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Prevalence of mold and asthma in the Vine City and English Avenue neighborhoods of Atlanta, Georgia

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Master of Public Health

Environmental Health

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B.A., Creighton University, 2013

Thesis Committee Chair: Dr. Andrea Winquist, MD, PHD

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Abstract

Prevalence of mold and asthma in the Vine City and English Avenue neighborhoods of
Atlanta, Georgia
By Samantha Eiffert

English Avenue and Vine City are communities located just west of downtown Atlanta. Residents in these communities have expressed concerns about the potential health effects of frequent flooding. Flooding can impact health by contributing to damp indoor environments, which facilitates mold growth (Brandt et al., 2006). A survey was conducted in these neighborhoods, with participants recruited from a random sample of homes in areas that tend to be wet and adjacent areas. The survey included a questionnaire, an environmental inspection, and a dust sample. Dust samples were tested using quantitative PCR, and results were expressed in terms of the environmental relative moldiness index (ERMI). It was hypothesized that houses located in wet areas would be more likely to have observed mold and higher ERMI values than houses located in adjacent areas. It was hypothesized that residents who had observed mold would be more likely to self-report a current asthma diagnosis, and asthmatic participants' homes would exhibit higher average ERMI values. Mold was observed in 35% of residences. ERMI values were high in these neighborhoods with a mean of 11.1 compared with the average ERMI value for homes in Atlanta of 9.82 (Vesper, personal communication). The prevalence of self-reported current asthma among participants was 14%. Residences in wet areas did not exhibit higher ERMI values or odds of observed mold overall. However, homes with basements in wet areas did have higher odds of observed mold (OR=5.45; p=0.12). Air conditioning use was associated with lower odds of observed mold and lower ERMI values ($p<0.05$), while reported leaks were associated with higher odds of observed mold and higher ERMI values ($p<0.05$). Participants who had lived at their current residence for two years or less had a positive association between observed mold and asthma (OR=1.18; p=0.811) and between ERMI values and asthma (OR=1.12; p=0.036). These neighborhoods showed high prevalence of mold and current asthma. In these neighborhoods, flooding likely contributes to mold in some cases, but the structural integrity and overall maintenance status of residences is also of concern because reported leaks were strongly associated with observed mold and ERMI values.

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Introduction/Background

English Avenue and Vine City are two communities that are located just west of downtown Atlanta and the Georgia Dome. Both communities are in the Proctor Creek Watershed (Figure 1). The watershed surrounds Proctor Creek, which drains into the Chattahoochee River. Overall, the Proctor Creek Watershed is 33% impervious, making the area prone to flooding (Fulk and Thomas-Burton, 2013). The areas of the watershed near English Avenue and Vine City contain an even higher percentage of impervious surfaces than the watershed overall. Residents in these communities have expressed concerns about the potential health effects of flooding. One of the potential ways in which flooding could impact health is by contributing to damp indoor environments, which can facilitate the growth of mold (Brandt et al., 2006). A review by Mendell et al. (2011) found evidence of positive associations between dampness or mold and multiple respiratory and allergic health conditions, including "asthma development and exacerbation, current and ever diagnosis of asthma, dyspnea, wheeze, cough, respiratory infections, bronchitis, allergic rhinitis, eczema, and upper respiratory tract symptoms" (Mendell, 2011). Other reviews have also found that dampness or mold is associated with respiratory allergies, wheezing, coughing (Mazur et al., 2006; Tischer et al., 2011) and bronchitis (Fisk et al., 2010).

Asthma is a particular concern in relation to damp indoor environments and mold. Several studies have demonstrated an association between damp and/or moldy indoor environments and asthma (Quansah et al., 2012; Strina et al., 2014; Spengler et al., 2004). One study in Finland found that for adults, the risk of asthma was related to visible mold in the workplace but not to water damage or water stains alone, with an odds ratio for newly diagnosed asthma in relation to visible mold of 1.54 (Jaakkola MS et al., 2002).

Another study found that respiratory illnesses were positively associated with adults working in buildings with water damage (Park et al., 2008). In a prospective cohort study, researchers found that in children, although the predictor associated with the largest number of cases of new asthma was parental atopy (with an adjusted incidence rate ratio (IRR) of 1.52), incident asthma was also related to the presence of a moldy odor with an adjusted IRR of 2.44. There was no significant effect on asthma incidence in that study for water damage, moisture, and visible mold (Jaakkola JJ et al., 2005). A study in Russia found that in children, when mold was present in the home, the odds ratio for current doctor-diagnosed asthma was 2.82 compared to when mold was not present in the home (Spengler et al., 2004). The flooding in English Avenue and Vine City could contribute to damp and/or moldy indoor environments. Therefore, it is possible that the frequent flooding in this area contributes to an increased prevalence of asthma.

Asthma is also a particular concern in populations with low socioeconomic status, which have been found to have a higher asthma prevalence than populations of higher socioeconomic status (CDC, 2013). More than 50% of the residents of English Avenue and Vine City live below the poverty line (Westside, 2013). While there are no local data about the prevalence of asthma in Vine City and English Avenue, a high asthma prevalence could be expected in these neighborhoods. Besides damp indoor environments and mold, several other factors could contribute to asthma morbidity in these neighborhoods. A study in Russia found that, in children, respiratory allergy and dry cough were associated with living near traffic, with odds ratios of 1.41 and 2.46 respectively (Spengler et al., 2004). A review by Hajime et al. (2011) demonstrated an association between air pollution and asthma exacerbation. Because these communities are located in an urban area, living near traffic could contribute to higher rates of asthma. Inner city children with asthma also tend to have sensitization to cockroaches and dust mites and to experience high levels of environmental tobacco smoke (Crain et al., 2002). Rosenstreich et al. (1997) found that for inner city children, the combination of cockroach allergy and high levels of exposure to cockroach allergen led to higher rates of hospitalization and unscheduled doctor's visits for asthma. Cockroach allergen and rodent allergen are present in higher levels for inner city populations and have also been found to be associated with asthma morbidity (Matsui, 2014). A review by Matsui (2014) cited additional factors that could be associated with asthma morbidity for inner city populations including potentially higher indoor air pollutant levels and nutritional or dietary factors. Individual, home-based interventions have been shown to be effective in reducing some of these environmental exposures including environmental tobacco smoke and cockroach allergen levels, and the reduction of these environmental exposures has been associated with a reduction in asthma symptoms among children with asthma (Morgan et al. 2004).

There are no generally accepted standards for measuring mold in residences (Brandt et al., 2006). A study by Reponen et al. (2010) tested three measures for mold including visual inspection for damage, moldy odor, and a novel measure called the "environmental relative moldiness index" (ERMI). They found that the ERMI showed the highest number of homes with mold, indicating that there may be mold present that is missed by visual inspection. ERMI is a metric that was developed by researchers at the U. S. Environmental Protection Agency (EPA) to assess mold contamination using DNA from 36 different types of mold. The 36 mold types include 26 "group-one" species that are associated with water damage and 10 “group-two” species that are present in homes regardless of water damage (Vesper et al., 2009). Dust samples are collected, and analyzed using quantitative polymerase chain reaction (PCR). The ERMI is calculated by taking the sum of the logs of the concentrations of the group one species and subtracting the sum of the logs of the concentrations of the group two species. The ERMI scale ranges from -10 to 20 or higher, with higher numbers indicating a higher degree of mold contamination (EPA, 2014). ERMI values measured in the American Healthy Homes Survey were divided into quartiles, with the lowest quartile having the lowest likelihood of having a mold problem, and the fourth quartile having the highest likelihood of having a mold problem. The cut points for these quartiles were -4, 0, and 5. Any ERMI value above 5 was in the fourth quartile, indicating the highest likelihood of having a mold problem (Roche, 2007; Vesper et al., 2009). The ERMI measurement is consistent over time (Kamal et al., 2014) and is potentially more sensitive (Vesper et al., 2009) and in better agreement with other measures of mold contamination (Reponen et al., 2010) than inspectors’ observations. ERMI values vary across the United States, and while humidity and precipitation can impact moisture levels inside of homes, it was found that the structural integrity of homes had a greater impact on moisture-associated mold levels than climate (Vesper et al., 2011).

Studies have demonstrated higher ERMI values in homes with a child with asthma than in randomly selected homes (Vesper et al., 2013; Kamal et al., 2014). These studies had the limitation of comparing randomly selected homes from different neighborhoods. Matching based on neighborhood could prevent confounding by unknown or unmeasured variables. Average ERMI values could differ between neighborhoods if the neighborhoods have different socioeconomic status or age of homes. Vesper et al. (2013) compared asthmatic children in communities in Boston, Kansas City, and San Diego to ERMI values from the American Healthy Homes Survey from the same states or regions. They found that the average ERMI value for houses with a child with asthma was 8.73, while the average ERMI value among randomly selected homes was 3.87 (Vesper et al., 2013). Kamal et al. (2014) found that the overall ERMI values for children with asthma in Detroit were higher than ERMI values found in previous studies. An association between ERMI values and asthma has also been found in adults. In a study conducted in Northern California, the median ERMI value for homes of adults with asthma or chronic rhinitis was 6, while randomly selected homes from the same geographic region in the American Healthy Homes Survey had a median ERMI value of 2 (Blanc et al., 2013). Reponen et al. (2011) used an advantageous study design that followed a birth cohort for seven years. They found that children living in homes with high ERMI values (≥5.2) at the age of one year had a significantly higher risk of being diagnosed with asthma at age seven years than children living in homes with lower ERMI values.

To address community concerns about potential health effects of flooding in the English Avenue and Vine City neighborhoods, we conducted a survey of homes in these areas to examine the prevalence of mold and mold-associated health conditions. We were particularly interested in examining the relationships between areas that tend to flood, damp and/or moldy indoor environments, and self-reported asthma among current residents. We hypothesized that homes located in wet areas, as determined by the Wetness Index (see below for definition), would be more likely to have observed mold and would have higher ERMI scores than homes located in non-wet areas. We also hypothesized that homes with observed mold and higher ERMI scores would be more likely to have a resident who reported asthma.

Methods

The survey was conducted by Eco-Action and Emory University, in collaboration with residents of Vine City and English Avenue, the West Atlanta Watershed Alliance, and other community organizations. The survey included the administration of a questionnaire, an indoor environmental inspection, and indoor dust sampling for ERMI testing. The survey sample was randomly selected among homes located in the study area, which was defined as wet areas or adjacent areas within the study boundaries of Donald Lee Parkway in the north, Martin Luther King Drive in the south, Northside Drive in the east, and Temple Street in the west (Figure 1). A map of Wetness Index values, obtained from the Environmental Protection Agency (EPA), was used to identify wet areas. The Wetness Index uses gridded topographic data, including local slopes, to classify wet areas. It is a computer model that takes the natural log of the local upslope of an area divided by the tangent of the local slope. Local upslopes are calculated by taking the steepest downslope of one cell and directing it towards one of eight neighboring cells. Each cell has an upslope value based on the accumulated area of upstream cells. The local slope considers the slope of each cell and its neighbors. The computer model uses this elevation data to predict runoff patterns and to identify soil moisture patterns (Sorensen et al, 2006).

For this study, a map of the Wetness Index values at a grid size of 30mx30m for the Proctor Creek Water shed was obtained from the EPA. Based on previous uses of the index by the EPA, we identified wet areas as areas with a wetness index greater than or equal to 500 (Figure 1). Many of the houses in the Proctor Creek Watershed area are located in wet areas according to this definition. The study area included these wet areas and a two-hundred-foot buffer zone around these wet areas within the study boundaries. Researchers walking through each street of the study area manually recorded addresses of all homes located within this study area (wet areas and buffer zone) that were not obviously vacant. Among the 1,954 recorded residences, 507 homes were randomly selected without consideration for the location of home in a wet or buffer zone area.

Data were collected between June and August of 2014. Two teams collected the data; each team consisted of an Emory Masters of Public Health student and a resident from one of the two communities. Each team received a list of the selected residences they were to visit, and visited each address three times on different days and times of day to ensure a wide range of people and schedules were captured by the survey. Residents were offered a $25 gift card to Walmart for their time if they chose to participate, and informed consent was obtained from the first willing resident at that address. The questionnaire portion of the survey was conducted first and took approximately twenty minutes. The environmental observation portion took between 15 and 30 minutes, depending on the size of the residence and the extent of mold or water damage present. A dust sample was collected using a Swiffer® cloth during either the questionnaire portion or the environmental observation portion. The team member who was not recording questionnaire responses or the observations was responsible for the dust collection, which typically included samples from surfaces (other than the floor) in the living room, kitchen, and the bedroom of the study participant.

The questionnaire asked about the history of flooding; whether the participant had observed mold growth or water damage in the residence; the locations of the observed mold or water damage; past and current doctor or nurse diagnosed health conditions (e.g. asthma, COPD, allergies, eczema), and current symptoms (e.g. cough, wheezing, skin rashes). Information about health conditions was collected only for the respondent, and not for other people in the residence. Information was also collected about the number of people living in the residence and their ages; the smoking status of the participant and other people living in the residence (including whether or not they smoked inside the residence); whether cockroaches, mice or rats were present in the residence and how frequently they were observed; the number of years the participant had occupied the residence; whether he or she owned or rented the property; whether there was air conditioning in the residence; and whether or not the participant used air conditioning on most days during the summer if it was present.

Study participants were told that as part of the environmental observation portion, the living room, kitchen, and bathroom must be observed, and if possible the participant's bedroom. Many participants allowed environmental observations in more rooms than the ones required. If the participant had a basement, it was also included in the environmental observation. The environmental observation portion included visual observation of mold or water damage that was apparent without moving furniture. If mold or water damage was observed, the location and size were recorded. In these cases, permission was requested to photograph the area. The type of flooring in each room was recorded, as well as the presence of rust on air vents and condensation on windows, as these are indicators of a damp indoor environment.

For data analysis, houses were classified as being either in a wet area according to the Wetness Index or in the 200-foot buffer zone. It was hypothesized that houses located in wet areas as determined by the Wetness Index would be more likely to have observed mold and higher ERMI scores than houses located in dry areas. Residents who had mold observed in their residences were hypothesized to be more likely to have self-reported a current asthma diagnosis, and participants with asthma were hypothesized to have higher ERMI scores. The hypothesized causal pathway is shown in Figure 2.

Several classifications for observed mold were considered. Classifications initially considered included any observed mold, as well as mold that was in locations indicating that it was potentially related to flooding. The mold classification used in the final analysis included all observed mold except mold that was only observed in the bathroom around caulk or on the shower curtain. Mold observed only on the caulk and/or shower curtain was excluded in the final analysis because mold in these locations tended to be linked with the number of people living in the residence and also might vary depending on cleaning habits and how recently cleaning was done. Mold observed in other areas of the bathroom was included in the final classification (referred to below as "observed mold").

The analysis of the overall hypothesis was considered in two specific aims. Aim 1 examined two measures of the presence of mold in the residence; presence of observed mold (except when observed only in the bathroom around caulk or on shower curtains) and dust ERMI values, in relation to the location of the home in a wet area or adjacent area. A chi-square test of association was used to assess the statistical significance of the crude association between the location of homes (i.e. whether they were in a wet area or buffer zone) and observed mold, and a t-test was used to examine the crude relationship between the location of homes and dust ERMI values. Multivariate analyses were then performed using logistic regression or linear regression adjusting for potential confounders including air conditioning use, reported leaks, the duration of time the participant had lived in the residence, and the number of people living at the residence. A history of flooding was not considered a potential confounder in these models because it was considered to potentially be in the causal pathway between location in a wet area and these measures of mold. To consider whether observed associations differed for residences with and without basements, two regression models were used, one for houses with basements and one for all other residences.

Aim 2 examined self-reported current asthma in relation to observed mold and self-reported current asthma in relation to ERMI values. A chi square test of association was used to assess the statistical significance of the crude association between self-reported current asthma and observed mold. Logistic regression was then used to examine the relationship between observed mold and self-reported current asthma. Variables that were considered for inclusion in the model as potential confounders were indoor smoking, air conditioning use, pets, cockroaches, mice, the duration of time the participant had lived in the residence, and the number of people living at the residence. To examine the association between self-reported current asthma and ERMI values, a t-test was used to assess the statistical significance of the crude association and a logistic regression model was used with current asthma as the outcome and ERMI as the predictor (considered as a linear term in the model). Variables considered as potential confounders in the logistic regression model included indoor smoking, air conditioning use, pets, cockroaches, mice, the duration of time the participant had lived in the residence, and the number of people living at the residence.

Results

From the 507 selected residences, a total of 150 complete surveys were obtained, with three additional surveys for which participants completed all or part of the questionnaire, but not the environmental inspection portion. Figure 3 shows the frequency of reasons for non-responses for the homes from which we did not obtain survey responses. Reasons for nonresponses included residences being inaccessible (for example, due to a large dog or a locked gate) or people refusing because they were uninterested or did not want to complete the environmental inspection portion of the survey. Table 1 summarizes the characteristics of the study population. Of the respondents, 89 were female and 64 were male. The median age was 47 years. A total of 52 respondents lived in EPA classified wet areas and 101 respondents lived in the buffer zone. The median number of years respondents had lived at their current residence was 2.5 and the median number of people living at each residence was 2. Eighty one respondents (53%) lived in a house, and 76% of respondents were renters. Of those living in houses, 30% reported having a basement. Thirty six percent of respondents either did not have air conditioning or reported not using it most days during the summer. Thirteen percent of respondents reported a history of flooding in their current residence while they lived there. Forty six percent of respondents reported experiencing at least one leak, and 39% of respondents reported at least one person who smoked inside of the residence. Twenty two respondents (14%) reported current doctor or nurse diagnosed asthma. Mold was observed in 53 of the residences (35%). ERMI values ranged from -

1.85 to 32.02, with a mean ERMI value of 11.12 (Figure 4). ERMI values were positively associated with observed mold. The mean ERMI value for residences with observed mold was 13.97 and the mean ERMI value was 9.55 for residences without observed mold (t-test $p<0.05$).

Without adjusting for other variables, the odds of mold being observed in a residence in a wet area was 0.42 times the odds of mold being observed in a residence in the buffer areas (odds ratio (OR)=0.42, 95% confidence interval (CI)=0.20-0.89). Table 2 shows the odds ratios for mold being observed, comparing wet areas to the adjacent areas, stratified by levels of other variables considered for inclusion in the model. These analyses indicated apparent effect modification of the association between presence of the house in a wet area and observed mold by whether or not the residence had a basement. The stratified odds ratios for the association between being in a wet area and having observed mold was 1.56 for houses with basements and 0.33 for all other residences. While the difference between these odds ratios was not statistically significant, separate models for residences with and without basements were considered because of the magnitude of the difference in the odds ratios. The results of the logistic regression models, adjusted for air conditioning use, reported leaks, the duration of time the participant had lived in the residence, and the number of people living at the residence, are shown in Table 3. In an overall model, location in a wet area was significantly inversely associated with having observed mold (OR=0.44; 95% CI=0.19-1.00). In the unstratified model, reported leaks were positively associated with observed mold (OR=2.98, CI=1.42-6.27), and having a basement was also positively associated with observed mold (OR=3.25; 95% CI=1.16-9.21). In the regression model restricted to residences without basements, after adjusting for the other variables in the model, there was still a negative association between being in a wet area and having observed mold (OR=0.35, 95% CI 0.14-0.88). Reported leaks were positively associated with observed mold (OR=2.8, 95% CI=1.23 and 6.26). The other variables in the model for residences without basements were not significantly associated with observed mold and had odds ratios very close to one. There were no significant associations with observed mold for the model restricted to houses with basements. However, among the 22 houses with basements, location in a wet area showed a positive, although nonsignificant, association with observed mold (OR=2.0, 95% CI=0.20-20.07).

Among 96 residences in dry areas, the mean ERMI value was 11.96. Among 50 residences in wet areas the mean ERMI value was 9.47. The lower ERMI values in wet areas were statistically significant on crude analysis using a t-test (p=0.020). In an overall linear regression model, adjusting for the same variables as in the analysis for observed mold, being in a wet area was again associated with having lower ERMI values (average ERMI value 1.91 units lower in wet areas than non-wet areas). In addition, no air conditioning use and reported leaks were significantly associated with higher ERMI values. Residents who reported not using air conditioning most days during the summer had a mean ERMI value that was 3.4 units higher than those who reported using their air conditioning most days during the summer (p=0.003). Residents who reported leaks had a mean ERMI value that was 2.9 units higher than those who did not report leaks (p=0.009). The linear regression analysis restricted to residences without basements showed that ERMI values for residences in wet areas were on average 2.9 units lower than residences in non-wet areas (p=0.025) (Table 4). In that model, the mean ERMI value among residences in which air conditioning was not used on most summer days was 3.4 units higher than among those in which air conditioning was used on most summer days, and the mean ERMI value among residences in which leaks were reported was 2.6 units higher than among residences with no reported leaks. In the linear regression model restricted to residences with basements, reported leaks was the only variable that was significantly associated with the ERMI measurement, with residences with reported leaks having mean ERMI values 5.4 units higher than residences without reported leaks (p=0.0496) (Table 4). In this model, restricted to houses with basements, mean ERMI values were 4.8 units higher among homes in wet areas than among homes in non-wet areas but this difference was not statistically significant (p=0.122).

Without adjusting for other variables, the odds of a study participant reporting current asthma among those living in residences in which mold was observed were 0.82 times the odds of a study participant reporting current asthma among those living in residences in which no mold was observed (OR=0.82, 95% CI=0.31-2.16). The association between observed mold and current asthma was also assessed when stratified by potential effect modifiers or confounders. The variables considered included the presence of mice, cockroaches, pets, air conditioning use, the number of people living in each residence, whether there was smoking inside the residence, and the duration respondents had lived at their current residence. The odds ratios for the association between observed mold and current asthma stratified by these variables are reported in Table 5. These analyses indicated possible effect modification by several variables, but none of the differences were statistically significant. Apart from the presence of mice, for which OR estimates were imprecise due to few people reporting mice, the variable with the largest difference in stratified odds ratios was the duration of residence. We considered models that were stratified by whether the respondent had lived at their current residence for two years or less or for more than two years. The purpose of stratifying the model by residence duration was to consider the possibility that people with asthma might tend to move out of moldy homes. The results of logistic regression models are shown in Table 6; these models included only indoor smoking and duration of residence, as the other variables did not appear to be confounders. No variables were found to be significantly associated with current asthma in the overall model. For the logistic regression model restricted to respondents who had lived at their current residence for two years or less, the odds of reporting current asthma among those with observed mold was 1.18 times the odds of reporting current asthma among those with no observed mold (Table 6). However, this was not statistically significant (p=0.811). In the logistic regression model restricted to respondents who had lived at their current residence for more than two years, the odds of reporting current asthma among those with observed mold was 0.59 times the odds of reporting current asthma among those with no observed mold, although this result was also not statistically significant (p=0.494).

Participants who reported having current asthma (21 people) had a higher mean ERMI value (13.498) than participants without current asthma (125 people, mean ERMI value 10.708). Using a t-test, this crude difference was not statistically significant (p-value of 0.0795). Logistic regression models were used to assess the association between the ERMI values and current asthma, controlling for potential confounders. As in the models for the association between current asthma and observed mold, smoking inside and duration of residence were the only variables included in the final models because there was no evidence of confounding by the other variables. The results of these models are reported in Table 7. In the overall model, ERMI values were positively associated with reported current asthma, but this was not statistically significant (OR per 1 unit increase in ERMI value=1.05, 95% CI=0.98-1.13). In that model smoking indoors and duration of residence were also not significantly associated with current asthma. For participants who had lived at their current residence for two years or less, the odds of reporting current asthma increased by 1.12 times with each 1 unit increase in the ERMI value. This result was statistically significant with a p-value of 0.036. Smoking inside the residence was also significantly associated with current asthma in this model with an odds ratio of 5.11 (p= 0.031). There were no statistically significant associations with current asthma in the regression model restricted to participants who had lived at their current residence for more than two years, but there was a positive association between ERMI values and current asthma in these models as well (OR=1.01, 95% CI=0.92-1.12).

Discussion

Overall, this survey found evidence of a high prevalence of mold in residences in these neighborhoods. The mean ERMI values for both the wet and dry areas are in the fourth quartile of the ERMI values that were observed in a national survey (Roche, 2007; Vesper et al., 2009). That is, they are in the group with the highest likelihood of having mold problems. The entire study area had an overall mean ERMI value of 11.1. The average ERMI value for homes in Atlanta in the 2008 American Healthy Homes Survey was 9.82 (Vesper, personal communication). The prevalence of observed mold was higher than what has been observed in other surveys with 35% of residences having observed mold compared to 1.5% of homes with observed mold in the living room or bedroom in the American Healthy Homes Survey (Vesper 2009) and 15.2% of homes with observed mold in a survey of low income housing in Boston (Adamkiewicz, 2014). The prevalence of reported current asthma was also higher than has been observed in other areas, with 14% of participants reporting current asthma in this study compared to 7.8% of participants reporting current asthma in the 2010 Georgia Behavioral Risk Factor Surveillance System (CDC BRFSS, 2010).

In our survey, we did not find that residences located in a wet area had higher odds of having mold observed than residences in adjacent areas, which is not what was hypothesized. However, there was a positive association between location in a wet area and observed mold among houses with basements, although this result was not statistically significant. If a participant reported experiencing leaks, the odds of observing mold were increased among residences without basements (OR=2.78, p=0.014) and among residences with basements (OR=5.45, p=0.124). Similar to the case for observed mold, location in a wet or dry area was associated with ERMI values in an unexpected way. Residences in wet areas tended to have lower ERMI values than those in dry areas. The unexpected finding of an overall lower prevalence of observed mold and lower average ERMI values among houses in wet areas may be due to something different about houses in wet areas that was not captured on the survey or environmental inspection, such as the age or overall maintenance status of the residences. We did not collect information about the building age or overall condition. It is possible that, in wet areas, flood-damaged residences may be mostly unoccupied. This could lead to the residences with occupants (and thus available for our survey) in those areas being predominantly residences that were in the best condition or that were built since the worst flooding had occurred. Our survey did not collect information that would allow us to assess this possibility, but it could be a reason for our unexpected findings.

Reported leaks and air conditioning use, were associated with ERMI values in the expected direction. The finding of an association between lower ERMI values and air conditioning use is consistent with the findings of a study by Reponen et al. (2013), which found that the mean ERMI value was 2.0 among residences that used air conditioning and 5.4 among residences that did not use air conditioning (Reponen et al., 2013). These findings indicate that while flooding may contribute to the high prevalence of mold in these neighborhoods, especially among houses with basements, it is not the only factor contributing to the high prevalence of mold. Home maintenance issues and associated leaks appear to also contribute to the high prevalence of mold in these neighborhoods.

There was no overall crude association between observed mold and current asthma. However, there was an overall crude positive association between ERMI values and current asthma, which was close to statistical significance. Participants who had lived at their current residence for two years or less had a positive association between observed mold and current asthma. This association was negative among participants who had lived at their residence for more than two years, but these results were not statistically significant. Smoking inside was the only variable found to be a confounder in these models, and smoking inside the residence was significantly associated with current asthma in the model restricted to those who had lived at their residence for two or less years (OR=3.803, 95% CI=1.035-13.975) but not among those who had lived in their residence for more than 2 years (OR=0.61, 95% CI=0.11-3.25).

Since this study is cross-sectional, the direction of any possible causation cannot be determined; measures of mold can only be said to be associated with asthma or with being in a wet area. The survey did not ask about the date of asthma diagnosis, so only the current prevalence of asthma can be determined and we do not know whether the asthma diagnosis preceded the person living in their current residence. It is possible that people who have asthma may move into certain houses and soon realize that the conditions are making their asthma worse, leading them to move out within a few years. If people with asthma have lived at their residence for more than two years, perhaps the conditions are more favorable and have not caused them to move. The presence of mold causing people with asthma to move out could be the reason for the negative association between observed mold and asthma among those who had lived at their residence for more than two years.

This study provides additional evidence of the usefulness of the ERMI measurement. ERMI values were positively associated with current asthma among our survey respondents, especially among those who had lived at their residence for 2 years or less. A strength of this study is the fact that all comparisons are between homes in the same neighborhoods. This adds to evidence from previous studies that have compared ERMI values for asthmatics and non-asthmatics to those for the general population from different neighborhoods, which could lead to bias in the results.

This study also has several limitations. One of the limitations is the cross-sectional nature of this study. Another limitation was the apparent failure to capture some of the differences between residences in dry areas and residences in wet areas. There were no questions about the age or overall maintenance status of the residences.

There could also be something different between the people who had been living at a residence for two years or less and people who had lived at their residence for more than two years that was not captured by the survey. Finally, the relatively small sample size limits the power of the analyses, and the relatively low response rate (despite intensive efforts to obtain participation) could have led to bias in our sample.

Conclusions

The communities of English Avenue and Vine City were concerned about the potential health effects of frequent flooding in their neighborhoods. This survey was conducted to address these concerns, and community members were involved in all phases of planning and conducting the study. Community engagement was essential to the success of this survey and will be critical to the success of identifying ways of addressing survey findings. Results of the study were shared with the community at two community forums and community-based organizations are in the process of planning next steps in response to survey results. The high prevalence of observed mold is of particular concern. Based on previous literature (Quansah et al., 2012; Jaakkola MS et al., 2002; Dales, 1991), the high prevalence of mold may be contributing to the high prevalence of asthma in these communities. Based on the study findings, while frequent flooding or living in a wet areas likely contributes to the mold in some cases (particularly in houses with basements), flooding does not seem to be the only factor contributing to the high prevalence of mold in these neighborhoods. The structural integrity and overall maintenance status of residences in the area is also of concern since reported leaks were strongly associated with observed mold and ERMI values. Air conditioning use was significantly associated with lower ERMI values for residences without basements.

Education of community residents about the relationships between mold and leaks and lack of air conditioning use, and about the potential health effects of mold could be one way of addressing the high prevalence of observed mold in these communities.

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Figures

Figure 1. Map of Study Boundaries. Street map is from ArcGIS World Street Map (Sources: Esri, HERE, DeLorme, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, TomTom, © OpenStreetMap contributors, and the GIS User Community); Wetness index map and stream map were obtained from US EPA.

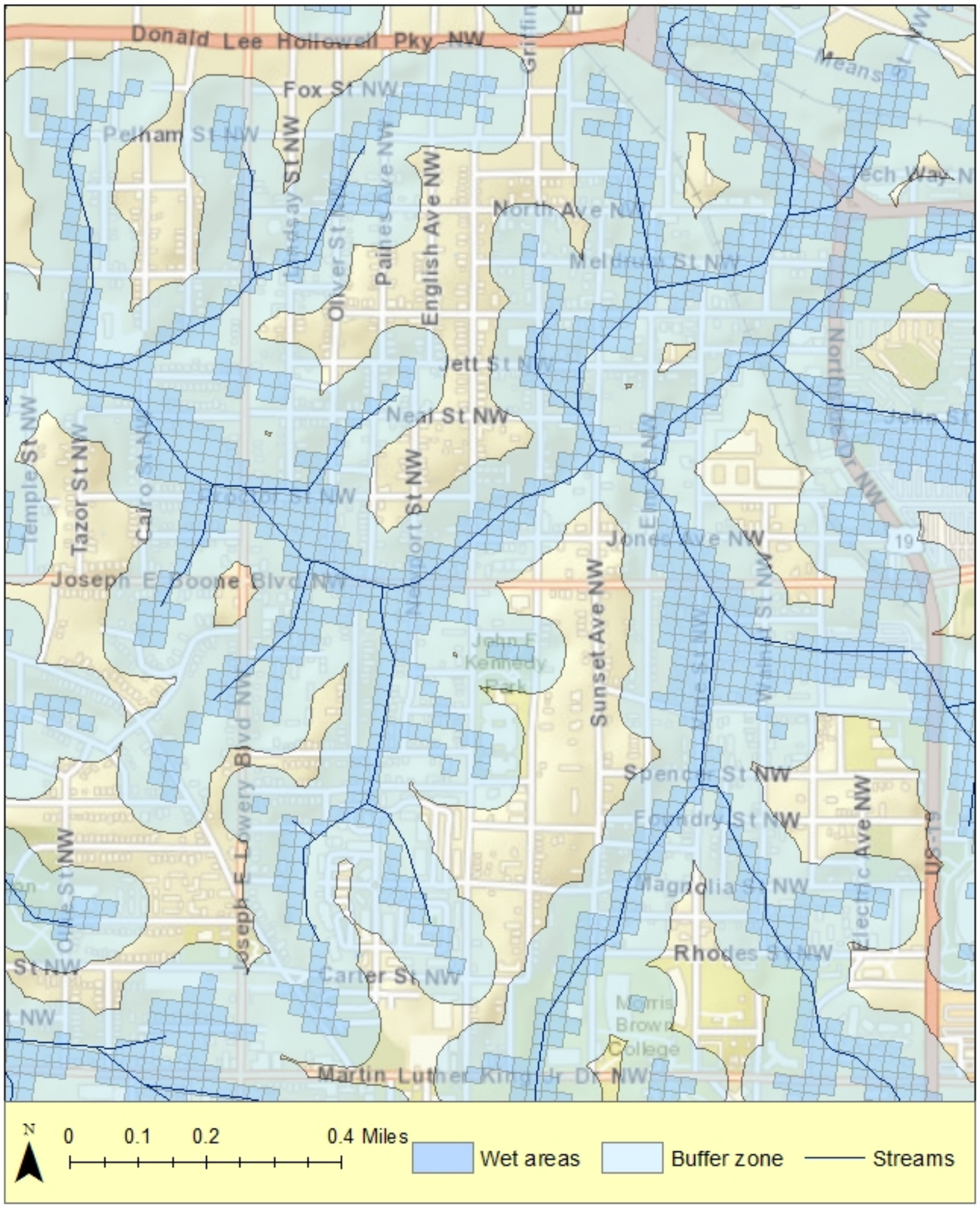

Figure 2. Hypothesized causal pathway between wetness index and asthma

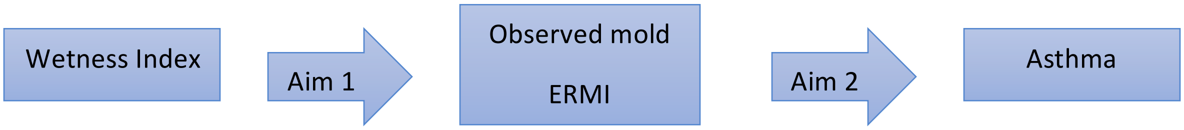

Figure 3. Frequencies of survey response and reasons for nonresponse

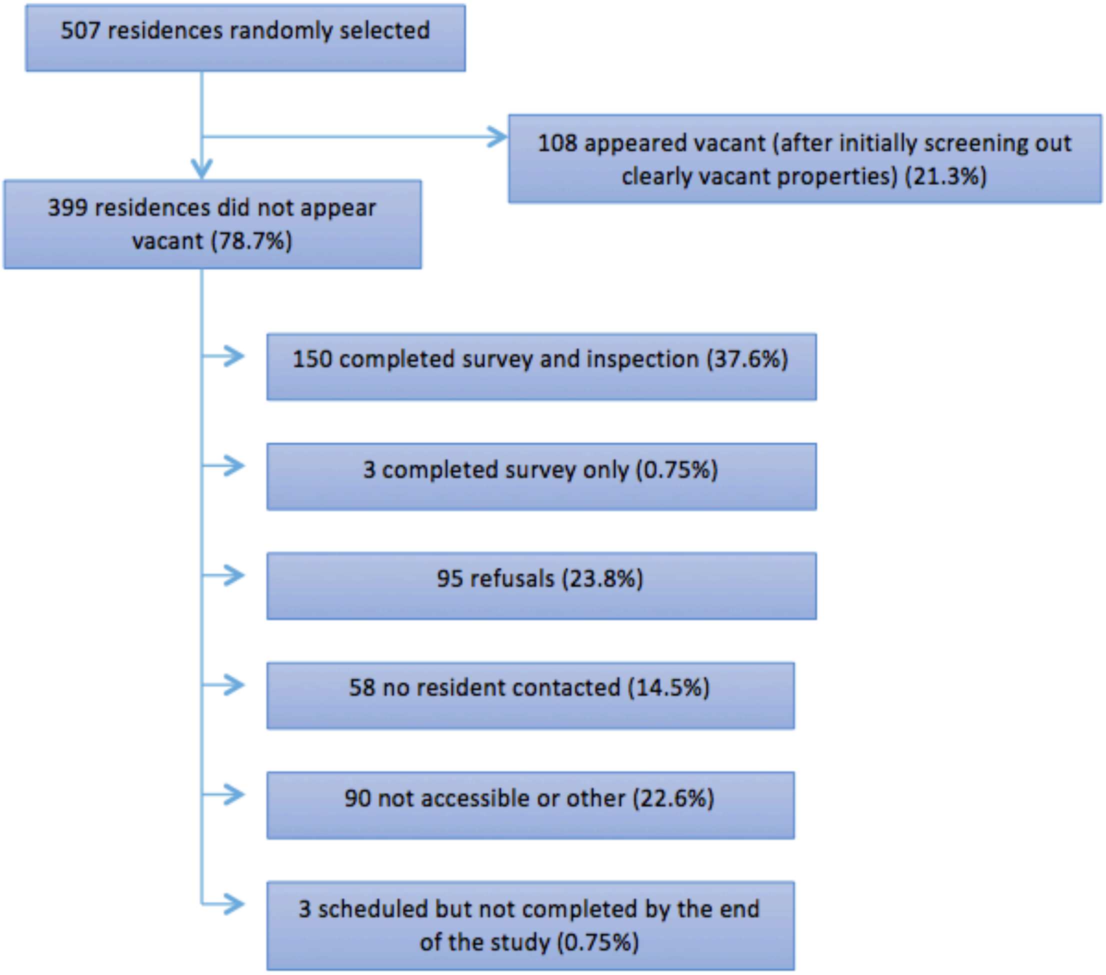

Figure 4. Distribution of ERMI values

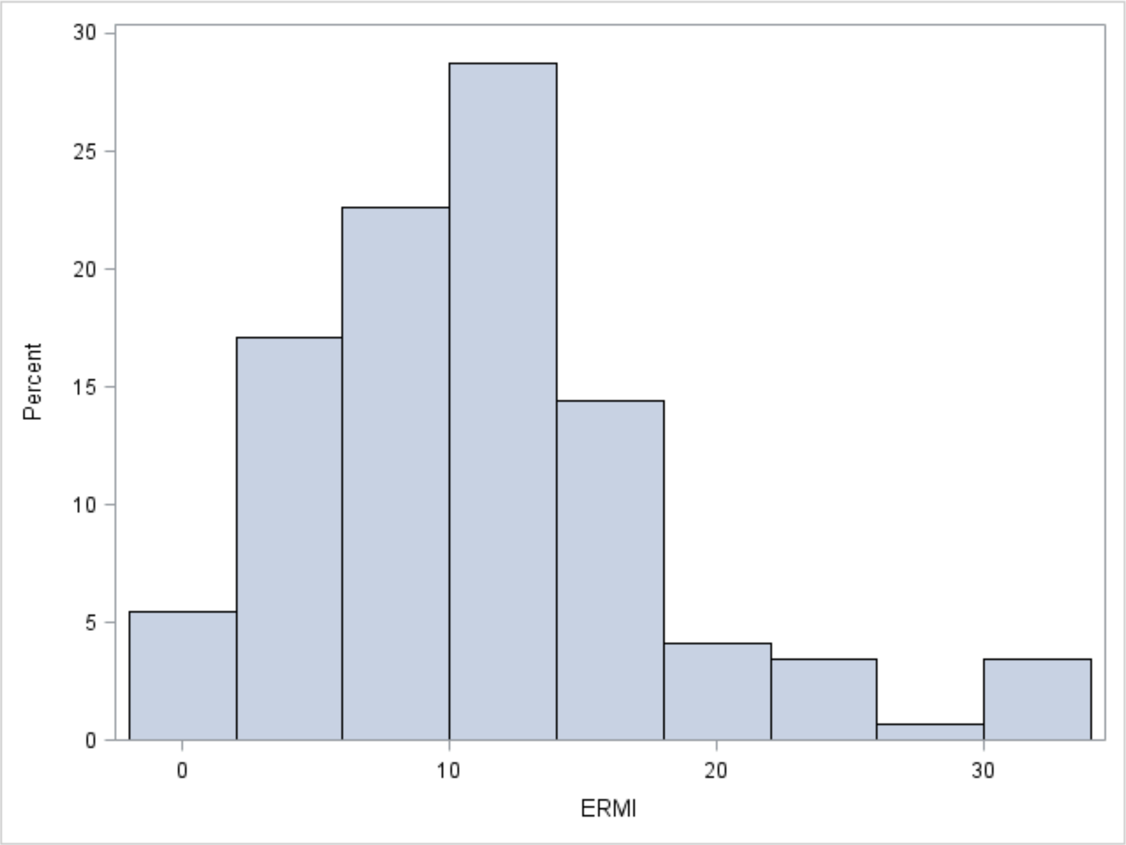

Table 1: Characteristics of survey respondents and their residences

		Number	Percentage
Demographics	Gender (N=153)		
	Female	89	58%
	Male	64	42%
	Renter/Owner (N=149)		
	Rent	113	76%
	Own	36	24%
	Age (N=152)	Median: 47	Range: 21-88
Residence characteristics	Location of residence (N=153)		
	Wet area	52	34%
	Dry area (buffer zone)	101	66%
	Type of residence (N=153)		
	Individual house	81	53%
	Basement	24	30%
	No basement	55	68%
	Unknown basement status	2	2%
	Apartment/Condo	54	35%
	Duplex	5	3%
	Townhouse	13	8%
	Duration at residence (yrs) (N=153)	Median: 2.5	Range: <1-84
	Number of people in residence (N=153)	Median: 2	Range: 1-12
Environmental characteristics in residence	Observed mold*(N=150)		
	Yes	53	35%
	No	97	65%
	Leaks (N=153)		
	Reported leaks	71	46%
	No reported leaks	82	54%
	Reported flooding (N=153)		
	Reported flooding	19	12%
	No reported flooding	130	85%
	Flooding prior to participant living in current residence	4	3%
	Mice (N=153)		
	Reported mice	15	10%
	No reported mice	138	90%
	Cockroaches (N=153)		
	Reported cockroaches	51	33%

	No reported cockroaches	102	67%
	Pets (N=153)		
	Reported pets	49	32%
	No reported pets	104	68%
	Smoking (N=153)		
	Smoking inside residence	59	39%
	No smoking inside	94	61%
	Air conditioning use (N=152)		
	Use AC on most days during the summer	98	64%
	No AC use on most days during the summer	54	36%
	ERMI values (N=146)	Median: 10.9	Range: -1.9-32
Reported health characteristics	Current asthma (N=152)		
	Yes	22	14%
	No	130	86%

*Observed mold excludes mold observed only in the bathroom around caulk or on the shower curtain.

Table 2. Stratified odds ratios, comparing the odds of observed mold for homes in wet areas to that for homes not in wet areas, by levels of variables considered for inclusion in the models for aim 1

Crude OR:0.4171	Stratified OR	Number of people	P-value for heterogeneity	Summary adjusted OR	95% CIs for adjusted OR	
Use AC	0.39	97	0.797	0.41	0.19	0.89
No AC	0.48	52				
House with basement	1.56	22	0.147	0.43	0.20	0.93
No basement*	0.33	128				
Rent	0.41	112	0.956	0.41	0.19	0.89
Own	0.43	34				
Reported leaks	0.41	70	0.835	0.44	0.20	0.96
No reported leaks	0.48	80				
≤ 2 people	0.38	77	0.803	0.41	0.19	0.89
>2 people	0.46	73				
≤ 2 years	0.31	74	0.672	0.39	0.18	0.85
>2 years	0.44	76				

*this includes all other types of residences (i.e. apartments, townhouses, duplexes), and houses that were not known to have basements

Table 3. Results of logistic regression models examining the association between the location of the residence in a wet area and observed mold

	Unstratified model				Residences without basements 127 observations				Residences with basements 22 observations			
	Odds Ratio	95% Confidence Intervals		P-value	Odds Ratio	95% Confidence Intervals		P-value	Odds Ratio	95% Confidence Intervals		P-value
Wet	0.44	0.19	1.00	0.050	0.35	0.14	0.88	0.026	2.00	0.20	20.07	0.558
Reported Leaks (yes vs. no)	2.98	1.42	6.27	0.004	2.78	1.23	6.26	0.014	5.45	0.63	47.35	0.124
Residence Duration (per 1 year increase)	1.01	0.99	1.04	0.356	1.02	0.99	1.06	0.243	0.99	0.93	1.06	0.814
Number of people (per increase of 1 person)	0.86	0.70	1.07	0.169	0.96	0.75	1.24	0.755	0.62	0.36	1.09	0.098
AC use (compares residences without AC use to those with AC)	1.00	0.46	2.15	1.000	1.00	0.42	2.38	0.994	1.16	0.12	11.15	0.901
Basement (yes vs. no)	3.25	1.15	9.21	0.026	–	–	–	–	–	–	–	–

Table 4. Results of linear regression models examining the association between the location of the residence in a wet area and ERMI values

	Unstratified model			Residences without basements 122 observations			Residences with basements 23 observations		
	Parameter estimate	Standard Error	P-value	Parameter estimate	Standard Error	P-value	Parameter estimate	Standard Error	P-value
Wet	-1.908	1.163	0.103	-2.888	1.268	0.025	4.846	2.980	0.122
Reported Leaks (yes vs. no)	2.877	1.08	0.009	2.561	1.197	0.034	5.357	2.535	0.050
Residence Duration (per 1 year increase)	-0.035	0.04	0.386	-0.028	0.05	0.575	-0.024	0.073	0.748
Number of people (per increase of 1 person)	-0.029	0.30	0.923	-0.082	0.376	0.829	-0.003	0.479	0.995
AC use (compares residences without AC use to those with AC)	3.446	1.139	0.003	3.418	1.292	0.009	3.612	2.575	0.179
Basement (yes vs. no)	0.683	1.499	0.649	–	–	–	–	–	–

Table 5. Stratified odds ratios comparing the odds of self-reported current asthma among residents of homes with observed mold to that among residents of homes without observed mold, by levels of variables considered for inclusion in the models for aim 2

Crude OR: 0.8217	Stratified OR	Number of people	P-value for heterogeneity	Summary adjusted OR	95% CIs for adjusted OR	
Smoke inside	0.65	56	0.787	0.74	0.28	1.98
No smoke inside	0.86	93				
Has mice	2.00	15	0.447	0.79	0.29	2.11
No mice	0.67	134				
Has cockroaches	0.53	50	0.505	0.77	0.29	2.04
No cockroaches	1.03	99				
Has pets	0.42	48	0.341	0.83	0.32	2.16
No pets	1.15	101				
Use AC	1.09	97	0.416	0.81	0.31	2.12
No AC	0.46	51				
≤ 2 people	0.79	77	0.926	0.82	0.31	2.17
>2 people	0.87	72				
≤ 2 years	1.46	73	0.326	0.92	0.35	2.43
>2 years	0.55	76				

Table 6. Results of logistic regression models examining the association between observed mold and current asthma

	Unstratified model				Duration of residence: ≤ 2 years; 73 observations				Duration of residence: >2 years; 76 observations			
	Odds Ratio	95% Confidence Intervals		P-value	Odds Ratio	95% Confidence Intervals		P-value	Odds Ratio	95% Confidence Intervals		P-value
Observed mold	0.82	0.30	2.26	0.699	1.18	0.30	4.68	0.811	0.59	0.13	2.64	0.494
Any smoking inside residence	1.81	0.71	4.60	0.213	3.80	1.04	13.98	0.044	0.61	0.11	3.25	0.559
Residence Duration (per 1 year increase)	1.46	0.56	3.80	0.435	–	–	–	–	–	–	–	–

Table 7. Results of logistic regression models examining the association between ERMI values and current asthma

	Unstratified model				Duration of residence: ≤ 2 years; 70 observations				Duration of residence: >2 years; 76 observations			
	Odds Ratio	95% Confidence Intervals		P-value	Odds Ratio	95% Confidence Intervals		P-value	Odds Ratio	95% Confidence Intervals		P-value
ERMI	1.05	0.98	1.13	0.135	1.12	1.01	1.25	0.036	1.01	0.92	1.12	0.788
Any smoking inside residence	1.67	0.64	4.32	0.293	5.11	1.16	22.57	0.031	0.49	0.09	2.64	0.403
Residence Duration (per 1 year increase)	1.46	0.57	3.77	0.434	–	–	–	–	–	–	–	–