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Secondhand Smoke Exposure and Smoke-free Policy in Philadelphia Public Housing

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Human Subjects Statement

This work was reviewed and approved by the Philadelphia Department of Public Health Institutional Review Board. All participants in the survey and home monitoring activities provided signed informed consent. Public area monitoring did not involve human subjects activities.

Conflict of Interest Statement

There are no conflicts of interest to declare for any authors of this work.

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Abstract

Objectives—Multi-unit housing environments remain significant sources of secondhand smoke (SHS) exposure, especially for vulnerable populations in subsidized housing. In Philadelphia, the largest US housing authority to implement smoke-free policies, we measured baseline resident smoking-related behaviors and attitudes, and longitudinal exposures to airborne nicotine, during policy development and implementation.

Methods—In 4 communities, we collected data in 2013, 2014, and 2016, before and after introduction of comprehensive smoke-free policies, interviewing persons in 172 households, and monitoring air-borne nicotine in non-smoking homes and public areas. Average nicotine level differences across years were estimated with multi-level models.

Results—Fifty-six percent of respondents smoked. Only 37% of households were smoke-free, with another 41% restricting smoking by area or time of day. The number of locations with detectable nicotine did not differ before and after policy implementation, with approximately 20% of non-smoking homes and 70%–80% of public areas having detectable nicotine. However, public area nicotine levels were lower in 2016, after policy implementation, than in 2013 and 2014 (−0.19 $\mu g/m^3$, p = .03).

Conclusions—Findings suggest that initial policy implementation was associated with reduced SHS exposure in Philadelphia. As HUD strengthens smoke-free policies, SHS monitoring can be useful to educate stakeholders and build support for policy enforcement.

Keywords

secondhand smoke; smoking control; smoking policy; health policy; public housing; vulnerable populations; air monitoring

Globally, 40% of children and 33%–35% of adult non-smokers are exposed to tobacco smoke, with secondhand smoke (SHS) exposure responsible for over half a million premature deaths from asthma and respiratory infections, ischemic heart disease, and cancers.[1] With regulation now reducing smoking in most public enclosed spaces, one major source of indoor exposure remains the home environment.

As smoking rates have declined, there has been a corresponding interest in smoke-free residential options.[2] Most campaigns to reduce in-home exposures use educational, rather

than regulatory strategies, but in multi-family housing, even the most motivated residents are often unable to control exposure, as ventilation does not mitigate SHS drift between units.[3] Market-based responses from the private multi-unit housing industry, based on reduced maintenance and insurance costs, and attractiveness to higher-income, non-smoking renters, are not seen as discriminatory, as smokers are neither legally nor publically viewed as a protected class.

However, as the burden of tobacco addiction has become increasingly borne by socially disadvantaged groups, including racial and ethnic minorities, the economically restricted, and the chronically physically and mentally ill, the issue of tobacco exposure in public multi-unit housing has come to the forefront of tobacco control policy. Populations most reliant on public housing, including children, pregnant women, the elderly, and those with preexisting health problems, are more vulnerable to the adverse effects of SHS. High concentrations of smokers in public housing communities, as well as the high proportion of the day spent at home by some groups of residents (eg, children, elderly, disabled and unemployed), means these vulnerable populations are exposed to SHS at rates far higher than persons in other residential settings.[4–6] Public housing itself may exacerbate SHS exposures, due to poorer ventilation systems, and structural defects in walls or doors that allow SHS drift. For all these reasons, controlling SHS in public housing communities is an important public health strategy.

Smoking restrictions in housing for low-income and other public entitlement populations raise legal and ethical issues, as it is precisely these tenants' inability to use conventional housing markets that creates the societal need for alternative housing. As a safety net, or "housing of last resort," public housing must attempt to accommodate all needs; meanwhile, as a public agency, it also must be a frugal steward of the public's funds, and meet the social goal of creating healthful communities.

The first jurisdictions in the United States (US) that implemented smoking bans in public housing did so in 1996;[7] adoption has accelerated since the 2009 HUD Healthy Homes Strategic Plan called for elimination of SHS in homes,[8] with at least 612 public housing authorities now having policies covering all or some properties.[9] In November of 2015, HUD released a proposed rule for mandatory smoke-free policy implementation within 18 months of authorization of the final rule; however, many local, state and federal public health initiatives for tobacco control already have prioritized development and implementation of smoke-free public housing.

Local public housing authorities manage a diverse portfolio of residential configurations, from high-rise and low-rise communities of varying sizes, to scattered sites and private ownership or subsidized approaches. They shelter diverse populations, including families, the elderly, the disabled, and those transitioning from incarceration and homelessness. The socio-geographic context of tobacco use in each community differs, as do important physical influences on SHS dilution and dispersion (including building age and material composition, ventilation, heating and cooling systems), and geographic influences such as climate. As new policies are developed and implemented, evaluating policy processes and outcomes in any given housing community is dependent on effective tools to monitor SHS exposures

over time. A 2015 review found that the majority of reports to date have been cross-sectional, and called for more longitudinal evidence, utilizing both self-reports and environmental measures.[10]

Goals of Current Study

In 2011, the Philadelphia Department of Public Health formed a partnership with the Philadelphia Housing Authority (PHA) to support and evaluate the smoke-free housing policy implementation process in Philadelphia, and engaged a local research partner to design and conduct the evaluation. PHA, the 4th largest public housing agency in the US, serves over 80,000 residents. In August 2015, after extensive resident input, PHA transitioned from a policy that allowed smoking only in individual units, to a smoke-free policy that forbids tobacco use in all indoor spaces in public house communities, including individual apartments and homes. A two-tiered policy was implemented, that included tobacco use as a lease violation in all new leases, but voluntary compliance (with warnings and education rather than penalties or evictions) for existing leaseholders.

After extensive formative work with stakeholders to identify meaningful and community-acceptable metrics and methods for evaluation, 4 communities were selected for evaluation. Evaluation metrics included resident surveys, structured observations of public tobacco use behaviors within communities, and passive vapor-phase nicotine monitoring to measure SHS exposure in both public areas and residential units, with continued monitoring across the policy development and implementation process. Recruitment and informed consent processes for each activity are described in the methods section.

We report the results of passive nicotine monitoring for secondhand smoke exposure in selected homes and public areas in 4 PHA communities, at 3 time points, one and 2 years before, and 9 months after implementation of a comprehensive smoke-free policy. Vapor-phase nicotine was used to quantify SHS at selected locations, as one measure of tobacco use within communities.[11–16] We also use data from resident surveys, to describe pre-implementation tobacco-related attitudes and behaviors and provide context to the monitoring results.

METHODS

Data Collection

The 4 PHA properties varied by development type (high-rise, mid-rise, townhome), location in the city, number and type of units (1–4 bedrooms), age and physical condition, and residential composition (senior citizens, families and individuals). In each community, we surveyed the public areas, and selected monitoring sites to represent the range of shared locations residents pass through or spend time in, within their housing communities.

Public area air monitoring and resident surveys were conducted in summer 2013, followed by household monitoring in fall 2013, with public area monitoring repeated in spring 2014, and household and public area monitoring repeated in spring 2016. Monitors were prepared and analyzed by the Second-Hand Smoke Exposure Assessment Laboratory at the Johns

Hopkins University, Bloomberg School of Public Health (Baltimore MD). Monitors were constructed from a filter cassette, filter paper soaked in sodium bisulfate and a windscreen.[15]

Public area monitoring—In each community, public area monitoring locations were selected to include entry ways and lounges, mail and laundry rooms, multiple hallways and stairwells, and elevators. Sampling logs with photographs captured placement date, time, location, and room dimensions, ventilation (windows, doors, air conditioning etc), tobacco odor and cigarette debris presence. In the first wave of monitoring (2013), we hung monitors for both 7 and 14 days in a subset of locations, to understand exposure variability over time, from both intermittent exposures as someone travels through the area while smoking, and drift from smoking in an adjacent apartment or outdoors. PHA maintenance staff and resident leadership were involved in the placement and monitoring process, and monitors displayed both project and PHA contact information. After placement, monitor locations were revisited once to note whether monitors had remained intact, or were lost or damaged. At retrieval, date, time and descriptive notes were recorded. The protocol included 10% field blanks and 10% duplicate monitors for calibration and reliability.[15]

Resident interviews—At each community, we recruited respondents through community meetings, flyers, and word-of-mouth. Residents called for appointments, and were interviewed onsite in private settings, with home-bound residents interviewed in their homes by request. Because official tenant rosters are confidential, and can be inaccurate due to moves or unlisted extra members of households, we used a modified stratified quota sampling plan. As we recruited participants at each site, we monitored participant gender, age, smoking status, and household size and composition, comparing our sample to PHA data on site residential composition, purposively recruiting diverse types of respondents to fill strata and reflect each community's total residential composition. Participation was limited to one adult resident per household.

Our 45-minute tablet-based structured survey captured tobacco use, cessation readiness, household tobacco use practices, knowledge and attitudes towards SHS and smoke-free policies, and general social and health information. Measures were adapted from existing tobacco surveys, as well as developed and pre-tested for this evaluation. Respondents signed informed consent, and received a $20 gift card for participation.

Residential monitoring—Households for residential monitoring were recruited from the resident survey respondents. Home monitoring was restricted to homes where no permanent resident smoked, and respondents reported allowing no smoking by visitors. Monitoring was not conducted in homes of smokers who maintained smoke-free homes but smoked elsewhere. This reduced the likelihood of capturing residual nicotine that these smokers "off-gas" after smoking in other locations, and helped to capture only smoke drifting from within the public housing community.

Residents were scheduled for monitor placement, during which monitors were hung by 2 project staff, with location on a shared wall, or where residents most noticed tobacco odor. Unit layout, room type, floor, size, date, and time were recorded at time of placement, as well as condition of the unit, and any evidence of smoking. Residents were given an air

monitoring FAQ sheet, study contact information, a pick-up appointment reminder card, and copy of their signed consent form. After one week, residents were re-contacted to ask if monitors were still in place, answer any questions, and confirm the 2-week retrieval appointment. Observation notes were collected at monitor retrieval. Upon successful retrieval, residents received a $25 gift card for their participation. After monitoring results were analyzed, letters were sent to participants explaining their own home and community public space monitoring results (with estimated cigarette-per-day equivalents), and educational information on SHS and cessation resources.

Nine months after the initial 2013 measurement, we hung monitors in the same public area locations in spring 2014. In spring 2016, 9 months after policy implementation, we monitored all public area locations for a third time. We also re-contacted all residents whose homes had been monitored in 2013. If residents could not be reached, had moved, or no longer maintained a smoke-free home, we recruited a non-smoking resident in the same community for home monitoring. Thus, final results reported here include 3 cycles of public area monitoring, 2 cycles of home monitoring, and one wave of baseline data from resident surveys.

Analysis

Respondent survey responses were retrieved from tablet software directly into SPSS for analysis. For this paper, we report selected survey data on resident and community characteristics, as well as tobacco behaviors and attitudes, to inform interpretation of the monitoring results in each community.

Monitors were returned to the Johns Hopkins University lab, where nicotine absorption was analyzed using mass spectrometry, with a lower limit of nicotine detection (LOD) of 0.021ug/ml, indicating the lowest level of nicotine that can be detected in liquid. We report nicotine concentrations in micrograms per cubic meter of air (ug/m^3), based on the volume of airflow during the exposure period. We also describe estimates of the equivalent cigarettes smoked per day, using findings from Kraev et al[16] 2009 study of household nicotine monitoring and self-reported household smoking levels.

To test whether levels of airborne nicotine changed over time, a multi-level random effects regression model[17] was used to compare average values of detectable nicotine in each community across the 3 time points. A random intercept term was used to account for the geographically nested nature of the data (clustering of locations within community), and allow each community's baseline level of nicotine to vary. We modeled the data in 2 ways. First, to examine whether the level of detectable nicotine differed across time periods, we used only the readings that were above the LOD. In addition, we conducted a second analysis that also included readings that were below the LOD, assigning these locations a value of 0.007 ug/m^3, a figure that represents the median (or midpoint) between 0 and the LOD for the exposure period.[18]

We did not model location-specific effects within each community, in part, due to some monitor loss in each wave, as well as our interest in overall community exposures, rather

than changes in exposure in any given location, such as a specific stairwell or corridor. Multi-level regression models were estimated using the GLLAMM program in STATA.[19]

RESULTS

Table 1 describes the 4 communities, their residential composition, physical configuration and size, and the public area and residential monitoring activities and locations in each community. The 4 communities varied in size from roughly 100 to almost 2000 residents. Whereas the smaller seniors-only community was composed of primarily single-occupant, one-bedroom apartments, the larger facilities included one-story and 2-story townhomes of up to 4 bedrooms, as well as tall high-rise towers. Residential composition varied as well. With the exception of the seniors-only community, children under age 18 comprised roughly half of the resident population.

The resident survey was completed by 172 household representatives. Most respondents were women, and respondents ranged in age from 21 to 87. Respondent household characteristics reflect differences seen in the description of the communities, with variation by community in residential tenure, household size, and proportion of households with children.

More than half of the respondents were current smokers, and only one-fourth had never smoked. Twelve percent had a smoker in their household. In terms of household rules, only 37% of the households had a full no-smoking policy for their home. However, an additional 41% of households did attempt to restrict smoking in some fashion, most typically, by limiting smoking to specific areas, or specific times of day, such as when children were not in the home. Unrestricted smoking was relatively uncommon, but was more than twice as common in the senior property (40%) than in the family-only communities (15% and 19%), with the senior/family community falling in between (25%).

To explore awareness related to tobacco use in their communities, we asked how often respondents smelled smoke in the public areas of their buildings. Thirty-seven percent smelled it at least several times a week, although in the 2 communities with senior residents, the rate was much lower (5% and 7%). Although a substantial proportion of the respondents were smokers themselves, when asked whether the smell of smoke in their community bothered them “a lot,” “some,” “only slightly,” or “not at all,” almost two-thirds of the respondents said they were bothered at least slightly, with only 35% stating it did not bother them at all. Respondents in the senior community were less likely to report being bothered (43%) than those in the family communities (68% and 72%).

The 3 final items in Table 1 are responses to 4-point Likert scales, measuring whether residents “strongly,” “somewhat,” “slightly,” or did “not at all” support policies restricting smoking (1) in apartments and residences, (2) in all common areas, and (3) in all outdoor areas. Fifty-six percent strongly or somewhat supported home bans, 89% supported common area bans (the current policy in 2013 at the time of the survey), and 55% supported outdoor bans. Support for home and outdoor bans was more common among family property residents than in senior properties, but common area bans were universally supported.

Table 2 reports the results of the common area and home monitoring for each time point. Information on blanks and duplicates is not included.

Public area monitoring

In the first cycle of public area monitoring in summer of 2013, we placed 68 monitors in 42 unique locations. We lost 15 monitors to vandalism or damage, but captured 53 readings in 33 unique locations, with 23 locations (70%) having readings above the LOD. The highest reading was 2.00 ug/m^3 (approximately equivalent to 6–10 cigarettes per day), recorded in a laundry room in a high-rise property. The average value was 0.44 ug/m^3.

We tested both 7- and 14-day monitoring periods, and found strong reliability between co-located 7- and 14-day readings, suggesting consistent site-specific tobacco use (results not shown). Vandalism was highest in elevators, which staff attributed to residents' long-standing practice of disabling smoke alarms in elevators, in order to smoke. Our observations captured contextual evidence of the tobacco geography across each community's public areas. In high-rise buildings, debris provided strong evidence of drug and alcohol use with smoking in stairwells, as well as tobacco-related vandalism (using burned cigars for graffiti). This suggests that tobacco control efforts may require broader security and enforcement strategies with some resident groups.

In spring of 2014, monitors were placed in the same 42 locations, for a 14-day period, with one blank and one duplicate at each property (a total of 50 monitors). Of the 50 monitors, 13 were missing at retrieval, and 37 monitors were sent for analysis. However, results from 4 monitors were determined to be unreliable due to damage to the membrane (2 ripped, 2 intact with puncture attempts/dimpling). Thus, 17 monitors overall were unusable (lost or damaged), representing 15 unique locations. In addition to blanks and duplicates, we captured usable readings from 27 unique locations.

Of 27 readings, 21 were above the LOD, meaning that in public spaces, 78% had detectable levels of nicotine in a 14-day period. The highest value of detectable nicotine was 1.29 ug/m^3(equivalent to 1–5 cigarettes per day). The average value was 0.41 ug/m^3(equivalent to less than one cigarette per day). The values from the damaged monitors ranged from 0.01 to 1.07.

In 2016, the third wave of public area monitoring, the same 42 locations were monitored; monitors were retrieved and analyzed from a total of 36 locations. Twenty-eight of 36, or 78%, had detectable levels of nicotine. The average level at locations with detectable readings was 0.23 μg/m^3; the highest reading was 0.93 μg/m^3 (equivalent to 1–5 cigarettes per day).

Although the *proportion* of monitors with detectable readings was similar in all 3 years, the *average value* of detectable readings in public area locations was significantly lower in 2016, compared to 2013 and 2014. The estimated average difference from the multi-level model was −0.19 μg/m^3 ($p = .03$) for 2016 values. There was no statistically significant difference between values from 2013 and 2014, and therefore, only a term to estimate 2016 differences was retained for the most parsimonious model. The estimate from the model which also

included results below the LOD was slightly lower, with an average difference of −0.14 (p = .06).

Home monitoring

In 2013, of the 172 survey respondents, only 48 were eligible for home monitoring, by reporting that neither they nor any of their home's residents smoked, nor did they allow visitors to smoke in their homes. Of those, 8 declined to participate in home monitoring, and 11 participants agreed, but did not follow through with scheduling prior to the end of the home monitoring period. Of the 29 residences where monitoring was initiated, all monitors were retrieved intact after 2 weeks and yielded analyzable results. Of 29 residences, which included 5 townhomes and 24 apartments, 21% had readings above the detectable level. The highest reading was 0.92 ug/m^3 (estimated by Kraev to be the equivalent of 1–5 cigarettes per day), and the average value was 0.29 ug/m^3 (equivalent to less than one cigarette per day).[16]

In 2016, we attempted to contact all eligible households from 2013 who had not refused to participate. This included those who participated in monitoring, as well as those who were eligible but were not reached and successfully scheduled in 2013. A total of 27 non-smoking households were recruited to participate, including 15 households that had participated in 2013, and 12 households participating for the first time. Six of the 27 households, or 22%, had detectable levels of airborne nicotine detected in the 14-day monitoring period, with a highest reading of 0.05 μg/m^3 (<1 cigarette/day) and an average reading of 0.03 μg/m^3 (<1 cigarette/day). Because so few households had detectable readings at either time point, no statistical comparison of average level of exposure was made for home monitoring; however, the results suggest reduced exposures for non-smoking homes.

DISCUSSION

Our study in Philadelphia adds to the literature on the measurement of SHS in public housing communities, settings where excess exposure combined with substantial underlying health risks create high priority tobacco control environments. Our data allow for discussion of both baseline behaviors and exposures, as well as the changes observed over time, which may be potentially related to smoke-free policy implementation.

Tobacco Use in Smoke-free Housing

Our results revealed a higher self-reported rate of smoking among residents participating in our survey than is generally seen in population-based surveys. Overall, Philadelphia's adult smoking rate in 2012 was estimated at 23.3%, significantly above CDC's national estimate of 18%[20] but significantly below the rate of 56% among our respondents. It is possible that our sample over-estimates the proportion of public housing residents who smoke, perhaps because our survey opportunity was more attractive to residents who had fewer daytime commitments and placed higher value on the modest incentive; thus our sample reflects a subpopulation within these communities that has fewer resources and may be most tobacco-addicted.

However, there is also evidence suggesting that our community-based data may more fully tap into excess tobacco addiction among specific subpopulations that may be hard to reach in larger telephone-based surveys used for national and citywide estimates. For example, the National Health Interview Survey reported a rate in 2013 of 41% among adults of all races who held a GED,[21] but the National Adult Tobacco Survey, which used cell phone sampling to increase participation among low resource hard-to-reach populations, reports a rate of tobacco product use of 52% among GED holders of all races.[22] Furthermore, both qualitative and structured analyses of data from low resource communities,[23] including public housing communities,[10,24] provide strong evidence that, in addition to individual determinants of tobacco behaviors such as race, gender, and socio-economic status, community-level hardship can strongly influence patterns of tobacco addiction.

Taken together, the self-reported rates of current smoking as well as the monitoring results confirm the extensive SHS exposure in these public housing communities. Although only a minority of households (37%) maintain fully smoke-free rules, our findings suggest that the majority of residents are aware of the negative impact of the current smoking behaviors within their community. For instance, 41% of households attempt to limit smoking within their homes, 64% are bothered by smoke in their community, and 56% support a ban that would include residential units.

Furthermore, residents were interested in the process and results of SHS monitoring. Although our protocol did not include home monitoring of smoking households, many smokers expressed interest in monitoring, to improve their understanding of how their in-home smoking practices impacted SHS exposures. Especially in households where restrictions on smoking demonstrate there is motivation to control SHS exposure for children or vulnerable household members, monitoring could be a useful tool to support household transition from less effective partial approaches to full household bans.

Our findings also support the well-recognized limitations of non-comprehensive smoke-free housing policies that allow for smoking households, non-smoking households, and smoke-free public areas in the same multi-unit buildings (the policy of the Philadelphia Housing Authority prior to August, 2015). Our monitoring results demonstrate that one in 5 non-smoking residential units and three-fourths of public areas had detectable levels of nicotine, with likely sources being drift from smokers' units and failure to eliminate active smoking in public areas, as well as drift indoors from outdoor smoking close to exterior doors and windows. Aggregate data were shared in 2013 and 2014 with resident leaders, and PHA staff members and leaders. These data were important in supporting stronger enforcement of existing common area bans, as well as passage in July 2015 of a comprehensive smoke-free policy by the PHA Board of Commissioners. The PHA is now the largest public housing agency in the US to have taken this action.

Comparisons to Experiences from Other Cities

In 2012, the Boston Housing Authority implemented a smoke-free policy, which unlike the current Philadelphia policy involved a lease modification, and implemented fines and other penalties. Several published studies of resident exposures provide a point of comparison for our results. For example, Russo et al[4] found a mean value of 0.43 ug/m^3 for nicotine in

public areas of Boston public housing communities, although data are not reported by smoking policy status. Arku et al[25] describe strong seasonal variation in exposures, with winter readings of both $PM_{2.5}$ and nicotine higher than those captured in summer. This suggests that our readings, conducted in summer and spring, may be conservative estimates of annual exposures, but that our lower proportion of LOD sites in summer compared to spring may accurately reflect seasonal trends. Arku et al[25] point out: "…elevated exposures during winter may be especially relevant for …young children and the elderly" due to both limited mobility and related increased exposure during cold weather, as well as vulnerability to health consequences of exposure. Other studies using salivary cotinine and $PM_{2.5}$ also support our findings.[2,6]

Our results also suggest that the 2-level policy adopted in August 2015, of mandatory smoking bans for new leaseholders, and a more voluntary ban for existing leaseholders, without formal citation or eviction consequences, also may be an effective initial strategy to introduce total indoor bans, and reduce overall SHS exposures. Interestingly, reports from the Boston and Cambridge Housing Authorities show significant decreases in airborne nicotine in both jurisdictions, similar to the average decrease in nicotine observed in Philadelphia, although Boston implemented a strongly enforced policy, whereas Cambridge only initiated a planning process with residents.[26] As other cities enact smoke-free multi-unit housing policies, evidence should be collected and disseminated to guide implementation decisions.

Limitations of the Current Study and Future Directions

There are recognized limitations of our findings, which therefore, only can suggest rather than confirm a relationship between policy implementation and nicotine levels. Because PHA implemented the policy change across all its multi-unit housing communities at the same time, we have no comparison communities where the policy was not implemented; thus, we only can discuss pre/post change in these communities. It is possible that other factors, such as an overall decline in tobacco use among all public housing residents, could drive the observed changes, rather than the policy implementation. Our 4 communities are diverse in resident demographics, age and structure, and other important features, but do not describe all communities in the PHA housing portfolio comprehensively. As well, Philadelphia has a unique tobacco culture among the predominantly African-American resident population of PHA communities. Therefore, these types of data collection activities should continue to be replicated in other diverse types of public and private multi-unit housing communities.

An additional challenge for monitoring tobacco use through air quality is the rising use of electronic cigarette (e-cigarette) products. Airborne nicotine monitoring is specific to tobacco products, but an increase in nicotine vapor from electronic cigarettes could mask decreases in SHS from traditional tobacco products. The Philadelphia Housing Authority ban includes e-cigarette use in indoor spaces, and therefore, in PHA communities, air-borne nicotine monitoring can continue to serve as one indicator of policy impact. However, if it was of value to distinguish between cigarette and e-cigarette use, fine particulate air monitoring may also be useful.

In Philadelphia, a strategic decision was made to focus on environmental rather than biomarker data collection; however, it is important to note that additional results from Boston[27] present evidence of the potential unintended consequences of smoke-free residential policies. Although SHS exposure within the housing communities in Boston (as measured by air-borne nicotine and particulate matter) was reduced, non-smoking respondents themselves were found to have higher levels of cotinine, a metabolite of nicotine, after policy implementation. One possible interpretation of these findings is that smokers altered their smoking behaviors in response to the smoke-free residential rules, but rather than reducing their overall tobacco use, they smoked in enclosed locations such as cars, or otherwise altered their tobacco use behaviors, increasing exposures for themselves and their non-smoking friends or community members.

The Philadelphia Housing Authority's policy development and implementation included an initial one-year process of resident-engaged planning and communication, led by a task force composed of resident leaders (both smokers and non-smokers) and other stakeholders. Outdoor designated smoking areas, as well as cessation classes and training for PHA on-site managers and staff, were part of the implementation process.

Although the number of both public and private locations with detectable airborne nicotine did not go down in number, the absolute level of exposure in public settings was significantly lower in 2016 than in 2013 and 2014. This suggests that tobacco use behaviors within the indoor settings in these communities may have been modified.

The less punitive structure of the policy implementation process was strategically negotiated between the Philadelphia Housing Authority and resident leadership. The exclusion of enforcement strategies specifying fines and eviction consequences for violation was essential to the endorsement and support of the new policy by resident leaders, some of whom are current smokers. At this point, it is unknown if the HUD final rule will compel the Philadelphia Housing Authority eventually to adopt stronger regulation and enforcement approaches, but during the development of a national level policy, this initial voluntary period appears to have coincided with a positive change in the tobacco use culture within the communities, and may help ease transition to stronger future regulation. However, long-term success of smoke-free policies will require equity across tenants by tenure as well as effective rules and penalties for staff to enforce.

IMPLICATIONS FOR TOBACCO REGULATION

As the PHA and its partners continue to develop and implement smoke-free policies and enforcement strategies, our data estimate that 63% of households will need to change their in-home smoking practices. Successful implementation of smoke-free public housing policies will depend on continued cessation support for individual smokers, as well as consistent, reasonable policy enforcement. A third crucial strategy will be education and communication campaigns to shift knowledge, attitudes, and behaviors among residents for community-level social norms to change. Our work demonstrates that community-partnered environmental monitoring has the potential to be a key element of the tobacco control education process. Given the challenges of policy implementation and enforcement in

resource-poor environments, continuing to share evidence from diverse communities will broaden the evidence base, and help community-level stakeholders choose appropriate strategies for long-term change.

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Table 1

Characteristics of Public Housing Communities and Their Residents Participating in SHS Monitoring

	Community 1	Community 2	Community 3	Community 4
Community Characteristics				
Resident Population	**Senior**	**Family & Senior**	**Family & Senior**	**Family**
Total # of Units	99	727	317	264
Total Residential Population	102	1,843	938	620
Type of Community	Mid Rise	High Rise & Townhomes	High Rise	High Rise & Townhomes
# of Buildings	1	4	3	2
# of Floors per Building	5	12	19	18
# of Townhomes	0	440	0	60
Resident Composition				
% ≥62 years old	61	13	5	4
% ≤ 6 years old	0	13	18	18
% 7–17 years old	0	27	31	36
2013 Resident Characteristics (Survey respondents, N = 172)				
Gender				
Female	57	77	92	94
Male	43	23	8	6
Race/Ethnicity				
Black/African-American	90	83	90	100
Other	10	17	10	0
Age				
21–40	0	13	35	23
41–65	76	58	58	74
66–87	24	28	7	3
Residential Tenure (%)				
<5 Years	67	43	42	23
5–10 Years	28	37	25	74
11+ Years	5	20	33	3
Household Size (%)				
Lives Alone	100	57	30	29
Lives w/1	0	30	28	29
Lives w/2+	0	13	42	42

	Community 1	Community 2	Community 3	Community 4
Community Characteristics				
Resident Population	**Senior**	**Family & Senior**	**Family & Senior**	**Family**
Children in Household				
1+ Person <5 years	0	7	15	16
1+ Person <18 years	0	20	43	48
Smoking Status (%)				
Never	14	22	28	32
Former	29	23	17	10
Current	57	55	55	58
Lives with Smoker (%)	0	15	13	10
Household Rules (%)				
No Smoking Allowed	29	35	42	39
Limited Smoking	33	40	43	42
Unlimited Smoking	38	25	15	19
Smells Smoke in Public Areas Several Times per Week or Daily (%)	5	7	73	48
Bothered by Smoke (%)	43	62	72	68
Strongly or Somewhat Support Ban on Smoking Inside Apt Units/Homes (%)	29	32	59	71
Strongly or Somewhat Support Ban on Smoking in Common Areas (%)	86	84	90	97
Strongly or Somewhat Supports Ban on Smoking in Outdoor Areas (%)	38	45	69	62

Table 2

Public Area and Non-smoking Residence Monitoring

	# of Locations Tested	# with Detectable Nicotine	% with Detectable Nicotine	Highest Levels of Nicotine Detected (and Cigarette Equivalents)[a]	Average Level of Nicotine for Detectable Levels (and Cigarette Equivalents)[a]
Public Area Monitoring					
2013	33	23	70%	2.00 μg/m^3(6–10 cig/day)	0.43 μg/m^3 (<1 cig/day)
2014	27	21	78%	1.29 μg/m^3 (1–5 cig/day)	0.40 μg/m^3 (<1 cig/day)
2016	36	28	78%	0.93 μg/m^3 (1–5 cig/day)	0.23 μg/m^3 [b] (<1 cig/day)
Non-smoking Residence Monitoring					
2013	29	6	21%	0.92 μg/m^3 (1–5 cig/day)	0.29 μg/m^3 (<1 cig/day)
2016	27	6	22%	0.05 μg/m^3 (<1 cig/day)	0.03 μg/m^3 (<1 cig/day)

Note.

[a]Based on Kraev et al's 2009 study of home nicotine monitoring and self-reported household smoking levels.

[b]Statistically significant ($p < .05$) average for 2016, compared to 2013 and 2014, adjusting for PHA community.