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Socioeconomic disparities in indoor air, breath, and blood perchloroethylene level among adult and child residents of buildings with or without a dry cleaner

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ABSTRACT

In many cities, dry cleaners using perchloroethylene are frequently located in multifamily residential buildings and often cause elevated indoor air levels of perchloroethylene throughout the building. To assess individual perchloroethylene exposures associated with co-located dry cleaners, we measured perchloroethylene in residential indoor air, and in blood and breath of adults and children residing in buildings with a dry cleaner as part of the New York City (NYC) Perc Project. We also measured perchloroethylene in indoor air, and in blood and breath of residents of buildings without a dry cleaner for comparison. Here, we evaluate whether an environmental disparity in perchloroethylene exposures is present. Study participants are stratified by residential building type (dry cleaner or reference) and socioeconomic characteristics (race/ethnicity and income); measures of perchloroethylene exposure are examined; and, the influence of stratified variables and other factors on perchloroethylene exposure is assessed using multivariate regression. All measures of perchloroethylene exposure for residents of buildings with a dry cleaner indicated a socioeconomic disparity. Mean indoor air perchloroethylene levels were about five times higher in minority (82.5 ug/m^3) than in non-minority (16.5 ug/m^3) households, and about six times higher in low-income (105.5 ug/m^3) than in high income (17.8 ug/m^3) households. Mean blood perchloroethylene levels in minority children (0.27 ng/mL) and adults (0.46 ng/mL) were about two and three times higher than in non-minority children (0.12 ng/mL) and adults (0.15 ng/mL), respectively. Mean blood perchloroethylene levels in low income children (0.34 ng/mL) and adults (0.62 ng/mL) were about three and four times higher than in high income children (0.11 ng/mL) and adults (0.14 ng/mL), respectively. A less marked socioeconomic disparity was observed in perchloroethylene breath levels with minority and low income residents having slightly higher levels than non-minority and high income residents. Multivariate regression affirmed that indoor air perchloroethylene level in dry cleaner buildings was the single most important factor determining perchloroethylene in blood and breath. Neither age, gender, nor socioeconomic status significantly influenced perchloroethylene levels in breath or blood. We previously reported that increased indoor air, breath, and blood perchloroethylene levels among NYC Perc Project child participants were associated with an increased risk for slightly altered vision. Thus, the disproportionately elevated perchloroethylene exposures of minority and low-income child residents of buildings with a dry cleaner shown here constitutes an environmental exposure disparity with potential public health consequences. Among residents of buildings without a dry cleaner, we observed some small increases in perchloroethylene breath and blood levels among non-minority or high income residents compared to minority or low income residents. These differences were not attributable to differences in indoor air levels of perchloroethylene which did not differ across socioeconomic categories, but appear to be associated with more frequent exposures dry cleaned garments.

1. Introduction

In New York City and in many other cities, dry cleaners using the solvent perchloroethylene are commonly located in multifamily residential buildings. Prior to the 1997 implementation of New York State dry cleaner regulations to control fugitive

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perchloroethylene emissions (NYSDEC (New York State Department of Environmental Conservation), 1997), indoor air of residences in such buildings was sometimes contaminated with perchloroethylene at concentrations as high as 55,000 μg/m^3 (Wallace et al., 1995; Schreiber et al., 1993, 2002). After implementation of the regulations, indoor air levels rarely exceeded 5000 μg/m^3 (McDermott et al., 2005). Elevated indoor air perchloroethylene levels are of concern because there is evidence that the central nervous system, including the visual system, may be adversely affected by inhalation of perchloroethylene at levels sometimes found in indoor air of residences co-located with dry cleaners (ATSDR (Agency for Toxic Substances and Disease Registry), 1997; NYSDOH (New York State Department of Health), 1997; Altmann et al., 1995; Schreiber et al., 2002; Storm et al., 2011).

The New York State Department of Health derived a health-based guideline of 100 μg/m^3 perchloroethylene in air, based on potential health effects to vision and the central nervous system and other factors. The guideline assumes continuous lifetime exposure, as well as exposure of more sensitive life stages such as children (NYSDOH, 1997, 2003). When indoor air perchloroethylene levels are elevated, the Department of Health advises that they be reduced to background and uses the 100 μg/m^3 guideline as a basis for making recommendations about the urgency of taking action. The possibility that residents in buildings with co-located dry cleaners may be exposed to indoor air perchloroethylene levels approaching or exceeding the 100 μg/m^3 guideline is a public health concern. Moreover, children may be especially vulnerable to elevated indoor air perchloroethylene exposures because their higher breath rate may lead to higher internal dose and/or greater health consequences than adults in the same exposure environment (Needham and Sexton, 2000; Stein et al., 2002; Schwenk et al., 2003).

To evaluate whether exposures exceeding 100 μg/m^3 were occurring and to assess the possible public health consequences among residents of buildings with co-located dry cleaners, we conducted the NYC Perc Project. This study evaluated the relationships between residential perchloroethylene exposure and alterations in visual contrast sensitivity and color vision. Study participants were adult and child residents of buildings with or without a co-located dry cleaner that used perchloroethylene and that were located in the New York City Borough of Manhattan. Perchloroethylene exposure was evaluated based on perchloroethylene levels in indoor air, exhaled alveolar breath, and blood. These measures were evaluated because they are directly correlated and because breath and blood perchloroethylene levels are widely accepted biomarkers of individual perchloroethylene exposure (ATSDR, 1997; ACGIH (American Conference of Governmental Industrial Hygienists), 2001; Gobba et al., 2003; Solet et al., 1990).

We previously reported higher indoor air perchloroethylene levels in residential buildings with co-located dry cleaners that were located in minority or low-income census block groups (which averaged 75 and 256 μg/m^3 respectively) compared with indoor air levels in buildings with co-located dry cleaners that were located in non-minority or higher income census block groups (which averaged 19 and 23 μg/m^3, respectively) (McDermott et al., 2005). We have also reported that elevated levels of perchloroethylene in indoor air, breath, and blood of all child NYC Perc Project participants (independent of socioeconomic characteristics) were associated with an increased risk for slightly altered vision possibly indicative of a subclinical nervous system effect (Storm et al., 2011). Subsequent investigation by the New York State Department of Health and the New York City Department of Health and Mental Hygiene found that higher indoor air perchloroethylene levels were not readily explained by differences in dry cleaner operation. Rather, they were more likely due to poor maintenance and/or faulty operation of dry cleaner vapor barrier enclosures (required by New York State Department of Environmental Conservation dry cleaner regulations (NYSDEC, 1997)) and by poor building ventilation and/or maintenance.

Together, these observations suggest that the presence of dry cleaners in multifamily residential buildings located in minority or low income neighborhoods contributes to an environmental health disparity (defined as a racial/ethnic or socioeconomic inequity in illness or exposure that is at least partially mediated by factors associated with physical, social, and built environments) (Payne-Sturges et al., 2006). To further evaluate the presence of a disparity at the individual resident level, as opposed to the building and neighborhood level, we stratify individuals here by residential building type (co-located or no co-located dry cleaner) and socioeconomic characteristics (i.e., race/ethnicity, income), and we evaluate the influence of these and other factors on perchloroethylene exposure (i.e., levels in indoor air, breath, and blood).

2. Methods

2.1. Study subjects

Our study population consisted of residents of 24 buildings with a co-located dry cleaner (dry cleaner buildings) and residents of 36 buildings without a co-located dry cleaner (reference buildings). All buildings were located in ZIP Code areas surrounding Central Park in New York City. Most residential dry cleaner buildings were identified from registration certificates submitted to comply with New York State dry cleaner regulations (NYSDEC, 1997). Others were identified from National Emissions Standards for Hazardous Air Pollutants (Perchloroethylene Dry Cleaners) records and from internet-based business directories (ReferenceUSA, InfoUSA Inc., Omaha NE; InfoSpace, InfoSpace, Inc., Bellevue WA). Early analytical results indicated that indoor air perchloroethylene levels in most apartments in dry cleaner buildings sampled were below or only slightly above, the Department of Health residential air guideline of 100 μg/m^3. Higher levels were found in dry cleaner buildings located in low-income, minority neighborhoods and in buildings elsewhere that had been the subject of a resident complaint. Since successful completion of the NYC Perc Project required that as many apartments as possible with elevated perchloroethylene levels be identified, the strategy for identifying buildings for inclusion was modified so that buildings located in minority or low-income ZIP Code areas and those that had been the subject of a complaint were prioritized. More details about the study area and building selection can be found in McDermott et al. (2005).

Dry cleaner establishments were contacted first by telephone and then visited to confirm that they were co-located in a building with occupied residences, were using perchloroethylene on-site, and that other businesses using volatile organic compounds (e.g., nail salons, shoe repair stores, photography developing, etc.) were not located in the same building. At the time of our visit, at least three other residential buildings with no dry cleaner or other business possibly using volatile organic compounds, and located at least one city block away from each dry cleaner building meeting the above inclusion criteria, were identified as reference buildings.

In ZIP Code areas with a mostly non-minority population, written material describing the NYC Perc Project was mailed to apartments in targeted dry cleaner and reference buildings using addresses obtained during visits to the building or through the U.S. Postal Service NYS Zip+4 Directory (U.S. Postal Service, 2000). Listed telephone numbers associated with targeted buildings were obtained through reverse address queries from Internet-based residential telephone directories (ReferenceUSA^{SM}, InfoSpace^{R}). Up to five calls to every residential telephone number were made at different times of day and on different days of the week beginning five days after study information had been mailed to addressees. Messages describing the study were left on all answering machines encountered. When a telephone call was answered or a return call was received, we asked whether an adult–child pair resided in the apartment. If so, the respondent was asked to complete a screening questionnaire to determine whether they were eligible for, and interested in, participating in the study.

In ZIP Code areas with mostly minority (either predominately Hispanic or predominately African-American) populations, recruitment was conducted through door-to-door visits by bilingual (Spanish/English) community health workers, consistent with recommendations for recruiting minority and lower-income populations (Cabral et al., 2003; Fitzgibbon et al., 1998; Grunbaum et al., 1996; Harris et al., 2003). Community health workers visited all residences in targeted buildings during afternoon and evening hours on different days of the week. Adults responding to door knocks were given a verbal description of the study and a written fact sheet describing the project in Spanish or English, whichever was appropriate, and were administered the screening questionnaire.