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A pilot study of total personal exposure to volatile organic compounds among Hispanic female domestic cleaners

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Abstract

Cleaners have an elevated risk for the development or exacerbation of asthma and other respiratory conditions, possibly due to exposure to cleaning products containing volatile organic compounds (VOCs) leading to inflammation and oxidative stress. This pilot study aimed to quantify total personal exposure to VOCs and to assess biomarkers of inflammation and pulmonary oxidative stress in 15 predominantly Hispanic women working as domestic cleaners in San Antonio, Texas, between November 2019 and July 2020. In partnership with a community organization, Domésticas Unidas, recruited women were invited to attend a training session where they were provided 3M 3500 passive organic vapor monitors (badges) and began a 72-hour sampling period

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at which time they were instructed to wear one badge during the entire period ("AT", for ***A***ll the ***T***ime), a second badge only while they were inside their home ("INS", for ***INS***ide), and a third badge only when they were outside their home ("OUT", for ***OUT***side). At the end of the sampling period, women returned the badges and provided blood and exhaled breath condensate (EBC) samples. From the badges, 30 individual VOCs were measured and summed to inform total VOC (TVOC) concentrations, as well as concentrations of the following VOC groups: aromatic hydrocarbons, alkanes, halogenated hydrocarbons, and terpenes. From the blood and EBC samples, concentrations of serum C-reactive protein (CRP) and EBC 8-isoprostane (8-ISP) and pH were quantified. Data analyses included descriptive statistics. The 72-hour average of personal exposure to TVOC was 34.4 ppb and ranged from 9.2–219.5 ppb. The most prevalent class of VOC exposures for most women (66.7%) was terpenes, specifically *d*-limonene. Overall, most women also experienced higher TVOC concentrations while outside their home (86.7%) as compared to inside their home. Serum CRP concentrations ranged from 0.3–20.3 mg/dL; 8-ISP concentrations ranged from 9.5–44.1 pg/mL; and EBC pH ranged from 7.1–8.6. Overall, this pilot study demonstrated personal VOC exposure among Hispanic domestic cleaners, particularly to *d*-limonene, which may result from the use of scented cleaning products.

Keywords

Air pollution; housecleaners; inflammation; Latina health; VOCs

INTRODUCTION

In 2019, nearly one million workers in the United States (U.S.) were classified as maids or housekeeping cleaners (BLS 2019). Numerous studies suggest that cleaners are at an elevated risk for the development or exacerbation of asthma and other respiratory conditions, but most of these studies have been conducted outside the U.S. among industrial cleaners who work in large commercial settings (e.g., professional cleaning companies, hospitals) (Dumas et al. 2016; Jaakkola et al. 2006; Kogevinas et al. 1999; Medina-Ramon et al. 2003, 2005, 2006; Quirce et al. 2010; Siracusa et al. 2013; Vizcaya et al. 2011; Zock et al. 2001, 2007). In contrast, domestic cleaners, who work in residential settings, are an understudied and overburdened population increasingly exposed to potentially harmful cleaning products that frequently contain volatile organic compounds (VOCs). A 2012 survey of more than 2,000 domestic workers in the U.S. found that two-thirds of housecleaners reported working with toxic cleaning supplies, and 29% and 20% reported suffering from skin irritation and trouble breathing, respectively (NDWA 2012). Similarly, Lindberg et al. (2021) demonstrated that residential bathroom cleaning tasks may expose home care aides to VOCs and potential respiratory hazards from the use of conventional or green cleaning and disinfecting products. Despite the large number of housecleaners with potential toxic exposures, U.S. labor laws generally exclude domestic cleaners, thus limiting protections for this workforce (NDWA 2012). While industrial and domestic cleaners may perform similar tasks, domestic cleaners are likely exposed to higher levels of VOCs because they often receive little to no training in the safe use of chemical cleaning products and they lack organized control measures and legislative protections. Still, the extent to which domestic cleaners are exposed to VOCs has not been thoroughly explored (NDWA 2012).

Among domestic cleaners, exposures to VOCs have been linked with adverse respiratory outcomes through inflammation (e.g., serum C-reactive protein (CRP)) and oxidative stress (pH and 8-isoprostane (8-ISP) concentration in exhaled breath condensate (EBC)) (Carpagnano et al. 2004; Kim et al. 2013; Ma et al. 2010; Montuschi et al. 1999; Tagiyeva et al. 2014; Wolkoff et al. 1998; Yoon et al. 2010). Although there is limited research to have quantified associations between VOC exposures and biomarkers of inflammation or oxidative stress in workers, total personal air VOC concentrations of less than 0.08 ppm using a direct reading instrument have been associated with elevated CRP levels among hairdressers in Taiwan, including a positive correlation between increased CRP levels and increased hours worked (Ma et al. 2010).

Because VOCs are ubiquitous in the environment, both indoor and outdoor sources represent important determinants of total personal exposure, even among occupationally exposed persons (Batterman et al. 2014; Dodson et al. 2007; Lioy 2006). That is, in addition to work-related VOC exposures, Hispanic women working as domestic cleaners may experience "double jeopardy," with higher VOC exposures in their neighborhood environments due, in part, to spatial inequalities in environmental hazards, such as living in close proximity to point sources of air pollution (Brown 1995; Crowder et al. 2010; Northridge et al. 2003; Stewart et al. 2015; Wu et al. 2012). The proximity to these local pollution sources significantly contributes to personal VOC exposures (Bari et al. 2015; Wu et al. 2012). Thus, any investigation of personal VOC exposures among Hispanic domestic cleaners must also consider both indoor and outdoor environments. The goals of this pilot study were to assess the feasibility of conducting personal VOC exposure assessment and to explore biomarkers of inflammation and pulmonary oxidative stress among this vulnerable, hard-to-reach population of female Hispanic domestic cleaners.

METHODS

Study Design and Recruitment

This pilot study was conducted among primarily Hispanic women working as domestic cleaners in San Antonio, Texas, between November 2019 and July 2020. Women were eligible to participate if they were at least 18 years or older, were working as domestic cleaners at the time of recruitment, were not exclusively employed by a company providing cleaning services, and spoke English or Spanish. Participants were initially recruited from among 56 Hispanic women working as domestic cleaners who had previously participated in a cross-sectional study assessing occupational and environmental hazards experienced by domestic cleaners. Details of the prior study were previously published (Whitworth et al. 2020). Women were recruited in collaboration with Domésticas Unidas (DU), a San Antonio-based grassroots organization affiliated with the National Domestic Workers Alliance (NDWA). In the prior study, women completed a baseline questionnaire in which they were asked to self-report health conditions, respiratory symptoms, work history, demographics, and willingness to participate in future studies. Approximately 97% of the women in the original study agreed to be re-contacted for future studies, thereby forming the eligible sampling frame from which eight women were recruited for the present study. An additional seven 'new' women were recruited following a similar recruitment strategy, for

a total of 15 women included in this study. In total, ten women were recruited in 2019 and five women were recruited in 2020, after the start of the COVID-19 pandemic. The study was approved by The University of Texas Health Science Center at Houston (UTHealth) Committee for the Protection of Human Subjects (HSC-SPH-17–0026).

Training Session

Upon initial contact, women were provided an overview of the study and, if interested, were scheduled to attend a small group training session limited to no more than five women. A total of five training sessions were conducted over a period of eight months from November 2019 to July 2020. All women attended the training session on a Monday, were asked to participate during a 'normal' week when they would be cleaning houses, and were instructed to initiate the 72-hr sampling period on the very next day, resulting in a sampling period lasting from Tuesday to Friday.

During each training session, women were provided a detailed explanation of the 72-hour personal air sampling campaign and the expectations of their participation, which included wearing three passive organic vapor monitors (OVMs), or badges, and completing a time-diary form. Women were also instructed that they would return for a follow-up session on the final day of the 72-hr sampling period. At the conclusion of the training session, English- and Spanish-speaking study staff obtained written informed consent, advising participants of the voluntary nature of their participation and the confidentiality of their data and of their ability to withhold responses on the questionnaire and the time-diary form or to terminate participation at any time. The baseline questionnaire used in the original study was administered to the four newly recruited women during the training session to ensure that similar demographic information was obtained among all women in the present study; women were provided a $10 incentive for completing this baseline questionnaire.

At the conclusion of the training session, participants received a sampling packet containing five 3M 3500 passive OVM badges (3M, Maplewood, MN), labeled A ("C1," for ***C***ontrol 1), B ("C2," for ***C***ontrol 2), C ("AT", for ***A***ll the ***T***ime), D ("INS", for ***INS***ide), and E ("OUT", for ***OUT***side), an instruction booklet, a pen, a highlighter, and the time-diary form. The time-diary form contained a chart of each hour of the day divided into 15-min blocked increments. Badges were also labeled with a study identification (id) number unique to each woman and no other identifiers. The 72-hr air sampling campaign started the day following the training session and terminated 72 hr later at which time they were scheduled for their follow-up session.

72-Hour Personal Air Sampling Campaign

As part of the 72-hour sampling campaign, women were instructed to wear a series of three badges on the collars of their clothing near their breathing zone. Women were instructed to keep badges C1 (unopened) and C2 (opened) in their respective containers as controls and to wear two of the three remaining badges (AT, INS, and OUT), except while sleeping, bathing, showering, or swimming. Badge AT was worn at all times during the 72-hr sampling period; badge INS was worn while each woman was inside her home; and badge OUT was worn when each woman left her home. Women were instructed to place badges INS and OUT in

their respective containers with their lids secured when they were not being worn. Badges AT and INS were to be placed on the bathroom countertop while showering or on the nightstand while sleeping and, if the woman was to go swimming during her sampling period, she was to place badges AT and OUT near where she was swimming but where it would be protected from getting wet.

To estimate the total amount of individual time that badges INS and OUT were worn, participants marked the number of minutes in 15-min increments that they spent inside their homes wearing badge INS or outside wearing badge OUT on the time-diary form during the 72-hr sampling period. Over the course of the air sampling campaign, study staff kept in contact with participants via telephone or text to ensure participants remembered the instructions, to clarify any doubt about the study procedures, and to answer any questions. A 72-hr sampling period was chosen to measure VOC exposures since it allowed the capture of VOC concentration spikes in addition to exposures with lower limits of detection (LODs) and better precisions than longer or shorter sampling periods (Heeley-Hill et al. 2021; Stock et al. 2008).

Follow-up Visit

On the day that the 72-hr VOC sampling period concluded, participants completed a follow-up visit, typically between 4pm and 8pm, during which they returned the badges and the time-diary form and provided blood and EBC samples. Study staff also conducted an exit interview at this time, asking participants about their experience and challenges implementing the study protocol, and provided the women with a $40 incentive for completing the study.

Blood specimens (~5mL) were obtained in a gold top BD Vacutainer® by a trained nurse. Specimens were labelled only with the woman's study id, placed in a plastic biohazard bag and then into a cooler with a frozen gel pack, and transported to a university laboratory in San Antonio within one hour of collection. At the laboratory, samples were centrifuged, and the separated serum was extracted by pipette, placed in 2mL plastic collection tubes and stored at −20°C for approximately three months for later analysis of CRP. One participant's blood sample was unable to be obtained after two venipuncture attempts.

EBC samples were also collected during the follow-up visit with a RTube® Breath Condensate Collection Device (RTube) using standard procedures (Respiratory Research 2019). EBC was collected without the addition of solvent or diluent and was divided into two equal samples for 8-ISP and pH analysis. Butylated hydroxytoluene (BHT), an antioxidant, was added to only the 8-ISP aliquots. Following EBC collection, the RTube containing the EBC specimen was labelled only with the woman's study id. The RTube was placed in a plastic biohazard bag and then into a cooler with a frozen gel pack and transported to the laboratory within approximately one hour. At the laboratory, EBC samples were extracted from the RTube by pipette and divided equally into two 2mL plastic collection tubes. One collection tube contained the woman's EBC only and one contained the woman's EBC with BHT at a ratio of 10 microliters BHT to 1mL of EBC. The tubes were stored at −80°C for approximately three months for later analysis of 8-ISP and quantification of pH.

VOC Exposures

VOCs were extracted from the five 3M 3500 OVM badges collected from participants. Thirty VOCs were analyzed using previously developed methods (An Han et al. 2020; Stock et al. 2008). Briefly, samples extracted with carbon disulfide (CS_2) were analyzed by a GC6890/XLS mass spectrometer (Agilent Technologies, Palo Alto, CA) using an RTX-624 column (Restek, Bellefonte, PA), 60-meter length, 0.25 mm internal diameter, and 1.4 μm film thickness, with constant flow rate of 1 mL/min, and using helium as a carrier gas. Scan (m/z= 35 to 260) and selective ion mode (SIM) for qualitative and quantitative analysis were used for all VOCs.

The air sampling badges were analyzed for 30 individual VOC compounds, which were further categorized into following four VOC groups: aromatic hydrocarbons (benzene, toluene, ethylbenzene, *m&p*-xylenes, *o*-xylene, styrene, 1,3,5-trimethylbenzene, 1-ethyl-2-methylbenzene, 1,2,4-trimethylbenzene, 1,2,3-trimethylbenzene, naphthalene), alkanes (*n*-pentane, isoprene, methyl *tert*-butyl ether, *n*-hexane, methylcyclopentane, methy ethyl ketone, 2,3-dimethylpentane, *n*-nonane, *n*-decane), halogenated hydrocarbons (methylene chloride, chloroprene, chloroform, carbon tetrachloride, trichloroethylene, tetrachloroethylene, 1,4-dichlorobenzene), and terpenes (α-pinene, β-pinene, *d*-limonene).

Biomarkers of Inflammation and Oxidative Stress

EBC pH was measured after nitrogen degassing (Wood et al. 2013). Serum CRP and EBC 8-isoprostane were analyzed using enzyme-linked immunosorbent assays (ELISA) following manufacturer's protocols (Cayman Chemical, Ann Arbor, MI). One EBC sample had an invalid pH measurement, and one woman did not have sufficient volume of EBC to measure pH, resulting in 13 pH measurements; one serum sample had an invalid CRP measurement and one woman did not provide a blood sample, resulting in 13 CRP measurements; and one woman did not have sufficient volume of EBC to measure 8-ISP, resulting in 14 8-ISP measurements.

Statistical Analyses

The demographic characteristics of the study population, based on the women's responses in the baseline questionnaire, were summarized using proportions. Descriptive statistics were calculated, including mean (+/− standard deviation), median, and range of TVOCs (ppb) for badges AT, INS and OUT. For badges AT, INS, and OUT, the proportion of contribution of each VOC category (i.e., aromatic hydrocarbons, alkanes, halogenated hydrocarbons, and terpenes) to the TVOC concentration was also calculated. Descriptive statistics for CRP and 8-ISP concentrations as well as EBC pH values are reported as means (+/− standard deviation), geometric means (+/− geometric standard deviation, GSD), medians, and ranges. Wilcoxon signed-rank tests were performed for comparing differences in TVOC medians in INS and OUT badges. All statistical analyses were performed in Stata 14.2 (StataCorp, LLC, College Station, TX).

RESULTS

Population Characteristics

Comparing those who participated in this study (n=8) from the original sample of 56, which constituted the original sampling frame, to those who did not (n=48), those who participated were more likely to have lived in the U.S. for 25 years or less (88% vs. 54%, P=0.076) and to have been ever smokers (50% vs. 20%, P=0.063) (data not shown).

Overall, among the 15 women in this current study, 60% were age 50 or greater (range from 31 to 65 years), and all but one (93.3%) self-identified as Hispanic and had lived in the U.S. for 25 years or less (Table 1). Most women (73.3%) reported living in a single-family home, 40% reported an income at or below $15,000 per year, and 60% had a high school education or less (Table 1). More than half (60%) of the women reported being former smokers, but none were current smokers (Table 1). Additionally, none of the women reported living with someone who smoked in the home, and, thus, there were no known sources of environmental tobacco smoke inside the home (data not shown). Almost half (47.7%) reported a history of trouble breathing, with 57.1% of those suffering from breathing difficulty while working, and only 53.3% reported ever covering their eyes, mouth, hands, or feet with protective equipment during work hours (data not shown).

VOC Exposures

The exposure concentration of TVOCs over the entire 72-hr sampling period from badge AT in the 15 participants ranged from 9.2 – 219.5 ppb with a mean of 34.4 ppb (SD = 53.6) and a median of 16.1 ppb (data not shown). Participant #6 experienced an exposure concentration of TVOCs of 219.5 ppb over the entire 72-hr sampling period, which was considerably higher than the other participants; the largest proportion of her TVOC exposure upon examining her INS and OUT badges occurred inside her home (95%) (Figure 1). Similarly, Participant #11 experienced an exposure concentration of TVOCs of 390.6 ppb in her OUT badge over the 72-hr sampling period, which was also substantially higher than the other participants (Figure 1). In general, most women (86.7%) experienced higher VOC exposures while wearing badge OUT as compared to wearing badge INS.

Overall, the majority (n=66.7%) of the women experienced the greatest proportion of TVOC exposure in badge AT from terpenes, with a mean percentage contribution of 56.1% (Figure 2). Of the remaining five women, four of the women's TVOC exposure was mostly from alkanes (mean percentage contribution 39%), and one woman experienced most of her TVOC exposure from halogenated hydrocarbons (percentage contribution 43%) (Figure 2). When exposures to specific VOC compounds (rather than VOC groups) in badge AT were examined, the highest exposures experienced by the women were from *d*-limonene (mean = 22.5 ppb; median = 4.3 ppb), followed by toluene (mean = 1.5 ppb; median = 1.1 ppb), α-pinene (mean = 0.8 ppb; median = 0.7 ppb) and β-pinene (mean = 0.7 ppb; median = 0.6 ppb) (data not shown).

The median TVOC concentrations were 15.4 ppb for the INS badge and 23.3 ppb for the OUT badge (p = 0.01) (Figure 1). Removing the two subjects who had extreme values (#6, high in INS; #11, high in OUT) resulted in median TVOC concentrations of 11.7 ppb for the

INS badge and 23.3 ppb for the OUT badge ($p < 0.001$) (data not shown). Additionally, the proportion of grouped VOC exposures was similar in the INS vs. OUT badges (Figure 2). In each case, terpenes still accounted for the highest proportion of TVOC exposures (Figure 2). After excluding one woman whose terpene exposures accounted for 98% of the TVOC INS badge concentrations, however, the proportion of terpene and alkane concentrations measured by the INS badges of the 14 remaining women was similar (35.4% compared to 32.2%) (data not shown).

Biomarkers of Inflammation and Oxidative Stress

Women's CRP concentrations ranged from 0.3 – 20.3 mg/dL. The mean CRP concentration was 5.0 mg/dL (SD = 5.7); the geometric mean was 2.5 mg/dL (GSD = 1.4); and the median concentration was 2.7 mg/dL (Table 2). Concentrations of 8-ISP ranged from 9.5 – 44.1 pg/mL, with a mean concentration of 21.0 pg/mL (SD = 11.1), a geometric mean concentration of 18.5 pg/mL (GSD = 0.5), and a median concentration of 17.0 pg/mL (Table 2). EBC pH values ranged from 7.1 – 8.6 with a mean pH of 8.3 (SD = 0.4), a geometric mean pH of 8.3 (GSD = 0.1), and a median pH of 8.4; one woman (7.7%) had an acidotic EBC pH of 7.1.

DISCUSSION

Overall, this pilot study demonstrated the feasibility of conducting a comprehensive personal VOC exposure assessment among a group of hard-to-reach Hispanic women working as domestic cleaners in San Antonio, Texas. Most of the women (86.7%) in this study had higher TVOC exposures in the OUT badge compared with the INS badge, unlike in the RIOPA study where most participants experienced higher VOC exposure inside their homes (Su et al. 2013). However, it may be difficult to directly compare this study's findings with those of RIOPA, as the OUT badge worn by the women in this study included exposure times during which the women may have been in the outside ambient environment as well as inside (cleaning) other people's homes. This serves as a limitation of this study, as it was not possible to designate specific occupational exposures.

Additionally, the impact of relative humidity during the 72-hr sampling period was not assessed, as the average annual relative humidity in San Antonio is around 55%, and in South Texas, unlike some climates in the U.S. there is not seasonal variability in meteorological conditions. In San Antonio, humidity ranges from approximately 50% in the summer to 62% in the spring, and, thus, it is unlikely that the sample collection rate was significantly affected by temporal variability.

Even so, most women in this study were exposed to higher concentrations of TVOCs while outside their own home than inside their home. The most common VOCs to which women were exposed were terpenes, a class of chemicals often found in cleaning supplies, which could imply increased occupational exposures among these women. In particular, the greatest average concentration of VOC exposures among participants was from *d*-limonene, which is a common additive in cleaning products and has been associated with contact dermatitis (Pesonen et al. 2014). However, *d*-limonene is also added as a fragrance and antimicrobial in personal care and laundry products, and because the VOC badges were

worn on the study participants' collars, personal care products from clothing, shampoo, body lotions, and fragrances could have contributed to both INS and OUT VOC exposures.

Compared with reference levels in Kushner et al. (2006), nearly 39% of the participants in this study demonstrated mildly or substantially elevated CRP levels. Although CRP is a nonspecific indicator of systemic inflammation, both short-term exposures to ambient air pollution (Li et al. 2017) and specific disease processes such as asthma (Deraz et al. 2012) have each been associated with increased CRP levels; CRP levels have also been used as markers of cardiovascular disease (Cozlea et al. 2013). Regarding 8-ISP, eleven out of 14 of the participants in this study had EBC 8-ISP concentrations that exceeded the reference range (9.26 pg/mL, range 2.46 – 10.71) among healthy adults described in Shoman et al.'s 2020 systematic review and meta-analysis. 8-Isoprostane is a prostaglandin-like compound produced by free-radical proxidation of arachidonic acid and is a reliable biomarker of lipid peroxidation via reactive oxygen species (Awad et al. 1996). When measured in EBC, 8-ISP reflects oxidative stress specific to the airways (Kharitonov et al. 2001). Finally, EBC pH informs airway inflammation and lung disease, particularly related to asthma, but also reflects insults related to other respiratory disease and exposures (Aldakheel et al. 2016; Davis et al. 2018). Only one woman in this pilot study had an acidotic EBC pH of 7.1, which is below the median EBC pH (8.0, interquartile range 7.8 – 8.1) reported from a study of healthy participants to establish normative reference values (Paget-Brown et al. 2006). Although these findings are suggestive of potential inflammation-related effects and cell and tissue damage related to oxidative stress, the results must be interpreted with caution given the small sample size in this study, the lack of a proper comparison group, and the lack of clinical history details on the participants (Pizzino et al. 2017). Therefore, these results remain suggestive and will need to be confirmed in larger studies.

These findings must be interpreted considering the methodologic limitations of this pilot study. Despite having a sampling frame from which to recruit women, the recruitment pace for the current study was slower than anticipated. Given domestics workers commonly unstable and unpredictable work schedules, the biggest barriers to recruitment were making initial contact with the women for participation and scheduling participants at a time when they were available to initiate the 72-hour sampling period and return on the final day. The recruitment challenges were further exacerbated by the COVID-19 pandemic, which resulted in a pause in the study in March 2020. Even so, recruitment resumed in July 2020. In future studies, based on lessons learned in this pilot project, recruitment efforts should be modified to better reach this population by making better use of community partners for outreach (e.g., by making direct contact with potential participants). It did not appear that the study procedures were overly burdensome for women who did participate in the study, as the end-of-study evaluation with the women did not reveal any information to indicate that the women did not wear the badges as intended or complete the time diary form as instructed; however, if so, the calculations of TVOCs per badge may have been biased due to measurement error, as the information regarding the corresponding times spent wearing each badge, which was used to calculate TVOCs, could have been misclassified if those times were not accurately recorded by the participants. For example, if a woman recorded more time than actually spent at a given location, her 'true' exposure to TVOCs inside the home or outside the home might be underestimated. On the contrary, a woman's exposure

to TVOCs might be overestimated if she reported less time than actually spent at her given location inside the home or outside the home. Still, the measurement error of personal TVOC exposure was unlikely in this pilot study since the women were asked to wear AT badges during the entire sampling period. In addition, given the nature of this pilot study and its focused investigation, it was not feasible to collect detailed activity data from the women with respect to cleaning activities; however, the women were asked to participate in the study during a 72-hr sampling period in which they would typically be working (i.e., cleaning houses). Finally, in this pilot study, participants were not asked about medication use, such as inhaled corticosteroids or other immunosuppressive drugs, which could have modulated biomarkers of inflammation and oxidative stress.

CONCLUSIONS

The results of this pilot study suggest that women working as domestic cleaners are exposed to VOCs both inside and outside their home but may experience higher VOC exposures outside their homes, which, in this study, included occupational exposures. Additionally, while they are exposed to myriad VOCs, these women were particularly exposed to terpene compounds, which are often found in scented cleaning products.

The goal of the future, larger-scale study for which this pilot is being conducted is to collect comprehensive time-activity data, including cleaning products used, and to examine epidemiologic associations between women's personal VOC exposures and biomarkers of inflammation and oxidative stress (in exhaled breath, urine, and blood samples), which was beyond the scope of this pilot study.

RECOMMENDATIONS

In addition to future investigations needed to replicate these findings, future studies involving domestic cleaner populations should assess the types of cleaning products used and the specific time periods during which those products are used while wearing air sampling monitors for the purpose of assessing potential associations between products used, VOC exposures, and biomarkers of inflammation and oxidative stress.

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Data availability statement:

The data that support the findings of this study are available from the corresponding author upon request.

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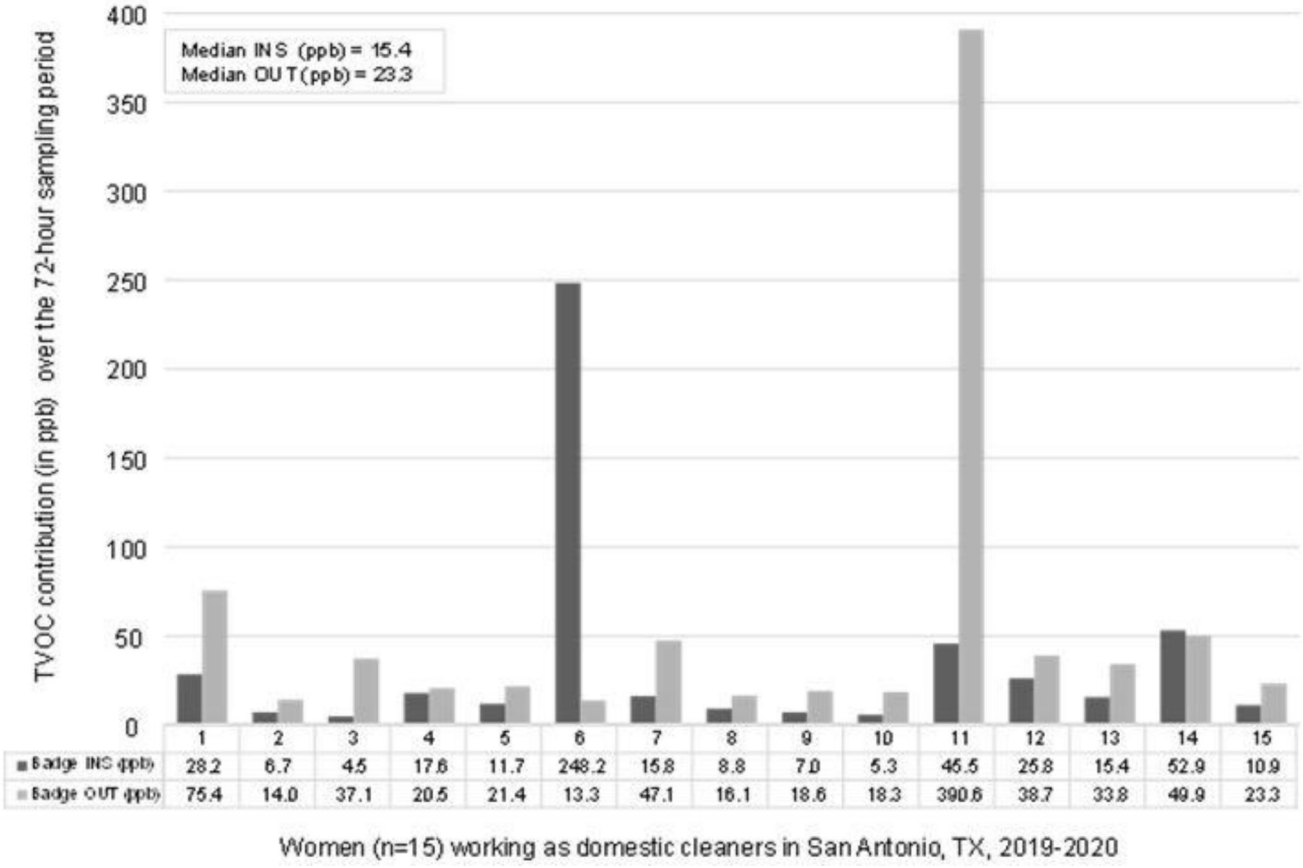

Figure 1.

Average total volatile organic compounds (TVOC) concentration (in ppb) from badges INS (worn while each woman was inside her home) and badge OUT (worn when each woman left her home) over the 72-hour sampling period among women (n=15) working as domestic cleaners in San Antonio, TX, 2019–2020.

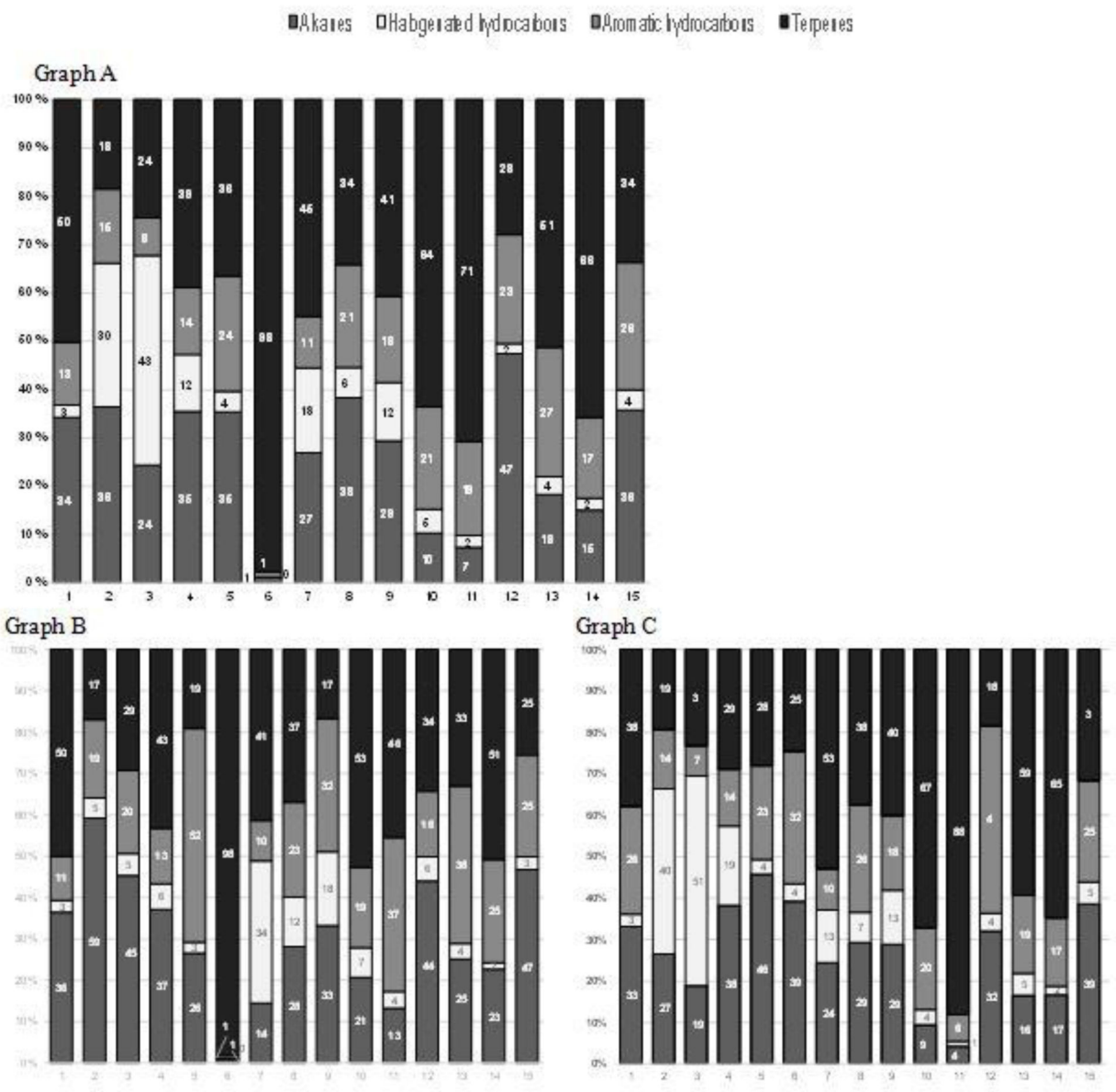

Figure 2.

Proportion (%) of total volatile organic compounds (TVOC) contribution by VOC groups over the 72-hour sampling period from the badge AT (graph A), badge INS (graph B), and badge OUT (graph C) among women (n=15) working as domestic cleaners in San Antonio, TX, 2019–2020.

Table 1.

Characteristics of women (n=15) working as domestics cleaners in San Antonio, Texas, 2019–2020.

	n (%)
Age	
< 40	1 *(6.7)*
40 – 49	5 *(33.3)*
50 – 59	5 *(33.3)*
≥ 60	4 *(26.7)*
Ethnicity	
Hispanic	14 *(93.3)*
Non-Hispanic	1 *(6.7)*
Years Lived in U.S.	
≤ 15	6 *(40.0)*
16 – 25	8 *(53.3)*
> 25	1 *(6.7)*
Education	
Primary/secondary school	2 *(13.3)*
High school	7 *(46.7)*
Some college or higher	6 *(40.0)*
Annual Household Income ($) [A]	
≤ $15,000	6 *(40.0)*
$15,001 – 25,000	3 *(20.0)*
≥ $25,000	1 *(6.7)*
Residence	
Single-family home	11 *(73.3)*
Multi-family/Apartment	4 *(26.7)*
Ever Smoked	
Yes	9 *(60.0)*
No	6 *(40.0)*

[A] One reported “Don’t know” and four reported “Refused to answer”

Table 2.

Biomarkers of inflammation and oxidative stress among women (n=15) working as domestic cleaners in San Antonio, Texas, 2019–2020.

	n	Mean (+/−SD)	Geometric Mean (+/−SD)	Median	Range
Serum CRP (mg/dL)	13[A]	5.0 (5.7)	2.5 (1.4)	2.7	(0.3 – 20.3)
EBC 8-ISP (pg/mL)	14[B]	21.0 (11.1)	18.5 (0.5)	17.0	(9.5 – 44.1)
EBC pH	13[C]	8.3 (0.4)	8.3 (0.1)	8.4	(7.1 – 8.6)

[A] One serum sample was not obtained and one CRP result was above the standard curve and was not included in the analysis

[B] One EBC sample was insufficient in volume

[C] One EBC sample was insufficient in volume and one pH result was very low (pH 5.7), suggesting contamination with stomach acid, and was not included in the analysis