ECONOMIC JUSTIFICATION FOR PROACTIVE REMEDIATION OF PRIVATE HOMES OF HIGH-USE ASTHAMATICS

C. Hostland[1], G. Lovegrove[1], D. Roberts[1]

[1]School of Engineering, University of British Columbia Okanagan, Kelowna, BC Canada V1V 1V7

ABSTRACT

Background

The direct burden on North America health care systems attributable to respiratory disease including specific asthmatic effects is in excess of $20 billion dollars yearly. It exceeds $61 billion dollars including indirect and external costs, with asthma rates continuing to climb.

Purpose

The purpose of this paper includes: 1) exposing the reversible economic impact of mould and dampness affected high-use asthmatics on the public health care system; 2) a social cost benefit analysis on patient and societal impact from mould and dampness and its reduction through remediation of residential indoor environments; and 3) a proposal for proactively addressing the significant patient cost and reversing the health impact of this demographic through a health care environmental asthma prevention program.

Methods

Literature review and a survey sampling of health care professionals was conducted 2012-2014 to develop and isolate the more significant public health care system costs related to untreated damp and mouldy indoor home environments of the high-use asthmatic to confirm prevention viability. A social cost benefit analysis was conducted using risk assessment.

Results

The total yearly public health care system and societal cost impact due to indoor mould and dampness to British Columbians is $153.3 million, for slightly over 4,400 asthmatics, which extrapolates to $1.84 billion in Canada and $ 18.4 billion in the United States. Savings accrued through program implementation are $97.4 million, a 63.5% reduction, after the first year in B.C. which projects to $ 1.17 billion in Canada and $11.7 billion for the U.S. The reduction in public health care system costs alone is 72% or $31.7 million in BC, projecting to $380 million in Canada, and $3.8 billion in the U.S.

Conclusions

The results support an economic justification towards developing a prevention public health care system approach to residential mould and dampness.

Keywords: Asthma, public health care system, indoor air quality, indoor mould and dampness, social cost benefit, public health care prevention approach, residential mould remediation.

INTRODUCTION

The onset and exacerbation of respiratory disease from damp and mould contaminated indoor environments is a substantial social and economic burden.[1,2,3,6,18,44,45] Adverse response to inhaled mould can occur from airborne fungi in the form of spores, hyphae, and/or fungal fragments.[4] The potential annual health care savings plus productivity gains from improved indoor environments may exceed $55B (2013) in the U.S. alone through reduced symptoms of sick building syndrome (SBS), building related illness (BRI), and respiratory disease.[1] The Center for Disease Control and Prevention determined the impact for 25.7 million US asthmatics to be $61.7B (2013) yearly for medical cost, lost work and school days, and early death.[5] The impact comprises a critical and increasing economic load on the health care system,[1,6] an increasing social burden on family and the overall fabric of society,[7] declining productivity in the workplace, and an overall retarding impact on our economy in North America.[2,3] Moreover, asthma rates continue to climb.[5,22]

Specifically, doctor assessed asthma onset and exacerbation incidence reviews associated with clinic, hospital, and emergency room visits focus on:

1) lack of treatment methods;
2) poor asthma education and action plans;
3) avoidance coping; and
4) self-management attitudes.[6,8]

This specifically excludes the review of the patient's home environment from diagnosis for mould and dampness. While controlling indoor mould (alongside dust mites, dampness, and other irritants, such as ETS and SHS, etc.) is considered in managing asthma, distinct measures are not defined nor is mould and dampness isolated for particular remedy.[43] The public health care system (PHCS) currently downplays the relationship between damp and mouldy homes and respiratory effects on occupants. As such, acting on its effects through insitu prevention measures that include remediation is not undertaken.[9] Although proper and timely medical treatment and trigger reduction action plans are essential to controlling asthma and its more extreme effects, remediation of residential indoor environments may hold more significant long term health benefits and cost savings.

Asthma-based health impacts are avoidable if recognized by the patient and dealt with promptly.[10,11] However, more than half of the asthmatic population lack the means to deal with the cause of their asthma.[18,30] Controlled studies on the health effects of mould and dampness remediation indicates a significant health benefit from environmental remediation.[15,16,41]

Eliminating dampness and excess mould in buildings reduces the occurrence of respiratory infections, urgent clinic and

hospital visits, and asthma medication use; and the direct costs associated with the PHCS.[3,12] Moreover, the indirect and external patient benefits of removing dampness and moulds from homes include:
1) reduction in anemia and general malaise;
2) increased productivity;
3) decreased sick days and missed school days;
4) increased well-being and function efficiency;
5) reduction in mental health issues; and,
6) reduction of side effects from asthma medication consumption.[12,13,14,15,16]

Approximately 6.5% of the asthmatic population is severe uncontrolled but consumes 60% of overall health care costs, which totals $43.2 million (2013) in British Columbia.[18] The U.S. EPA term “high-use” will be used to represent the severe uncontrolled asthmatic demographic in this paper. The average cost of treating the asthmatic population rises from a system-average patient cost of $331 to $6,366 per year per high-use asthma patient.[18] Further, effects of mould on asthmatics significantly increases with severity (OR 2.34 (95%CI:1.56-3.52).[32] This exposes the need to address the high-use asthmatic demographic and find ways to reduce its impact.

The main purpose of this paper is to validate an economic basis for a proactive approach to reduce the social and economic burden of consequential mould and dampness in homes through a public health care initiated environmental asthma prevention program (EAPP).

METHODS

To determine the viability of an asthma care prevention program, a PHCS cost analysis and an overall social cost benefit analysis (SCBA) was conducted on the economic impact. Data was gathered from extensive literature review and Kelowna General Hospital (KGH) and health care profession survey samplings from 2012 - 2014. Sensitivity and risk analysis were conducted to account for data variability and to estimate confidence intervals at minimum 95% significance levels.

Previous research has focused on the cost of care of the aggregate asthmatic population.[17] As cost is known to be directly related to severity,[19,20] this paper builds on that research to isolate the more significant health care system costs related to untreated indoor home environments of the high-use asthmatic to confirm prevention program viability. The direct costs to the PHCS were determined by Monte Carlo Simulation-based (MCS) risk analysis techniques, which relies on repeated random sampling of the data including analysis of its variability factors (standard deviation) to obtain accurate numerical results by running cost based scenario simulations to provide the mean value, confidence interval, and confidence levels based on the public health care cost equation provided at the bottom of table 2. Cost savings from reduction in healthcare utilization subsequent to environmental remediation was then calculated using research-based impact reduction factoring with its measured variability. Estimated costs of remediating home indoor environments and administering the prevention program were also included.[21] MCS risk analysis was used to test how much results were influenced by the data variability. This was found to be an appropriate method for the variation level of the data provided.

The 1) indirect and 2) external cost functions were added, then totaled with the direct cost component using MCS, including: 1) loss of productivity, asthma medications and ambulance cost, early retirement, morbidity, and mortality; and, 2) loss of well-being or Quality of Life (QoL), in-house family and nursing care, social worker/ special needs, welfare payments, long term disability, low cost housing subsidy, community care and involvement, and social services support.

RESULTS

Table 1 identifies the primary health and health care component sutilized for this study. The conventional direct, indirect, and external cost elements of the SCBA were modified to address the differing methodologies utilized by the researchers in this field.

Table 1 Health Care Cost Data Variable Definition

Cost to public health care system (PHCS)	
A	Emergency Department admission
B	Critical care bed stay
C	Standard care bed stay
D	Hospital - daily drugs
E	Hospital - exit drugs
F	Doctor (GP + spec.) visits
Cost to patient/ society	
G	Ambulance
H	Yearly Drug Regime
I	Lost days/ productivity
J	Early retirement
K	Mortality
Externalities	
L	Loss of well-being (QoL)
M	Nurse visits/ direct in-house care / family
N	Loss of patient's societal contributions
O	Welfare
P	Long term disability
Q	Low cost housing subsidy
R	Social worker/ special needs

Sources: U.S. EPA 2001, Univ. Kent UK 2012

Analysis was completed on the cost impact and cost savings to the PHCS for high-use asthmatics to address the consideration for a health care prevention program approach. The overall social cost benefit was then analyzed to provide the societal cost impact and cost benefit for comparative purposes.

Direct costs to PHCS for untreated high-use Asthmatics

The direct health care service costs for the cost categories provided in Table 1and frequency of utilization of the PHCS by asthmatics were thoroughly researched through peer reviewed journals and augmented by a survey of hospital and professional health care providers where research data was found incomplete. Table 2 summarizes the rates and costs for emergency department (ED) and physician/ clinic visits, standard and critical care hospitalization durations, hospital admissions, and asthma medication usage in stay and at exit. The supplemental tables provide the specifics of line item costs and references.

Table 2 Cost to public health care system (PHCS)

Category	Subject	Min	Max	Mean	SD
A1	Emerg. Dept. costs per visit	$251.00	$428.00	$331.62	$58.09
A2	Emerg. Dept. visits per year	1.4	2.85	1.894	0.52
B1	Crit care bed charge	$3,108	$3,108	$3,108	$100
C1	Std care bed charge	$1,010	$1,075	$1,043	$32.50
B2	Hosp admissions per year	1.06	1.7	1.09	0.5
B3	Crit care duration (days)	1	2	1.5	1.0
C2	Std care duration (days)	0.88	7	3.25	2.17
D1	Daily hosp drug cost	$5.55	$18.00	$11.78	$6.23
D2	Drug use duration (days)	3	5	4	1
E	Exit hospital drugs	$115	$175	$134.87	$33.72
F1	Physician/ clinic costs/visit	$32.95	$239.01	$107.07	$79.37
F2	Physician/ clinic visit frequency	3.49	3.49	3.49	1.75
Health care cost (XX) = A1*A2+B1*B2*B3+C1*B2*C2+D1*D2+E+F1*F2					

Note: This table summarizes data found in literature. Gaps were augmented by a survey sample of health care professionals. It provides data for validating risk assessment.

Research data was compiled through published government statistics and relevant peer-reviewed journal publications. The population-based asthma hospitalization rate for Canada is 7.2% derived from hospitalization rates of 280/100,000 for adults 25+ and 1,400/100,000 for children 0-24 years.[21] This totals to 202,317 annual hospitalizations due to asthma from a population of 2,817,200 asthmatics.[22] 18% of asthmatics visited the ED nationally in 1996/7. [23, 24] Combined, 40% of ED visits culminated in hospitalization. Research confirmed 28% - 56% of asthma patients required ED treatment and 6.9%-10.1% required hospitalization.[18,26,27,28,29] The U.S EPA determined 1.67 ED visits and 0.732 hospital visits for high-use patients per year. [30] The survey data from KGH health care providers, including asthma care specialists and emergency room doctors, augmented the research data obtained from literature for: duration of hospital admission standard care and critical care stays; daily hospital and exit medication usage; and confirmed the most recent costs. An algorithm (Table 2) combining the health care usage and components was developed to sum total the overall cost of care. MCS trials on the cost component algorithm were run 10,000 times using the normal function to approximate overall costs to a 95-98% confidence level.

The mould and dampness affected high-use asthma group for British Columbia was calculated in Table 3. A study of multiple countries attributes 22.1% of high-use asthma onset or exacerbation to indoor mould and dampness. [31] Mudarri and Fisk value of 21.0% (95% CI 12 - 29) was based on North American specifics.[31] The value of 35.1% determined by Jaakkola was adjusted to 20.8% for this study to account t for the difference between odds ratios and rate ratios.[33] The value used in the assessment was averaged to 21.3% with a standard deviation (SD) of 0.57%. The percentage of high-use asthmatics from the overall asthma population was determined in supplemental table S2 by taking the normalized mean of 9 available studies.

Table 3 Affected Population based on Monte Carlo Simulation

Affected population of BC				
Asthmatics (BC)	318,051*			
Percentage high-use	11.1% +/-4.71%			
% environ affected	21.3% +/- 0.57%			
			Population	**SD**
* 2010		**Total***	**4,433**	**1,912**
	*Monte Carlo risk analysis confidence level: 95%			

The cohort of high-use asthmatics in British Columbia affected by mould and dampness was calculated to be 4,433 (95% CI: 2500-6350) from an overall asthma population of 318,051.[23] The median health care cost impact was calculated from the model to be $9,895 (95%CI: 5100-14,700) per person-year. The total health care burden from high-use asthmatics is the sum of all hospital care costs multiplied by the number of visits per year. The model projects the total yearly cost to the PHCS for high-use asthmatics in British Columbia to be $43,860,000 (98%CI: 13,884,000-73,840,000).

Public health care system cost savings

Research suggests health care and hospital usage drops over time with environmental remediation measured against the baseline.[15,16,30,34] Based on hospitalization recovery records, the decrease in health impact recovery from uncontrolled asthma attacks depending on severity can range from a few days to a few weeks.[26,34,35,36] A local survey of professional remediation firms expert in mould remediation provides a range of $1,500 - $8,500 CAD (2013) for mould and dampness remediation of homes with the median value of $4,519 (95%CI: 4040-5000) as a one-time cost. Management and administration of the program would utilize existing health care personnel to identify and assess the patient candidate and their residence, monitor and record their health response using self-reporting and hospitalization records. To ensure sustainability of the program, measuring and reporting the cost savings on a quarterly basis is included. For personnel training and systems integration, a one-time sum of $250,000 for a Province-wide prevention program has been assumed in the calculations. This is a first level estimate to be verified after program delineation.

The PHCS cost reduction component values (supplemental tables S3 and S4) were inputted into the MCS. Results gave individual high-use PHCS cost savings of $7,144 (98%CI: 3,650-10,650) per patient-year. The first year PSHC cost impact benefit of the affected population totals $12.1 million in savings for Provincial implementation including administration costs and residence remediation but excluding social benefits and $31.7 million, a 72.4% reduction, each year thereafter. This is extrapolated to be $380 million in PHCS cost savings in Canada and $3.8 billion in the U.S. based on relative asthma populations for a health care environmental asthma prevention program after the first year.

Sensitivity analysis

The study results sets the PHCS yearly cost per high-use asthmatic at $9,895 (98%CI: 5,100-14,700) and projects the total yearly cost to the PHCS for high-use asthmatics in British Columbia to be $43,861,853 (98% CI:13,880,000-73,840,000). Sadatsafavi identified $56.1 million in health care funds going to asthma on a broad analysis basis with 60% (43.2 mil, 2013) of it being consumed by a population of 5,941or high-use asthmatics based on that study's calculation of the severe uncontrolled cohort.[18] The MCS cost value of $43.8 million aligns with the Sadatsafavi value but the number of projected high-use patients (5941 vs. 4433) in B.C. varies by 25% with the study.[18] This variance can be attributable to study interpretation of asthma severity data with the study results considered conservative.

Societal cost of not remediating proactively

In addition to PHCS savings from environmental remediation, patient and societal costs savings were generated from reduction in indirect costs to patients and society, and cost of externalities impacts. The reduction was derived from research summarized in supplemental table S4.[15,16,30,34,38,40] With a 44.52% (SD 19.27%) reduction in patient/ societal costs and 66.78% (SD 24.21%), using MCS, the overall societal savings are $97.4 million, or a 63.5% reduction, after remediation of environmentally affected homes of high-use asthmatics in British Columbia after the first year. This extra polates to a yearly social cost benefit of $1.2 billion dollars in Canada and $11.7 billion in the U.S using asthma population as a basis for the extrapolation. A Summary of costs and benefits of proactively remediating indoor environments in British Columbia is described in Table 4.

Table 4 Summary of costs and benefits*

BC Population	Current Cost	New Cost	Net Cost Savings
Direct (PHCS)	43.8	12.1	31.7
Indirect	32.8	18.1	14.7
Externalities	76.7	25.7	51.0
Total	**153.3**	**55.9**	**97.4**
Remediation/admin cost 1st year			(20.3)
		Total	**77.1**

* millions of dollars

Summary Conclusions and Recommended Future Initiatives

The economic impact of high-use asthmatics on the health care system and society at large and the significant health and cost benefit in undertaking prevention measures is highlighted in this paper. This is supported by a cost-benefit approach to develop a proactive means to address the problem of ill-health in homes primarily due to damp and mouldy environments through a health care environmental asthma prevention program (EAPP).The asthma-based cost analysis in this report demonstrates the potential for significant economic benefits that extrapolate to $380 million in PHCS cost savings in Canada and $3.8 billion in the U.S. based on relative asthma populations for a health care environmental asthma prevention program after the first year. The social benefits are more significant with yearly savings in the order of $100 million in British Columbia, $1.2 billion in Canada and $12 billion in the U.S.

The use of economic modeling and remedial prevention programs as a means to deliver health care solutions is not new. Results indicate public health care system impact and financial outlay can be reduced by over 60% through prevention methods, with a financial payback in the first year using a literature verified and practitioner augmented social cost-benefit risk analysis methodology. With over 60% of asthmatics uncontrolled for exacerbation management after years of health care focus on training and education to control patient asthma, it appears an in-home environmental asthma prevention program may provide more success.

Study results should be field verified as part of mobilizing policy review by the Ministry of Health to undertake proactive remediation programs in mouldy and damp homes of respiratory patients that are verified as illness causing. By proving significant PHCS and social cost benefits for the removal of excessive moisture and mould of affected asthma patients from residential indoor environments, this paper exposes a compelling value equation to develop a proactive prevention health care approach to respiratory disease that is critical to the well-being of families, their communities, and the local and national economy. Delivering tangible health and environment benefits to thousands of individual patients and redirecting funding to other critical health care programs would be key outcomes of such a prevention program.

Limitations and comparatives

Accurate data gathering from national and regional asthma literature was limited by regional variations in identifying cost categories, different asthma conditions, along with direct and indirect scopes varying by study. Measurement method and what constitutes scope also varied by study. Inconsistencies in definition and data may affect results. The medical costs associated with adult respiratory disease is underestimated by not tracking side effects from pharmaceuticals used to treat asthma such as exacerbation of cardiac events and the compounding of other serious medical conditions and may be overestimated by disease overlap considerations. The possible overlap effects between the various respiratory diseases and asthma and various indoor environmental hazards and irritants and asthma exacerbation has not been addressed. Social cost benefit analysis accuracy is restricted by the aforementioned data limitations and by scope delineation. Factors that are known to affect asthmatics include genetics, age, sex, ethnicity, environmental tobacco smoke (ETS) environments, obesity, degree of biodiversity in the environment, lifestyle, urban versus rural environments, outdoor air pollution, and income levels. Research used in this paper that is directly focused on health response to damp and mouldy environments is assumed to have addressed these risk factors through study exclusion techniques. The extent of ill-health to mould and dampness exposure levels and mould types requires further research.

ACKNOWLEDGEMENTS

We would like to acknowledge the University of British Columbia graduate program for its support and research recommendations and the various health services and Interior Health personnel of the Okanagan region and local Professionals in the gathering of relevant data for this paper.

Supplemental Tables

S1 Historical cost of high-use asthma patient care per patient-year

Research	Base	2013 value	$$ adjust CDN	lost prod adj	$$ adjusted
Ojeda et al (2013)	$6,395 USD	0	2.50%	($1,600)	$4,955
EPA (2001b)	$4,038 USD	25.50%	2.50%	0	$5,194
Sadatsafavi (2010)*	$5,656 CAD	12.56%	0.00%	0	$6,366
CDHS (2003)	$3,572 USD	28.70%	2.50%	0	$4,711
Kim et al 2012 - severe	$5,141 USD	0.30%	2.50%		$5,285
Kim et al 2012 –uncontr.	$7,010 USD	0.30%	2.50%		$7,206
* 2006 costs					
				Mean	$5,619.50
				SD	878.84

Research results, other than the older EPA results contain incomplete data to segregate the high-use from moderate asthmatics with any accuracy.

S2 Asthma severity as a fraction of the population (sources noted)

A. Relationship mild to severe		mild %	moderate %	severe %
Sadatsafavi		67.1	25.5	7.4
USEPA 2001B		70	25	5
Thorax 2000		57		
Smith et al				20
Serra-Battles				14
Antonicelli et al				7.8
Braman 2006	(10-20 - ave 15)			15
NAEPP... (1996)		70	20	10
Kim et al	(10-20 - ave 15)			15
	Mean	66.025	23.5	11.15
	normalized	**65.6**	**23.3**	**11.1**
	SD	**5.34**	**2.48**	**4.71**

B. relationship uncontrolled to controlled

	uncontrolled	controlled
Sadatsafavi (2010)	63.50%	36.50%
Seung (2005)	57.00%	43.00%
ICES (2006)	56.00%	44.00%
mean	**58.83%**	**41.17%**
SD	**3.32%**	**4.07%**

S3 Reduction in health care costs due to remediation

Category	Subject	Mean	SD
A2	ED visits per year	-62.45%	26.58%
B2	Hosp admissions per year	-72.50%	30.90%
D1	Daily hosp drug cost	-59.00%	14.75%
F2	Physician/ clinic visit frequency	-88.73%	1.62%

Sources: USEPA (2001b), Kercsmar (2006), Howden (2007), Burr (2007).

S4 Reduction in patient and societal costs (sources noted)

Reduction in Patient and Societal costs

USEPA (2001b)	Lost workdays	-39.00%	
Cascadia (2009)	Lost WD/ incr prod	-40.30%	
	average	-39.65%	
USEPA/Kerc	Ambulance	-88.83%	
Burr (2007)	Yearly drug regime	-59.00%	
Burr (2007)	breathing issues	-52.00%	No medical comparatives
Kim (2011)	Mortality		No reduction information
	mean	-44.52%	

Mean	**-44.52%**
SD	**19.27%**

Reduction in Externalities

* no direct data from literature. Propose mean & SD of personal impact reductions
- not weighted

Howden (2007)	ED admission	-38.00%
USEPA (2001b)		-33.90%
Kercsmar (2006)		-90.90%
		-87.00%
USEPA (2001b)	hospitalization	-72.50%
USEPA (2001b)	clinic visits	-88.30%
Kercsmar (2006)		-90.90%
		-87.00%
USEPA (2001b)	Lost workdays	-39.00%
Cascadia (2009)	Lost WD/ incr prod	-40.30%

Mean	**-66.78%**
SD	**24.21%**

S5 Indirect Patient/ Societal/ Externality costs (sources noted)

INDIRECT COSTS				
(Ambul/ drugs/lost work days/ productivity/early retirement/ mortality)				
Based on Direct cost				
BMC (2009)	**16.3-92.3%**	**54.30%**		
BMC (2009)	**49.2-112.8%**	**81.00%**		
AAFA (2011)		**81.20%**		
Lee (2011)		**81.80%**		
			Mean	**74.58%**
			SD	**11.71%**
EXTERNALITIES				
QoL/family/welfare/LTD/secial needs				
Based on Indirect + Direct costs				
Kim (2011)		**100%**		
			Mean	**100%**
			SD	**15.70%**

REFERENCES

1. Fisk, W. **Indoor Air Quality Handbook**. Publication. 2001. New York, Mc Graw-Hill.
2. Fisk, W.J. , Lei-Gomez, Q. , and Mendell, M. J. **Meta-analyses of the associations of respiratory health effects with dampness and mould in homes.** *Indoor Air, 2007 17*(4), 284-296.
3. Fisk, W.J. ,*et al*. **Association of residential dampness and mould with respiratory tract infections and bronchitis: a meta-analysis**.

Environmental Health 2010; 9:72 doi:10.1186/1476-069 x-9-72.

4. American College of Occupational and Environmental medicine. **Adverse Human Health Effects Associated with Moulds in the Indoor environment.** 2011. http://www.acoem.org/AdverseHumanHealthEffects_Moulds.aspx Aug. 2014.
5. CDC. **Vitalsigns. Asthma in the US.** www.cdc.gov/vitalsigns/asthma 2014
6. Bahadori, K. *et al*. **Economic burden of asthma: a systematic review**. *BMC Pulmonary Med. 2009, 9:24.*
7. Geltand, E.W. **The impact of asthma on the patient, the family, and society**. *Review. Johns Hopkins Advanced Studies in medicine.*2008.
8. AL-Jahdali, H., Anwar, A., *et al*. **Factors associated with patient visits to the emergency department for asthma therapy.** *BMC pulmonary Medicine* 2012, 12:80.
9. Wu, Jacobs, Mitchell, Miller, and Karol. **Improving Indoor Environmental Quality for Public Health.** *Environmental Health Perspectives,*vol 115 #6 June 2007 p 956.
10. Samet*et al*. **Moving into the 21st Century.** *Am J Public Health Indoor Environments and Health*: vol 93, no.9. Sept 2003.
11. Kilburn, Kaye, H. **Neurobehavioral and pulmonary impairment in 105 adults with indoor exposure to moulds compared to 100 exposed to chemicals.** *Toxicology and Industrial Health* 2009*;* 25(9-10) 681-692.

12. Takaro Tim K., Krieger James. **The Breathe-Easy Home: The Impact of Asthma-Friendly Home Construction on Clinical Outcomes and Trigger Exposure**. *Amer J Public Health*. Jan 2011. Vol 101, No. 1.
13. Bornehag, C-G., Blomquist G., *et al*. **Dampness' at home and its association with airway, nose, and skin symptoms among 10,851 pre-school children in Sweden: a cross sectional study**: *Indoor Air 2004;14(suppl 7):59-66.*
14. Bornehag C-G, Blomquist G, Gyntelberg F, Jarvholm B, Malmberg P, Nordvall L, Nielsen A, Pershagen G, Sundell J.**Dampness in buildings and health**: *Indoor Air;* 11(2):72–86.(2001).
15. Burr, M.L., Matthews, I. P., Arthur, R. A., Watson, H. L., Gregory,C. J., Dunstan, F. D. J., Palmer, S. R. **Effects on patients with asthma of eradicating visible indoor mould: a randomized controlled trial.** *Thorax;2007;* 62:767-772.
16. Howden-Chapman *et al*. **Effect of insulating existing houses on health in equality: clusterr and omized study in the community.** *BMJ* 2007 334:460- doi:10.1136/bmj.39070.573032.80.
17. Bernstein, J. A., Alexis, N., *et al*.**The health effects of non industrial indoor air pollution.** *J AllergyClinImmunol 2008;121:585-91.*
18. Sadatsafavi, M., Lynd, L., Marra, C., Carleton, B., Tan, W.C., Sullivan, S., FitzGerald, J.M. **Direct health care costs associated with asthma in British Columbia.** *Can*

Respir J. 2010 Mar-Apr; 17(2): 74–80.

19. Godard, P., Chanez, P., Siraudin, L., Nicoloyannis, N., Duru, G. **Costs of asthma are correlated with severity: a 1-yr prospective study.** *EurRespir J.* Jan 2002;19(1):61-7.
20. Serra-Batlles, J., Plaza, V., *et al*. **Costs of Asthma according to the degree of severity.** *Eur. Respir. J. 1998; 12: 1322-1326.*
21. U.S. EPA. **Guiding Principles for Monte Carlo Analysis.** EPA/630/R-97-001. March 1997.
22. Public Health Agency of Canada. **Respiratory Disease in Canada Report *Life and Breath***. Cat.: HP35-8/2007E-PDF ISBN: 978-0-662-47060-1.
23. Statistics Canada: **table 105-0501**; cat. # 82-221-x. Last modified 2013-06-17. www.statscan.gc.ca/tables-tableaux/sum-som/Io1/cst01/health50a-eng.htm.
24. Health Canada. **Economic Burden of Illness in Canada, 1998**. Ottawa: Health Canada Population and Public Health Branch. ISBN 0-662-33144-1 1998 www.hc-sc.gc.ca.
25. Health Canada. **Residential indoor air quality guidelines: Moulds**. Ottawa: Health Canada. HC Pub.:4075E. ISBN: 978-0-662-45739-8. 2007.
26. Seung and Mittman, S.J., Mittman, N. **Urgent Care Costs of uncontrolled asthma in Canada, 2004**. *Can Respir J.*2005;12(8):435-436.
27. CHIS, **California Health Interview Survey**. (2003). http://healthpolicy.ucla.edu/chis/Pages/default.aspxAug. 2014.

28. Braman, Sydney, S. **The Global Burden of Asthma**. *Chest;* 2006;130, 4S-12S.

29. Rowe**,** B.H**.**, Villa-Roel**,** C**.**, Abu-Laban**,** R.B**.**, Stenstrom**,** R**.**, Mackey**,** D**.**, Stiell, I.G., Campbell, S., Young, B. **Admissions to Canadian hospitals for acuteasthma: a prospective, multicentrestudy**. *Can Respir J.*2010 Jan-Feb; 17(1):13-4.

30. U.S. EPA. **Cost of Illness Handbook**. Report prepared by ABT Associates, Inc. For the US EPA, Office of Pollution Prevention and Toxics. Available online at http://www.epa/gov/opptintr/coi_handbook. 2001.

31. Mudarri, D., andFisk, W. J. **Public health and economic impact of dampness and mould**. *Indoor Air*, 2007:*17*(3), 226-235.

32. Zureik, *et al*. **Sensitization to airborne moulds and severity of asthma: cross sectional study from European Community respiratory health survey**. *BMJ* 2002;325:411.

33. Jaakkola*et al.* **Indoor dampness and moulds and development of adult onset asthma**. *Env Health Pers.*2002v.110(5): 543-547.

34. Kercsmar*et al*. **Reduction in Asthma Morbidity in Children as a result of Home Remediation Aimed at Moisture Sources**. *Environmental Health Perspectives.* 2006;vol 114.8 p 1574 – 1580.

35. CDHS, California Department of Health Services. **California county asthma hospitalization chart book**. September 2003.

36. UMMC, University of Maryland Medical Center. **Asthma in Adults: an indepth report on how asthma**

is diagnosed, treated, and managed in adults. 2014. http://umm.edu/health/medical/reports/articles/asthma-in-adults.

37. AAFA, Asthma and Allergy Foundation of America. **Cost of Asthma**. March 2014. http://www.aafa.org/display.cfm?id=6&sub=63.
38. Kim, Chang-yup, *et al*. **The financial Burden of Asthma: A Nation wide Comprehensive Survey Conducted in the Republic of Korea.** *AllergyAsthmaImmunol Res.* 2011 January;3(1):34-38.
39. Lee, Y.H., Yoon, S.J., Kim, E.J., Kim, Y.A., Seo, H.Y., Oh., IH. **Economic burden of asthma in Korea.** *Allergy Asthma Proc.* 2011 Nov-Dec 2011;32(6):35-40. doi: 10.2500/aap.2011.32.3479.
40. Cascadia. **High performance Buildings – What sit Worth?** Publication. May 2009.
41. Menzies, D., Popa, J., Hanley, J., Rand, T., Milton, D. **Effects of ultraviolet germicid allights installed in office ventilation systems on workers' health and wellbeing: doublé-blind multiple crossover trial**. *The Lancet*. Vol 362, no. 9398, p1785-91 Nov. 2003.
42. Cooley*et al.***Correlation between the prevalence of certain fungi and sickbuilding syndrome.** *Occup Environ Med*. 1998;55:579-584.
43. NAEPP Guidelines on Asthma. www.nhlbi.nih.gov/health-pro/guidelines/current/asthma-guidelines/full-report. Oct. 2014.
44. Bousquet et. al. **The public health implications of asthma**. *Bulletin of*

he World Health Organization.July 2005, 83(7).

45. Bedouch et. al. **Trends in Asthma-Related Direct Medical Costs From 2002 to 2007 in British Columbia, Canada: A Population Based-Cohort Study**. PLOS ONE, Dec. 2012. DOI: 10.1371/Journal. pone.0050949.
46. Braido., F. Failure**in Asthma Control: Reasons and Consequences.** Scientifica vol.2013, article ID 549252 doi. 10.1155/2013/549252.
47. **A Pocket Guide for Physicians and Nurses**: Updated 2015. Global Initiative for Asthma. http://www.ginasthma.org/documents/1/Pocket-Guide-for-Asthma-Management-and-Prevention. Jan. 2015.
48. **Asthma Society of Canada. Asthma**. ca/adults/lifestyle/indoor.php Nov. 2014.
49. ICES (2006). The Burden of Asthma in Ontario. ICES Investigative Report. Toronto: Institute for Clinical Evaluative Sciences; 2006.
50. World Health Organization, WHO (2009). World Health Organization Regional Office for Europe: WHO guidelines for Indoor Air Quality: Dampness and Mold. Bonn, Germany; 2009: http://www.euro.who.int/_data/assets/pdf_file/0017/43325/E92645.pdf Nov. 2014.
51. Adams, R. J., Smith, B. J., Ruffin, R. E. (2000). Factors associated with hospital admissions and repeat emergency department visits for

adults with asthma. Thorax 2000;55:566–573.

52. Kupczyk, Maciek (2012). Risk factors for anexacerbation-prone asthma phenotype. Amer. Thor.Soc. Int. Conf. May 2012 session A92.