

Pilot study of mold populations inside and outside of Puerto Rican residences

B. Bolaños-Rosero · D. Betancourt · T. Dean ·
S. Vesper

Received: 12 March 2013 / Accepted: 29 April 2013 / Published online: 10 May 2013
© Springer Science+Business Media Dordrecht 2013

Abstract Puerto Rico has the highest asthma prevalence in the US. In the states, mold exposures have been linked to the development and exacerbation of asthma. For a pilot study of mold populations in Puerto Rico, dust and air samples were collected in January 2013 inside and outside of residences ($n = 10$) in the north eastern quadrant of Puerto Rico. Inside and outside (protected from rain) settled dust was collected by wiping above floor or ground-level surfaces with a SwifferTM duster cloth. Air samples were collected in five of the residences inside and five matching outside onto Malt Extract Agar and also onto G25N Agar. The dust (5 mg) was analyzed using mold-specific quantitative PCR and mold contamination estimated using the Environmental Relative Moldiness Index (ERMI) metric. Air sampled (150 l) plates were incubated and resulting mold colonies enumerated. The ERMI values were significantly ($p = 0.03$) greater inside the homes than outside, 20.37 versus 12.55, respectively.

Aspergillus penicillioides, *A. sydowii*, *Chaetomium globosum*, the *Eurotium* group and *Penicillium crustosum* and *A. ustus* were found in significantly greater numbers inside than outside Puerto Rican residences based on the Wilcoxon rank sum test. However, after correction for multiple comparisons using the Holms–Bonferroni test, only the *Eurotium* group remained significantly greater. Air samples suggested higher culturable concentrations of molds outside but the differences were not significantly different. Although this is a small study, it suggests that some people in Puerto Rico are exposed to significantly higher mold concentrations indoors than outdoors.

Keywords Puerto Rico · Mold · Dust · Air · ERMI

B. Bolaños-Rosero (✉)
Microbiology Department, Medical Sciences Campus,
University of Puerto Rico, PO Box 365067, San Juan,
PR 00936-5067, USA
e-mail: benjamin.bolanos@upr.edu

D. Betancourt · T. Dean
United States Environmental Protection Agency,
Research Triangle Park, NC, USA

S. Vesper
United States Environmental Protection Agency,
Cincinnati, OH, USA

1 Introduction

The prevalence of asthma in Puerto Rico is approximately 16.5 % compared with 8.4 % for the whole US (CDC 2012). In some areas of Puerto Rico, 46 % of elementary children had asthma (Loyo-Berríos et al. 2006). In 2000, 30.6 % of interviewed subjects reported having one to three visits to emergency departments as a result of asthma in the previous year (Pérez-Perdomo et al. 2003). Therefore, understanding the environmental exposures in Puerto Rican homes may provide insight into the differences in

asthma prevalence between the states and Puerto Rico. One important exposure might be mold contamination based on reviews of the scientific literature regarding mold and its association with respiratory illness (IOM 2004; WHO 2009).

The development of asthma has been prospectively linked to infant exposures in homes with high levels of mold, as described by their Environmental Relative Moldiness Index (ERMI) values (Reponen et al. 2011, 2012). The ERMI scale was developed by the US Environmental Protection Agency (US EPA) in conjunction with the Department of Housing and Urban Development (HUD) to standardize the assessment of the mold contamination in US homes (Vesper et al. 2007). For the ERMI analysis, a DNA-based technology, mold-specific quantitative PCR (MSQPCR), was used to measure the concentration of 36 indicator molds in settled dust samples.

Of the 36 molds, 26 are Group 1 species found in water-damaged homes and 10, Group 2 species found in homes independent of water damage and that generally come from outdoors (Vesper 2011). Greater populations of specific Group 1 molds have been associated with the development of asthma, but not Group 2 molds (Reponen et al. 2012). The ERMI scale ranges from about –10 to 20 (and even higher in about 1 % of homes in the states). Reponen et al. (2011, 2012) found that high ERMI values measured in an infant's home was predictive of the development of asthma by age seven. Therefore, we wanted to evaluate the mold populations in Puerto Rican homes by using the ERMI metric.

2 Materials and methods

Between January 25 and 28, 2013 dust samples ($n = 10$) were collected from residences of people known to the senior author who lived in private homes ($n = 3$), apartments ($n = 3$), condominiums ($n = 3$), or hotel rooms ($n = 1$) primarily in the north eastern quadrant of Puerto Rico. None of the homes reported water damage in the last year, but visible mold growth was common on wood (e.g., wood doors, shelves), leather (e.g., furniture, shoes) and painted surfaces. A moldy odor was detected in three residences. At the time of sampling, windows were open (as they are year round typically in Puerto Rico) except in one home which utilized an internal recirculating

air-conditioning system. In addition, outside dust samples ($n = 8$) were collected in the vicinity of the buildings where these inside samples were taken. (In two cases, one outside sample matched two inside samples.) The relative humidity was also measured at each location using the Protimeter Moisture Measurement System (MMS) meter (Protimeter, Marlow, UK).

Inside settled dust was collected by wiping above floor-level surfaces with a SwifferTM duster cloth (Proctor and Gamble, Cincinnati, OH, USA). Outside settled dust samples were obtained by wiping with a SwifferTM duster cloth above ground-level surfaces which were protected from rain. Sufficient dust was accumulated so that the cloth became visibly darkened.

Air samples were collected in five of these same inside and five outside residences using the MicroBio Air Sampler MB2 (Parrett, London, UK). A total of 150 liters of air was sampled onto Malt Extract Agar (MEA) (Oxoid, Basingstoke, UK) and also onto glycerol agar G25N Agar (prepared in the laboratory). The plates were incubated for 7–10 days in the case of MEA and for 10–15 days in the case of G25N at 25 °C. The mold colonies were then enumerated on each plate. For the calculation of the corrected colony counts for the MicroBio Air Sampler (i.e., accounting for the positive hole correction), we used the MicroBio Data Input software that came with the equipment.

Each dust sample was sieved through 300 μm pore nylon mesh (Gilson Company, Lewis Center, OH, USA). The DNA from each dust sample (5.0 ± 0.1 mg dust) was extracted, as previously described (Haugland et al. 2004), and the DNA purified using the DNA-EZ kit (GeneRite, Cherry Hill, NJ, USA).

Each of the 36 molds in the ERMI was quantified by mold-specific quantitative PCR (MSQPCR), as previously described (Haugland et al. 2004). Briefly, the standard MSQPCR assays contained 12.5 μl of “Universal Master Mix” (Applied Biosystems Inc., Foster City, CA, USA), 1 μl of a mixture of forward and reverse primers at 25 μM each, 2.5 μl of a 400 nM TaqMan probe (Applied Biosystems Inc.), 2.5 μl of 2 mg/ml fraction V bovine serum albumin (Sigma Chemical, St. Louis, MO, USA) and 2.5 μl of DNA free water (Cepheid, Sunnyvale, CA, USA). To this mix was added 5 μl of the DNA extract from the sample. All primer and probe sequences used in the assays are at the website: <http://www.epa.gov/nerlc/www/moldtech.htm>.

Table 1 Comparison of the means and standard deviations (SD) of the Sum of the Logs of the Group 1 (Sum Group 1) molds, Sum of the Logs of the Group 2 (Sum Group 2) molds

	Swiffer inside (mean)	SD	Swiffer outside (mean)	SD	<i>t</i> test
Sum Group 1	34.14	12.15	27.20	6.54	0.17
Sum Group 2	13.77	4.75	14.65	15.33	0.68
ERMI values	20.37	8.60	12.55	12.94	0.03

The ERMI value for each home was calculated, as shown in Eq. 1, by taking the “Sum of the Logs” of the concentrations of the 26 Group 1 species (s_1) and subtracting the “Sum of the Logs” of the concentrations of 10 Group 2 species (s_2) (Vesper et al. 2007).

$$\text{ERMI} = \sum_{i=1}^{26} \log_{10}(s_{1i}) - \sum_{j=1}^{10} \log_{10}(s_{2j}) \quad (1)$$

The statistical differences between the Sum of the Logs of the Group 1 species (SLG1), the Sum of the Logs of the Group 2 species (SLG2) and the ERMI values for inside and outside dust samples were compared using the Student's *t* test. The statistical differences between the rate of detection of the molds inside versus outside were evaluated by a paired Student's *t* test and the comparison between the concentration of the molds, as measured in the air samples (inside vs. outside), was evaluated by Student's *t* test.

The statistical analysis of the differences in concentrations in the dust samples of individual mold species between inside and outside Puerto Rican residences was evaluated by the Wilcoxon rank sum test. Corrections for multiple comparisons were made using the Holms–Bonferroni test. Analyses were performed in SAS version 9.3 (SAS Institute, Cary NC, USA) and R version 2.14 (R Foundation for Statistical Computing, Vienna, Austria).

3 Results and discussion

The relative humidity in the various locations sampled varied from 58 to 80 %. The ERMI values measured inside the residences in Puerto Rico were significantly greater ($p = 0.03$) than the average ERMI value for the outside samples from the same vicinity, 20.37 versus 12.55 (Table 1). The sum of logs of the Group 1 species were greater inside than outside, but not

and the Environmental Relative Moldiness Index (ERMI) values for SwifferTM dust samples inside and outside homes in Puerto Rico

significantly ($p = 0.17$). However, the sum of logs of the Group 2 species were virtually the same inside and outside and therefore, not significantly different ($p = 0.68$).

The average rate of detection for the Group 1 molds inside was 71 % compared with 61 % in the outside samples (Table 2). These averages were significantly different in a paired Student's *t* test ($p = 0.007$). However, the average rate of detection for the Group 2 molds inside was 85 and 84 % in the outside samples, and these averages were not significantly different in the same test ($p = 0.86$).

Aspergillus penicillioides, *A. sydowii*, *Chaetomium globosum*, the *Eurotium* group and *Penicillium crustosum* from the Group 1 molds and *A. ustus* from the Group 2 molds were found in significantly greater numbers inside than outside Puerto Rican residences based on the Wilcoxon rank sum test (Table 2). However, after correction for multiple comparisons using the Holms–Bonferroni test, only the *Eurotium* group remained significantly greater. *Penicillium spinulosum* was the only mold of the 36 ERMI species not detected in either the indoor or outdoor samples.

Most of the molds cultured on Malt Extract Agar or G25N Agar were species of *Aspergillus*, *Penicillium* or *Cladosporium* (data not shown). On MEA, the average concentration of molds inside was 443 and outside 515 CFU/m³ of air. On G25NA, the average concentration of molds inside was 515 and outside 863 CFU/m³ of air. These differences were not significant (data not shown).

Most Puerto Rican homes are open year round to the outdoor environment. The abundant rainfall and high temperatures promote the high relative humidity in the outdoor air and therefore inside homes, as we observed in this study. Unlike homes in the states, most homes in Puerto Rico lack air-conditioning and dehumidifiers. However, unlike homes in the states, Puerto Rican homes are generally built of concrete or block and very little wood or dry wall is used. As a

Table 2 The log of the median concentration (cells per mg dust) of each of the 36 molds in dust samples from Swiffer™ dust samples inside and outside Puerto Rican study homes

Group 1	% D	Median	LIQ	UIQ	% D	Median	LIQ	UIQ	Wilcoxon rank sum test		Exact <i>p</i> value
									Z	<i>p</i> value	
<i>Aspergillus flavus</i>	70	0.78	0.00	1.57	75	0.70	0.24	1.17	−0.59	0.56	0.55
<i>Aspergillus fumigatus</i>	60	0.45	0.00	1.28	75	0.90	0.15	1.19	0.36	0.72	0.71
<i>Aspergillus niger</i>	90	2.09	1.65	2.56	100	2.11	1.96	2.64	0.53	0.59	0.59
<i>Aspergillus ochraceus</i>	80	1.19	0.78	1.57	62	0.93	0.00	1.50	−0.49	0.62	0.62
<i>Aspergillus penicillioides</i>	100	3.14	2.08	3.98	100	1.63	1.51	2.74	−2.09	0.04	0.03
<i>Aspergillus restrictus</i>	80	2.92	1.92	3.48	75	1.80	0.85	2.30	−1.70	0.09	0.09
<i>Aspergillus sclerotiorum</i>	60	0.82	0.00	1.59	87	1.39	0.45	2.77	0.99	0.32	0.32
<i>Aspergillus sydowii</i>	100	1.89	1.00	2.15	50	0.59	0.00	1.44	−1.92	0.05	0.05
<i>Aspergillus unguis</i>	80	0.83	0.30	1.59	50	0.45	0.00	1.19	−0.77	0.44	0.42
<i>Aspergillus versicolor</i>	80	1.36	0.70	2.34	62	0.39	0.00	1.89	−1.12	0.26	0.27
<i>Aureobasidium pullulans</i>	100	2.79	2.32	3.15	100	3.23	2.80	3.97	1.51	0.13	0.12
<i>Chaetomium globosum</i>	100	1.33	1.15	1.92	75	0.95	0.39	1.36	−2.18	0.03	0.03
<i>Cladosporium sphaerospermum</i>	100	2.27	0.70	3.28	100	2.21	1.34	3.54	0.18	0.86	0.84
<i>Eurotium group</i>^a	100	1.61	1.40	2.18	87	0.89	0.39	1.31	−2.98	0.00	<0.00
<i>Paecilomyces variotii</i>	60	0.30	0.00	1.00	25	0.00	0.00	0.24	−1.32	0.19	0.19
<i>Penicillium brevicompactum</i>	40	0.00	0.00	1.11	0	0.00	0.00	0.00	−1.89	0.06	0.10
<i>Penicillium corylophilum</i>	10	0.00	0.00	0.00	0	0.00	0.00	0.00	−0.78	0.43	1.00
<i>Penicillium crustosum</i>	50	0.30	0.00	1.38	0	0.00	0.00	0.00	−2.19	0.03	0.04
<i>Penicillium purpurogenum</i>	60	0.76	0.00	1.54	50	0.50	0.00	1.78	−0.05	0.96	0.94
<i>Penicillium spinulosum</i>	0	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00	1.00	ND
<i>Penicillium variabile</i>	50	0.15	0.00	0.48	25	0.00	0.00	0.15	−0.86	0.39	0.44
<i>Scopulariopsis brevicaulis</i>	40	0.00	0.00	0.60	25	0.00	0.00	0.35	−0.48	0.63	0.62
<i>Scopulariopsis chartarum</i>	70	0.72	0.00	1.38	75	0.85	0.35	1.28	0.09	0.93	0.91
<i>Stachybotrys chartarum</i>	50	0.42	0.00	1.86	38	0.00	0.00	0.74	−0.98	0.33	0.33
<i>Trichoderma viride</i>	80	0.93	0.48	1.68	100	1.56	0.96	1.90	0.84	0.40	0.40
<i>Wallemia sebi</i>	100	3.04	2.34	4.23	100	2.79	2.14	3.42	−0.93	0.35	0.36
	Avg %D					Avg %D					
	71					61					
Group 2											
<i>Acremonium strictum</i>	60	0.30	0.00	0.60	50	0.24	0.00	0.98	0.19	0.85	0.85
<i>Alternaria alternata</i>	100	1.27	1.18	1.36	100	1.16	1.10	1.30	−0.53	0.59	0.59
<i>Aspergillus ustus</i>	90	1.13	0.48	1.30	38	0.00	0.00	0.72	−2.04	0.04	0.03
<i>Cladosporium cladosporioides</i> (Type 1)	100	2.71	2.20	3.36	100	3.95	3.02	4.21	1.56	0.12	0.12
<i>Cladosporium cladosporioides</i> (Type 2)	100	1.00	0.85	1.38	100	1.66	1.05	2.49	1.11	0.27	0.27
<i>Cladosporium herbarum</i>	100	1.95	1.90	2.20	100	2.02	1.98	2.04	0.40	0.69	0.69
<i>Epicoccum nigrum</i>	100	1.14	0.60	2.04	87	1.76	1.09	2.45	0.71	0.48	0.47
<i>Mucor racemosus</i>	100	1.64	0.95	2.32	100	2.65	0.59	2.88	0.27	0.79	0.78
<i>Penicillium chrysogenum</i> (Type2)	50	0.15	0.00	1.28	87	0.48	0.30	0.63	0.64	0.52	0.52
<i>Rhizopus stolonifer</i>	50	0.15	0.00	0.95	75	1.07	0.50	1.19	1.15	0.25	0.25

Table 2 continued

Group 1	% D	Median	LIQ	UIQ	% D	Median	LIQ	UIQ	Wilcoxon rank sum test		Exact <i>p</i> value
									Z	<i>p</i> value	
	Avg %D				Avg %D						
	85				84						

Bolded species are significantly different

% D, % of samples in which mold was detected; Avg %D, average % D for all samples; LIQ, lower interquartile range; UIQ, upper interquartile range; ND, not determined

^a However, the difference remains significant only for the *Eurotium* group, after Holms–Bonferroni test for multiple comparisons

result, one might expect that the mold contamination in Puerto Rican homes to be very different from homes in the states.

We found that 35 of the 36 ERMI molds were also common in Puerto Rican homes. Based on the ERMI values, Puerto Ricans are exposed to moldy environments both inside and outside their residence. However, the ERMI values inside were significantly greater than outside. This suggests that molds are actively growing inside Puerto Rican homes and, it appears to be mainly the Group 1 molds amplifying indoors. On the other hand, the Group 2 molds were detected inside and outside at about the same high rate, (85 vs. 84 %, respectively).

Although the sums of the Logs of the Group 1 molds were not significantly different inside versus outside, some specific Group 1 mold populations (e.g., *Aspergillus penicillioides*, *A. sydowii*, *Chaetomium globosum*, the *Eurotium* group and *Penicillium crustosum*) were in significantly greater concentrations inside than outside. Some of these molds will grow in high humidity conditions (Samson and van der Lustgraf 1978; Beguin 1994; Gock et al. 2003) on organic materials such as textiles, food, bedding, leather and materials coated with resins and lacquers, such as furniture (Woodcock et al. 2006; Meneses 2004).

There has been only one previous study of indoor molds in Puerto Rican homes, and it utilized culturing (on Sabouraud Dextrose Agar) to identify and quantify the molds (Lopez-Almodovar et al. 1979). However, the molds (mostly *Cladosporium* and *Penicillium*) were only identified to the genus level in this study. Velez et al. (2009) sampled outside air (cultured on Rose Bengal Agar) in the municipality of Caguas, but the molds cultured (mostly *Cladosporium*) were only identified to genus. In our companion of air sampling

to the dust sampling, we also found mostly *Cladosporium*, *Aspergillus* and *Penicillium*, but we were not able to distinguish significant differences in mold populations inside compared to outside based on these air samples.

Quintero et al. (2010) sampled the aeroallergens in the outdoor air of San Juan, Puerto Rico and by microscopic identification (not culturing) found that basidiospores and ascospores predominated. This predominance of basidiospores and ascospores in the outdoor air was confirmed by the San Juan Station of the National Allergy Bureau of the American Academy of Allergy Asthma and Immunology (AAAAI 2012). However, without identifying the indoor and outdoor molds at the species level, it is difficult to interpret the results of these previous studies in Puerto Rico.

Our study represents the first to use MSQPCR to identify and quantify mold species in Puerto Rican homes and to utilize the ERMI metric to describe the mold contamination. However, the ERMI metric has been applied to quantitatively describe mold contamination in the UK, France and Singapore (Vesper et al. 2005; Meheust et al. 2012; Yap et al. 2009). Although our study has many limitations, primarily, the very small number of homes and the small geographic area of the island sampled, this study does demonstrate that some homes in Puerto Rico have very high ERMI values. Whether the high average ERMI values in Puerto Rican homes contributes to the higher prevalence of asthma remains to be seen. For comparison, the average ERMI value in the homes of asthmatic children was 8.7 in the cities of Boston, Kansas City and San Diego (Vesper et al. 2013).

Many recent reviews of the scientific literature have shown that there is evidence of a link between asthma

and exposures to damp, moldy buildings (IOM 2004; WHO 2009). An intervention study for children with established asthma demonstrated that remediation for mold, based on their ERMI metric, resulted in a 90 % reduction in the asthmatic children's need for ER visits and hospitalizations (Kercsmar et al. 2006). However, it is likely that the tropical environment will pose some unique mold exposure scenarios.

4 Conclusion

These results suggest that some people in Puerto Rico may be exposed to highly mold contaminated residences, even beyond what is found in the outdoors.

Acknowledgments Our thanks go to the individuals and families who allowed us to sample their residences.

Conflict of interest The U.S. Environmental Protection Agency (EPA) through its Office of Research and Development, collaborated in the research described here. Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official EPA policy. Mention of trade names or commercial products does not constitute endorsement or recommendation by the EPA for use. Since MSQPCR technology is patented by the US EPA, the Agency has a financial interest in its commercial use.

References

- AAAAI (American Academy of Allergy Asthma and Immunology). (2012). National Allergy Bureau reading charts. <http://www.aaaai.org/nab>. Accessed August 2012.
- Beguin, H. (1994). Mold biodiversity in homes II. Analysis of mattress dust. *Aerobiologia*, 11, 3–10.
- CDC (Centers for Disease Control and Prevention). (2012). Trends in Asthma Prevalence, Health Care Use, and Mortality in the United States, 2001–2010 <http://www.cdc.gov/nchs/data/databriefs/db94.pdf>. Accessed August 2012.
- Gock, M. A., Hocking, A. D., Pitt, J. I., & Poulos, P. G. (2003). Influence of temperature, water activity and pH on growth of some xerophilic fungi. *International Journal of Food Microbiology*, 81, 11–19.
- Haugland, R. A., Varma, M., Wymer, L. J., & Vesper, S. J. (2004). Quantitative PCR of selected *Aspergillus*, *Penicillium* and *Paecilomyces* species. *Systematic and Applied Microbiology*, 27, 198–210.
- IOM (Institute of Medicine). (2004). *National Academies of Science. Damp indoor spaces and health*. Washington, D.C.: The National Academies Press.
- Kercsmar, C. M., Dearborn, D. G., Schluchter, M. D., et al. (2006). Reduction in asthma morbidity in children as a result of home remediation aimed at moisture sources. *Environmental Health Perspectives*, 114, 1574–1580.
- Lopez-Almodovar, C., Rodriguez, M., & Roure, L. A. (1979). Hongos Alergenicos en Viviendas en Puerto Rico. *Boletín de la Asociación Médica de Puerto Rico*, 71, 133–141.
- Loyo-Berrios, N. I., Orengo, J. C., & Serrano-Rodríguez, R. A. (2006). Childhood asthma prevalence in northern Puerto Rico, the Rio Grande, and Loíza experience. *Journal of Asthma*, 43, 619–624.
- Meheust, D., Gangneux, J.-P., Reponen, T., Wymer, L., Vesper, S., & Le Cann, P. (2012). Correlation between Environmental Relative Moldiness Index (ERMI) values in French dwellings and other measures of fungal contamination. *Science of the Total Environment*, 438, 319–324.
- Meneses, I. R. (2004). Case study on residential humidity control at U.S. Coast Guard Bayamon housing. Accessed August 2012, at http://smartech.gatech.edu/jspui/bitstream/1853/4826/1/meneses_ivan_r_200412_mast.
- Pérez-Perdomo, R., Pérez-Cardona, C., Disdier-Flores, O., & Cintrón, Y. (2003). Prevalence and correlates of asthma in the Puerto Rican population: Behavioral Risk Factor Surveillance System. *Journal of Asthma*, 40, 465–474.
- Quintero, E., Rivera-Mariani, F. E., & Bolanos-Rosero, B. (2010). Analysis of environmental factors and their effects on fungal spores in the atmosphere of a tropical urban area (San Juan, Puerto Rico). *Aerobiologia*, 26, 113–124.
- Reponen, T., Lockey, J., Berstein, D. I., Vesper, S. J., Levin, L., Zheng, S., et al. (2012). Infants exposed to specific molds correlated with age seven asthma. *Journal of Allergy and Clinical Immunology*, 130, 639–644.
- Reponen, T., Vesper, S., Levin, L., Johansson, E., Ryan, P., Burkle, J., et al. (2011). High Environmental Relative Moldiness Index during infancy as a predictor of age seven asthma. *Annals of Allergy, Asthma & Immunology*, 107, 120–126.
- Samson, R. A., & van der Lustgraf, B. (1978). *Aspergillus penicilloides* and *Eurotium halophilicum* in association with house-dust mites. *Mycopathologia*, 64, 13–16.
- Velez, C., Gonzalez, A., & Rentas, A. R. (2009). Isolation and identification of airborne fungi that can cause asthma: A case study from Eastern Puerto Rico. *International Journal of Environmental Technology and Management*, 10, 243–259.
- Vesper, S. (2011). Traditional mold analysis compared to a DNA-based method of mold analysis. *Critical Reviews in Microbiology*, 37, 15–24.
- Vesper, S., Barnes, C., Ciaccio, C. E., Cox, D., Dewalt, G., Jacobs, D. E., et al. (2013). Higher Environmental Relative Moldiness Index (ERMI) values measured in homes of asthmatic children in Boston, Kansas City and San Diego. *Journal of Asthma*, 50, 155–161.
- Vesper, S. J., McKinstry, C., Haugland, R. A., Wymer, L., Ashley, P., Cox, D., et al. (2007). Development of an Environmental Relative Moldiness Index for homes in the U.S. *Journal of Occupational and Environmental Medicine*, 49, 829–833.
- Vesper, S. J., Wymer, L. J., Meklin, T., Varma, M., Stott, R., Richardson, M., et al. (2005). Comparison of populations of mould species in homes in the UK and USA using Mold-Specific Quantitative PCR (MSQPCR). *Letters in Applied Microbiology*, 41, 367–373.

- WHO Europe (World Health Organization Europe). (2009). *WHO guidelines for indoor air quality: Dampness and mold*. Copenhagen, Denmark: World Health Organization.
- Woodcock, A. A., Steel, N., Moore, C. B., Howard, A. J., Custovic, A., & Denning, D. W. (2006). Fungal contamination in bedding. *Allergy*, *61*, 140–142.
- Yap, J., Toh, Z. A., Goh, V., Ng, L. C., & Vesper, S. (2009). Assessment of mold concentrations in Singapore shopping centers using Mold Specific Quantitative PCR (MSQPCR) analysis. *Indian Journal of Microbiology*, *49*, 290–293.