

Second-Hand Smoke in Multi-Unit Dwellings: **Literature Review**

These summaries, along with NSRA commentary, are meant to provide brief descriptions and analysis of some of the key peer-reviewed studies that have a bearing on the issue of second-hand smoke (SHS) in multi-unit dwellings (MUDs). The review is divided into 3 categories: no-smoking policies; air transfer and exposure to SHS; and third-hand smoke (THS). The articles in each category are listed in reverse chronological order. It is strongly recommended that anyone interested in citing these studies for their own use read the articles directly and not rely solely on our interpretation of them.

No-Smoking Policies

1. "A qualitative evaluation of 40 voluntary, smoke-free, multiunit, housing policy campaigns in California." Satterlund TD, Treiber J, Kipke R et al. *Tobacco Control* 2013; doi:10.1136/tobaccocontrol-2012-050923.

Using final evaluation reports of state-funded smoke-free multi-unit campaigns submitted to the California Tobacco Control Program (n=40), this study sought to identify key components of successful campaigns.

Key findings:

- 6 common ingredients of successful campaigns were identified:
 - i. Learning the local multiunit housing context, which includes selecting "policy ready" targets;
 - ii. Finding and using champions;
 - iii. Partnering with like-minded organizations;
 - iv. Building relationships with apartment landlords and tenants;
 - v. Collecting and using local data; and
 - vi. Making a compelling case to decision makers.
2. "Cost-savings associated with prohibiting smoking in U.S. subsidized housing." King BA, Peck RM & Babb SD. *American Journal of Preventive Medicine* 2013; 44(6):631-4. doi: 10.1016/j.amepre.2013.01.024.

This study calculated the annual economic costs to society that could be saved by prohibiting smoking in all American subsidized housing. Healthcare costs related to second-hand smoke, renovation costs to units where smoking is permitted and smoking-attributable fire costs were included.

Key findings:

- The total estimated cost-savings would be \$521 million/year (range: \$270 - \$892 million);
- This includes \$341 million in SHS-related health care costs (range: \$169 - \$611 million); \$108 million in renovation expenses (range \$61 - \$169 million); and \$72 million in smoking-attributable fires (range: \$41 - \$113 million); and

- In public housing alone (housing owned or operated by a Housing Authority, as opposed to private subsidized housing) total cost savings were calculated to be \$154 million (range: \$80 - \$265 million).
3. “Attitudes, experiences, and acceptance of smoke-free policies among US multiunit housing residents.” Licht AS, King BA, Travers MJ et al. *American Journal of Public Health* 2012; 102:1868-1871. doi: 10.2105/AJPH.2012.300717.

The first nationally representative study of multi-unit housing residents, this research sought to assess what percentage of respondents: lived in a building with a no-smoking policy, had a smoke-free home rule, experienced SHS infiltration from a neighbouring unit and supported the implementation of smoke-free building policies. Data came from 2 nationally representative random-digit telephone surveys (including cell phone numbers) of American adults living in multi-unit housing (2 waves of sampling: n=164, n=254 with response rates of 44% and 31%).

Key findings:

- 29% of respondents reported living in a building with a no-smoking policy;
 - 79% reported having a smoke-free home rule (this was associated with being a non-smoker, having a higher education and having children in the home);
 - Of those reporting having a smoke-free home rule, 44% reported SHS infiltration in the past 12 months; and
 - 56% of all respondents indicated support for smoke-free building policies.
4. “Implementation of a smoke-free policy in subsidized multiunit housing: Effects on smoking cessation and secondhand smoke exposure.” Pizacani BA, Maher JE, Rohde K et al. *Nicotine & Tobacco Research* 2012; doi: 10.1093/ntr/ntr334.

This research evaluated cessation-related behaviour, policy knowledge and compliance, and SHS exposure among a sample of low-income tenants living in private subsidized housing (n=440 among 17 buildings) in the Portland, Oregon area. Guardian Management Limited Liability Company implemented a 100% smoke-free policy, with no grandfathering, that came into effect January 1st, 2008. In addition to prohibiting smoking indoors, the policy also prohibited smoking within 25 feet of buildings.

The study comprised two waves of self-administered surveys, and results are based on responses from tenants who completed both waves (overall response rate was 78%--\$25 cheques were offered as an incentive). The first wave of questionnaires (Time 1) was sent 4 months post-policy, and wave 2 questionnaires were sent one year later, in May 2009 (Time 2). In addition, 11 building managers participated in in-person, semi-structured interviews within 6 weeks of policy implementation and 7 subsequent times throughout the study period via online questionnaires.

Key findings:

- A quit rate of 14.7% was reported by tenants (quit was defined as being a former smoker for at least 6 months at Time 2); 41% cited the smoke-free policy as part of the reason for quitting and 27% said it was the main reason;
- Almost half of respondents (49%) who identified as smokers reported smoking less at Time 1; 29% cited the smoke-free policy as part of the reason and 29% said it was the main reason;
- Most smokers (85%) at Time 1 knew that smoking was prohibited indoors but only 68% correctly reported that smoking was also prohibited outside on porches and patios. At Time 2 knowledge that smoking was prohibited outside increased to 84%;

- Self-reported smoking indoors dropped significantly from 59% pre-policy to 17% at Time 1, and this number did not change significantly between Time 1 and Time 2; most non-compliance with the smoke-free policy occurred outside, and this non-compliance was significantly related to policy knowledge at Time 2 along with evidence that mobility limitations among tenants played a role;
- Non-smokers reporting SHS infiltration in their units decreased significantly from 41% pre-policy to 17% at Time 1 (there were no significant differences between Time 1 and Time 2); and
- 91% of managers reported finding the smoke-free policy difficult to enforce yet 73% indicated that they were personally in favour of it, citing improved tenant health and reduced costs due to smoking-related damage.

Note: this study is in some ways a follow-up to the study by Drach LL et al., 2010, (listed in this section at #12) which had found discouraging adherence to Guardian's smoke-free policy 5 months after it was implemented. Generally, it appears that over time tenants who smoke have managed to cut down somewhat, have become more aware of the outdoor prohibition and increased their adherence to the policy.

5. "Secondhand smoke and smokefree policies in owner-occupied multi-unit housing." Hewett MJ, Ortlund WH, Brock BE et al. *American Journal of Preventive Medicine* 2012; 43(5S3):S187-S196.

Approximately 170,000, or 8% of Minnesotans, live in owner-occupied common-interest communities (CICs) including condominiums, housing cooperatives and planned communities. The purpose of this study was to estimate the prevalence of SHS infiltration in CICs in Minnesota and assess owners' attitudes toward SHS exposure in their homes and their interest in smoke-free policies. Targeted population samples were derived from lists purchased from InfoUSA.com, and households were divided into two categories: multi-family dwelling units (MFDUs – apartment-style buildings) and single family dwelling units (SFDUs – townhouses, row houses, etc.). A total of 495 surveys were completed (319 via mail, 176 via telephone) for a response rate of approximately 36%.

Key findings:

- 28% of CIC households reported SHS infiltration in the past 6 months, and 59% of those indicated that it bothered them a lot; among owners with patios, decks or balconies, 40% reported SHS incursion in the preceding 6 months;
- 78% of respondents agreed that it was important for their unit to be free from SHS from neighbouring units, and approximately 79% indicated they would definitely (63.1%) or probably (16.4%) choose a no-smoking building;
- 75% of respondents agreed that prospective buyers should have a right to know about SHS incursions in the unit they are considering, yet only 61.5% agreed that sellers should have to disclose SHS incursions; and
- An overwhelming majority (93%) of respondents indicated that in the case of a CIC adopting a no-smoking policy, existing owners who smoke should be grandfathered indefinitely.

6. "Moving multiunit housing providers toward adoption of smoke-free policies." Pizacani B, Laughter D, Menagh K et al. *Prev Chronic Dis* 2011;8(1).
http://www.cdc.gov/pcd/issues/2011/jan/10_0015.htm.

Despite the benefits that no-smoking policies can offer, many landlords and property managers remain hesitant to prohibit smoking in their buildings, often citing economic and legal issues. This

case study chronicles a 6-year campaign, which used a “stages of change” smoking cessation model, undertaken by tobacco control advocates in Oregon. Key elements of the campaign included first assembling the right people and gathering information from colleagues; conducting informational interviews with housing sector stakeholders; convening an advisory board; commissioning a public opinion survey; holding landlord focus groups; presenting data to the advisory board and developing a multi-pronged communications strategy. Lessons learned include the importance of building partnerships with stakeholders, collecting local data to shape public awareness and focusing on the financial benefits instead of the public health rationale.

7. “A systematic examination of smoke-free policies in multiunit dwellings in Virginia as reported by property managers: Implications for prevention.” Jackson SL & Bonnie RJ. *American Journal of Health Promotion* 2011;26(1):37-44.

The researchers conducting this study sought to measure the market for smoke-free housing in Virginia and to identify barriers preventing the adoption of no-smoking policies. Semi-structured telephone interviews were conducted in a randomized cross-sectional sample of 263 property managers from 4 cities.

Findings are as follows:

- 100% smoke-free policies were extremely rare, existing mostly in senior and public housing buildings;
- 94% of property managers without a no-smoking policy indicated that they were not intending to make their buildings smoke-free, citing lack of demand from tenants (overwhelming the main reason), privacy concerns, legal constraints and anticipated difficulties with implementation, monitoring and enforcement;
- Just over half (53%) of all property managers agreed that SHS is capable of infiltrating neighbouring units, but only one quarter (26%) believed that exposure to SHS was a health hazard for tenants; and
- 60% believed that a no-smoking policy would be beneficial in terms of maintenance.

The results of this survey indicate that smoke-free housing is not yet a social norm in Virginia. It appears there is a latent demand for smoke-free housing that has not yet translated into tenants actually verbalizing to property managers their desire for it. The findings demonstrate the need to educate property managers about SHS, and the need to educate tenants that they can and should demand more smoke-free housing options—because without demand supply will be low.

8. “Estimates of smoking-related property costs in California multiunit housing.” Ong MK, Diamant AL, Zhou Q et al. *American Journal of Public Health* 2011: e1-e3. doi:10.2105/AJPH.2011.300170.

California multiunit housing (MUH) owners and managers (n=343) were surveyed in this study to ascertain their burden of smoking-related costs, costs prevented as a result of no-smoking policies, and the economic benefits of implementing 100% smoke-free policies. Respondents were asked to estimate smoking-related costs in the past 12 months, beyond standard operations, in a variety of categories including cleaning and maintenance, garbage collection, property and fire insurance, legal costs, etc.

Key findings:

- One-third of properties were reported as being 100% smoke-free (but less than half had no smoking policy at all);

- There were 3X as many small properties (less than 16 units) that were reported as being smoke-free as there were large properties—likely a response to their higher per unit smoking-related costs;
- 27% of owners and managers reported smoking-related costs: a mean cost of \$4,252 after accounting for withheld deposits, or \$282 per unit;
- Smoking-related costs incurred in MUH with complete smoking bans were less prevalent than in MUH with partial or no smoking bans (19% vs. 27%) and lower (\$991 vs. \$1339).

9. “Cost-effective smoke-free multiunit housing media campaigns: Connecting with local communities.” Modayil MV, Consolacion TB, Isler J et al. *Health Promotion Practice* 2011; Vol 12, Suppl. 2, 173S–185S; doi: 10.1177/1524839911405848.
http://hpp.sagepub.com/content/12/6_suppl_2/173S.full.pdf+html.

This study set out to demonstrate the success of the California Tobacco Control Program’s media campaign to achieve positive attitudes and support for smoke-free multiunit housing among the state’s diverse ethnic populations. The campaign’s short-term and intermediate goals were to educate, improve awareness and increase demand for smoke-free multiunit housing. The long-term goal was to reduce SHS exposure through the voluntary adoption and implementation of smoke-free multiunit housing policies. Two TV ads, a print ad and two radio ads communicated that SHS can permeate throughout multiunit housing buildings and that it is toxic and harmful for everyone. Individual level exposure to the campaign was assessed along with population-level attitude and behaviour trends and a cost effectiveness analysis. Both community and individual-level changes were noted as a result of the media campaign—demonstrating that media-led campaigns can influence public opinion. The study emphasized the importance of combining strategies that are not just cost-effective but also simply more effective. For example, the state’s African American adult population proved to be the most costly at \$3.63 per capita; however, this group was also most likely to increase their attitudes and support of smoke-free housing.

10. “Landlord attitudes and behaviours regarding smoke-free policies: Implications for voluntary policy change.” Cramer ME, Roberts S & Stevens E. *Public Health Nursing* 2011. Jan-Feb;28(1):3-12. doi: 10.1111/j.1525-1446.2010.00904.x. Epub 2010 Oct 25.

This study sought to determine landlord attitudes and behaviours towards smoke-free housing policies—real impacts experienced by those who had implemented policies were compared to expected impacts by those landlords who had not. One hundred and eighteen landlords from Nebraska completed the cross-sectional survey, representing 24,080 units on 974 properties housing 34,399 tenants.

Results are as follows:

- 73.7% of respondents indicated they had no smoking policy of any kind, and just 16% reported having 100% smoke-free policies;
- 10.7% of respondents with smoke-free policies reported increased vacancy rates compared to 53.6% of respondents without policies who anticipated increased vacancies;
- 3.7% of respondents with smoke-free policies reported increased turn-over rates compared with 50% of those without policies who expected increased rates;

- Concerns regarding economic losses associated with 100% smoke-free policies were largely unfounded—expectations and attitudes of the majority of landlords need to be met with education and social marketing messages to increase the supply of smoke-free housing in Nebraska.

11. “Multiunit housing residents’ experiences and attitudes toward smoke-free policies.” King BA, Cummings MK, Mahoney MC et al. *Nicotine & Tobacco Research* 2010; 12(6):598-605.

Data from the New York State Adult Tobacco Survey (NYATS), an on-going random digit-dialed survey, were mined to assess the prevalence of, and predictors for, personal smoke-free home policies, infiltration of SHS from neighbouring units and support for 100% smoke-free policies. Survey respondents who self-identified as multi-unit housing residents (n=5,936; smokers n=1,129) were included in the analysis.

Findings are as follows:

- 73.1% of all respondents reported a personal smoke-free home policy (35.2% smokers, 81% non-smokers);
- Statistically significant predictors for smoke-free home policies included being Hispanic, having 16 or more years of education and having children less than 18 years at home;
- 46.2% reported SHS infiltration at some point in the past 12 months, 16% reported at least once per week and 9.2% reported daily SHS infiltration;
- 55.6% of all respondents registered support for a ban on smoking anywhere in their building (26.6% smokers; 61.6% non-smokers).

12. “The acceptability of comprehensive smoke-free policies to low-income tenants in subsidized housing.” Drach LL, Pizacani BA, Rohde KL et al. *Preventing Chronic Disease* 2010; 7(3).

The objective of this research was to evaluate the acceptability of a 100% smoke-free policy among low-income, mostly elderly or disabled tenants living in private subsidized housing (n=688 among 17 buildings) in the Portland, Oregon area. Guardian Management Limited Liability Company implemented a 100% smoke-free policy, with no grandfathering, that came into effect January 1st, 2008. In addition to prohibiting smoking indoors, the policy also prohibited smoking within 25 feet of buildings. In May 2008, surveys were mailed to 839 tenants, along with a \$2 incentive and a promise to pay \$25 for each completed survey—the response rate was 82%. Telephone follow-up interviews were conducted with 23 tenants (5 current, 10 former and 8 never smokers).

Key findings:

- Most tenants (74%) were very or somewhat happy with the smoke-free policy, but support reflected smoking status: only 30% of current smokers were happy compared with 85% of former smokers and 92% of never smokers;
- Acceptance and adherence to the policy were related: at 5 months post-policy, 62% of smokers reported that they did not abide by the policy; and
- The main objection to the policy cited by smokers was that it was unfair, given that there was no grandfathering.

13. "Prevalence and predictors of smoke-free policy implementation and support among owners and managers of multiunit housing." King BA, Travers MJ, Cummings M et al. *Nicotine & Tobacco Research* 2009; 12(2): 159-63.

Similar to the 2007 Hewett study but broader in scope and with a larger sample size, this study was designed to assess the nature, extent and predictors of smoke-free policy implementation and support among owners and managers of multiunit housing across Western New York State. A cross-sectional survey was completed by 127 participants providing a 62% response rate. Just thirteen percent of respondents indicated they had a no-smoking policy in place for at least one of their buildings, yet 75% indicated interest in adopting such a policy. The major barriers identified included concerns over higher vacancy rates and a smaller pool of potential tenants, as well as questions regarding the legality of no-smoking policies. Among owners and managers who already had no-smoking policies in place, motivators included high tenant demand and knowledge that the policies would reduce either insurance or tenant turn-over rates. All owners and managers with policies in place indicated that they were likely to continue with their policies. Significantly, no-smoking policies were associated with buildings less than 30 years old. Given the high level of interest reported in no-smoking policies, this study suggests that more knowledge about no-smoking policies within the housing sector could increase the supply of smoke-free housing.

14. "Secondhand smoke in apartment buildings: Renter and owner or manager perspectives." Hewett MJ, Sandell SD, Anderson J et al. *Nicotine & Tobacco Research* 2007; 9: S39-S47.

This study explored the views of Minnesota renters and apartment owners or managers about SHS transfer between units in multi-family buildings and about smoke-free housing. The study found that SHS transfer between units in multi-family buildings is common, with approximately half of renters reporting they were currently experiencing it (10% of them experiencing it often or most of the time). Forty-nine decision-makers, representing a convenience sample, were interviewed. Owners and managers who lacked a no-smoking policy (59% of sample) had low levels of interest in smoke-free policies and negative expectations regarding their impact on vacancy rates, turn-over and staff time requirements. Decision-makers who did have a no-smoking policy (41%) generally had positive experiences and almost all were very likely to continue offering smoke-free buildings or units in the future. These decision-makers reported almost entirely neutral or positive effects on all key factors related to profitability. Finally, the study found that low-income renters living in publicly assisted housing had an almost identical level of interest in smoke-free buildings as households with higher incomes.

15. "Preferences and practices among renters regarding smoking restrictions in apartment buildings." Hennrikus DJ, Pentel PR & Sandell SD. *Tobacco Control* 2003; 12:189-194.

This is one of the first peer-reviewed studies on renter preferences regarding smoking policies for multi-unit buildings. Renters (n=301) living in large apartment buildings in a suburb of Minneapolis, Minnesota were asked to complete a mailed survey. The survey asked about the official smoking policy in place for their building, their preferences for smoke-free policies, their experiences with second-hand smoke infiltration from other

units in their building, and the actions they had taken about their involuntary exposure. There was considerable disagreement amongst respondents regarding the presence or absence of current smoke-free policies in their buildings; however, an impressive 79% of non-smokers indicated a preference for a smoke-free building (versus just 18% of smokers). Forty-six percent of all respondents reported smelling SHS in their units that did not originate there, and 90% of those reported being bothered by it. However, despite experiencing and being bothered by involuntary exposure to SHS, the vast majority of respondents indicated that they did not bother to notify or complain to their building manager or owner. The study points out that tenants' failure to notify management or complain about SHS may be an impediment to the adoption of more smoke-free policies for multi-unit apartment buildings.

Air transfer and exposure to second-hand smoke

1. "Tobacco smoke exposure in a sample of Boston Public Housing Residents." Levy DE, Rigotti NA & Winickoff JP. *American Journal of Preventive Medicine* 2013; 44(1):63-66.

In October 2012, the Boston Housing Authority (BHA) adopted a no-smoking policy that prohibited smoking in its entire portfolio (11,000 units). Prior to implementation, this study sought to assess SHS exposure among non-smoking tenants. Participants were recruited with flyers posted in BHA buildings (n=51 from 38 households). Surveys were administered, followed by a saliva sample to objectively assess for cotinine (a metabolite of nicotine).

Key findings:

- 66% of respondents from non-smoking homes reported smelling SHS in their homes;
 - 88% of residents had detectable cotinine levels (indicating exposure to SHS), and the mean cotinine level was more than 5X than what has been reported in national data (despite the fact that the national study used a more sensitive cotinine test);
 - Residents living in households with strict no-smoking rules had lower cotinine levels than residents living in homes with less strict policies; and
 - Curiously, respondents who reported smelling SHS more frequently registered lower cotinine levels than those residents who reported smelling SHS less often – perhaps an indication that chronic exposure to SHS desensitizes people to its smell.
2. "National and state estimates of secondhand smoke infiltration among U.S. multiunit housing residents." King BA, Babb SD, Tynan MA et al. *Nicotine & Tobacco Research* 2012; doi: 10.1093/ntr/nts254.

This study sought to calculate national and state estimates regarding the number of Americans living in multi-unit housing, their sociodemographic characteristics, and what percentage of them are exposed to SHS from neighbouring units. Data were pulled from the 2009 American Community Survey (n=1,917,748, a national annual household survey conducted by the U.S. Census Bureau) and the 2006-2007 Tobacco Use Supplement to the Current Population Survey (n=240,000).

Key findings:

- In 2009, 79.2 million (25.8%) Americans lived in multi-unit housing;
- Approx. 62.7 million multi-unit residents reported having smoke-free rules at home;
- Given a reported SHS infiltration rate of between 44% and 46.2%, approx. 27.6 – 28.9 million Americans living in multi-unit housing with smoke-free rules were exposed to SHS in their own homes.

3. “Secondhand smoke transfer and reductions by air sealing and ventilation in multiunit buildings: PFT and nicotine verification.” Bohac DL, Hewett MJ, Hammond SK et al. *Indoor Air* 2011; 21:36-44.

The goal of this study was to explore the potential of reducing exposure to SHS via air transfer in multi-unit dwellings by both reducing leakage between units and improving ventilation. A convenience sample of 6 multi-unit buildings in Minnesota was chosen based on number of units, age of building, number of storeys, type of heating system and presence of bathroom/kitchen exhaust fans. In the first year of the study inter-unit air leakage tests, “gas bomb” tests (perfluorocarbon tracer, or PFT) and nicotine transfer tests were conducted before any sealing or ventilation treatments were completed. In the second year these tests were conducted again between the air sealing work and the ventilation work so that the results of each intervention could be evaluated separately. Using best practice techniques, 4 to 5 hours were spent sealing each unit in the first two buildings, 7 to 10 hours per unit for another 3 buildings, and 24 hours per unit for the 6th building. Ventilation work involved installing new exhaust systems and air regulators and replacing fans for continuous operation.

Key findings:

- Airflow between units in apartment buildings can be significant, with upper unit floors experiencing greater infiltration than lower floors;
- The transfer rate of nicotine is typically 6X lower than that of other gases; when used as a SHS tracer it greatly underestimates the presence (and exposure potential) of other chemicals found in SHS;
- Careful air sealing and ventilation adjustments were able to reduce air transfer between units by a median of 29% for all buildings in the study; and
- Many air leakage paths and ventilation problems in buildings cannot be practicably sealed or fixed after construction—these are best addressed (i.e. more effective and less expensive) during construction.

4. “Tobacco smoke exposure in children who live in multiunit housing.” Wilson KM, Klein JD, Blumkin AK et al. *Pediatrics* 2011; 127:85-2.

The authors of this study hypothesized that children living in apartments have higher cotinine levels than those who live in detached homes. Cotinine is a metabolite of nicotine and indicates biochemical evidence of tobacco smoke exposure. Data from the 2001-2006 National Health and Nutrition Examination Survey (NHANES) were used (n=5002 children ages 6-18, who lived in a household in which no member was reported to smoke inside the home). The NHANES included a questionnaire along with a physical examination complete with blood and urine samples. Controlling for other demographics such as income and

ethnicity, the study revealed that 73% of children from smoke-free homes of any kind were exposed to SHS, and that children living in apartments registered 45% more exposure than those living in single detached homes. However, the NHANES did not collect information about home smoking bans—it is unknown how many children had parents who smoked outside the home, whose “off-gassing” and THS would undoubtedly confound results. Likewise, it is not clear if exposure was the result of SHS infiltration from neighbouring units, or from outside the home in the community.

5. “Indoor concentrations of nicotine in low income multi-family housing: Associations with smoking behaviors and housing characteristics.” Kraev TA, Adamkiewicz G, Hammond SK et al. *Tobacco Control* 2009; 18: 438-444.

This study sought to examine SHS exposure in low-income, multi-unit residences across the Greater Boston area. To assess exposure, a random sample of residents from 49 units completed an interviewer-administered questionnaire on household smoking behaviour. The results of the survey were compared to readings from passive diffusion monitors that collected vapor-phase nicotine (placed in participants’ main living areas) and to the buildings’ air exchange rates over the same one-week period. Sixty-nine percent of the participants in the study identified themselves as non-smokers and 31% self-identified as smokers. Thirty-two percent of all participants reported daily exposure to SHS in their home. Nicotine was detected in 89% of non-smoking homes (where neither residents nor visitors smoked). Frequent reports of SHS coming from other units or hallways were associated with increased levels of nicotine concentrations in non-smoking homes, proving that SHS travels between units. The authors conclude that non-smokers living in multi-unit buildings with neighbours who smoke may be at risk of involuntary exposure to SHS in their own homes.

6. “Use of a population-based survey to describe the health of Boston Public Housing residents.” Digenis-Bury EC, Brooks DR, Chen L et al. *American Journal of Public Health* 2008; 98: 85-91.

This study compares the health of public housing residents (n=393) in Boston with other residents in the same city (n=2526). Using random digit-dialing within regions, researchers found that public housing residents reported overall poorer health status (33%) than other city residents (9.3%) by virtually all measures, including ever diagnosed hypertension (36% vs. 17.4%), current asthma (19.2% v. 9%) and ever diagnosed diabetes (13.8% v. 5.3%). Reported current smoking rates were 34.4% for public housing residents and 20.6% for other city residents. The survey also indicated that over half of all public housing households had children present and tenants were more likely to spend more time at home than other city residents (due to unemployment, inability to work because of disability, retirement, etc.). It is important to note that despite public housing tenants reporting an elevated smoking rate of 34.4%, this still leaves a majority of tenants in Boston Public Housing that do not smoke and who likely prefer to avoid exposure to SHS. This study makes an important contribution to the body of evidence regarding the health status of public housing tenants and offers compelling reasons for decision-makers to prohibit smoking in public housing.

Third-hand Smoke

1. "Thirdhand cigarette smoke in an experimental chamber: evidence of surface deposition of nicotine, nitrosamines and polycyclic aromatic hydrocarbons and de novo formation of NNK." Schick SF, Farraro KF, Perrino C et al. *Tobacco Control* 2013; 0:1-8. doi:10.1136/tobaccocontrol-2012-050915.

Polycyclic aromatic hydrocarbons (PAH) and tobacco-specific nitrosamines (TSNA) are found in SHS and are highly carcinogenic (cancer-causing). Nicotine is the most abundant organic compound released during smoking. This study sought to test what happens to PAHs, nicotine and TSNA when SHS is aged for 60 minutes under laboratory conditions. Using a smoking machine, mainstream and sidestream smoke were generated and piped into an experimental chamber with a ventilation rate that mimicked normal residential conditions. Sorption (the chemical process whereby gas-phase molecules are absorbed or adsorbed onto a surface) and deposition (the adhesion of particles to surfaces) of these compounds were measured on three different surfaces: stainless steel, paper and terry cloth.

Key findings of the study:

- The majority of the PAHs (~60%), nicotine (~70%) and TSNA (~80%) found in SHS end up on surfaces and are not removed under normal ventilation conditions (in other words, they literally stick around as THS);
 - Sorption and deposition of these compounds increased in the chamber when terry cloth was introduced (in other words, it acted like a sink as opposed to the flat, impermeable stainless steel); and
 - An observed ten-fold increase in the ratio of NNK (a potent TSNA) to nicotine over a period of time suggests that the sorbed nicotine may have reacted to form NNK. This is consistent with findings from Sleiman M et al., 2010.
2. "Thirdhand smoke and exposure in California hotels: non-smoking rooms fail to protect non-smoking hotel guests from tobacco smoke exposure." Matt GE, Quintana PJE, Fortmann AL et al. *Tobacco Control* 2013; 0:1-9. doi:10.1136/tobaccocontrol-2012-050824.

This study, which used a stratified random sample of 40 hotels with (n=10) and without (n=30) 100% smoke-free policies, investigated for the presence of THS in and around guest rooms and measured guests' exposure to compounds found in THS. Nicotine and 3EP (air and surface) were measured to determine SHS infiltration/THS presence, and two validated biomarkers of tobacco smoke exposure, cotinine (a metabolite of nicotine) and NNAL (a metabolite of NNK—a potent carcinogen) were also utilized. At hotels that permitted smoking, reservations were made for one smoking and one non-smoking room. For 100% smoke-free hotels, a reservation was made for one room. Four hotels were sampled per month. Non-smoking researchers stayed in each room for approx. 14 hours and were instructed to touch various objects and to keep the windows closed. Baseline urine and finger wipe samples were taken prior to the researchers checking in.

Key findings:

- In non-smoking rooms of hotels that permitted smoking, surface nicotine levels were more than 2X higher than rooms in 100% smoke-free hotels, and this difference was statistically significant (this indicates that SHS seeped from smoking into non-smoking rooms, and persisted as THS);

- Air 3EP measurements were more than 7X higher in non-smoking rooms of smoking hotels than rooms in 100% smoke-free hotels, and this difference was statistically significant (which indicates the presence of SHS infiltration);
- Visits in smoking rooms generated the highest concentrations of nicotine on researchers' fingers, and these levels were significantly higher than those found after staying in non-smoking rooms of 100% smoke-free hotels and hotels that permitted smoking;
- Surface nicotine levels were significantly and positively associated with air and finger nicotine levels and with urine cotinine levels;
- Air nicotine levels were positively and significantly associated with air 3EP levels, finger nicotine and urine cotinine;
- Urine cotinine showed positive and significant associations with surface nicotine, air nicotine, air 3EP and finger nicotine levels.
- These findings demonstrate that partial smoking bans neither prevent SHS/THS pollution in non-smoking rooms nor protect guests from exposure.

3. "Associations between self-reported in-home smoking behaviours and surface nicotine concentrations in multiunit subsidized housing." Hood NE, Ferketich AK, Klein EG et al. *Tobacco Control* 2012; doi: 10.1136/tobaccocontrol-2012-050666.

The objective of this study was three-fold: (1) to determine how well self-reported home smoking behaviours correlate with objective measures of surface nicotine concentrations (SurfNicConc); (2) to identify the SurfNicConc that best distinguished between smoking and non-smoking homes, and (3) to identify factors independently associated with SurfNicConc. Tenants (n=301) in Ohio living in private subsidized housing without a no-smoking policy were surveyed in person regarding household smoking behaviour. A wipe sample to determine the presence of surface nicotine (THS) was also collected (n=279).

Key findings:

- 56.6% of respondents reported indoor smoking in their homes, and these respondents differed by education level and employment status from tenants who reported no smoking;
- Mean SurfNicConc was significantly different between non-smoking and smoking homes (11.4 µg/m² vs. 90.9 µg/m²) and between homes with complete, partial and no voluntary home smoking restrictions; and
- The researchers concluded that because of the strong positive association between indoor SurfNicConc and reported in-home smoking behaviour, this approach can be used to inform interventions to address exposure to SHS in multi-unit dwellings. Also, SurfNicConc was recommended as an objective measure to evaluate the effectiveness of no-smoking policies in subsidized housing.

4. "When smokers move out and non-smokers move in: Residential thirdhand smoke pollution and exposure." Matt GE, Quintana PJE, Zakarian JM et al. *Tobacco Control* 2011; 20:e1.doc10.1136/tc.2010.037382.

This study is the first to investigate the presence of thirdhand smoke (THS) pollution in residential settings. Although not focused specifically on multi-unit dwellings, the study sought to compare smoker and non-smoker homes before and after residents moved out. One hundred smokers and 50 non-smokers who reported that they would be moving were recruited to participate in the first of this two-phase study. Non-smokers who moved into the homes were recruited into phase 2: n=25 for former smoker homes and n=16 for former non-smoker homes. Resident surveys accompanied by the testing for nicotine in dust, household surfaces, residents' fingers and

children's urine cotinine served as the pre and post measures for the study.

Key findings:

- Dust and surfaces in former smoker homes had higher contamination levels than former non-smoker homes: nicotine contamination was 7X higher on living room surfaces, 5X higher in living room dust, 7-8X higher on the index fingers of non-smokers in former smoker homes, and children's urinary cotinine levels were 3-5X higher;
- THS accumulates in dust and on surfaces that persists for weeks and months, even after thorough cleaning;
- The main avenues of exposure to THS are thought to be in dust and from contaminated surfaces (as opposed to inhalation);
- A secondary but important finding is that smoker homes were vacant for a median of 62 days compared to 34 days for non-smoker homes. Moreover, smoker homes were more likely to require new flooring and painting—and were thus more expensive to turn over.

5. "Thirdhand tobacco smoke: Emerging evidence and arguments for a multidisciplinary research agenda." Matt GE, Quintana JE, Destailats H et al. *Environmental Health Perspectives* 2011; 119(9):1218-26. Epub 2011 May 31.

The authors of this comprehensive paper review the emerging evidence on THS and set out arguments in favour of an interdisciplinary research agenda to fill the gaps in current knowledge. For example, not all constituents of THS have yet been identified, and it is premature to assess the health risks of exposure to THS without evidence from clinical outcomes. The paper emphasizes that it is premature to adopt public policies regarding potential THS health risks; however, it is noted that customer complaints regarding the smell of stale SHS have already triggered numerous voluntary smoke-free policies in hotels and car rental companies. The goal of the proposed research agenda is to connect the research on risk assessment with research to reduce and prevent tobacco use, to reduce exposure to smoke pollutants and tobacco-related diseases.

6. "Secondary organic aerosol formation from ozone-initiated reactions with nicotine and secondhand tobacco smoke." Sleiman M, Destailats H, Smith JD et al. *Atmospheric Environment* 2010, doi:10.1016/j.atmosenv.2010.07.023.

Using the controlled environment of a laboratory, this study sought to assess the role of a common air pollutant (ozone) in the creation of "ultrafine" particles (UFP) when mixed with second-hand smoke. "Ultrafine" particles are a health concern because of their chemical composition, their potential to induce inflammation, and the fact that they lodge deep in the lung and increase the risk of adverse respiratory and cardiovascular health effects. The emerging science of THS is important: researchers are starting to demonstrate that the reaction of SHS (or specifically nicotine) with ambient air pollutants can actually form products that pose a greater threat to health than the reactants. For example, an earlier study published by the same lead author and colleagues found that nicotine can react with ambient nitrous acid (HONO) to form potent carcinogenic (cancer-causing) tobacco-specific nitrosamines (TSNAs). The concentrations of UFP formed from the reaction of SHS with ozone in this study were 8X higher than those measured in fresh SHS and 10X higher than those found in typical urban environments.

7. "Third-hand smoking: Indoor measurements of concentration and sizes of cigarette smoke particles after resuspension." Becquemin MH, Bertholon JF, Bentayeb M et al. *Tobacco Control* 2010;19:347-348. <http://tobaccocontrol.bmj.com/content/19/4/347.full>.

The authors of this article rightly assert that the toxicity and health effects of exposure to

“thirdhand” smoke (THS) have not yet been documented through quantitative data. In this study, researchers measured the concentration and sizes of cigarette smoke particles in a non-ventilated furnished room immediately following smoking, 4 hours later and then 24 hours after that. To “resuspend” the THS particles, dust and surfaces in the room were manually agitated along with the use of a ventilator.

Key findings:

- The airborne particles were “ultrafine” in size (a health concern because of their chemical composition, their potential to induce inflammation, and the fact that they lodge deep in the lung and increase the risk of adverse respiratory and cardiovascular health effects);
- The concentration of particles was divided by 100 four hours following smoking, and then again by 100 twenty-four hours after that;
- After “resuspension” the concentration was multiplied by 100 again.

The results demonstrate that aged smoke particles (THS) are capable of becoming airborne (“resuspending”) and that the concentration is much lower than that of SHS.

8. “Formation of carcinogens indoors by surface-mediated reactions of nicotine with nitrous acid, leading to potential *thirdhand smoke* hazards.” Sleiman M, Gundel LA, Pankow JF et al. *Proceedings of the National Academy of Sciences of the United States of America (PNAS)* 2010; doi: 10.1073/pnas.0912820107 (Feb. 2010).
www.pnas.org/content/early/2010/02/04/0912820107.full.pdf+html

Only the second peer-reviewed study to use the term third-hand smoke, this research sought to demonstrate that nicotine residue from second-hand smoke, which readily sorbs (sticks) to indoor surfaces, can react with ambient nitrous acid (HONO) to form potent carcinogenic (cancer-causing) tobacco-specific nitrosamines (TSNAs). HONO, present in the indoor environment from unvented combustion appliances and from chemical reactions, is often found at higher levels than outside. Nicotine is the most abundant organic compound found in second-hand smoke, deposits almost entirely on indoor surfaces, and persists in the indoor environment for weeks to months. In laboratory experiments, vaporized nicotine was adsorbed onto cellulose as a model indoor material and then exposed to HONO for 3 hours.

The researchers found NNA {1-(*N*-methyl-*N*-nitrosamino)-1-(3-pyridinyl)-4-butanal}, a tobacco-specific nitrosamine (TSNA) absent in fresh tobacco smoke, to be a major product, along with two others—NNK {4-(methylnitrosamino)-1-(3-pyridinyl)-1-butanone} and NNN {*N*-nitroso nornicotine}. Moreover, given the low volatility of TSNAs and their ability to persist in the indoor environment, they represent an unappreciated health hazard through skin exposure, dust inhalation, and for infants, ingestion. The study emphasizes the need for more research in this area to better understand the health implications of these potent cancer-causing compounds that impregnate the various surfaces and furnishings of indoor environments.

9. “Beliefs about the health effects of ‘thirdhand’ smoke and home smoking bans.” Winickoff JP, Friebely J, Tanski SE et al. *Pediatrics* 2009;123: e74-e79.

This study is the first published one to coin the term third-hand smoke, and defines it as residual tobacco smoke contamination that remains after a cigarette is extinguished. The study sought to demonstrate that beliefs about thirdhand smoke are associated with household smoking bans. Using data from the Social Climate Survey of Tobacco Control (an annual cross-sectional survey, n=1478), researchers found that 65% of non-smokers versus 43% of smokers agreed that thirdhand smoke harms children and that adults’ beliefs about the health effects of exposure to

thirdhand smoke are independently associated with home smoking bans. Strict smoking rules were more than three times more prevalent among non-smoker households (88.4%) than smoker households (26.7%).

10. "Gas-phase organics in environmental tobacco smoke: 2. Exposure-relevant emission factors and indirect exposures from habitual smoking." Singer BC, Hodgson AT & Nazaroff WW. *Atmospheric Environment* 2003; 37: 5551-5561.

This article describes month-long experiments to investigate sorption effects on potential SHS exposures under habitual smoking conditions. Cigarettes were smoked by machine in a 50 m³ furnished room over a three-hour period 6-7 days/week with varying levels of continuous ventilation. Organic gas concentrations were measured during 3 hour 'active' smoking periods, including one hour immediately following, for 10 hour 'post-smoking' periods and measurements were also taken for 10 hour 'background' periods for comparison. The researchers found that reemission (off-gassing) of some volatile hazardous air pollutants accounted for approximately 47-71% of potential daily exposures.

In other words, non-smokers can be exposed to SHS even when no active smoking occurs (indirect exposure), due to the sorbing and later reemission (off-gassing) of organic compounds. The experiments also revealed that non-smoker exposure to certain gas-phase organic compounds can be reduced both by increasing the ventilation rate and by prohibiting smoking for at least one hour before entering a room. However, it should be noted that these measures were not effective for all compounds and that potential indirect exposure to lower volatility toxic compounds including polycyclic aromatic hydrocarbons persisted.

11. "Gas-phase organics in environmental tobacco smoke. 1. Effects of smoking rate, ventilation, and furnishing level on emission factors." Singer BC, Hodgson AT, Guevarra KS et al. *Environmental Science & Technology*, 2002; 36(5): 846-853.

This study, and the second part that follows, are important contributions to the body of evidence regarding the indoor environmental persistence of second-hand smoke (SHS). The objective of this study was to monitor the effect of SHS (or environmental tobacco smoke—ETS—as it's referred to in this study) sorption in a 50 m³ ventilated room constructed and furnished with materials typical of many residences and office buildings. The emission and sorption of 26 gas-phase organic compounds were measured in 24 experiments under varying conditions related to furnishing levels, smoking rates and room ventilation rates. This study indicates that sorption in a furnished room with a low ventilation rate results in decreased emissions of several important SHS organic compounds, including cresols and nicotine, by up to an order of magnitude when compared to emissions from a highly ventilated and lightly furnished room. The results therefore indicate that sorption (and later off-gassing) in a typical indoor environment can greatly affect exposures of non-smokers to gas-phase organic compounds found in ETS.

12. "Sidestream cigarette smoke toxicity increases with aging and exposure duration." Schick S & Glantz SA. *Tobacco Control* 2006; 15: 424-429.

This study does not specifically deal with second-hand smoke in multi-unit dwellings per se, but offers some extremely valuable information about the toxicity of 'aged' (30 minutes and 90 minutes) versus 'fresh' (10 seconds) sidestream tobacco smoke. Sidestream smoke refers to the smoke that comes off the end of an idling cigarette, versus what is blown out of a smoker's mouth and nose (mainstream smoke). The information is also particularly valuable in that the data come from previously unpublished experiments performed by Philip Morris at its formerly secret

laboratory in Germany. In these experiments, lab rats were exposed to aged and fresh SHS for 5 hours/day, 7 days/week to 7 hours/day, 7 days/week. The rats' noses, larynxes and trachea were then sectioned and examined by a veterinary pathologist for pathological changes. Using total particulate matter as the measure of smoke exposure, the results of these studies indicate that, compared to fresh sidestream smoke, aged sidestream smoke (at least 30 minutes) increases toxicity 4x for 21-day exposures and 2x for 90-day exposures.

Given that particulate matter travels relatively well through cracks and ventilation systems in multi-unit dwellings, these studies offer additional evidence in favour of smoke-free buildings. Non-smoking residents are not only involuntarily exposed to "fresh" second-hand smoke, but also to aged SHS which deposits on surfaces and becomes more toxic over time.