sustainable home health: an integrated approach to address mold related indoor air quality and illness

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Sustainable home health: An integrated approach to address mold related indoor air quality and illness

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Abstract: Mold and dampness in indoor environments is associated with respiratory disease. Close to half of North American homes have damp or moldy environments, yet home assessment is not commonly prescribed by health care practitioners in relationship to consequential health effects from mold proliferation. The economic impact of indoor mold on health in North America is measured in the tens to hundreds of billions of dollars each year from lost productivity, lost time from work and school, direct health care costs, and family impacts primarily due to respiratory ailments. To accurately diagnose consequential health impacts a person's health should be viewed holistically as a combined consequence of their genetics, lifestyle, and long term environmental exposure. An integrated, sustainable, system-based-approach, including home specific medical diagnosis and indoor air quality (IAQ) home assessment should be developed and implemented jointly by the medical profession, the IAQ industry, overseeing organizations, and Governments. If successful, this approach would not only raise awareness and reduce the consequential health effects of indoor mold, but also save significant costs to the affected, the health care system, and to society at large.

Key words/ phrases: asthma, damp environments, ill-health, indoor air quality, IAQ, mold.

Practical implications

The practical implications of this research paper include an enhanced awareness of the effects of indoor mold on occupants, the healthcare system, employers, and society at large in terms of personal, financial, and social impact. Actions resulting from the recommendations outlined in this paper can positively affect how the mold-affected are diagnosed and treated and how affected home environments can be addressed through proactive measures that reduce or eliminate the problem of mold and dampness in homes.

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Introduction

Prolonged ill-health is a major cause of family and marital dysfunction due to increased stress and anxiety, as well as lost productivity in the workplace (Shaw *et al.* 1997). Residential housing regularly exhibits problems with contaminant hazards such as mold, lead, asbestos, and chemicals stemming from uninformed product selection at the time of construction which can be compounded by improper ventilation and air mixing, insufficient air filtration, water intrusion and extended high internal moisture levels, and lack of habitat care. All these can cause serious health related problems for occupants, but it is the failure to directly address dampness and mold issues that contribute to building-related sickness in indoor environments that has resulted in hundreds of millions of sick days, emergency room visits, hospital stays and significant reduction in productivity each year (Fisk *et al.* 2000, 2010). The full social impacts have yet to be fully measured.

People in developed nations spend more than 90% of their time indoors with more than half of that time in their home environments (US EPA 1989). A World Health Organization (WHO) report suggests 30 percent of new and remodeled buildings worldwide may have complaint related indoor air and environment quality issues (IAQ) with up to 50% having a prevalence of water damage and dampness (WHO 2009) and a prevalence of mold and dampness in upwards of 38% of homes in Canada (Dales *et al* 1991). Almost 60% of homes in Taiwan have mold growth (Wan & Li, 1999). Buildings are known to develop long-term IAQ related problems due to poor operation, deferred maintenance, and inadequate building design for pre-described occupant activities (US EPA 2011). Epidemiological studies have shown a link between poor IAQ and asthmatic symptom frequency (NAS 2000, Daisey 2003). A 3 to 15 fold increase was observed in building related disease symptoms and building related asthma from exposure to significant levels of *Stachybotrys chartarum* and *Aspergillus species* from building systems design, construction, and operation protocols that created excess moisture and high humidity levels (Hodgson *et al.* 1998). Dampness is associated with respiratory symptoms (Howden-Chapman *et al* (2005, 2007). Exposure to indoor molds produced respiratory disease in humans thru both allergic and non-allergic mechanisms (Hope, Simon 2007) and particularly asthma symptoms (Jaakkola & Jaakkola, 2004).

The purpose of this paper is to expose the disjoint between indoor mold related illness and medical opinion and enhance awareness with the following objectives: 1) bring awareness to home specific assessment to create a holistic approach to addressing mold related indoor air quality and illness; 2) expose the economic impact of mold related illness on society; and 3) integrate medical, site assessment, and IAQ products and services to develop a sustainable approach to combat mold-related health impacts.

Methods

A review of the literature was conducted, including peer reviewed journal papers found using the academic search engines, Web of Science, Compendex, Pubmed, Google Scholar, and from specific journal tables of contents, public web-based general literature, and industry sources. Site based information gathering and service provision scoping and costing through local data accumulation in the Okanagan, British Columbia, Canada is also reported.

This paper is organized to further the subject of sustainable home health by introducing the problem of indoor mold and ill-health, reviewing the health effects from indoor mold and dampness, and revealing how it is being addressed by the medical and indoor air quality professions and service providers. This paper then discusses the gap between regulated environments of the public and commercial domains and the unregulated residential environment and the economic effect of not addressing the residential environment proactively. The paper then concludes with recommendations towards closing these gaps using an integrated approach between the professions.

Health effects from mold

Of the household environmental issues determined by regulators, mold and its effects are the least defined, but can be a significant cause, and therefore indicator, of present and potential occupant ill-health (CMHC 2011). At present, no minimum standard or quantitative prescription exists for acceptable levels of mold or mold types in buildings (Lawrence 2001). Although, qualitative evidence indicates moderate levels of mold types in buildings can cause significant health impacts to otherwise healthy individuals and reduction in mold quantity and type reduces that effect (Fisk 2010). The lack of a quantifiable disease connection to indoor mold may in part be due to the broad use of the term "mold" which comprises a wide category of specific organisms that may or may not be present or elicit illness in individual humans. Molds are microscopic fungi that are highly adapted to grow and reproduce rapidly in damp to semi-damp environments. Fungal colonies produce spores and hyphae that generate allergens, microbial toxins (mycotoxins or biotoxins), and microbial volatile organic compounds (MVOC) through the mold lifecycle. Specific molds cause allergenic reactions in some humans and pathogenic (a significant health concern) reactions in others. Strong evidence exists that indoor molds in buildings increase the risk and severity of asthma (Jaakkola & Jaakkola, 2004). High levels of airborne mold affect most of the population to varying degrees (EPA 2012); but those who are more seriously affected are the environmentally sensitized, immune compromised, or those with underdeveloped immune systems, particularly the elderly and children (Antova *et al.* 2008, Tischer *et al.* 2011, Simoni *et al*. 2005). A higher level of exposure to living molds or a higher concentration of allergens on spores and mycelia results in a greater likelihood of illness, although levels and limits that cause illness are not known (Brandt *et al*. 2006).

In general, poor health from mold exposure can include sore throat, nasal congestion or chronic runny nose, cough, wheezing, and increased asthmatic and allergic symptoms which can be misdiagnosed as flu-like effects (Bornehag *et al.* 2004 , Health Canada 2007, Mendell *et al* 2011, Palaty 2009, Wu et al. 2007). Inhalation of fungal spores or their toxins can also cause infections such as aspergillosis. MVOCs are capable of causing irritation to the eyes and upper respiratory tract, ABPA (allergic broncho-pulmonary aspergillosis) and sinusitis. Colonizing fungi such as aspergillus fumigatus can cause bronchial inflammation and constant allergic response in asthmatics (Srikanth *et al.* 2008). Depending on the type and amount of mold present in a home, the amount and degree of exposure, and the health condition of the occupant, health effects can range from insignificant short term effects to significant allergic reaction and illness (CMHC 2011). Damp indoor environments and mold are associated with coughing, wheezing, and upper respiratory tract symptoms in otherwise healthy people (Fisk et al 2007, IOM 2004, WHO 2009).

The consequences of mold exposure in buildings include asthma, allergies, hypersensitivity disorders, rhitonitis, and severe respiratory infections (Jacques 2011, Jaakkola *et al* 2002, Lawrence *et al* 2001, Park *et al* 2004). The prevalence of respiratory symptoms were consistently higher (50% for lower respiratory tract and 20-25% for upper respiratory tract) in homes with reported molds or dampness averaging 37.8% in the 13,495 homes surveyed (Dales *et al.* 1991). Statistically, 21% (95% [CI], 12-29%) of current asthma is attributable to mold/ dampness in US homes with a 30-50% increase in respiratory health outcomes (Sahakian *et al.* 2008). Alternately, 4.6 million current US asthma cases of the 21.8 million people reported to have asthma were attributable to dampness and mold. This poses a significant public health risk (Mudarri & Fisk 2007) and social impact.

Indoor Environments

It is recognized that between 20-50% of North American homes have damp or moldy environments (Verhoeff & Burge 1997, Zock 2002). Poor maintenance and substandard construction practices lead to high levels of moisture and the proliferation of toxic molds (Singh 2010). Removal of molds and dampness from homes has a positive effect on the health of occupants. Symptoms of asthma and rhinitis improved and medication use declined following removal of indoor mold in homes (Burr *et al.* 2007). Toxic mold development from dampness has been identified as a major contributor to poor health as evidenced by the improvement of health upon relocation (Lawrence & Martin 2001, Shaw *et al.* 1997), upon removal of molds and dampness (Bernstein *et al.* 2008, Kercsmar *et al* 2006), and by ultraviolet (UV) irradiation remediation (Burr et al 2007). The cost of removing mold and dampness from homes to the extent health is not impaired can vary from a few thousand dollars to tens of thousands of dollars depending on the extent of the underlying causal problems. These problems can range from an intermittent plumbing leak to wholesale floods and from poor building envelopes to significant ventilation and filtration deficiencies. For homes that have not been catastrophically damaged due to flood and have been built with a good level of care, the range for typical mold remediation and moisture related repairs have been estimated, per affected home, to be in the range of $2,000 - $6,000 from interviews with Okanagan mold remediation firms. Remediation of mold affected environments includes removing mold contamination, sanitizing the affected environment, and cleaning the air of airborne fungal debris with high-efficiency particulate air (HEPA) filtration. This cost range to remove dampness and mold contaminants can be a fraction of the cost of health care for the environmentally sensitized asthmatic.

From the professional experience of Healthy Homes IAQ it has been observed that fear that mold in their homes was causing or may be causing adverse health effects, was verified to be the primary concern of occupants from over 600 hundred interviews and consultations between 2002 and 2012. Reports of long-term flu-like symptoms were prevalent. For clients who did not pinpoint mold as a primary concern, on subsequent investigation, mold was determined to be a possible cause or potential cause of their health concerns. In approximately 25% of cases, IAQ inspection requests came after failure of medical or hospital visits, subsequent medical testing or after the purchase of IAQ equipment such as ionizers, UV irradiation, and portable HEPA cleaners, to resolve their health concerns. A large proportion of inquiries came from young mothers or mothers-to-be with concerns about potential mold related issues such as black staining on window sills that ultimately were not a health concern to the investigator. This suggests an acute awareness of the general public towards mold as a health effect, but also

confusion on the cause, proliferation, and effects of mold in indoor environments, in the general solutions available, and on the best methods to be taken towards the development of appropriate health based solutions. Unaddressed, fear can be expressed through irrational psychosomatic behavior. As such, resolving real or perceived indoor environmental issues is critical to the health and well-being of occupants.

Building related illness

The first challenge to diagnosing a home or building related illness is including the home in the diagnosis, as part of a two part methodology: medical assessment and environmental assessment. Either might take the lead in this symbiotic relationship; but societal norms are that those with health concerns tend to undertake a general medical assessment first with a visit to their doctor. When the patient is treated in a medical facility without home environment assessment, the symptoms of an indoor environment induced respiratory affliction can be readily passed off as flu-related or diagnosed as a general, non-specific allergic reaction, with the treatment tending towards cold, allergy, and flu medication and, initially, a wait and see approach by the doctor. Health assessment in relation to specific indoor mold environments is not generally included in medical curricula nor in the procedures generally laid down in medical practice (Lawrence 2001).

If the emergency room patient is having a mild asthmatic attack, the practice is to place them on an inhaler and promptly discharge. If the asthmatic patient enters the emergency room in a critical state, they are placed in emergency care until stabilized, then released with medication. General hospital practice is to culture sputum and check white blood counts for abnormalities. The patient is then released back into their environment to recommence the cycle of ill-health development again. In defense of existing medical practice, doctors are not easily able to draw conclusions outside their profession especially without verified disease pathways for mold induced sickness. They do not have access to observe the environmental conditions that may be triggering the effect. As such, only prescription medication for confirmed disease types is dispensed. Doctor's may share in the concern with toxic environmental mold, but remain unable to effect change in means and methods to deduce and treat.

The medical profession, in general, continues to assess the health affected person independent of their environment (Wu *et al.* 2007) which can lead to delay in diagnosis, misdiagnosis or in the worst case, non-diagnosis when the home environment plays a role in the health problem. Table 1 identifies the elements in the provision of a holistic medical patient service considering all aspects of their condition. The absence of professional home IAQ assessment is clear.

There have been some efforts to advance mold related illness awareness within the medical profession. Findings, such as those published by the University of Connecticut in tandem with the US EPA (Storey *et al.* 2004), assist health care providers in understanding how mold from indoor environments adversely affects the health of occupants. But as of yet these findings are not incorporated into general medical curriculum nor hospital/ medical procedures to positively affect how building related mold issues are being addressed clinically. Nor is the diagnosis and reparation of mold affected homes included in medical insurance policies.

Professional assessment of IAQ issues in the home

The most trained and knowledgeable professional in the environmental service industry is the environmental consulting engineer (ECE). The use of science-based environmental assessments to remedy regulation failures in commercial/public (i.e. non-residential) environments is necessary by regulation (eg. Worksafe BC). The ECE is called upon to determine the extent of environmental impact, prescribe corrective measures based on industry regulations, oversee the cleanup, and certify environmental compliance for (re)occupancy. Regulation based professional indoor air quality or environmental reports can be extensive and therefore expensive through an ECE, which renders the same process economically infeasible to the average homeowner. As such, the ECE has not been present in the evaluation, assessment, and prescription of indoor air quality issues in homes to any great extent. With a charge out rate of $175 - $250 per consultant hour, site visits, testing, and reporting can run into several thousand dollars for baseline services, and much more for specialized analysis. Although there is willingness of building owners, there is not generally an economic ability to have residential indoor environments assessed (Wellington ***et al.*** 2005). This is a significant barrier to be overcome by homeowners; even more so with residential tenants. As such the ECE tends not to be involved in residential mold related issues unless the projects are of a much larger scale (commercial strata developments or Government owned complexes).

An alternate version of the ECE is the certified IAQ consultant or mold assessor who are primarily residential and small building focused and less costly in comparison to the ECE, providing practical solutions within a limited suite of services. IAQ consultants and mold assessors are not regulated and have limited outside professional criteria to conform to. They can be trained and certified through the indoor air quality association (IAQA) and as such are considered an independent third party if not associated with a remediation firm or IAQ product supplier. Site delivered third party professional assessments by IAQ consultants endeavor to expose and reverse through recommendation the incidence of toxic environments through site assessment and specific field testing (as required). Results and recommendations are provided in report form. Environmental hazard issues that exceed the IAQ Consultant or mold assessor skill set are generally referred to an ECE. However, the IAQ Consultant encompasses a very small segment of the indoor air quality service industry. Found in single or small consultant groups, they can belong to organizations such as the IAQA. The certified IAQ consultant is expected to be guided by the following definition:

> *The goal of a building investigation is to identify and solve indoor air quality complaints in a way that prevents them from recurring and which avoids the creation of other problems. To achieve this goal, it is necessary for the investigator(s) to discover whether a complaint is actually related to indoor air quality, identify the cause of the complaint, and determine the most appropriate corrective actions* (US EPA 2012).

Canada Mortgage and Housing Corporation (CMHC) developed a program in the mid-1990's called the "Residential Indoor Air Quality Investigator Program" that introduced the issues surrounding IAQ in homes to professionals – builders, architects, engineers and other residential specialists and provided a general overview program for the assessment of indoor environments and solutions (CMHC 2011). CMHC trained IAQ practitioners have a broad, elementary scientific-based training to assess and prescribe solutions to assist homeowners in

reducing or eliminating the environmental stressors affecting their homes. These investigators charge in the range of $500 - $800 for a visual only site assessment. Testing is excluded in the base assessment requirements and would add $450 - $600 to the cost of assessment per residence for basic air testing. These costs tend to be acceptable to all but the lowest income demographic. Recently, Healthy Indoor Partnership (HIP) took over CMHC's IAQ training program in 2012. The IAQ Investigator certification courses are accessed by not only IAQ consultants, but IAQ product service providers, insurance companies, and government of Canada personnel. HIP is expanding the CMHC protocol and updating the courses to ensure relevance in this emerging industry. This is important to note as there are a limited number of IAQ consultants who conduct residential assessments in North America.

In Canada, HIP's "Investigator Program" adds a few more certified IAQ consultants each year of the 20 to 60 who take the course. Over more than a decade since its inception, there were only 46 confirmed individuals in Canada as of 2010 who completed the CMHC program and may be practicing in the field. Of this, only 12 were outside BC, Ontario, and Quebec. No Canadian IAQ Association exists to support the small number of qualified professionals in this field. Of the 46, only 6 were found to be consultants who weren't also contractors, suppliers, or laboratories as well. The largest association for IAQ resides in the USA but also with few consultants who aren't also contractors, suppliers, or laboratories (IAQA Dec 2011). This speaks to the clear lack of qualified third party IAQ professionals and professional oversight for this industry.

Opinions vary widely on what investigative and testing methods are necessary, as well as what constitutes an unhealthy environment based solely on mold level in a home. There is no specific number that defines either safe or unsafe mold exposure. Some experts have proposed airborne mold guidelines; however none of these have been adopted by regulatory agencies. For example, CMHC's perspective that a visual only assessment is sufficient to determine IAQ related health issues in a home differs from research that indicates air testing for mold is a good indicator of indoor air quality in building environments (Cabral 2010). There is, though, suggested means and methods that take into account the health and well-being of the occupant prescribed in reference documents such as the New York State IAQ protocol (NYSTMTF 2010), EPA IAQ protocol (USEPA 2012), and Canadian construction association document (CCA) 82 to name a few. These outline the cause of mold proliferation, the possible and probable health effects, and describe remedial solutions to reduce or abate health consequences. A proper assessment should take into account these reference documents, while describing the existing indoor environment and how it can be made healthier through prescriptive means.

Specifically, this assessment should include, at minimum, a comprehensive check list conducted by a well-trained IAQ professional of what is wrong or unfavorable in the indoor environment, with description and a ratings scale, and a detailed description of how to reverse those site conditions found unfavorable. This backed up with lab analysis of the indoor molds present would help to support the inspection recommendations. Further, a means to determine whether the indoor environment being investigated could be considered hazardous would significantly advance the field of indoor environmental remedy. As well, being able to teach and train the homeowner on best practices while delivering results has been found to be essential, if not crucial.

Over the last decade many inspectors that are capable of collecting mold samples have been trained for work in the home inspection field. These inspectors are usually associated with a

remediation contractor or testing lab and are rarely qualified for a full independent environmental home site assessment. This level of service for the homeowner costs between $300 - $500 for generic air testing and lab results. Again, this tends to fit the financial ability of a large proportion of society. Specific (value added) consulting work to help the homeowner understand the results would be in addition to this service if available by the home inspector and if affordable by the homeowner. The limitation of this method of testing only for customer based IAQ solutions is that air tests alone provide questionable results. Industry oversight organizations such as CMHC, Health Canada, and EPA, as well as researchers, and IAQ Consultants state that testing without professional site assessment is not an accurate or recommended method for IAQ assessment.

Indoor air quality service and product industry

The professional consultant approach can be expensive and complicated, and the health affected occupant usually has neither the necessary time nor money (US EPA 2012). The less daunting and increasingly available approach is to seek IAQ related products and services directly. Products include portable air purification systems, self-administered mold testing, air scenting agents, and air "freshness" products. Product services include carpet and duct cleaning and whole house customized air filtration and mechanical ventilation systems. The IAQ product and product service industry has developed and evolved through an unregulated business environment and to some extent is based on lowest price and salesmanship. As such, gathering information to make an informed decision can be fraught with confusing alternatives, competing designations, and value judgments which may lead to misinterpretation of environmental requirements, improper diagnosis, and costly misdirection (Lawrence & Martin 2001). Table 2 is a summary of service providers competencies deduced from scientific review of the industry from 1999 to present in the Okanagan valley regions of British Columbia, Canada (with which the authors are most familiar). As the industry grows and matures, it is possible that the confusion will be reduced and overlapping technologies and services will merge into a more seamless delivery system with a primary focus on the best interests of the health affected occupant.

Consumer marketed indoor air quality products include: portable and fixed, room and whole house air purification systems; low VOC construction products; non-lead based products; and non-chemical, biodegradable cleaning products. IAQ products are sold in stores, by mail, and over the internet. As the marketplace for IAQ products is not generally regulated, unsubstantiated claims can be made. Chemical cleaners may be marketed as "mold killers" for example. Biodegradable and chemical free cleaners and chlorofluorocarbon (CFC) free aerosols (actually regulated) are now readily available in stores. But beside these products are chemically enhanced, VOC based "deodorants" and cleaners. Products purporting to be "earth friendly" and "IAQ" specific require further scrutiny to ensure accuracy of product claims.

Scented consumer products and air freshener/masking agents are found in homes that can directly or indirectly mask mold related indicators and otherwise obvious odours that could indicate an active biologic environment. The efficacy of the use of home air fresheners and scented laundry products were examined by a University of Washington study and found to be potentially health affecting at best and toxic or hazardous by US federal law at worst (Caress

2004). A study by the National Resource Defense Council (NRDC) added to the public debate. In testing 14 different air fresheners sold at a drug store, the study concluded that many contained chemicals that could cause developmental and reproductive problems, especially for infants (NRDC 2007). The University of California at Berkeley performed a study on air fresheners and household cleaners that discovered ethylene-based glycol ethers, classified by the EPA as hazardous air pollutants (Science Daily 2006). These are but a few examples of the IAQ product industry purporting to solve indoor air quality problems by odour masking techniques. These methods can result in the continuance of mold proliferation and ill-health in residences.

Product and service providers have found an increased consumer awareness of indoor environmental issues that could be leveraged into product sales utilizing terms such as “IAQ” or “IAQ specialist service”. Regularly, house and carpet cleaners, duct cleaners, and heating and ventilation contractors now include these terms in marketing their existing products or they add product lines deemed to contain indoor air quality benefits but are generic in nature. Those demonstrating the necessary care and attention commensurate with demonstrable customer indoor air quality needs deserve the opportunity to offer services within the context of their profession; but some may have expanded into indoor air quality services without the necessary expertise or awareness. This scenario is played out in households that include environmentally sensitive occupants in some cases where a contractor’s premise for IAQ based renovation work was found to be exaggerated or misinformed due to lack of building science and indoor environmental knowledge. This supports a concern that IAQ focused contractors may inadvertently take advantage of homeowner fears to realize increased work opportunities. The distinction is stark and can only be overcome with consumer awareness and quality standards set by industry. The IAQ profession can be better served by driving a value based service as opposed to a price based one, which includes the IAQ Professional as a key component.

The cost of various services is provided in table 3 based on general trade information from the Okanagan valley region. With cost a key driver in the decision making process towards undertaking environmental assessment and product and service purchase by the environmentally affected, homeowners are initially led to choose the most economical and perhaps less overall capable solutions. Product suppliers provide non-personalized simplistic IAQ based solutions through industry specific products and services denoted above. The adverse effects of IAQ are not a simple or generic problem–solution couplet. In fact determining IAQ solutions is a complex process (Cabral 2010); an approach that exposes the cause, determines the specific effects, and engineers a solution that endures - a solution that is sustainable. This sustainable solution usually requires house specific professional IAQ input for accurate validation of indoor environmental cause and effect. Understanding environments accurately requires rigor and a thorough assessment using the scientific method. IAQ solutions necessarily include an understanding of all aspects of the building’s indoor air quality both by visual assessment and, as required, by lab based sampling methods. This is missing in generic products and product oriented services that are not based on specific homes and occupant conditions. In short, products and services that are obtained without professional environmental assessment likely do not address the underlying problems associated with environmental impacts, leading to continuing failure in resolution of the problem.

Regulation based IAQ solutions

Federal government legislation regulated via the Canadian Department of Justice Occupational Health, and Safety, and, the US department of Labor Occupational Safety and Health Administration makes employers responsible for the health and safety of their workers in workplace environments. However, others do not regulate the residential environment under any active IAQ standards in either Canada or the USA.

Worksafe BC (2012) manages the regulation of the health and safety of workers in indoor environments in British Columbia by charging employers with this responsibility. Worksafe BC audits employers, and conducts incident assessments to ensure solutions are applied and remedies proven. In the workplace, it is accepted that mold, perceived or visible, can cause sickness and regulations require thorough professional assessment and remediation upon complaint to meet Worksafe BC (2012) criteria in commercial and public spaces. For example, the response and recourse for a worker who develops sickness on the job is overseen by a certified occupational health specialist, who takes into consideration the materials of the trade, within the worker's environment. Residential environments have no such regulatory criteria. The residential Tenancy Act and ombudsman do not have sufficient regulatory power or funding to protect tenants from hazardous indoor environments. Local municipal authorities typically will not act on tenant environmental complaints, claiming lack of legal clout. Law enforcement will not intercede between landlord and tenant unless a criminal act has been perpetrated.

This lack of oversight is exacerbated by a lack of awareness of building owners and a limited access by knowledge based organizations for verification and assessment purposes. For example, in 2011 over five million homes transferred ownership in North America (CREA, NAR 2012), with many of those reviewed by professional home inspectors, yet mold identification and assessment is specifically excluded from home inspection protocol (ASHI, CAHPI 2012). Many millions more homes go through municipal permitting for additions and renovations that would allow IAQ assessment to compliment the building official inspection and verification process, yet audits are not required.

Government and NGO based IAQ initiatives

If the health affected person seeks IAQ solutions directly through internet search engines, they find that government agencies such as CMHC, Health Canada, HUD, EPA, state websites, and non-government organizations (NGOs) have now added significant IAQ support information to their websites, some prominently. The sites in general deliver to the observer "how to" knowledge on various defined indoor air quality subjects that provide guidance towards better IAQ in the home in general. Refer to Table 4 for a relevant list of reference websites and table 5 for Government and NGO literature references. The general population identifies "mold" as the most significant public health issue in terms of 'web hits' at 16.1 million (Google 2012). The significant term "asbestos" registered less, at 5.7 million web hits compared to 1.6 million for volatile organic compounds (VOC) and 1.0 million for radon (which kills 20,000 people each year in the USA (US EPA 2012)), with other serious and significant IAQ subject matter lagging far behind. Yet, most residential clients with mold related health concerns have little knowledge as to how their mold problem was caused or how it could be remedied. There is concern but little knowledge. This appears to indicate that consumer awareness programs have been effective in

creating awareness to the point of concern, but are ineffective in transferring relevant knowledge to those affected to assuage ill-conceived concerns.

There have been breakthroughs though as healthy homes initiatives are being promoted in a broader US Federal Healthy Homes program. This includes the effects of mold and asthma triggers that have shown some effectiveness in modifying individual's traits towards internalizing IAQ initiatives (Brown *et al.* 2010). As well, the US Department of Housing and Urban Development (HUD 2003), the EPA, and state legislators appear to be set to codify at least the environmental mold aspect of IAQ (Indoor Environment 2012). Florida and Virginia, and other states have recently enacted (and then repealed due to cost cutting measures) a law regulating mold assessors that may ultimately require the setting of minimum specific fungal count levels as the regulations get tested legally (Indoor Environment 2012). Note that this regulation was not for the overall IAQ of a home; but only pertains to mold testing assessment. Regulation, even to a limited extent, can ensure indoor environments meet a standard that can be measured. This can then support the development of a sustainable initiative for better IAQ in homes.

In 2008, the Government of Alberta instituted a regulation of residential tenancies that included identifying and directing the remedy of poor IAQ environments specifically due to mold growth. The initiative had no punitive force behind it and recently has been reduced to providing recommendations only. Moreover, no assessments or studies have been conducted to verify whether prescribed remedies were undertaken or whether tenants were better off after the intervention. This information is useful to validate what is already confirmed and proven in commercial environments: baseline indoor air quality standards must be met; and when not, remedy is necessary for the health of the occupants.

In addition to federal, state/ provincial IAQ regulations, the ideal of IAQ residential building assessment for the public good can be found in a few municipality level initiatives and studies. One such program is outlined in HUD's *Healthy Homes – Assessing Your Indoor Environment* which introduced a program in New York State called the "Cooperative Extension Office" (HUD 2007). Within this outreach, educators respond to resident indoor air quality concerns by visiting the home, conducting a visual assessment with the homeowner, advising them of health and safety hazards, and making specific recommendations to correct described IAQ issues. Further research on the costs associated with the initiative should assist in developing an overall social cost benefit value to the program. This could form the basis for a sustainable community-based IAQ resource program.

Although these types of consumer education programs are available in the US, they have limited effect, as many regions, municipalities, and districts cannot enforce regulatory limitations towards any type of home intervention. Government regulations and intervention programs to correct residential hazards have long been rebuked by civil liberties groups, private citizens, landowners, and the courts. There have also been many Government funded pilot projects and studies throughout the years that have introduced homeowners to indoor environmental issues and how to economically improve their indoor environments (US EPA 2007). Unfortunately, pilot projects have unsustainable long term funding models and built-in short term focus with little to no monitoring, assessment, or strategic follow-up.

The economic effect and its impact on our society

In the absence of supporting government policies and proactive education programs, economics plays an important if not central part in the occupant's decision to determine the cause and effect of the health issues that may pertain to their home environment (Cabral 2010, Wu *et al*. 2007). Through professional experience at healthy Homes IAQ, it was observed from 2002 to 2012 that over 25% of health specific enquiries could not afford services at any cost; most others had a threshold of less than $200 - $600. The majority of those who could not afford an IAQ service at any cost were renting tenants. Substandard housing for those less able to correct are three times as likely to have indoor dampness issues that is the source of physical impairment (Wu *et al.* 2007). The many studies presented in the literature indicate mold related environmental issues tend to happen more often in inner-city low income households. In these instances, resolution of health impacts is generally limited to superficial medical treatment with likely no attention to indoor environmental causes. There is a cost to society when indoor environments are left in a toxic state. The cost in terms of impact on the US economy has been measured in the billions of dollars ($2 – 40 billion) from loss of workplace productivity alone due to building related ill health (Fisk 2001, Kosonen & Tan 2004). In addition, the major cause of the increase in respiratory-related sicknesses over the years is due to asthma from inadequate indoor air quality, with an estimated to cost Canadians over $700 million per year in direct costs and over $800 million per year in indirect costs for health care (PHAC 2007). In terms of reduced life and loss of well-being, and overall social impact, there are consequences that have yet to be measured, but they appear to be significant enough to motivate society to address indoor mold environments proactively, in a sustainable manner, using an integrated, systems-based approach.

An integrated approach utilizing the health care system

An integrated approach to bridging the gap between patient medical requirements, medical and industry support methods, and home indoor environment realities could include a framework that would focus the medical profession on an indoor home environment data capture diagnosis approach and the IAQ service industry on a health-based approach both based on good science (population health and epidemiological data) and regulation. Proactive measures to the challenges facing mold affected occupants can also be solutions that may well reverse spiraling health care costs by reducing reactive treatments. Moreover, by taking a proactive approach to identifying patients that may be environmentally affected and undertaking on-site prescriptive measures that positively reduce their health impacts due to mold and dampness, the cost of their healthcare may be significantly reduced. To facilitate this more proactive approach the medical profession can more thoroughly prepare medical practitioners through enhanced education and training and by providing key insights to indoor mold related issues to better demonstrate the effects of environmental impacts on their patient's health. Supporting methods in the developmental stages, such as, use of flow charts and decision trees that describe cause and effect relationships between mold exposure and ill-health could assist front-line doctors in increasing precision and accuracy of diagnosis and treatment.

The home inspection industry and other service providers who undertake residential inspection programs can be trained and better resourced to identify environmental indicators of

potential ill-health conditions with simple yet effective protocols and general solution based recommendations undergirded by developing science based testing methods. A standard environmental assessment protocol, taking into account criteria set out above, can be developed for site condition and for test results assessment. Importantly, though, accurate medical evaluation is required to establish the validity of site assessment protocols (Lawrence 2001). Further, literature shows that where clinical tests failed to identify cause, site air testing did find the cause of ill-health in patients (Cabral 2010). This underlines the interdependency as well as importance of a symbiotic professional relationship between medical and IAQ professionals in assuring the most accurate and useful diagnosis for the affected person is provided. Training municipal building officials to identify poor indoor environments and giving them the means and methods to address tenant health and environmental complaints with enforceable measures can help to resolve long standing issues with substandard housing stock in our communities. Further, adding mold assessment criteria (perhaps the same decision tree protocol noted above) to the municipal building permitting and verification process would help identify homes that require environmental upgrading based on existing occupant health impact characteristics. Using Government policy oversight by enacting regulations in the form of standards of practice and codes of conduct for product service providers for home environments, substandard living conditions can be brought to light for remedial repair. The extent of substandard indoor environments can only be broadly estimated, but is likely significant. All these methods can form an integrated, systematic approach for moving forward to reduce mold affected environments and occupant ill-health.

Concluding remarks

The prevalence of mold and damp environments in North American housing stock can be a significant source of ill-health in occupants. Manifestation of mold related ill-health can take the form of influenza-like respiratory symptoms that can mask mold related disease as a primary cause. This can delay site verification and accurate diagnosis for an extended period of time if not indefinitely. Inadequate and disjointed responses involving health care professionals, health authorities, government policy analysts, IAQ professionals, IAQ products, and IAQ service providers exacerbates the challenge in identifying and remediating unhealthy indoor environments and misses the mark in educating and training the public at the most appropriate time – when they are being affected by their indoor environment.

Access for homeowners to permanent residential IAQ solutions to ill-health is contingent on 1) proper initial direction, 2) accurate medical responsiveness, 3) regulation of the products and services directed at the home environment, 4) better awareness of IAQ industry product and service pitfalls, 5) affordability, 6) availability of proper professional investigative services, and 7) lifelong training and education. Early access to readily available, science-based information from an economical baseline assessment of the home environment can assist in advancing health related issues toward sustainable solutions.

The review of literature found a proliferation of recent research on this subject that indicates a broadening academic acceptance of a stronger association between mold and ill-health in indoor environments. This bodes well for the development of solutions to better diagnose indoor environment based illness in a timely manner to benefit the health afflicted and society at large. A sustainable solution encompasses proper thorough professional assessment,

prudent environmental cleanup methods, appropriate industry regulation, enhanced homeowner awareness and training, economic prudence, and verification of effects. This sustainable solution by definition must include a strong business case to provide economic justification to support shifting the burden to a societal collective from the individual, to overcome an historic societal pattern of non-recognition and non-action. This will be left to future research.

Solutions to reversing spiraling health care costs for reactive treatments are possible through an integrated systems-based approach between health care providers, medical profession, IAQ professional, and product service industries. This paper offers some scenarios to assist this effort.

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