CALIFORNIA INSTITUTE FOR RURAL STUDIES

MOLD AND ASTHMA: A LOOK AT CO-OCCURRENCE IN TWO RURAL COMMUNITIES IN CALIFORNIA

ENVIRONMENTAL JUSTICE AND HOUSING

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Abstract

In many previous studies, indoor-mold contamination is associated with an increased risk of asthma and respiratory illness. This study sampled indoor-mold contamination and measured the prevalence of asthma/respiratory illness in two low-income, Latin@ communities, Mecca and Coachella, in the Eastern Coachella Valley (ECV) of California. The study consisted of a random household health survey that included questions designed to assess asthma/respiratory illness coupled with an environmental assessment that measured mold contamination in house-dust samples using the Environmental Relative Moldiness Index (ERMI) scale. Our data show about 11% of adults and 17% of children in both Mecca and Coachella suffer from asthma/respiratory illness. The average ERMI values in Mecca and Coachella housing (10.3 and 6.0, respectively) are in the top 25% of ERMI values for United States (US) homes. Overall, the homes surveyed in these California communities had an average prevalence of occupant asthma of 12.8% and an average ERMI value of 9.0. The prevalence of asthma/respiratory illness in the Latin@ communities of Mecca and Coachella and the mold contamination in their homes appear to be greater than the averages for the rest of the US. The higher levels of mold contamination in their homes appears to be associated with a greater risk of asthma/respiratory illness for these low-income, Latin@ communities.

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Introduction

Between 1980 and 1995 the prevalence of asthma in the US nearly doubled. , The increase continued more gradually between 2001 and 2010 and, for most demographic groups, the incidence of asthma seems to have leveled off or declined slightly. However, there is one group of US residents in which the prevalence of asthma continues to rise significantly: the poor, defined as those with a family income below the Federal Poverty Level (Akinbami, Simon, & Rossen, 2016).

There are large populations of people living in poverty in rural areas of California. These rural poor are frequently Latin@, primarily Mexican; often agricultural workers living with their families (Schwartz, von Glascoe, Torres, Ramos, & Soria-Delgado, 2015). Whereas in Mexico, the prevalence of asthma in children is low (Hunninghake, Weiss, & Celedón, 2006), if Mexican children move to the US, their asthma risk increases significantly (Barr, et al., 2016). Jerschow et al. found that among foreign-born Mexicans, rates of asthma were greater after relocation to the US versus before relocation (adjusted hazard ratio 2.90 for after versus before relocation) (Jerschow, Strizich, & Xue, 2017). In a study of asthma among Spanish speaking children living on both sides of the Arizona-Mexico border, the adjusted odds ratio (OR) for asthma was significantly higher (OR=4.89) in the US Hispanic children when compared to their counterparts in Mexico (Carr, et al., 2017).

FIGURE 1 INDEX LOCATION MAP SHOWING ECV REGION IN RIVERSIDE COUNTY

In 2015, the California Institute for Rural Studies (CIRS), funded by The California Endowment, launched a comprehensive regional health and housing survey of five communities in the Eastern Coachella Valley, a primarily Latin@ region of low-wage workers. This study included the communities of Mecca and Coachella from which the health data shared in this paper originated. As part of the housing and health study, Loma Linda University (LLU) partnered with CIRS in

the design of the survey instrument and the sampling frame and launched an independent project to study mold within housing in these two communities.

It has been known for many years that exposure to mold in damp buildings increases the risk of asthma and respiratory illness (Institute of Medicine of the National Academies, 2004) (World Health Organization , 2009). However, accurate quantification of mold exposure has been limited by traditional methods used to quantify these exposures such as short duration air samples that are counted or cultured (Vesper S. , Traditional mould analysis compared to a DNA-based method of mould analysis, 2011). The US EPA, and the US Department of Housing and Urban Development (HUD), developed an alternative method: the Environmental Relative Moldiness Index (ERMI) scale (Vesper, McKinstry, Haugland, & al., 2007). Samples of dust are collected using surface sampling and then a panel of 36 indicator-molds is quantified from the dust collected using DNA-based assays (Vesper, McKinstry, Haugland, & al., 2007). The ERMI scale ranges from -10 as the lowest mold contamination to 30 as the highest mold contamination. The ERMI methodology has been used in six previous epidemiological studies of asthma and higher ERMI values were consistently associated with asthma development and/or exacerbation (Vesper & Wymer, The relationship between environmental relative moldiness index values and asthma, 2016) (Reponen, Vesper, Levin, & al, 2011).

- The first goal of this research was to try to obtain an accurate estimate of asthma/respiratory illness for both adults and children based on the California Institute for Rural Studies survey, using multiple questions to make the assessment.
- The second goal was to examine the level of mold contamination in various types of housing in these communities, as defined by their ERMI values, and determine the relationship between the ERMI values and the prevalence of asthma/respiratory illness.

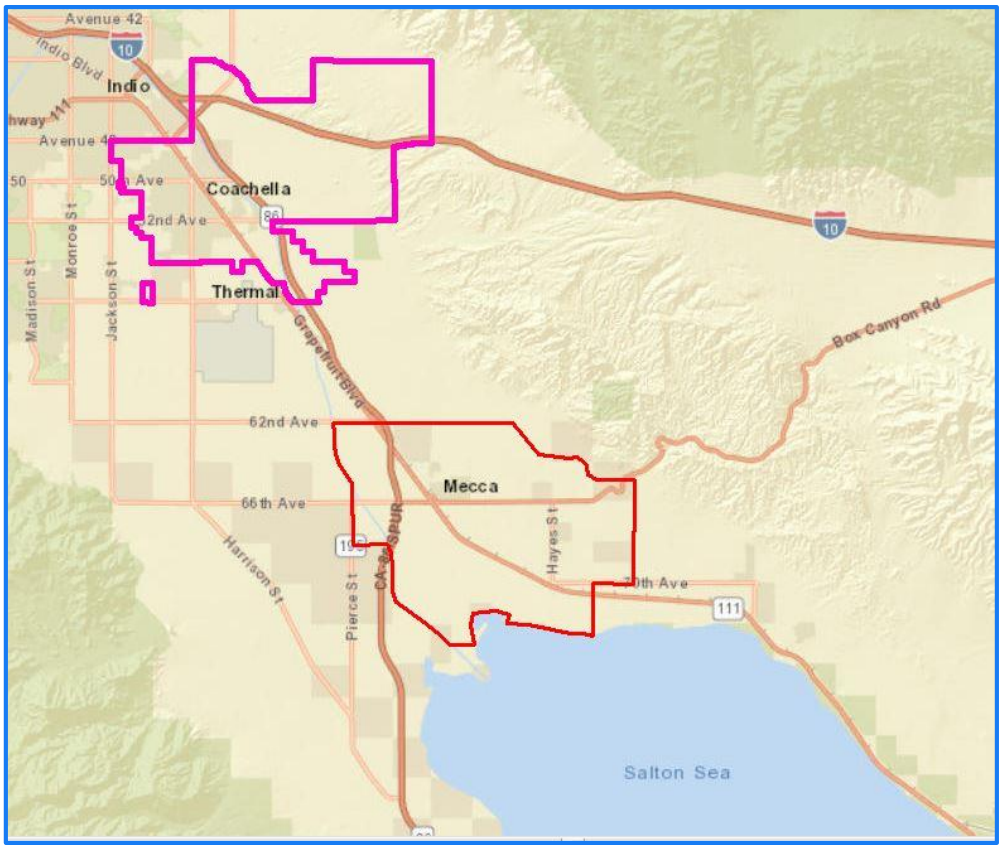

FIGURE 2 STUDY AREA

Material and Methods

The study was conducted in accordance with the ethical principles set forth in the Declaration of Helsinki of the World Medical Association, and the protocol was approved by the Loma Linda University Institutional Review Board (IRB #5140048). The Loma Linda University IRB is registered with the U.S. Office for Human Subject Research Protection (IRB#0000383).

Types of housing

Since this was a study on housing and health, to determine if housing had any health impacts, residences in the communities were divided into four types: apartments, modern tract homes, mobile homes, and mixed-use neighborhoods. An apartment was defined as a structure with multiple families in individual units. A modern home was defined as a single-family home built after 1990 (as determined from city development records). A mobile home was defined as a potentially mobile structure that sits upon two axels and jack stands that are hidden from view using foundation panels. A residence in a mixed-use neighborhood could be any type of housing but included areas where other informal housing units were built within the primary household's parcel

boundaries, including rental rooms in out-buildings. To be sure that informal housing was included in our study, we segregated neighborhoods or sections of communities that had clearly mixed types of housing to create this stratum.

Study design -- Sampling

Farmworker families comprise a large proportion of the communities of Coachella and Mecca, communities that have historically been dependent on agriculture. The vast majority of these families come from Mexico. Many issues lead to farmworker families being underrepresented in surveys and in the US Census. Rural locations are often remote and families may live in informal housing that is off the grid with no recognized street address. Even in the communities of Coachella and Mecca which are clearly delimited census designated places, there are scores of accessory housing units that go undetected from the street, that do not have unique addresses and that may or may not have phones. Latin@ households with some undocumented residents may be unwilling or afraid to answer questions or may refuse to answer the door.

This study addressed those factors by using extensive on-the-ground observation and household enumeration (Mines, Ward, & Schenker, 2007)prior to sampling for the in-person surveys. In addition, surveys were administered by trusted community members who work in the community as volunteer health educators.

To identify the "universe of residences", the study team reviewed satellite images to define groups of dwellings – the sampling strata -- and the geographic limits of these strata. The strata sampled were: mobile homes, apartments, modern tract homes and "mixed use" neighborhoods. Once the strata were identified, they were divided into blocks and blocks for sampling were selected randomly from each stratum. Once this was completed, the residences within each sampling block were enumerated.

Researchers ground truthed the blocks selected to be sure the residences selected were, in fact, in use as homes. The field research team walked the limits of the blocks to both validate the locations of the households and correct any incorrect or missing addresses within the sampling frame.

From this enumeration and on the ground validation process, a total list of residences in each block was created and a sampling interval determined. that would yield approximately 350 individual interviews per community. Once the interval was decided upon, a random start was taken and residences were sampled at the determined intervals to be certain to obtain the number of interviews needed for the study.

The survey administrator then gave teams of trained local community health promotoras[1] lists of pre-selected addresses that were chosen using the methods described above. No dwelling substitutions were allowed and surveyors validated the house location through visits from the survey supervisor and a GIS device used during the time of the survey. This resulted in randomly selected households in the communities of Mecca (n=342) and Coachella (n=353) (Figure 2).

Study Design – Survey Instrument

The asthma section of the California Institute for Rural Studies questionnaire was adapted from previous (validated) Spanish language farmworker assessments, standard health surveys and validated again using external consultants and internal stakeholders. The questions related to asthma diagnosis, treatment and symptoms were used to establish the prevalence of asthma/respiratory illness in the communities. Adults who answered "yes" to any of the five-following questions were categorized as positive for asthma/respiratory illness.

1- Have you ever been diagnosed with asthma?
2- Are you currently being treated for asthma?
3- Have you had an asthma attack severe enough to limit activity?
4- Are you currently taking asthma medication?
5- Do you have daily, weekly or severe cough?

If the parent or guardian of a child within the household answered "yes" to any of the four-following questions, that child was categorized as positive for asthma/respiratory illness.

1- Has your child ever been diagnoses with asthma?
2- Are you able to obtain asthma medication for your child?
3- For the child with asthma, have you ever had to take the child to the emergency room for their asthma?
4- Does your child have a persistent cough?

Dust sampling and analysis

A subset of homes from the survey sample was sampled for mold analysis with permission from the occupant. From this subset, Mecca (n=50) and Coachella (n=61), a dust sample was collected by wiping the tops of doorways, bookshelves, and other above floor surfaces using a SwifferTM Sweeper cloth (P&G, Cincinnati, OH) (Vesper, et al., 2015). The environmental sampling team member collecting the dust sample wore a disposable glove to avoid contaminating the sample. After collection of the dust sample, the cloth was

[1] Promotoras are trained health volunteers from the community.

placed in a zippered plastic bag and labeled with a unique study number. Samples were kept at room temperature until returned to the lab, where the samples were frozen at -20^{o}C until analyzed.

Each dust sample was sieved (300 µm pore size) and five mg of each sieved dust sample was extracted to recover the mold DNA, which was then purified using the DNA-EZ kit (GeneRite, Monmouth Junction, NJ). Each of the 36 ERMI molds was quantified by mold specific quantitative PCR (MSQPCR) assays (R. A. Haugland, 2004).

The ERMI metric classifies 36 indicator mold species into two groups. Group 1 includes the 26 species indicating water damage, and Group 2 consists of ten species commonly found in homes across the US, that primarily come from outside the home (Vesper S. , Traditional mould analysis compared to a DNA-based method of mould analysis, 2011). The ERMI calculation takes the results from the concentrations (cell equivalents/mg dust) of each of all the molds collected and mathematically converts these into a single number.

The concentration of each of the 26 Group 1 molds is converted to a log and then the sum of the logs of the Group 1 (s1i) molds is determined. Similarly, the concentration of each of the ten Group 2 molds is converted to a log and then the sum of the logs of the Group 2 (s2j) molds is determined. The arithmetic difference, s1i - s2j, is the ERMI value for the home (Vesper, McKinstry, Haugland, & al., 2007). The larger the ERMI value the greater the mold contamination.

Statistical analysis

Before analysis, all data was coded to remove identifying information including addresses and names.

The statistical difference between the average ERMI values in Mecca and Coachella was evaluated using a Student T-test. The statistical analysis of the differences in concentrations of 36 individual mold species in Mecca and Coachella homes were evaluated with the Mann-Whitney rank sum test. These differences were then corrected for multiple comparisons using the Holms–Bonferroni test. All analyses were performed in SAS version 9.3 (SAS Institute, Cary NC) or R version 2.14 (R Foundation for Statistical Computing, Vienna, Austria).

Results

The respondents' answers to the questions about national identity, gender and occupation are summarized in Table 1. Both communities are 98% Latin@. Clearly more residents of Mecca work in agriculture than do those in Coachella with 40% of both males and females in Mecca in this occupation and 22% of both male and female residents of Coachella involved in agriculture. About 85% of the families reported yearly income less than $20K/year as seen in Figure 1. Compared to the State of California where 14.3 % of residents made less than $24,000 a year (Public Policy Institute of California, 2017), this is stunningly high.

TABLE 1 NATIONAL IDENTITY, GENDER AND OCCUPATION

		Mecca	Coachella
National Identity		**Percentage**	**Percentage**
	Latin@	98	98
	Other	2	2
Gender			
	Male Adult	48	46
	Female Adult	52	54
Occupation			
Male			
	Agriculture	41	24
	Other	33	45
	None listed	26	31
Female			
	Agriculture	39	20
	Other	26	42
	None listed	35	37

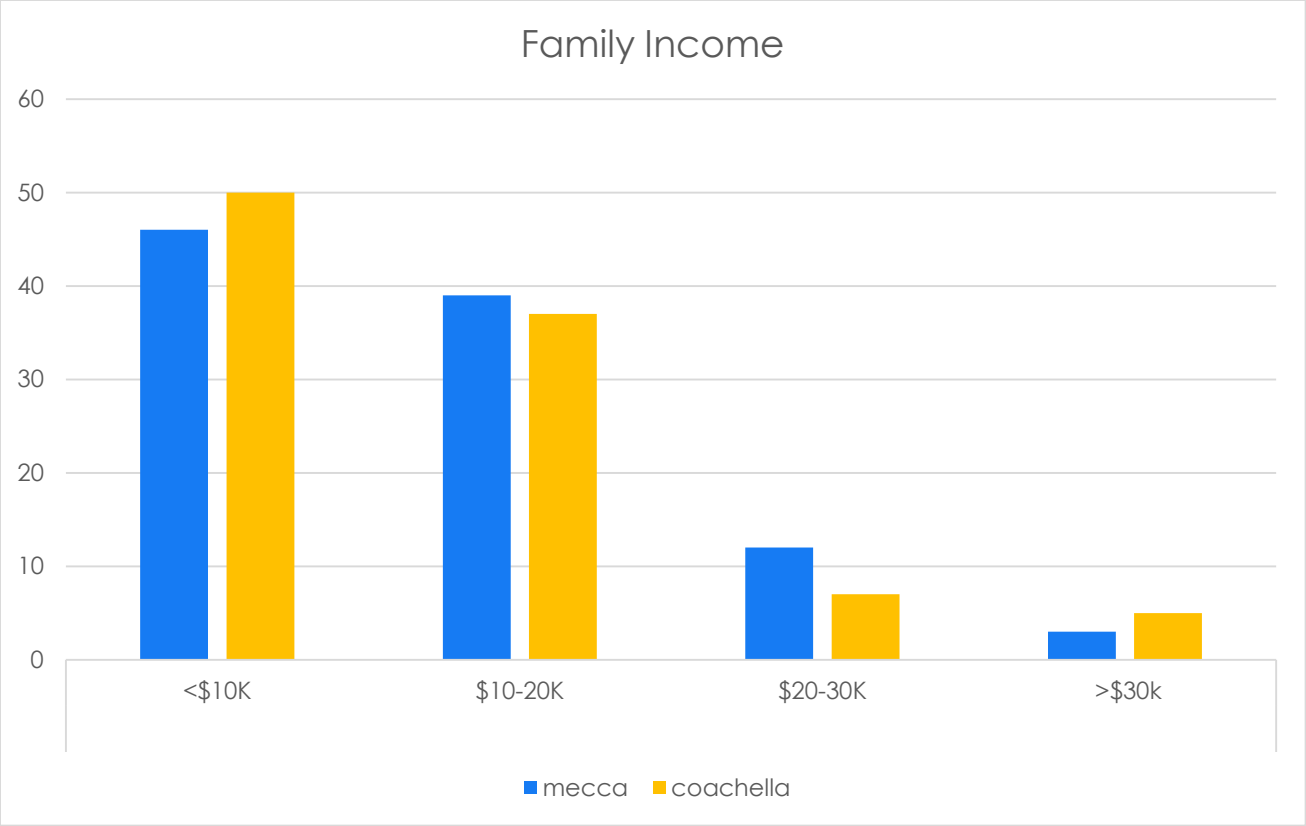

FIGURE 3 FAMILY INCOME IN MECCA AND COACHELLA BY %

The percentage of adults and children that met our definition of asthma/respiratory illness in the ECV communities was 11% and 17.5%, respectively (Table 2). The overall prevalence of asthma/respiratory illness was highest for children living in mixed-use neighborhoods in both Mecca (32.3%) and Coachella (40%) (Table 2). Adults living in mobile homes in Mecca had the highest percentage of asthma/respiratory illness in that community. While adults living in mixed-use neighborhoods in Coachella had the highest percentage of asthma/respiratory illness in that community (Table 2).

TABLE 2 CHILDREN AND ADULTS BY % WITH ASTHMA/RESPIRATORY ILLNESS AND WHERE THEY LIVE

	Mecca			
	children		adults	
	Asthma %	Population %	Asthma %	Population %
Apartment	18.3	54	13.1	31
Modern Tract	17.9	12	5.4	27
Mobile Home	6.1	21	14.5	22
Mixed Use	32.3	13	12.1	20
All	**17.5**		**11.1**	
	Coachella			
Apartment	19	21	8.8	26
Modern Tract	17.7	46	12.7	47
Mobile Home	13.2	29	9	25
Mixed Use	40	4	42.9	2
All	**17.5**		**11.3**	

The average ERMI value in all Mecca housing (10.3) was significantly greater than the average ERMI value in all Coachella housing (6.0) (Table 3). Mobile homes and mixed-use neighborhoods in Mecca had average ERMI values nearly twice as high as values in apartments or modern homes in Mecca (Table 3). In Coachella, all four types of housing had similar average ERMI values.

TABLE 3 ERMI VALUES BY COMMUNITY AND HOUSING TYPE

	Mecca		Coachella		
	n	ERMI	n	ERMI	P value
Apartment	16	7.1	17	4.9	
Modern Tract	18	7.8	22	6.1	
Mobile Home	7	17.2	18	7	
Mixed Use	10	15.3	3	5.9	
Total	51		60		
WAEV		**10.3**		**6**	**<0.05**

The prevalence of asthma/respiratory illness for all occupants (both adults and children together) was compared to the combined average ERMI values for Mecca and Coachella (Table 4). Housing in mixed-use neighborhoods had the highest percentage of occupants with asthma/respiratory illness (17.4%) and the highest average ERMI values (13.2) while apartments had the lowest percentage of occupants with asthma/respiratory illness (9.3%) and the lowest average ERMI value (5.9).

Overall, the homes surveyed in the ECV communities of Mecca and Coachella had an average prevalence of occupant asthma of 12.8% and an average ERMI value of 9.0 (Table 4).

TABLE 4 PREVALENCE OF ASTHMA COMPARED TO ERMI VALUES, BOTH COMMUNITIES

	Total	Average
	% illness	ERMI
Apartment	9.3	5.9
Modern Tract	13	6.9
Mobile Home	11.2	9.8
Mixed use	**17.4**	**13.2**
Average	**12.8**	**9**

The populations of the 36 ERMI molds were compared in Mecca vs. Coachella housing to determine if there were any significant differences (Table 5). The populations of four of the Group 1 molds (Aspergillus ocharceus, A. sydowii, A. versicolor, and Stachybotrys chartarum) occurred in significantly greater numbers in Mecca samples compared to Coachella. None of the populations of Group 2 molds were significantly different in Mecca and Coachella housing.

TABLE 5 COMPARISON OF 36 ERMI MOLDS BY COMMUNITY

	Mecca	Coachella	
	AVG CE/mg dust	AVG CE/mg dust	Wilcoxon p-value*
Group 1 molds			
Aspergillus flavus	1221	29	0.55
Aspergillus fumigatus	361	36	0.57
Aspergillus niger	1668	964	0.005
Aspergillus ochraceus	**229**	**12**	**<0.001**
Aspergillus penicillioides	44	25	0.18
Aspergillus restrictus	3	2	0.42
Aspergillus sclerotiorum	0	0	0.38
Aspergillus sydowii	**22027**	**20**	**<0.001**
Aspergillus unguis	555	10	0.19
Aspergillus versicolor	**748**	**8**	**<0.001**
Aureobasidium pullulans	126	133	0.72
Chaetomium globosum	4	2	0.96
Cladosporium sphaerospermum	113	26	0.47
Eurotium amstelodami	2347	187	0.001
Paecilomyces variotii	74	15	0.002
Penicillium brevicompactum	11	9	0.11

Penicillium corylophilum	17	165	0.92
Penicillium crustosum	154	7	0.13
Penicillium purpurogenum	5	6	0.92
Penicillium spinulosum	0	0	0.92
Penicillium variabile	17	7	0.85
Scopulariopsis brevicaulis	279	3	0.11
Scopulariopsis chartarum	193	9	0.11
Stachybotrys chartarum	**123**	**4**	**<0.001**
Trichoderma viride	0	5	0.9
Wallemia sebi	90	55	0.02
Group 2 molds			
Acremonium strictum	1	1	0.9
Alternaria alternata	2576	79	0.009
Aspergillus ustus	1719	6	0.24
Cladosporium cladosporioides 1	82	98	0.94
Cladosporium cladosporioides 2	123	60	0.52
Cladosporium herbarum	155	209	0.16
Epicoccum nigrum	85	115	0.46
Mucor group	48	22	0.12
Penicillium chrysogenum 2	6057	25	0.11
Rhizopus stolonifer	71	22	0.26

Discussion

Based on National Health Interview Survey (NHIS) questions[2], the Centers for Disease Control and Prevention reported the prevalence of asthma for the US as a whole was 7.6% for adults and 8.4% for children. It is difficult to make an accurate assessment of asthma prevalence in the Eastern Coachella Valley, since many residents do not have access to medical care. Our estimate of asthma/respiratory illness in each community separately was11% for adults and 17.5% for children based on the answers to a suite of questions in our randomized survey.

The overall estimate of asthma/respiratory illness for adults and children combined in these ECV communities was 12.8% (Table 4). These results are similar to the Health Assessment and Research for Communities' (HARC) 2016 data for adults but higher than their estimate for children, which reported 10.9%

[2] For adults, "Have you ever been told by a doctor or other health professional that you had asthma?" and "Do you still have asthma?"; and for children, "Has a doctor or other professional ever told you that [sample child] had asthma?" and "Does [sample child] still have asthma?" [18].

(33,368) of Coachella Valley adults, and 13.7% (13,536) of Coachella Valley children as having asthma[3].

The average ERMI values for the four types of homes in the Eastern Coachella Valley (n=111) ranged from 5.9 to 13.2 with an overall average of 9.0 (Table 4). In the broader context, the homes (n=17) randomly selected from Riverside County during the 2006 HUD American Healthy Homes Survey had an average ERMI value of 1.97 (Vesper, McKinstry, Haugland, & al., 2007). This suggests that mold contamination was much greater in housing in the Eastern Coachella Valley when compared to housing in Riverside County generally.

There are a several likely sources of water-damage in ECV housing that could lead to mold growth, although the specific sources of moisture in homes were not determined in this study.

- A plausible and possible source of moisture in ECV housing is swamp coolers. These evaporative devices are effective in desert regions such as the ECV where they are common. Evaporative cooling by swamp coolers works by bringing humidified air into the home. If swamp coolers are not well maintained, they can lead to excess moisture and mold growth.
- Plumbing leaks can occur in any type of housing but older homes, such as those that are found in mixed-use neighborhoods, are more likely to experience these.
- Precipitation may account for some moisture, with intense rain events occurring annually. Home maintenance and repair are critical to preventing mold growth from rain and in older dwellings this can be a challenge for residents living in poverty.

Health organizations worldwide have reported links between water-damage and indoor-mold contamination and asthma or poor respiratory health (Institute of Medicine of the National Academies, 2004) (World Health Organization , 2009). In six previous epidemiological studies, homes with higher ERMI values were associated with occupant asthma (Vesper & Wymer, The relationship between environmental relative moldiness index values and asthma, 2016).

In one prospective epidemiological study with pregnant women, home environments and children's health were monitored for seven years, until a physician could make a diagnosis of asthma. Settled-dust collected in each home was analyzed for mold contamination based on its ERMI value. Infants living in homes with high ERMI values --i.e., in the top 25% of US homes (ERMI >5.2) -- had more than twice the risk of developing asthma than those in lower

[3] May 1, 2018 press release. http://harcdata.org/press-releases/

ERMI value homes (Reponen, Vesper, Levin, & al, 2011). Three molds were associated with asthma development in this study (T. Reponen, 2012), one of which was *Aspergillus ochraceus*. This mold was found in high concentrations in Mecca housing where asthma prevalence in children reached 32%. While these results do not prove that mold causes asthma, the mold contamination, measured as ERMI values, appears to be correlated with housing conditions related to asthma.

There are limitations to this study. Because of a lack of affordable housing and low incomes, people living in the same home may not be related. As a result, we were unable to consider atopy[4] as an important confounder in the analysis.

It was impossible to obtain a definitive diagnosis of asthma based on a physician's evaluation of each adult or child. Our health data are self-reported. Self-reported health outcomes are frequently unreliable. To help alleviate error, we chose to ask a series of multiple redundant questions to assess asthma occurrence from different angles. For adults, we asked whether the adult had ever been diagnosed with asthma but we also asked about current symptoms and asthma medications. Similarly, with data on children where many of the children in these households have never seen a physician, questions were designed for redundancy.

Other potential exposures inside and outside the home were not quantified. Also, a relatively small number of each of the housing types was tested. Despite the acknowledged limitations, results from this study provide evidence that conditions in Mecca and Coachella homes are conducive to an increased risk of asthma/respiratory illness and emphasize the need to improve the environmental conditions in area homes (Gold, et al., 2017).

Conclusions

Housing in the Eastern Coachella Valley communities of Coachella and Mecca had ERMI values that placed them in the top 25% of homes in the US. Results from self-reported health outcomes related to asthma show that the prevalence of asthma in the communities of Mecca and Coachella is much higher than for the US generally. Prevalence of asthma in the US as a whole was 7.6% for adults and 8.4% for children. The overall prevalence of asthma/respiratory illness for children living in mixed-use neighborhoods was 32.3% in Mecca and 40% in Coachella. Prevalence of asthma/respiratory illness for adults living in mobile homes in Mecca was 14.5%, double the national levels, and adults living in

[4] Atopy -- "The genetic tendency to develop allergic diseases." MedicineNet Definition

mixed-use housing in Coachella was 42.9%, more than five times the national levels! The average ERMI values in Mecca and Coachella housing (10.3 and 6.0, respectively) are in the top 25% of ERMI values for US homes.

THE U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA) THROUGH ITS OFFICE OF RESEARCH AND DEVELOPMENT COLLABORATED IN THE RESEARCH DESCRIBED HERE. IT HAS BEEN SUBJECTED TO THE AGENCY'S PEER REVIEW AND HAS BEEN APPROVED AS AN EPA PUBLICATION. MENTION OF TRADE NAMES OR COMMERCIAL PRODUCTS DOES NOT CONSTITUTE ENDORSEMENT OR RECOMMENDATION BY THE EPA FOR USE. THE FINDINGS AND THE CONCLUSIONS IN THIS REPORT ARE THOSE OF THE AUTHORS AND DO NOT NECESSARILY REPRESENT THE VIEWS OF THE US EPA. MSQPCR IS A U.S. EPA PATENTED TECHNOLOGY AND ITS COMMERCIAL APPLICATION CAN PROVIDE ROYALTIES TO THE US EPA.

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