Adoption Process Among Custodians

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The University of Connecticut Health Green Cleaning Study was initiated after the Connecticut (CT) legislature required the use of environmentally preferable products (EPP) for cleaning within stated owned buildings (Public Act No. 07-100). The study used a community-based participatory research approach, whereby the union community and researchers jointly addressed health and safety concerns, participated in measuring exposures and health effects, reviewed data and interpreted findings. Using mixed methods, the study characterized custodians' exposure to EPP, evaluated the link between exposures and health effects, investigated barriers to implementing EPP and Green Cleaning programs and implemented training to improve the acceptance of Green Cleaning programs. Focus group themes suggest that custodians take pride in their work, taking satisfaction in a "well-done" job. Barriers to implementing EPP programs that were addressable through education, included misconceptions about greater effort for application, EPP ease of use for workers with limited English proficiency (LEP), misuse of disinfectants, and need for training.

Although the CT law requiring EPP use was enacted four years before the start of the study, less than 50% of the cleaners used by custodians at the sites were EPPs. A significant relationship was observed between occupational exposures to traditional cleaning chemicals and urinary monoethyl phthalate concentrations. Custodians' use of EPP cleaning products did not always show reduced phthalate levels. However, urinary phthalate excretion levels from EPPs did not exceed those of conventional cleaners. Significant linear associations were observed between increased typical traditional cleaning product exposure and increased odds of upper and lower respiratory symptoms, dermal reactions, and musculoskeletal symptoms affecting the upper extremity, back, and lower extremity. Increased typical green cleaning product exposure was associated with dermal and back and lower extremity musculoskeletal symptoms. Green cleaning products had weaker associations with health symptoms than traditional cleaning products. The Clean with Green Working Group, ConnectiCOSH, Green Cleaning Advisory Board and the UCHC research team reviewed and summarized the results from early phases of the study (i. e. focus groups and the Green Cleaning and Health Survey) to develop a training program using the Small Group Activity Method (SGAM) to address the study goal: to improve the acceptance and proper use of EPP. CEUI and ConnectiCOSH health and safety trainers provided Green Cleaning training to 296 participants during 22 sessions at 7 sites. The training materials were translated into Spanish and Polish and posted on the website (http://oehc. uchc. edu/greencleaning. asp).

Section 1

Traditional cleaning products are associated with both acute and chronic health problems. The federal government has defined "green" products and services , more accurately called *"environmentally preferable" products (EPPs)*, as agents and processes that "have a lesser or reduced effect on human health and the environment when compared with competing products or services that serve the same purpose" (Office of Federal Environmental Executive, 1998). The process used to establish health-based criteria for EPPs is a response to the growing scientific evidence that associates adverse health effects with some agents and a potential conflict between a demand for environmental sustainability and health outcomes. Custodians are among the first workers to be impacted by EPP substitution. The expectation is that worker exposure and health risks to cleaning products containing hazardous chemicals can be reduced by adopting these new technologies and products. The importance of characterizing custodians' exposure to cleaning chemicals is explicit, as this occupational group makes a transition from traditional cleaning chemicals to institutional EPPs, and is implicit to a better understanding of the impact on the health of end-users of EPPs.

This study is designed to investigate the use and impact of EPPs and disinfectants among custodians, to assess health effects, and to implement effective strategies to prevent harmful exposures, to reduce potential health risks, and to evaluate impacts. In addition, the characterization of phthalates, a specific chemical species that has instigated precautionary concerns, may help to provide a quantitative rationale for exposure reduction to target constituencies. Characterization of potential toxicity may also assist with transitions to EPPs. The overall proposal takes a community-based participatory research approach whereby the union leadership and membership participates with researchers and management health and safety personnel to jointly address health and safety concerns, participate in measuring exposures and health effects, and review data as it is generated.

Significant Findings

- Focus group themes suggest that custodians take pride in their work taking satisfaction in a "well-done" job. Barriers included misconceptions about greater effort for application, EPP ease of use for workers with limited English proficiency (LEP), misuse of disinfectants, and need for training.
- Although the CT law requiring EPP use was in place for 4 years before we performed this study, less than 50% of the cleaners used by custodians at the sites were EPPs.
- A significant relationship was observed between occupational exposures to traditional cleaning chemicals and urinary monoethyl phthalate concentrations. Custodians' use of EPP cleaning products did not always show reduced phthalate levels. However, it was notable that urinary excretion levels from EPPs did not exceed those of conventional cleaners.
- Significant linear associations were observed between increased typical traditional cleaning product exposure and increased odds of upper and lower respiratory symptoms, dermal reactions, and musculoskeletal symptoms affecting the upper extremity, back, and lower extremity
- CEUI and ConnectiCOSH health and safety trainers provided Green Cleaning training to 296 participants during 22 sessions at 7 sites. One session was offered to EH&S managers. Six sessions had a Spanish language interpreter. The training materials were translated into Spanish and Polish and posted on the website (http://oehc. uchc. edu/greencleaning. asp).

Translation of Findings

Even though legislation had been in effect for 5 years, state-based custodians were still exposed to traditional cleaning chemicals. Traditional cleaning chemicals are associated with higher

health risks including dermal, upper and lower respiratory and upper extremity, back and lower extremity musculoskeletal symptoms, as compared to EPPs. However EPP products are associated with health risks including dermal and back and lower extremity musculoskeletal symptoms. In terms of phthalate exposure, custodians appear to have both work and non-work place exposures to phthalates.

Custodians working with their bargaining unit representatives and health and safety supervisors were highly amenable to participatory education aimed at altering work practices. Despite the barriers of low to moderate income, English as a second or even tertiary language, and a general perception of the limited value of their work, custodians approached EPP with unexpected resiliency due to sense of pride and professionalism in their work and fluid understanding of the association between potential work exposure and health effects.

Furthermore, this research served the purposes of translation or research to practice by establishing an evident link between workforce and end user exposure. Monoethyl phthalate exposures from the workplace replicated the magnitude or non-work exposures. While this type of proportionality is unusual in occupational medicine, it offers a perspective on the multi-source and end-user considerations that are more representative of environmental health.

Outcomes

The following training materials were translated into Spanish and Polish and posted on the website (http://oehc. uchc. edu/greencleaning. asp) :

- Workbook: Green Cleaning in Your Workplace – participant and trainer versions
- Fact Sheet: A Green Cleaning Program for Connecticut Facilities
- Fact Sheet: Equipment for Green Cleaning
- Fact Sheet: Where is the Shine and Smell with Green Cleaning Products?
- Fact Sheet: Disinfectant Use in Green Cleaning Programs
- Fact Sheet: A Green Cleaning Program for Animal Laboratories
- Fact Sheet: Green Cleaning for Food Service

- Nearly 300 custodian and managers have been trained.
- A dedicated modular questionnaire suitable for broader use in custodian and EPP research developed
- Scripts for qualitative research with focus groups on EPP related issues
- An efficient educational approach where English is not the primary language and finite resources limit the multi-lingual presentations
- Extension of principles of Community-based Participatory Action Research by utilizing established labor oriented (ConnectiCOSH) and environmentally oriented (The Clean with Green Working Group) educational groups

Impact

- The State of Connecticut has an established and ongoing educational program in EPP
- An unfunded, unaccounted State mandate has been reinforced with quantitative data
- A program for advancing the outreach and health protection responsibility of a public sector bargaining unit has been demonstrated
- An important exposure question on the comparability of EPPs and traditional cleaners has been answered
- A model for attributing fractionated exposures from the work and home environments has been placed in the occupational and environmental health literatures.

Section 2 Scientific Report

I. Background

Traditional cleaning products are associated with both acute and chronic health problems. Acute health problems from exposure to cleaning products include eye, nose and throat irritation, skin irritation and burns, coughing, fatigue, dizziness, headaches, vomiting, cramps and diarrhea (Anderson, Wells et al. 2007, Arif et al. 2008). Chronic health effects may include asthma (Reinisch, 2001; Medina-Ramon, 2003;Zock, Plana et al. 2007; Mazurek, Filios et al. 2008) and other respiratory ailments (Mendell 2007), birth defects, reproductive disorders and brain damage (Zheng, Cantor et al. 2001; Nazaroff and Singer, 2004).

US and European investigators have documented occupational cleaners as being at risk for asthma and other respiratory complications (Karjalainen et al 2002; Arif et al, 2003). The California physician reporting system for occupational-related injury and illness found that janitors and cleaners had the highest prevalence of asthma for any occupational group (Reinisch, 2001). Arif et al (2008) reported that cleaners had double the risk of work related asthma and were five times more likely to report work related asthma than comparable workers not engaged in cleaning. Prevalence of occupational asthma was also found to be high (29%) among female janitors, housekeepers, and cleaners in Sao Paulo (Medina-Ramon, 2003).

Case reports, occupational disease registry-based reports and epidemiologic studies have identified factors in cleaning associated with the risk of asthma (Jaakkola and Jaakkola, 2006; Medina-Ramon et al. 2005; Rosenman et al. 2003). Disinfectants and floor care products are two of the most commonly identified categories of cleaning products associated with asthma among custodians and cleaners. At the Massachusetts Department of Public Health, indoor air pollutants (21%) and cleaning products (17%) accounted for the most frequently reported cases of occupational asthma between 1993 and 2002. Reported asthmagens included irritants such as acids, ammonia, or bleach; and disinfectants such as formaldehyde, glutaraldehyde, and quaternary ammonia compounds. Disinfectants and sanitizers have had the fastest growth among cleaning products, with sales over $700 million (http://www.cleanlink.com). There has been the most concern with sodium hypochlorite and quaternary ammonium compounds. Medina-Ramon et al. 2006 found that lower respiratory tract symptoms were significantly associated with exposure to diluted bleach, degreasing sprays/atomizers (e.g. furniture cleaning, oven cleaning, floor mopping) and air fresheners. Rosenman et al. (2003) reported 16 cases of work-related asthma associated with floor cleaners. Ammonia and sodium hypochlorite, which are active ingredients in floor strippers and disinfectants, are strong respiratory irritants (Arif et al, 2008). In this study, increased risks of asthma and chronic bronchitis were associated with specific job tasks, such as mopping the floor (unadjusted OR 2.8), cleaning windows (unadjusted OR 1.6), thorough kitchen cleaning (unadjusted OR 2.2), and cleaning mirrors and ovens (unadjusted OR 2.0).

Typical floor finish products include plasticizers, and contain ingredients such as glycol ethers, phthalates, and tributoxy ethyl phosphate. There is a growing body of literature linking some of these ingredients, such as phthalates, to increases in asthma and allergic responses (Bornehag et al, 2004; Jaakkola and Knight, 2008). Phthalates represent a class of chemicals that are commonly used as plasticizers in building materials, as well as consumer and personal care products. Plasticizers in vinyl flooring, carpet backing, wall and floor coverings are significant sources of airborne phthalates, primarily Di-(2-ethylhexyl) phthalate (DEHP) and Dibutyl phthalate (DBP). Biomonitoring studies indicate that exposure to phthalates in the US

population is widespread (CDC, 2008). Recent studies suggest that phthalate metabolites measured in urine are useful biomarkers of exposure (Kato et al. 2004;Hauser et al. 2006;Adibi et al. 2008; Adibi et al. 2009). Hauser et al. (2008) found that it is important to characterize inter-and intra-subject variability of urinary phthalate monoesters. Custodians experience multiple sources of exposure to phthalates in the workplace, and may represent a high-risk occupational group. No studies have characterized these different sources of phthalates in a custodial work environment.

The formulation of cleaning products is changing rapidly as new environmentally preferable chemical ingredients replace traditional chemicals. The federal government has defined "green" products, more accurately called *"environmentally preferable" products (EPPs)*, as products and services that "have a lesser or reduced effect on human health and the environment when compared with competing products or services that serve the same purpose" (Office of Federal Environmental Executive, 1998). Continued growth is expected since these "green" cleaners account for only 2% to 5% of the products sold in the $17.5 billion U.S. cleaning products market. The growing scientific evidence of adverse health effects of some agents and the demand for environmental sustainability has initiated a process for establishing health-based criteria for In 2009, in addition to prohibiting carcinogens, mutagens, and reproductive hazards, some EPP screens limited the use of certain ingredients, such as phthalates and asthmagens. EPPs are also sold as concentrates with dilution and dispensing systems as a mechanism to control application rates. It is expected that worker exposure and health risks to cleaning products containing hazardous chemicals will be reduced by adopting these new technologies and products.. However, the impact on the health or end-users of EPPs, such as the impact of use of concentrates, invites study. Custodians are some of the first workers to be impacted by the new green economy. The cleaning industry employs 2.8 million custodians who use more than 6.5 billion pounds of cleaning products (Ashkin, 2006). To date, there are no reported studies that characterize custodians' exposure to cleaning chemicals in this period of transition from traditional cleaning chemicals to institutional EPPs.

To clarify, SDSs do not contain information on EPP status. "Green" cleaning alternatives to traditional cleaning agents are certified as EPP by third-party organizations, such as Green Seal and Ecologo. For purposes of this study, EPP is defined as an industrial or institutional cleaner certified by as Green Seal (GS) under the GS-37 Standard (restroom, glass, carpet, and general purpose cleaners), GS-40 Standard (floor care products) and Ecologo Standards 110, 112, 146, and 147.

This study was designed to investigate the use and impact of EPPs and disinfectants among custodians, to assess health effects, to implement effective strategies to prevent exposures and reduce potential health risks, and to evaluate impacts. In addition, the characterization of phthalates as a specific chemical species of concern may help to provide a quantitative rationale for exposure reduction to these target constituencies and assist with transitions to EPPs. The overall study takes a community-based participatory research approach whereby the union leadership and membership participates with researchers and management health and safety personnel to jointly address health and safety concerns, participate in measuring exposures and health effects, and review data as it is generated.

II. Specific Aims

Aim 1: To identify barriers and incentives for implementing green cleaning programs.

Aim 2: To identify language and cultural barriers for janitors that may inhibit implementation or use of green-cleaning products.

Aim 3: To provide an actual-use characterization of exposures to cleaning products among janitorial workers.

Aim 4: To differentiate and compare the exposures to green-cleaning and prior traditional cleaning product use.

Aim 5: To identify disorders or adverse health events from the use of cleaning products, with the objective of assessing health impacts of green cleaning products.

Aim 6: To develop an intervention to improve the acceptance of green cleaning programs, to ensure proper use of green cleaners and disinfectants, and to standardize the adoption of "green cleaning" products among custodians working at the various state institutions.

III. Methods

Green Cleaning Study

In 2007, the Connecticut legislature passed Public Act No. 07-100 requiring the use of cleaning products that meet standards set by environmental certification programs such as Green Seal or Ecologo within state owned buildings. This provided researchers with a rare opportunity to study the transition of the use of traditional cleaners to green or environmentally preferable products (EPP). Using a community-based participatory research (CBPR) a research team consisting of the University of Connecticut Health Center (UCHC), Connecticut Employees Union Independent - Service Employees International Union (CEUI) Local 511 Coalition for a Safe and Healthy Connecticut (CSHC), and the Connecticut Council of Occupational Safety and Health (ConnectiCOSH) was formed. A partnership agreement was developed that outlined the goals of the study and general roles and tasks for the research team (CEUI-SEIU, CSHC, ConnectiCOSH, and UCHC). These partners met each month to discuss all aspects of the study. During these meetings, the survey instruments were generated, worker recruitment strategies were developed, and study results, fact sheets, and manuscripts were reviewed. In addition, the chief stewards and members of the Working Group discussed related study issues with the CEUI-SEIU education director (on an as needed basis), who then communicated information to the UCHC research team. All aspects of the study were approved by the UCHC Institutional Review Board (IRB #10-050).

Connecticut Employees Union Independent - Service Employees International Union (CEUI) Local 511, representing 4,000 state employees, has taken a leading role in providing support to its members on the green cleaning law. CEUI was one of the first unions to join the Coalition for a Safe and Healthy Connecticut, and work on advocacy campaigns to replace toxic chemicals, such as phthalates and Bisphenol A, with safer alternatives in workplaces and consumer products. The union formed a special committee, the "Clean with Green" Working Group (Working Group), composed of the educational director and five chief stewards representing several large state institutions. The group recognized the need to improve the education and delivery of a green cleaning program across state institutions; however, to achieve this, they needed more information from the various partners. The group committed extensive time to

give guidance on the research questions of this study during the grant application process with UCHC.

From their membership of 4,000 state employees, the Working Group identified 456 custodians and 49 cooks (with cleaning and disinfection job duties) who were working with EPP, disinfectants, and/or traditional cleaning products. The total potential sample was 505 from six institutions. The number of custodians per institution ranged from 16 to 166. UCHC research staff contacted EH&S staff from each institution to explain the study and request their participation. EH&S staff from each institution submitted a letter to UCHC to document participation approval for the study. Green cleaning introduction at these institutions varied in duration from six months to five years.

Focus Groups

Ten focus groups of union custodians, environmental health/safety, cooks, and facilities staff were conducted to ascertain the perceptions of cleaning chemical use, health, and transitioning to EPP. Five state institutions participated in this phase of the study.

Custodial Focus Groups: Nine focus groups were conducted with custodians. Sessions were segregated by job task. Only one institution included food service personnel and custodians together as participants. The principal investigator used a focus group script to lead the discussion with English-speaking custodians, and two members of the research team recorded notes (UCHC member and Working Group member). One focus group was conducted with Polish speaking custodians and one was conducted with Spanish speaking custodians. Staff from ConnectiCOSH (Spanish-English) and a member of CEIU (Polish-English) facilitated these focus groups. UCHC research staff coordinated with the managers and supervisors from each institution to request release time from work for custodians to participate in the focus groups. Focus groups were conducted on work time (seven were during first shift and two were conducted during third shift). The supervisors assisted UCHC research staff with some of the focus group logistics (e.g. meeting room locations, reminding custodians about the meeting).

Recruitment of custodians targeted opinion leaders of the facilities using a sociogram type of approach to identify people who co-workers reported as being influential. Members from CEUI-SEIU serving on the Working Group identified opinion leaders from their institutions to participate in the focus groups. A stepwise process was followed: 1) the research team developed a flyer describing the study and purpose of the focus group; 2) Working Group members from each institution posted flyers on their campus to provide general information about the study; 3) a description of the study was also placed in the union newsletter; and 4). Working Group members then discussed the study with 5-10 fellow custodians from different areas of their campus, and asked them who they talked to about work-related issues. From these conversations, a list of potential opinion leaders was developed from each institution or facility, and these workers were asked to participate in the focus groups.

Management Focus Group: Focus groups of facility managers, supervisors and EH&S staff were conducted separately from those of custodians. UCHC research staff invited EH&S staff and facility manager to participate in a focus group. Each institution sent one representative to UCHC to participate in the management focus group.

Focus Group Script: An open-ended focus group script was designed to 1) characterize perceived incentives and barriers to adoption of EPPs, 2) compare chemical use and best practices and 3) consider issues among bilingual worker populations. The script was developed

by university faculty experienced in survey and focus group script design. It was refined after several reviews by the Working Group to ensure comprehensiveness, relevance, and understandability of questions. Participants were assured of individual confidentiality of the discussion and were asked not to disclose the discussion outside of the focus groups; names were not used during the focus groups so that there would not be a record of the specific individual speaking on the transcript. Transcripts were reviewed only by the study team. Polish and Spanish transcripts were translated by a certified translation service with the University of Massachusetts-Amherst.

Focus groups were digitally recorded, professionally transcribed, and reviewed for accuracy. Transcripts were imported into ATLAS Ti, a software package designed to handle unstructured qualitative data to assist in reporting recurrent themes, links among the themes, and supporting quotations (http://www.atlasti.com). Transcribed data were analyzed using the constant comparative method of qualitative data analysis to identify recurrent themes until "theoretical saturation" was achieved; that is, no new themes emerge through subsequent data analysis (Glaser & Strauss, 1980; Strauss & Corbin 1998). Coding used the integrated approach, (Bradley, Curry, & Devers, 2007) where a provisional "start list" of codes based on existing scientific literature and the experience of the team (Miles & Huberman, 1994) was refined during analysis from subsequent interviews. The final version of the code structure was based on a review by two researchers and two community members (one union and one consultant). Two research team members independently re-coded the transcripts based on the final codes and where discrepancies occurred, data was re-coded to consensus. Coding was performed on each focus group, and then reviewed as a combined dataset. The software allowed identification of the focus group, which allowed for differentiating custodians from the managers and from the ESL group. Statements from each transcript were rated as positive or negative to determine if there was a significant difference in attitude between the focus groups.

Green Cleaning and Health Survey

A cross-sectional survey of typical cleaner use and associated health symptoms in cleaners and custodians was conducted in 2011 and 2014 among 6 agencies. Participating custodians completed the Green Cleaning and Health Survey in which they answered questions about dermal, musculoskeletal, and respiratory symptoms and typical cleaning product exposure. Surveys were available in English, Spanish, and Polish. All state employed custodians working at each of the six agencies were eligible to complete the survey. We also surveyed contract custodians at two of the institutions

Demographic and Work History: A series of demographic and work history questions included the following: age, gender, language (English, Spanish, Polish, other), smoking status (non-smoker, current smoker), number of years working in a job using cleaning products, working status (part time or full time), worker type (state worker or contract worker).

Dermal, Respiratory, and Musculoskeletal Symptoms: Dermal symptoms were assessed using two questions, "in the last 12 months, have you had skin rashes, itching, or redness on hands or arms that last more than one week?" and "in the last 12 months, have you had skin chapping or cracking on hands or arms that last more than one week". Participants were considered to have dermal symptoms if they answered "yes" to either question. Respiratory symptoms were assessed using questions adapted from the European Community Respiratory Health Survey II (ECRHS 2002) and the Behavioral Risk Factor Surveillance System (Gentry et al. 1985). Participants were considered to have upper respiratory symptoms if they answered "yes" to any of the three questions, "in the last 12 months, have you had any nasal allergies, including hay

fever", "in the last 12 months, have you had sinusitis or sinus problems", or "in the last 12 months, have you had hoarseness". Participants were considered to have lower respiratory symptoms if they answered "yes" to either of the two questions "in the last 12 months, have you had chest tightness" or "in the last 12 months, have you had wheezing or whistling in your chest". Doctor diagnosed asthma was assessed by asking "Have you ever been told by a doctor, nurse, or other health professional that you had asthma". Work related asthma was assessed using the question "Have you ever been told by a doctor, nurse, or other health professional that you had work-related asthma". Participants were considered to have current asthma if they had either doctor diagnosed asthma or work-related asthma and answered "yes" to any of the three questions "do you still have asthma", "have you had an asthma attack anytime in the last 12 months", or "are you currently taking any medicine (including inhalers, aerosols and tablets) for asthma". Musculoskeletal symptoms of the upper extremity, back, and lower extremity were assessed using one question each, "in the last 12 months, have you had pain or discomfort (in neck, shoulders, arms, or hands for a week or more/in back every day for a week or more/in legs or feet every day for a week or more)". Participants were considered to have upper extremity, back, or lower extremity musculoskeletal symptoms if they answered "yes" to the corresponding musculoskeletal question.

Cleaning Product Exposure: Detailed information about characteristics of custodians' typical cleaning product exposure was collected using responses from the Green Cleaning and Health Survey. A list of cleaning products used at each agency was included in the survey. To develop the lists used in the survey, a researcher from the Green Cleaning and Health Study contacted representatives from each agency to identify a list of cleaning products being used at that institution, and then performed walkthrough assessments of custodial closets within the agency to confirm the products that were being used at each agency. On the survey, participants indicated how frequently (none or don't use/less than 1 hour per day/1 to 3 hours per day/4 to 6 hours per day/7 to 8 hours per day) they used each product on their agency-specific list during a typical 8 hour workday. Custodians were not required to indicate whether they understood whether a product on the list was traditional or green. All products were listed in the survey by their applied name only in alphabetical order with no indication of whether they were classified as traditional or green. In survey post-processing, a researcher from the Green Cleaning and Health Study classified each cleaning product as either "green" if it was included in the Ecologo or Ecoseal (Ecoseal 2014) databases, or "traditional" if it was not included in either database. Frequency of use was assigned a numeric value (none or don't use = 0/less than 1 hour per day = 1/1 to 3 hours per day = 2/4 to 6 hours per day =3/7 to 8 hours per day =4), and each participant was assigned a traditional and a green cleaning product exposure score calculated by summing the frequency values of each traditional or green product used by that participant. Participants were then categorized into low, medium, and high exposure tertiles based on their scores. Two categorizations summarizing exposure to traditional and to green cleaning products were thus created for each participant. The tertile cutoffs for traditional cleaning product exposure were 12 and 20: the 33% of participants with a traditional cleaning product exposure score less than 12 were categorized as having low exposure, the 34% of participants with a traditional cleaning product exposure score between 12 and 20 were categorized as having medium exposure, and the 33% of participants with a traditional cleaning product exposure score greater than 20 were categorized as having high exposure. The tertile cutoffs for green cleaning product exposure were 9 and 16.

Statistical Analysis: Due to small sample sizes and differences in task performed among two participating institutions, the data analysis was restricted to custodians, lead custodians, and supervising custodians recruited from four state institutions: three universities and one university-affiliated hospital. We used descriptive statistics to describe the distribution of health

symptoms and confounders in our population. Using SAS v 9. 3 Statistical Software (Cary, NC), we performed logistic regression analyses with each health outcome treated as a dichotomous dependent variable and traditional or green exposure category as a categorical independent variable to get estimates of the odds of health outcomes associated with traditional or green exposure category. To test for trend (p-values), we also performed logistic regression analyses with traditional or green exposure as a continuous variable. Due to the limited prevalence of severe lower respiratory symptoms, doctor diagnosed asthma, work-related asthma, and current asthma in our population we did not perform analyses on these symptoms. All analyses were adjusted for working status, worker type, age, gender, language, smoking status, and number of years working in a job using cleaning products. While accepted missing health symptoms data, if participants had missing data for a confounder variable we replaced it with the mean (continuous) or most frequent (categorical) value from the overall dataset (Table 1). All confounders except for years working in a job using cleaning products (continuous) were treated as categorical variables. We evaluated p-values and odds ratios. Two-tailed p<0. 05 was considered significant.

Biomonitoring for Phthalate Exposures

To characterize custodians' temporal variation of phthalate exposure over the course of the day, analyses were conducted to evaluate urinary phthalate metabolite concentrations and observing occupational and non-occupational exposures. We employed a repeated measures sampling strategy collecting four urine samples over a 24-hour work period from 68 custodians working at 4 survey sites.

Site Surveys: The four sites included in the study were state university campuses (Sites A and B), a hospital (Site C), and a residential training facility for individuals with developmental disabilities (Site D). Prior to participant enrollment, each institution was visited to interview the management staff who order, purchase and manage the inventory of cleaning products and the equipment and to perform walkthrough visits. Safety data sheets (SDS) were requested for all cleaning products and disinfectants and several custodial closets at each building were inspected to characterize the cleaning chemicals (e. g. , EPP or traditional) and application equipment that was available to custodians at each institution. Some institutions provided a list of product names, and others provided copies of all their SDS.

Custodian Recruitment: Participants were recruited from April-June 2011. The study team developed a flyer describing the urinary monitoring phase of the project, and provided it to the Environmental Health & Safety or Facility Departments on each campus. The Facility Departments distributed the flyers to custodians. UCHC research staff also gave short presentations and answered questions about the urinary monitoring phase of the study to groups of workers at union meetings. Union representatives also talked with workers at their designated sites. Workers who were willing to participate contacted their union representative or departments, thus affirming the purely voluntary nature of the study. Targeted custodians included those working during first and third shift. A date for obtaining informed consent from each worker was arranged by the research team. All workers gave signed informed consent and were reimbursed $50 for participation.

Urine Sample Collection: Four urine samples were collected. First void (typically morning, except for third shift) urine samples were collected at home to represent phthalate exposure before work and before use of any personal care products. A second pre-shift urine sample was collected at the work site before workers started their cleaning duties and represents potential phthalate exposure from personal care products used prior to shift. A third post-shift sample

was collected in the workplace. The fourth sample was collected at bedtime in the worker's home. Given the short half-life of phthalates in urine, we expected to observe work-related exposures in both the post-shift and bedtime exposures. The day before urine collection, each worker was provided four 120mL sterile plastic specimen cups (prescreened for phthalates) with instructions. A study team member collected the first three urine samples from custodians on site, and returned the next morning to collect the fourth (before bedtime) urine sample. Workers were asked to place their before bedtime urine sample in a plastic bag in their home refrigerator overnight. Specimens were transported to the UCHC laboratory on wet ice in a cooler.

Potential predictors of phthalate levels: Interview, formal questionnaires, and observations were used to collect information on potential predictors of urinary phthalate concentrations including demographic, personal care product, and workplace factors. During sample collection, participants were asked information about their gender, age, race and/or Hispanic ethnicity, and primary language. At the end of the sampling period, participants were asked to complete a product use questionnaire to indicate types of personal care and household products used within the last 24 hours, over the duration of urine collection. Participants were also asked if they had smoked in the past 24 hours.

Workplace factors were collected by one of five observers, trained by the UCHC industrial hygienist to conduct work observations on the day of urine monitoring. Each observer followed one to four workers during each hour of the shift. A data collection form developed by the National Institute of Occupational Safety and Health (NIOSH) was modified and used by the observers (LeBouf et al. 2014). During each hour of the work shift, observers recorded custodian cleaning tasks, and the use of cleaning products. The number and type of rooms (e. g. bathroom, office, etc.) as well as the surfaces/objects (e. g. floors, toilets, desks), the use of personal protective equipment (e. g. gloves), cleaning equipment and tools (e. g. microfiber cloths, mops, brooms) were also documented.

All chemical products used by each custodian over the observation period were recorded. The products were grouped according to type: traditional, EPP or disinfectant.. For each product type, the frequency of use of within the chemical group over the 8-hour shift was also captured. A product was recorded on the observation sheet if used at least once during the 1-hour observation period of the shift. Exposure intensity was coded as none, low, or high. A worker was assigned none when he or she reported no chemical use. A categorization of low exposure intensity was given when a worker was observed using the product less than 4 times over the 8 hourly observation periods. Likewise, a category of high exposure intensity was assigned when the worker was observed using the product 4 or more times over the 8 hourly observation periods. The total time of chemical use and the quantity of chemical use was not recorded. The categories of reported use are consistent with a prior evaluation of exposures among custodians using the interval of more or less than 4 hours to describe exposure intensity (Obadia et al. 2009).

Laboratory Methods: Each urine sample was transferred to a 15-mL Corning centrifuge tube (# 430052) and placed in a freezer at -20 °C. The UCHC research team transferred samples to Harvard School of Public Health Department of Environmental Health (HSPH) in June 2011 (within four months of collection). HSPH stored all samples in a freezer at -80 °C until analysis by December 2011.

We chose to identify urinary phthalates most likely found in a typical custodian's work environment including low molecular weight phthalates that may be associated with fragrances found in cleaning products (diethyl phthalate (DEP), dimethyl phthalate (DMP), and dibutyl

phthalate (DBP) and high molecular weight phthalates including butyl benzyl phthalate (BBP) and bis 2-ethylhexyl phthalate (DEHP) which may be in building materials. DEP was also targeted because it is commonly found in consumer and personal care products (Dodson et al. 2012). The urinary monoester metabolites of these targeted phthalates include: monoethyl phthalate (MEP for DEP), monomethyl phthalate (MMP for DMP), monobutyl phthalate (MBP for DBP), mono-benzyl phthalate (MBzP for BBP), and mono(2-ethylhexyl) phthalate (MEHP for DEHP).

Five different phthalate monoester metabolites in urine (MEHP, MMP, MBzP, MEP, and MBP) corresponding to DEHP, DBP, BBP DEP, and DBP were quantified using liquid chromatography-tandem mass spectrometry (LC-MS/MS) according to the analytical and quality control methods previously described (Chen et al. 2012). The limit of quantitation (LOQ) for each phthalate metabolite was: MEP (0. 5 ng/mL), MEHP (1. 00 ng/mL), MBzP (0. 25 ng/mL), MMP (0. 25 ng/mL), and MBP (0. 5ng/m).

Urine creatinine was measured photometrically, as a unit of concentration, using kinetic colorimetric assay technology with a Hitachi 911 automated chemistry analyzer (Roche Diagnostics, Indianapolis, IN). Unadjusted concentrations are reported in nanograms per milliliter (ng/mL). All the reported urinary metabolite concentrations were adjusted for creatinine. Creatinine-adjusted concentrations are reported in micrograms per gram (µg/g). Concentrations below the limit of quantitation were substituted with a value equal to the LOQ divided by 2 for statistical analyses. Analysts were blind to all participant information.

Statistical Methods: Median urinary levels were lower than mean values in most cases, suggesting skewed distribution of the data. Log10 transformations were performed to generate approximate log-normal distributions. Geometric mean (GM) values for urinary phthalates with geometric standard deviations (GSD), medians, 25 and 75 percent quartiles, and the range of unadjusted and adjusted for creatinine, were calculated. Correlation between the metabolites was evaluated with Spearman correlation coefficients.

Mixed effects models, using a random intercept for each individual, were performed on log10 transformed creatinine-adjusted urinary phthalate concentrations. Potential predictors of urinary phthalate levels included demographic factors, workplace factors, as well as personal care products were entered into the exposure model. First, univariate analyses were performed to identify statistically significant differences by demographic, and workplace and personal care product characteristics. P-values from these comparisons were presented. Multivariate models were created separately for each metabolite by considering univariate predictors that were statistically significant at $p<0.10$. Due to potential collinearity, simple kappa coefficients were calculated to determine the correlation between categorical variables and weighted kappa coefficients were calculated to determine the correlation between ordinal variables. The kappa coefficients were generally in the "slight" (0-0. 20) to "fair" (0. 21-0. 40) agreement categories for most pairs of predictors, with only one pair (shampoo and conditioner use) having "moderate" agreement (kappa coefficient = 0. 48) and one pair (laundry detergent and fabric softener use) having "substantial" agreement (kappa coefficient = 0. 77) (Landis and Koch 1977). Because 13% of urine creatinine levels were less than 30 µg/g, which is considered outside the normal range (clinically dilute), mixed model results were confirmed by removing these values. Study results were not affected by excluding urine creatinine levels less than 30 µg/g, therefore, all sample results were used in analyses. Likewise, similar results were observed when creatinine was modeled as a predictor or unadjusted phthalate concentrations. Statistical significance was set as $p<0.05$, unless otherwise noted. All statistical analyses were performed in SAS 9. 3 (SAS Institute Inc., Cary, NC).

Training

A training program was developed as the intervention to address the study goal: to improve the acceptance and proper use of EPP. Development of the training program took a two-prong approach: content and method. The first step was to determine the relevant content. The Clean with Green Working Group, ConnectiCOSH, Green Cleaning Advisory Board and the UCHC research team reviewed and summarized the results from earlier phases of the study (i. e. focus groups and the Green Cleaning and Health Survey). The training topics that emerged were: overview of a green cleaning program; the differences between cleaning, sanitizing and disinfecting and; how to read product labels. The partners used their extensive experience in safety training to develop the training topics into a curriculum that that was applicable to workers from varying cultural, economic, and language backgrounds. Next, the training method incorporated the Small Group Activity Method (SGAM) which has been used extensively by CEUI and ConnectiCOSH. The method uses group activities that draw on the experiences and knowledge of participants and emphasize participant involvement in the learning process. The role of the trainer is that of a facilitator as opposed to expert instructor. The method has been shown to be highly effective both for retention of information and for initiating change in health and safety practices (Luskin, Somers et al. 1992; Lippin, Eckman et al. 2000) (i.e. implementation of green cleaning best practices).

The research team organized two 4-hour green cleaning Train-the-Trainer (TTT) sessions to prepare CEUI and ConnectiCOSH safety trainers. At the first TTT, the research team discussed the preliminary study findings and purpose of the training. A draft of the workbook was distributed to the trainers who reviewed the content and provided feedback for revisions. Once the revisions were incorporated into the workbook, a second TTT provided trainers with an opportunity to practice the teaching method. A lead trainer from ConnectiCOSH modeled how to effectively lead a small group activity. Trainers were then asked to work in pairs to co-lead one of the small group activities in the workbook. The remainder of the trainers responded from the perspective of participants. At the end of each activity, the lead trainer facilitated a discussion to provide the trainers with feedback on the strengths of their presentations and areas in need of improvement. To field test the curriculum, three pilot trainings were offered at one site. Five trainers led at least one pilot training session with a total of 23 participants (May 2013). The training materials were modified based on feedback from the trainers, participants and study team members.

Trainings were coordinated by CEUI, ConnectiCOSH and UCHC who contacted EH&S managers, requested trainer release time, gathered training materials, arranged for translators when needed, etc. EH&S managers at each site recruited participants, reserved conference rooms, arranged for release time and collected cleaning product containers to be used in one of the small group activities. The trainings were offered during regularly scheduled work time in conference rooms, break rooms or classrooms with an average of 16 participants. As a small incentive for attending the training, participants were given a $5.00 gift card. Trainers worked in pairs to facilitate the two hour trainings. The priority population for the trainings was 200 CEUI custodians and 150 contract custodians in Connecticut.

The research team designed a pre-training satisfaction survey and a post-training satisfaction survey to measure attitudes and beliefs about EPP and satisfaction with the content and method of the training. The pre-training survey consisted of 7 demographic and background information questions and 9 multiple choice questions on satisfaction of EPP with responses options on a

scale of one (strongly disagree) to five (strongly agree). The post-training survey consisted of the same questions with 11 additional questions on training satisfaction with responses options on a scale of one (strongly disagree) to five (strongly agree) and two open-ended questions.

Participants were asked to complete the surveys at the beginning of the training and again at the end of the training. Participants were informed that completing the surveys was voluntary and not all participants who attended the training completed the surveys. The surveys were anonymous. Respondents' names or other identifying information were not associated with the surveys. The data was analyzed and reported in the aggregate.

Five questions on the pre and post-training satisfaction surveys were included in the Green Cleaning and Health Survey administered in 2011 and 2014. This allowed the researchers to estimate a green cleaning satisfaction baseline and to evaluate the impact of the training approximately three to six months after completion of the training.

IV. Results and Discussion

Aim 1: *To identify barriers and incentives for implementing green cleaning programs.*

Ten focus groups (with a total of 64 participants) were conducted to investigate barriers and incentives to implementing green cleaning programs. Specific focus groups were conducted for primarily Spanish speakers, primarily Polish speakers, and facilities and occupational health staff. Focus group data were transcribed (and translated into English when necessary) and analyzed using Atlas TI, a qualitative analysis software. Data were independently coded by two study team members and reviewed by the lead community partner and consultant to achieve consensus. Themes included: satisfaction in a "well-done" job, more effort required for job, lack of involvement in EPP selection process, EPP ease of use for workers with limited English proficiency (LEP), misuse of disinfectants, health complaints, and need for training.

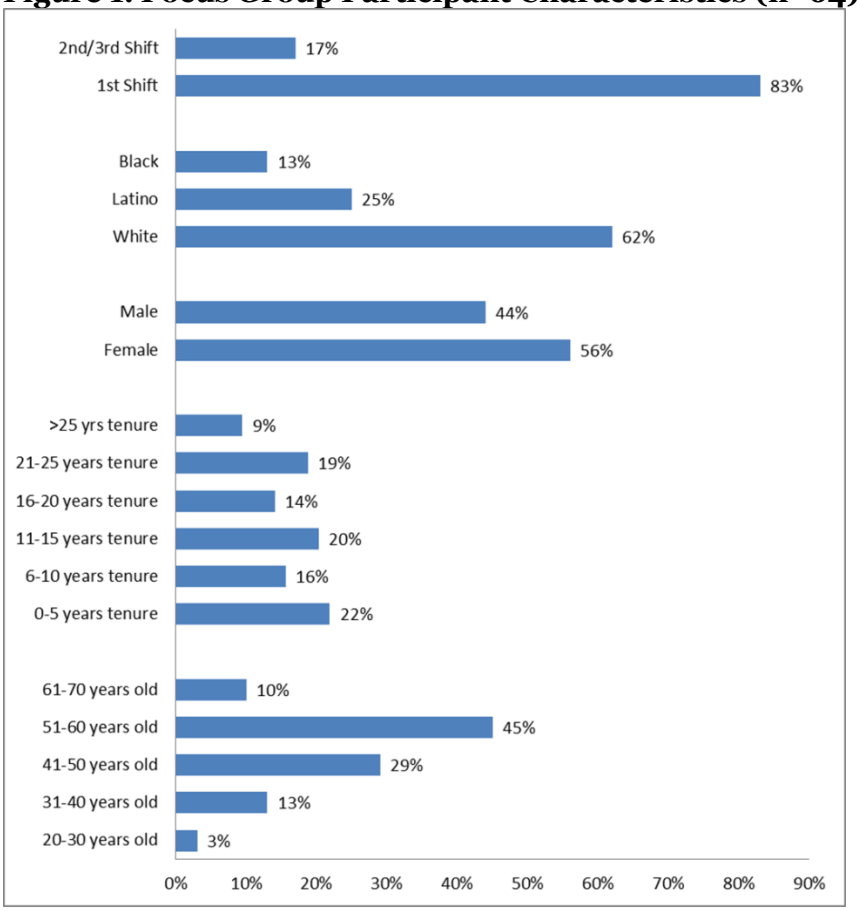
Sixty-four workers participated in the focus groups (Table 1). The participants were typically older, with long seniority, and ethnically diverse (Figure 1). English was the primary language for 62 percent of the participants, Polish for 19 percent, and Spanish for 19 percent. Participants had a mean of 12 years of education. Fifty-nine workers participated in the custodial focus groups and five participated in the management focus groups.

Seven salient themes emerged related to the transition from traditional cleaners to EPP: satisfaction in a "well-done" job, more effort required for job, lack of involvement in EPP selection process, EPP ease of use for workers with English as a second language (ESL), misuse of disinfectants, health complaints, and need for training.

Table 1. Focus Group Location and Number of Participants (n=64)

Focus Group Location	Participants (n)
Site A	
Focus Group 1 (Spanish)	7
Focus Group 2	3
Site B	
Focus Group 3	6
Focus Group 4	7
Site C	
Focus Group 8 (Polish)	9
Focus Group 9	7
Site D	
Focus Group 5	7
Site E	
Focus Group 6	6
Focus Group 7	7
Managers/EH &S Staff (combined sites)	
Focus Group 10	5

Figure 1. Focus Group Participant Characteristics (n=64)



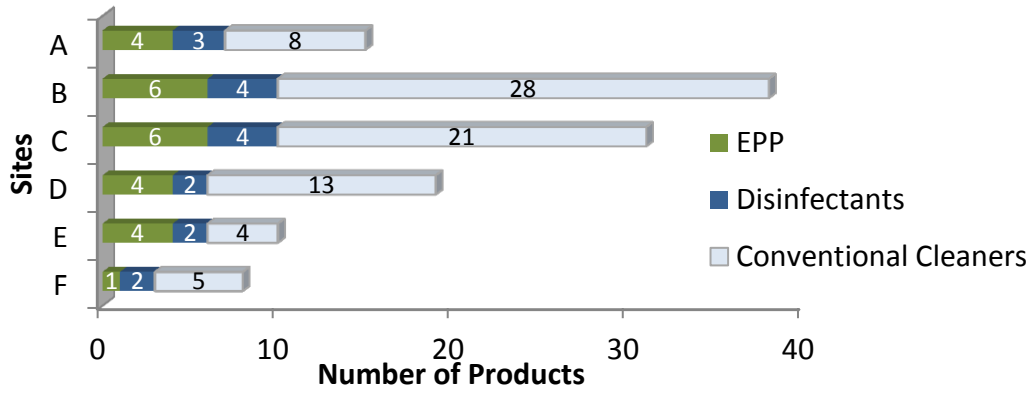
Aim 2: *To identify language and cultural barriers for janitors that may inhibit implementation or use of green-cleaning products.*

Language barriers were a central theme for the focus groups of custodians with limited English proficiency (LEP) (Spanish or Polish) and were an emerging theme for the aggregated focus group data. The following evidence relies on interviews and qualitative data. Many of the focus group participants reported that most existing training programs and written materials are in English, thus limiting access to information. Custodians with LEP reported reliance on supervisors or co-workers as interpreters during training and on the job. They also reported the superiority of a co-worker or supervisor to observation. Custodians with LEP typically rely on bilingual co-workers because of concerns of ignorance appearing as a performance measure. Although bilingual supervisors were reviewed positively, there is generally one for an entire department. Written materials had limited usefulness for custodians with LEP. For example, product labels and instructions are not always in Spanish and rarely in Polish. Custodians noted that the MSDS are only in English, and the printing is small and complex, having limited usefulness even for fluent English speakers. Custodians reported that posters with pictures and symbols were very helpful.

Aim 3: *To provide an actual-use characterization of exposures to cleaning products among janitorial workers.*

In 2007, the Connecticut legislature passed Public Act No. 07-100 requiring all state agencies to procure and use environmentally preferable products (EPPs) certified by Green Seal or Ecologo. The statute exempts disinfectants since green alternatives are not available. Researchers examined custodial closets and discussed contents with custodians at six sites to investigate cleaning product actual use patterns (July to October 2010). The EPPs appeared to have greater day-to-day use. However, many conventional cleaners remained in use and a greater number of conventional cleaners than green cleaners were available with proportions varying by site. Figure 2 presents the number of EPPs, disinfectants, and traditional cleaners that were in custodial closets at the six sites.

Figure 2: Number and proportion of cleaning products in custodial closets at the six observed sites.



Aim 4: *To differentiate and compare the exposures to green-cleaning and prior/ traditional cleaning product use.*

The research team utilized two data sources to address this aim. First, the study team developed and administered the Green Cleaning and Health Survey with feedback from the CEUI-SEIU steering committee and the Green Cleaning Advisory Board. The survey was finalized in the Fall of 2011 and administration was completed in March, 2012 (n = 417, approximately 85% response rate) and again in 2014 (n=437, approximately 85% response rate).

2011 Green Cleaning Survey:

The number of chemicals used at each site is presented in table 2. The percentage of EPP chemicals varied by site, but ranged from about 20-40%. The tertile cutoffs for traditional cleaning product exposure were 12 and 20: the 33% of participants with a traditional cleaning product exposure score less than 12 were categorized as having low exposure, the 34% of participants with a traditional cleaning product exposure score between 12 and 20 were categorized as having medium exposure, and the 33% of participants with a traditional cleaning product exposure score greater than 20 were categorized as having high exposure. The tertile cutoffs for green cleaning product exposure were 9 and 16.

Table 2: Cleaning Chemical Characteristics by Site

	Total Cleaning Chemicals N	Traditional or Disinfectants N (%)	EPP N (%)	Total Exposure Score*	Traditional Exposure Score*	EPP Exposure Score*
Site A	35	26 (74)	9 (26)	39 (14)	21 (7)	18 (7)
Site B	33	21 (63)	12 (37)	31 (10)	17 (7)	14 (4)
Site C	29	24 (79)	5 (21)	16 (8)	10 (6)	7 (3)
Site D	26	19 (73)	7 (27)	38 (12)	23 (8)	15 (6)

* The exposure index was developed by identifying whether the cleaning product was EPP and assigning each frequency score with a numeric value (none or don't use = 0/less than 1 hour per day = 1/1 to 3 hours per day = 2/4 to 6 hours per day =3/7 to 8 hours per day =4). Each participant was assigned a traditional and a green cleaning product exposure score calculated by summing the frequency values of each traditional or green product used by that participant.

Biomonitoring for Urinary Phthalates:

As part of the biomonitoring sub-study, the safety data sheets (SDS) of the most common types of traditional cleaners and EPP were evaluated for more detailed chemical information to identify the types of ingredients found in these products. As expected, phthalates were not listed as an ingredient on MSDS. A total of 73 SDS were collected across four sites, and ingredients were reviewed to determine if chemical ingredients were comparable to other occupational studies involving housekeepers, janitors, and custodians. Ingredients in traditional products were typical of those reported in other occupational cleaner studies found in the literature (Bello et al. 2009). No studies were found in the literature that described the ingredients commonly found in EPPs. EPP ingredients in our study include chemicals such as alcohol ethoxylates, hydrogen peroxide, fruit derived acids (e. g. citric acid), as well as other ingredients found in traditional cleaners such as glycols and ethanolamine. Ingredients were not available on 3 SDS from EPPs, and the following statement was listed: "this product does not contain toxic chemicals at levels which require reporting under SARA Section 313 and 40 CFR Part 372." In

addition, “fragrance” was listed; however, few manufacturers provide complete disclosure of fragrance ingredients on SDS for any type of cleaning product including EPPs.

Based on observations over a shift, custodians reported using both traditional and EPP cleaners as well as disinfectants during their shift. Twelve custodians exclusively used EPP products, eleven custodians exclusively used traditional products and one custodian exclusively used disinfectant over the work shift. The remaining 44 (65%) participants used a mixture of two or more types of product types. The percentage of none, low and high cleaning product use were similar for traditional and EPP products, with 50% or more of the participants categorized as low use (Table 3) and a smaller percentage of 16% and 21% observed for the higher use category for the traditional and EPP categories respectively.

Table 3: Characterization of cleaning product usage and duration by observational assessment at 4 largest sites among 68 employees, n (%)

Cleaning Product	No Use	≤ 4 hours	>4 hours
Traditional Cleaners	18 (26)	39 (57)	11 (16)
Environmentally Preferable Products (EPP)	20 (29)	34 (50)	14 (21)
Disinfectants	36 (53)	16 (23)	16 (24)

A total of 68 workers provided a total of 269 urine samples (Table 4). Sixty-five workers provided all four urine samples, 3 workers lacked one sample, and 5 samples were not collected according to protocol. We only report urinary creatinine-adjusted levels. Urinary phthalate levels were detected in 90% or more of the urine samples, with the exception of MMP with 76% of samples with concentrations above the LOD. Twenty-four workers had one or more urine samples with low creatinine levels <30μg/g, and these workers varied in age, came from all four sites and worked during different shifts. Correlation between urinary metabolites was weak with spearman correlation coefficients ranging from -0. 003 to 0. 28 (data not shown).

With the exception of MMP with 24% of samples below the limit of detection (BDL), few samples were BDL with all samples above detection for MEP and MBzP and 6% and 10% BDL for MBP and MEHP respectively. Geometric mean (GM) urinary metabolite concentrations remained similar in magnitude, and were not statistically different, across the four time periods for the three metabolites most likely to be associated with cleaning chemical use MBzP, MBP, and MEHP (Table 4). However, statistically significant differences across collection times were observed for urinary MEP (p=0. 001) and MEHP (p=0. 03) concentrations. While the highest concentration of MEP were observed before shift (137 (4. 1), GM (GSD)), the highest concentration of MMP was observed before bedtime (3. 2 (5. 3), GM (GSD)). Notably, the highest urinary concentrations of MEP (11,377 μg/g), MBP (5,498 μg/g), MBzP (12,409 μg/g) were found among workers just beginning their shift (pre-shift). In comparing the geometric means between the current study population and NHANES 09-10, creatinine-adjusted urinary phthalate concentrations were higher among this population of custodians for each phthalate analyzed.

Urinary Phthalate Concentrations by Workplace Factors

Creatinine adjusted urinary-phthalate concentrations by workplace characteristics and exposure factors are presented in Table 5. Statistically significant differences in urinary MEP (p=0. 04), MEHP (p<0. 0001), MMP (p=0. 04) and MBzP (p=0. 01) concentrations were observed between sites with trends by phthalate metabolite varying by site. The majority (76%) of

Table 4: Creatinine adjusted urinary phthalate metabolite concentrations (µg/g) among 68 custodians across the four sampling time periods or the U. S. population 20 years or older from the National Health and Nutrition Examination Survey from 2009-2010.

	Below LOD n (%)	Time (n)	First Void (67)	Before Shift (67)	End Shift (68)	Before Bed (67)	All (269)	NHANES 09-10
MEP	0 (0)	GM (95% CI)	110 (80.4-150)	138 (97.5-195)	111 (79.4-154.2)	78.6 (56.6-109)	107 (91.0-126)	73.0 (65.1-81.9)
MMP	64 (24)	GM (95% CI)	2.95 (1.99-4.39)	1.78 (1.12-2.84)	3.06 (2.03-4.59)	3.23 (2.16-4.83)	2.69 (2.18-3.30)	1.09* (<LOD-1.23)
MBP	17 (6)	GM (95% CI)	23.0 (18.5-28.7)	21.0 (15.0-29.3)	17.1 (12.6-23.2)	17.8 (13.8-23.1)	19.6 (17.0-22.5)	14.3 (13.0-15.7)
MEHP	26 (10)	GM (95% CI)	7.16 (5.60-9.17)	6.30 (4.43-8.97)	6.46 (4.81-8.67)	7.90 (6.11-10.2)	6.93 (6.00-7.99)	1.65 (1.43-1.90)
MBzP	0 (0)	GM (95% CI)	8.87 (7.32-10.8)	8.57 (6.43-11.41)	9.09 (7.33-11.3)	8.65 (6.88-10.9)	8.79 (7.84-9.86)	5.94 (5.31-6.66)

Notes: LOD, limit of detection; Geometric mean; *median; proportion of results below the limit of detection were too high to provide a valid geometric mean.

Table 5: Geometric mean of creatinine-adjusted urinary phthalate concentrations (µg/g) by workplace characteristics and exposures

	N	(%)	n	MEP	MEHP	MBP	MMP	MBzP
Site								
A	21	(31)	82	114	10.8	15.7	1.8	8.4
B	5	(7)	20	179	3.4	15.5	4.4	21.0
C	24	(35)	95	147	10.0	22.0	2.1	9.9
D	18	(26)	72	57	3.1	23.1	5.2	6.3
		p-value		0.04	<0.0001	0.40	0.04	0.01
Shift								
1st shift	52	(76)	205	109	7.3	18.4	2.4	8.9
3rd shift	16	(24)	64	101	5.8	24.0	4.1	8.5
		p-value		0.82	0.36	0.28	0.15	0.88
EPP Intensity								
none	20	(30)	79	94	4.8	24.4	2.5	8.4
medium	34	(50)	134	112	7.0	17.5	2.3	8.4
high	14	(21)	56	116	11.3	18.9	4.2	10.6
		p-value		0.63	0.01	0.35	0.28	0.45
Traditional Intensity								
none	18	(27)	72	87	9.7	25.3	3.5	9.7
medium	39	(57)	153	95	7.0	17.4	2.2	6.9
high	11	(16)	44	231	3.9	19.2	3.4	17.1
		p-value		0.05	0.01	0.32	0.77	0.21
Disinfectant Intensity								
none	36	(53)	72	130	7.3	18.2	2.8	9.3
medium	16	(24)	153	157	9.3	20.9	2.5	13.1
high	16	(24)	44	47	4.6	21.6	2.6	5.2
		p-value		0.01	0.17	0.60	0.80	0.05
Cleaning Location								
Patient rooms	14	(21)	56	42	3.6	26.6	6.0	6.4
Classroom, office, laboratory	54	(79)	213	137	8.2	18.1	2.2	9.5
		p-value		0.0004	0.002	0.14	0.01	0.11
Toilets Cleaned								
None	19	(28)	76	142	7.2	23.4	3.8	12.0
1 - 10	28	(41)	110	79	7.0	18.2	2.1	7.4
11 - 19	17	(25)	68	113	6.9	15.6	2.6	7.8
20 or more	4	(6)	15	196	5.5	37.7	2.7	11.1
		p-value		0.23	0.96	0.25	0.54	0.16
Stripping floors								
yes	8	(12)	32	146	3.6	16.5	5.5	14.1
no	60	(88)	237	103	7.6	20.0	2.4	8.2
		p-value		0.44	0.03	0.60	0.10	0.07
Workday								
Tuesday	41	(60)	162	90	5.7	18.7	2.4	7.2
Wednesday	9	(13)	36	113	12.0	27.6	6.4	12.4
Thursday	18	(26)	71	157	8.1	18.3	2.2	11.7
		p-value		0.28	0.06	0.45	0.09	0.04

Table 6: Predictors of log-transformed creatinine-adjusted urinary MEP concentration

	MEP	
	ß (SE)	p-value
Fixed Effects		
Intercept	4.24 (0.66)	<0.0001
Site		0.60
A	0.24 (0.58)	0.68
B	-0.54 (0.81)	0.50
C	0.33 (0.59)	0.58
D	Reference	
Urine Order		0.003
First Void	Reference	
Before Shift	0.20 0.13	0.14
End Shift	0.001 0.13	0.99
Before Bedtime	-0.30 0.13	0.03
Traditional Intensity		0.050
None	Reference	
Medium	0.36 (0.30)	0.23
High	1.28 (0.52)	0.01
Disinfectant Intensity		0.32
None	Reference	
Medium	0.19 (0.34)	0.57
High	-0.47 (0.41)	0.25
Type of Area Cleaned		0.27
Patient rooms	Reference	
Classroom, office, laboratory	0.68 (0.61)	0.27
Gender (Female)	-0.17 (0.29)	0.57
Race (Non-White)	0.41 (0.45)	0.36
Hispanic	-1.81 (0.77)	0.02
Language		0.11
English	Reference	
Spanish	1.53 (0.77)	0.05
Other	0.43 (0.49)	0.39
Shampoo	-0.88 (0.29)	0.003
Random Effects		
s^2_{BW} (Full)		0.73
s^2_{BW} (Intercept)		1.29
Between worker variability explained		44%
s^2_{WW} (Full)		0.57
s^2_{WW} (Intercept)		0.60
Within worker variability explained		6%

Notes: Between-worker (s^2_{BW}) variance estimates from fully adjusted or intercept only models. Within-worker (s^2_{WW}) variance estimates from fully adjusted or intercept-only model.

participants worked first shift and no significant differences in urinary phthalate concentrations were observed between shifts.

A statistically significant (p=0. 01) higher concentration of MEHP was observed with increasing EPP intensity. Differences in the remaining urinary phthalate levels by increasing EPP intensity were not significant. Trends in urinary phthalate concentrations were also observed with increasing traditional cleaning chemical intensity with significant (p=0. 05) increases in MEP and significant (p=0. 01) decreases in MEHP observed. Significant differences in urinary phthalate concentrations were also observed with differences in disinfectant intensity for MEP (p=0. 01) and MBzP (p=0. 05), but no trends were observed.
Urinary phthalate concentrations varied by cleaning location with significant increases in MEP (p=0. 0004) and MEHP (p=0. 002) and decreases in MMP (p=0. 01) observed for participants cleaning classrooms, offices and laboratories as compared to patient rooms. No significant trends in urinary phthalate concentrations were observed by number of toilets cleaned. A small percentage (12%) of participants reported stripping floors and had significantly (p=0. 03) lower MEHP concentrations.

Most custodians worked Monday through Friday, except for workers on third shift who started on Sunday evening. Statistically significant (p=0. 04) differences in urinary MBzP concentrations were observed with increased concentration on Wednesday and Thursday as compared to Tuesday. Similar, although not statistically significant, trends were also observed for MEHP and MMP.

Multivariate models considering all univariate predictors that were statistically significant at the p<0. 10 level for each phthalate are presented in Table V. For creatinine-adjusted MEP concentrations, statistically significant predictors in the multivariate model included identification as Hispanic, urine order, intensity of traditional products used, and use of shampoo. Conditioner was not included in the model to their moderate agreement (kappa = 0. 48). As compared to a null model, the multivariate model explained 44% of the between worker and 6% of the within worker variability. For creatinine-adjusted MEHP concentrations, no statistically significant predictors were observed in the multivariate models although, as compared to a null model, the multivariate model explained 43% of the between worker. For creatinine-adjusted MMP concentrations, week day was the only statistically significant predictor observed in the multivariate model, which as compared to a null model, the multivariate model explained 38% of the between worker and 3% of the within worker variability. For creatinine-adjusted MBzP concentrations, statistically significant predictors in the multivariate model included intensity of disinfectant products used and use of laundry detergent.

Discussion: The geometric mean (GM) of each phthalate metabolite concentrations observed within this population of custodians were higher than the GM concentrations and outside the 95% confidence intervals of the concentrations observed among adults in the 2009-2010 NHANES study. To clarify, these elevated levels reflect divergence from national norms, but are not necessarily indicators of toxicity. Since phthalates are ubiquitous chemicals it is difficult to identify sources of exposure. Yet, our data suggests that custodians are exposed to phthalates, specifically MEP, from occupational as well as from non-occupational sources.

Given the short half-life of phthalates in urine, we expected to see an increase in urinary phthalate level across a work shift in the post-shift and bedtime samples, however these trends were not observed. This may be a reflection of the multiple sources of phthalate exposures from both home and work environments.

Connecticut is one of several states in the US implementing green cleaning programs as a result of a state law introduced in 2007. Although the law was in place for four years before we performed this study, less than 50% of the cleaners used by custodians at the sites were EPPs. We hypothesized that traditional, but not EPP cleaning chemicals would be a source of phthalate exposures. However, EPP cleaning chemicals are not universally free of phthalates since different standards are used for different cleaning chemical product groups. At the time of this study, cleaning products certified under the Green Seal Standard for Industrial and Institutional Cleaners (GS-37), which includes general purpose, restroom, and carpet cleaners, prohibited phthalates. However, GS standards for other cleaning products such as floor care products (GS-40) and hand cleaners (GS-41) allow International Fragrance Association (IFRA)-approved fragrances. IFRA approves approximately 3000 fragrance ingredients including phthalates, such as DEP.

Since DEP is a phthalate that may be linked to fragrances in cleaning products (Dodson et al. 2012), we expected to observe workplace predictors of MEP, the urinary metabolite for DEP, in our study. When we classified urinary metabolite levels by cleaning chemical exposure intensity, we did observe an increase in MEP with increasing intensity of exposure to traditional cleaning chemicals, and this result persisted in the multivariate models. This association also remained after adjusting for EPP product use (data not shown). Our results indicate that DEP may be related to the fragrance used in traditional cleaners, however, we were unable to confirm since phthalates were not listed on the SDS for the cleaners.

Custodians' use of EPP cleaning products did not always show reduced phthalate levels. However, it was also notable that urinary excretion levels from EPPs did not exceed those of conventional cleaners. The incomplete adoption of EPPs, despite statutory requirement, was an incidental finding, but one meriting further investigation. Custodians appear to be at risk for occupational exposure to phthalates related to traditional cleaning chemical exposures, although exposures outside of work also contribute to phthalate exposures.

Aim 5: *To identify disorders or adverse health events from the use of cleaning products, with the objective of assessing health impacts of green cleaning products.*

Health effects was a theme that emerged from the focus group data analysis including: respiratory symptoms associated with previous and current cleaners (though perceived to be more widespread with conventional cleaners); greater adverse ergonomic impact with EPPs, due to increased need to scrub and more frequent buffing; and positive ergonomic impact with the use of microfiber systems instead of buckets.

Within the 2011 Green Cleaning and Health Survey, a total of 329 custodians participated in the study and completed the survey (Table 7). The distribution of dermal, respiratory, and musculoskeletal symptoms in our population is shown in Table 8. Few custodians in our population had severe lower respiratory symptoms (6%), doctor-diagnosed asthma (13%), work-related asthma (4%), or current asthma (6%) (Table 8).

Odds ratios for health symptoms by category of traditional and green exposure are shown in Figure 3. We observed significant trends for increased odds of dermal ($p<0.01$), upper ($p=0.01$) and lower respiratory ($p=0.01$), and upper extremity ($p<0.01$), back ($p<0.01$), and lower extremity ($p=0.01$) musculoskeletal symptoms associated with increased typical traditional cleaning product exposure. We observed significant trends for increased odds of dermal ($p=0.03$) and back ($p=0.04$) and lower ($p=0.02$) extremity musculoskeletal symptoms associated with increased typical green cleaning product exposure. Despite some positive trends observed

for green cleaning product exposure, for any set of health symptoms, the magnitudes of the effects risk estimates associated with green cleaning product exposure were not as large as the uniformly smaller than the odds of symptoms effects associated with traditional cleaning product exposure.

Table 7: Population characteristics

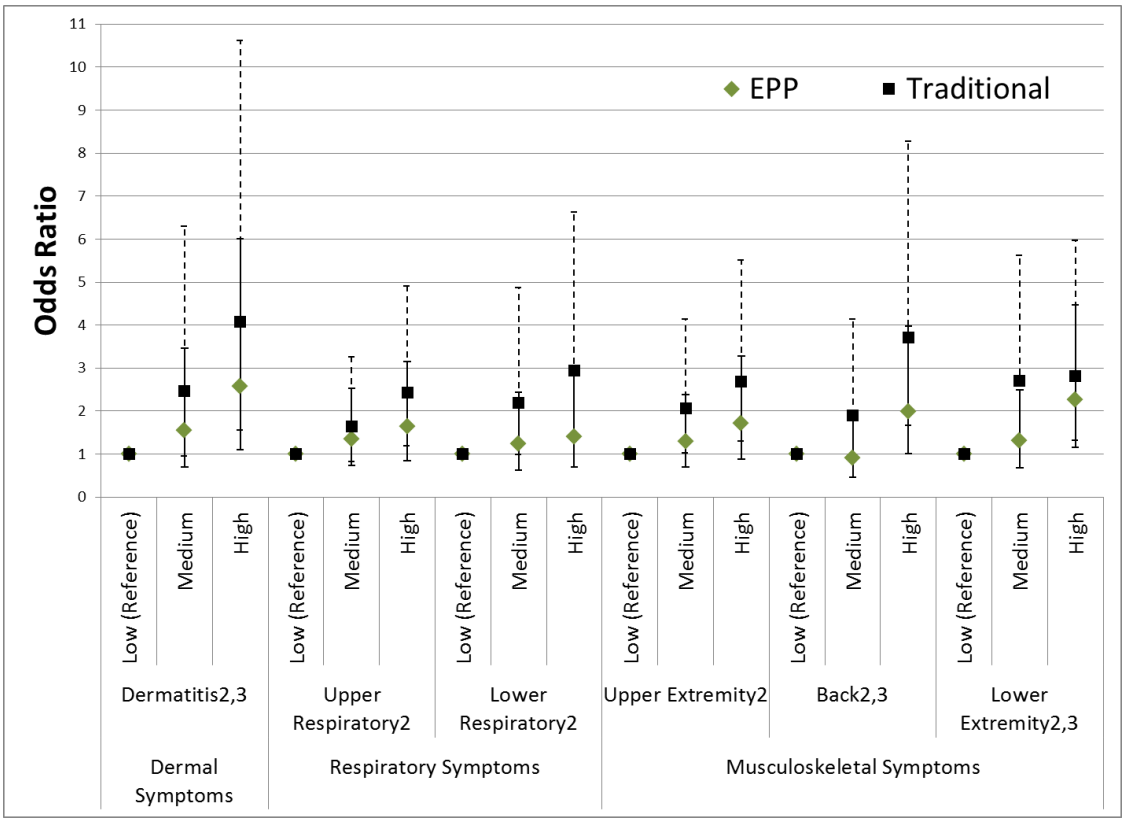
		N (%) or Mean (SD)	
Gender	Female (reference)	185	(56)
	Male	131	(40)
Work Schedule	Full Time (reference)	292	(89)
	Part Time	29	(09)
Type of Job	State (reference)	238	(72)
	Contractor	60	(18)
Primary Language	English (reference)	167	(51)
	Spanish	66	(20)
	Polish	56	(17)
	Other Language	29	(09)
Smoking Status	Non-Smoker	253	(77)
	Current Smoker	55	(17)
Age (years)	20-30	21	(06)
	31-40	44	(13)
	41-50	102	(31)
	51-60 (reference)	124	(38)
	61-70	33	(10)
Years Working with Cleaning Products		12	(9)

Table 8: Distribution of reported health symptoms

		N	**(%)**
Dermal	Dermal Symptoms	63	(19)
Respiratory	Upper Respiratory Symptoms	139	(42)
	Lower Respiratory Symptoms	84	(26)
	Doctor Diagnosed Asthma	44	(13)
	Work-related Asthma	14	(4)
	Current Asthma	44	(13)
Musculoskeletal	Upper Extremity Symptoms	138	(42)
	Back Pain Symptoms	100	(30)
	Lower Extremity Symptoms	116	(35)

Note: numbers may not add up to 329 due to missing values

Figure 3: Odds of symptoms by traditional and EPP exposure score



Conclusions: We observed significant linear associations between increased typical traditional cleaning product exposure and increased odds of dermal, upper and lower respiratory and upper extremity, back, and lower extremity musculoskeletal symptoms, while increased typical green cleaning product exposure was associated with dermal and back and lower extremity musculoskeletal symptoms. We also provided the first evidence that green cleaning products had weaker associations with health symptoms than traditional cleaning products.

Aim 6: *To develop an intervention to improve the acceptance of green cleaning programs, to ensure proper use of green cleaners and disinfectants, and to standardize the adoption of "green cleaning" products among custodians working at the various state institutions.*

CEUI and ConnectiCOSH health and safety trainers provided Green Cleaning training from July to November, 2013. Nine trainers trained 296 participants during 22 sessions at 7 sites. One session was offered to EH&S managers. Six sessions had a Spanish language interpreter.

Table 9: Training participants n(%) by site and union status

Location	CEUI	Contract
Southern Connecticut State University	65 (22)	
University of Connecticut Storrs	58 (20)	
Central Connecticut State University	17 (6)	39 (13)
Southbury Training Center	7 (2)	
Eastern Connecticut State University	50 (17)	
Private Agency		30 (10)
Managers	7 (2)	
University of Connecticut Health Center (Pilot)	23 (8)	
Subtotal	227 (77)	69 (23)
TOTAL	296	

Based on responses from the Satisfaction Survey, the participants were typically older, worked first shift, spoke English as their primary language, were male, had seniority, were union members and were custodians/housekeepers (Table 10 and Table 11).

Table 10: Training participant demographics

	n (%)
Age (41-60 years)	145 (55. 3)
First Shift	146 (55. 7)
Primary Language: English	143 (54. 6)
Male	144 (55. 0)
Years Worked (over 15 years)	66 (25. 2)
Union	185 (71. 2)

Table 11: Training participant work characteristics

	n (%)
Custodian/Housekeeper	199 (75. 9)
Lead/Supervising custodian	39 (14. 9)
Supervising custodian	13 (5. 0)
Manager	3 (1. 1)
Other	12 (4. 6)

Results show an increase in mean scores for all but one of the green cleaning satisfaction items. These findings indicate that the participants increased their knowledge of recommended green cleaning methods and increased satisfaction with EPP. The 'Need stronger cleaners' is the one item with a slight decrease in mean score (pre = 3.83, post = 3.82). One of the intents of the training was to provide participants with information that would enable them to reduce their perceived reliance on strong cleaners which tend to be more toxic. Although the reduction is minimal, the trend is in the right direction suggesting a possible greater acceptance of green cleaners and increase in knowledge related to recommended green cleaning methods.

Results from t-tests indicate that the post-training mean scores were significantly higher for the majority of the items (Table 12). Further revisions to the curriculum and additional training may be needed for product labels, PPE, and need for stronger cleaners. Results from the items

related to satisfaction with the training indicate high ratings for the training content, teaching method and logistics (Table 13).

Table 12: Satisfaction with Green Cleaners

Item	Pre n	Pre Mean (SD)	Post n	Post Mean (SD)	p
Green cleaners safer for my health	233	3.78 (1.04)	257	4.17 (.79)	.000
Product labels have important information on how to use products safely	232	4.03 (.99)	255	4.09 (.91)	.488
Difference between cleaning, sanitizing and disinfecting	232	3.91 (1.03)	257	4.29 (.77)	.000
Green cleaning products may be used in different ways	226	3.46 (.97)	255	4.00 (.89)	.000
Important to choose right cleaning product and Personal Protective Equipment	233	4.18 (1.03)	256	4.32 (.79)	.100
Green cleaners better for environment	232	3.90 (1.11)	238	4.26 (.78)	.000
Recommend green cleaners to others	231	3.83 (1.09)	238	4.05 (.93)	.020
Green cleaners work as well	228	3.15 (1.18)	234	3.48 (1.16)	.003
Need stronger cleaners	231	3.83 (1.09)	231	3.82 (1.10)	.899

Range: 1 (strongly disagree) to 5 (strongly agree)

The findings indicate that the participants were very satisfied with the training content, approach and logistics. As noted in the following table, mean scores on the training items suggest that participants agreed with the statements related to training.

The following training materials were translated into Spanish and Polish and posted on the website (http://oehc. uchc. edu/greencleaning. asp) :
• Workbook: Green Cleaning in Your Workplace - participant version
• Workbook: Green Cleaning in Your Workplace - trainer version
• Fact Sheet: A Green Cleaning Program for Connecticut Facilities
• Fact Sheet: Equipment for Green Cleaning
• Fact Sheet: Where is the Shine and Smell with Green Cleaning Products?
• Fact Sheet: Disinfectant Use in Green Cleaning Programs
• Fact Sheet: A Green Cleaning Program for Animal Laboratories
• Fact Sheet: Green Cleaning for Food Service

Table 13: Satisfaction with Training (Agree/Strongly Agree)

Item	N (%)	Mean (SD)
The training gave me information to do my job safer and healthier	196 (82)	4.15 (.898)
The training gave me information to do my job better	182 (75)	4.04 (.957)
I will share the information that I have learned with others	188 (78)	4.05 (.892)
The trainer was able to answer participants' questions	217 (90)	4.20 (.790)
The workbook was easy to follow	215 (89)	4.16 (.822)
The workbook provided useful information	211 (89)	4.19 (.843)
The presentation was well organized and informative	211 (88)	4.18 (.853)
I participated in the training by sharing my ideas and experiences	110 (87)	4.07 (.936)
The training was at a good location	203 (82)	4.07 (.930)
The training was at a good time of day	206 (83)	4.05 (.944)
The training was for the right amount of time (not too short and not too long)	204 (82)	4.01 (.896)

V. Summary Conclusions

- Focus group themes suggest that custodians take pride in their work taking satisfaction in a "well-done" job. Barriers to implementing EPP programs, including misconceptions about more effort required, EPP ease of use for workers with limited English proficiency (LEP), misuse of disinfectants, and need for training may be addressed through education.
- Although the CT law requiring EPP use was in place for four years before we performed this study, less than 50% of the cleaners used by custodians at the sites were EPPs.
- A significant relationship was observed between occupational exposures to traditional cleaning chemicals and urinary MEP concentrations. Custodians' use of EPP cleaning products did not always show reduced phthalate levels. However, it was also notable that urinary excretion levels from EPPs did not exceed those of conventional cleaners.
- Significant linear associations were observed between increased typical traditional cleaning product exposure and increased odds of dermal, upper and lower respiratory and upper extremity, back, and lower extremity musculoskeletal symptoms, while increased typical green cleaning product exposure was associated with dermal and back and lower extremity musculoskeletal symptoms. We provide the first evidence that green cleaning products had weaker associations with health symptoms than traditional cleaning products.

CEUI and ConnectiCOSH health and safety trainers provided Green Cleaning training to 296 participants during 22 sessions at 7 sites. One session was offered to EH&S managers. Six sessions had a Spanish language interpreter. Results related to satisfaction with green cleaners show an increase in mean scores for all but one item indicating an increase in knowledge of recommended green cleaning methods and satisfaction with EPP. Findings related to training indicate that participants were very satisfied with content, approach and logistics. The training materials were translated into Spanish and Polish and posted on the website (http://oehc. uchc. edu/greencleaning. asp).

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