Global Indoor Health Network (GIHN)

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Global Burden of Indoor Air Contaminants

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Section I. Overview

Astute physicians and healers have been aware of the existence of environmental toxins for more than a thousand years. The list of substances, both naturally occurring and manmade, which may cause harm to the human organism, is continually growing.

Curiously, while heart disease, cancers and rare exotic illnesses frequently grab headlines, illness due to environmental sources, though incredibly common, often receive little or no media coverage. As a result, there is poor understanding, and acceptance, of the concept that our environment is capable of slowly poisoning its inhabitants. This is surprising considering the thousands of research papers and reports on this topic.

This paper provides a discussion of this topic, along with statistics and financial costs.

We will start with a few specific quotes highlighting the significant harm caused by indoor air pollution:

In a 2016 report by UNICEF focusing on the impact on children:

The UNICEF report highlights the significant impact of indoor and outdoor pollution on children and emphasizes the urgent need for countries to take action now. They say it very succinctly with the comment "the impact is commensurately shocking."[1]

The UNICEF report highlights the significant impact of indoor and outdoor pollution on children and emphasizes the urgent need for countries to take action now. They say it very succinctly with the comment "the impact is commensurately shocking."

In a 2009 report by the World Health Organization (WHO) on dampness and mould:

> Indoor air pollution – such as from dampness and mould, chemicals and other biological agents – is a major cause of morbidity and mortality worldwide. [2]

In a 2010 report by the WHO on indoor air quality and selected pollutants:

> Indoor exposure to air pollutants causes very significant damage to health globally—especially in developing countries.[3]

In a 1989 report from the U.S. Environmental Protection Agency (EPA):

> Health effects from indoor air pollution cover the range of acute and chronic effects, and include eye, nose, and throat irritation, respiratory effects, neurotoxicity, kidney and liver effects, heart functions, allergic and infectious diseases, developmental effects, mutagenicity, and carcinogenicity.[4]

There are statistics available regarding the illnesses caused by some (individual) indoor air contaminants (such as tobacco, radon, lead, asbestos, and solid cooking and heating fuels). However, the illnesses caused by many other indoor air contaminants are not currently being tracked in any country. As a result, there is not one combined statistic available regarding the number of illnesses and deaths caused by indoor air pollution.

Nevertheless, there are several estimates of the financial and statistical impact of various indoor air pollutants. When you consider the total impact of these contaminants, it is important to consider both the acute and chronic health effects.

We will provide several key statistics in this paper. These statistics should catch the attention of every physician, every lawmaker and every layperson reading this paper. These numbers are greater than all the cancers and all the heart disease combined.

It is time we pay more attention to the indoor air we breathe. It is time for our world leaders to address this important, and costly, public health issue.

Brief summary of the history of indoor environmental exposures

Thousands of books, research papers and reports have been written on this topic, so we will make only a few brief comments.

Occasionally, an environmental illness becomes national news overnight. Legionnaires' Disease, caused by the *Legionella* bacteria, became a media superstar in the summer of 1976 as hundreds of people became ill at the American Legion convention in Philadelphia, Pennsylvania. This is the exception for most environmental poisons.

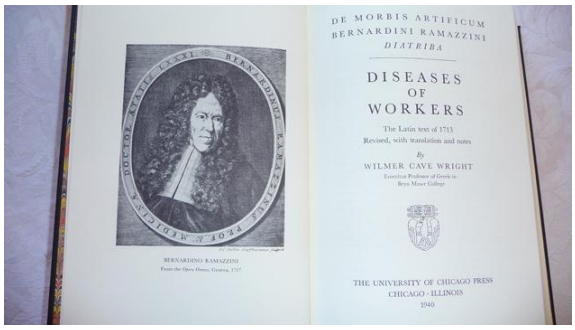
Typically, a few individuals discover the toxic potential of a substance (such as asbestos) and publish their findings. However, history has shown that it may take 3-4 decades or longer for the public and Western medicine to accept (or uncover) the truth about the danger.

If we look at tobacco as an example, it was 50 years before the truth was revealed and, yet, the tobacco companies are still continuing to produce and sell those products.

This delay in widespread awareness of scientific findings is not new and was certainly around in the times of Copernicus (1473-1543), Galileo (1564-1642) and others whose theories and proofs were opposed by powerful controlling bodies. In time, however, the truths of their works prevailed.

Another important environmental health publication in history was a book by Bernardini Ramazzini in 1700. He published a book titled "De Morbis Artificum" (Diseases of Workers)

that discussed the health hazards affecting workers including chemicals, dust, metals and other agents.



This book highlights a number of environmental toxins, most of which have already been accepted as capable of causing significant disease. Studying their individual histories of usage and poison potential discoveries confirms that we, as people and as physicians, are usually slow to accept that these substances—found in most homes, schools and workplaces—are capable of harming us and our children.

To learn more about the decades-old strategy of denying the health effects of environmental exposures, read our paper on "Naysayers and Deniers." It provides a detailed discussion of Big Business and other naysayers and their long-term strategy to deny the health effects of tobacco, mold and other toxins.

<u>Brief summary of the financial impact</u>

The U.S. EPA estimates that up to ½ of all U.S. buildings are water-damaged, and the bill to correct all these spaces is enormous. State and Federal governments do not want to pay this price, nor do school districts or other employers. Building insurers have quietly exempted themselves via the addition of mold riders in their policies (non-existent 20 years ago).

On a global basis, "the prevalence of indoor dampness varies widely within and among countries, continents and climate zones. It is estimated to affect 10–50% of indoor environments in Australia, Europe, India, Japan and North America. In certain settings, such as river valleys and coastal areas, the conditions of dampness are substantially more severe than the national average."[2]

Meanwhile, more and more people are getting sick in the buildings where they live, attend school and work. By keeping the issue hushed, government agencies and Big Business have avoided payment and have pushed the costs onto the "little guy" (i.e., the individual homeowners, small businesses, etc.).

In a 2016 report, they estimated the cost of healthcare and lost earnings due to illness caused by endocrine-disrupting chemicals at $340 billion in the U.S. They also provided an estimate of these same costs for Europe, showing an annual cost of $217 billion.[5]

A 2017 report from Europe reported the annual cost of asthma and chronic obstructive pulmonary disease at €82 billion ($93 billion).[6]

In Finland, the estimated the cost of health problems associated with mould and damp is 450 million euros each year. If you add the cost of repairing the problems, the total reaches 1.4 billion euros.[7]

Another study estimated the cost of air pollution (indoor and outdoor pollution) of 53 countries in the European Region at $1.6 trillion. This is nearly 1/10 of the gross domestic product (GDP) of the entire European Union.[8]

The estimated cost of indoor and outdoor pollution in the European Region is $1.6 trillion. This is nearly 1/10 of the gross domestic product (GDP) of the entire European Union.

If you look at the other side of the equation, billions of dollars could be saved if we implemented specific steps aimed at improving indoor air quality.

According to a 2000 report by Fisk, et al "the estimated potential annual economic savings plus productivity gains, in 1996 dollars, are approximately $40 to $200 billion" if we would implement specific scenarios to improve indoor environmental quality in U.S. office buildings.[9]

Imagine how big those savings would be if we also made these changes in schools, homes and other structures around the world.

Individuals, employees, teachers, students, families and potentially millions of people are suffering, while Big Business works hard to protect their financial interests.

Indoor air contaminants cause significant damage to health globally.

It is staggering to comprehend the enormous impact on our global society as literally millions of individuals and families are harmed by contaminants inside our homes, schools and workplaces. The financial costs are equally staggering with estimates in the hundreds of billions of dollars. The statistics presented throughout this paper should catch the attention of every physician, every lawmaker and every layperson.

Changes over the years in building philosophy, construction materials, pesticides, usage patterns, etc., along with new awareness and improved testing capabilities, have brought us to the understanding that some buildings are sick and can make their occupants sick. Shoddy construction practices and environmental disasters also contribute.

People spend approximately 90% of their time indoors. As such, it is a disconcerting thought that the structures where we live, work and go to school might lead to significant and even deadly health problems.

As a society, we trust and even cherish many of these places. Yet some harbor hidden and harmful dangers.

Imagine how different things could be if the truth came to light and all vested parties worked together to improve our indoor air. Imagine the impact on future generations.

- Medical costs would drop significantly.
- Doctors would have accurate, reliable information and be able to provide proper medical diagnosis and treatment.
- We could reverse the huge increase in asthma rates and reduce the billions of dollars being spent on asthma-related illnesses.
- Builders and construction firms would have the information they need to create safe and healthy homes, schools and workplaces.
- Teachers and students could teach and learn in schools with healthy indoor air, increasing their productivity, improving their education and attendance, and increasing their chances for success in school and in the future.
- Employees could work in buildings with healthy indoor air, increasing worker productivity and decreasing sick days and workers' compensation claims.
- Disability claims would drop significantly, reducing the cost and administrative burden of the rapidly increasing number of social security and private employer disability cases.
- Poor indoor air quality situations would be handled correctly, enabling business owners and landlords to properly remediate and remove contaminants, and prevent homeowners, tenants and employees from losing their homes and jobs as well as their lifetimes of achievements.

In other words, we would create a healthier, more productive society worldwide.

Throughout this paper, we will discuss many indoor air contaminants. For an in-depth discussion of the various types of indoor air contaminants, read our paper titled "Indoor Air Contaminants."

When evaluating the impact of indoor air contaminants, it is important to consider all of the possible sources and the acute and chronic health effects.

Section II. Statistics Regarding the Health Effects of Indoor Air Contaminants

There are statistics available regarding the illnesses caused by some (individual) indoor air contaminants (such as tobacco, radon, lead and solid cooking and heating fuels). However, the illnesses caused by many other indoor air contaminants are not currently being tracked in any country. As a result, there is not one combined statistic available regarding the number of illnesses and deaths caused by indoor air pollution. Nevertheless, there are several estimates of the financial and statistical impact. In addition, there are countless statements in reports from government agencies and researchers that illustrate the significant health effects of indoor air pollution and other environmental exposures. When you consider the total impact of these contaminants, it is important to consider both the acute and chronic health effects. The following discussion will highlight the serious health threat posed by indoor air pollution.

Worldwide

Countries around the world are showing an increased interest in the health effects of indoor and outdoor air pollution. In this section, we will present information from three sources—a 2016 report from UNICEF, a 2012 report on the Global Burden of Disease, and several reports from the World Health Organization.

UNICEF (2016)

A 2016 report by UNICEF (United Nations International Children's Emergency Fund) highlights the significant impact of indoor and outdoor pollution on children and emphasizes the urgent need for countries to take action now. The report focuses on the increased risk to children, but these pollutants are affecting adults and children around the world. The impact on children is described as follows:

> Children breathe twice as quickly as adults, and take in more air relative to their body weight. Their respiratory tracks are more permeable and thus more vulnerable. Their immune systems are weaker. Their brains are still developing.[1]

> Ultrafine, airborne pollutants -- caused primarily by smoke and fumes -- can more easily enter and irritate children's lungs, causing and exacerbating life-threatening disease. Studies show these tiny particles can also cross the blood-brain barrier, which is less resistant in children, causing inflammation, damaging brain tissue, and permanently impairing cognitive development. They even can cross the placental barrier, injuring the developing fetus when the mother is exposed to toxic pollutants.[1]

As the report states, "the sheer numbers of children affected are staggering. Based on satellite imagery, in the first analysis of its kind, this report shows that around the world today, 300 million children live in areas with extremely toxic levels of air pollution. Approximately 2 billion children live in areas where pollution levels exceed the minimum air quality standards set by the World Health Organization. These data don't account for the millions of children exposed to air pollution inside the home."[1]

It goes on to say that "the impact is commensurately shocking. Every year, nearly 600,000 children under the age of five die from diseases caused or exacerbated by the effects of indoor and outdoor air pollution. Millions more suffer from respiratory diseases that diminish their resilience and affect their physical and cognitive development."[1]

> Together, outdoor and indoor air pollution are directly linked with pneumonia and other respiratory diseases that account for almost one in 10 under-five deaths, making air pollution one of the leading dangers to children's health.[1]

Global Burden of Disease (2012)

One methodology used to evaluate the impact on global health due to certain causes of disease and injury is known as the Global Burden of Disease (GBD).

> The original Global Burden of Disease Study (GBD 1990 Study) was commissioned by the World Bank in 1991 to provide a comprehensive assessment of the burden of 107 diseases and injuries and ten selected risk factors for the world and eight major regions in 1990.[10]

The WHO published their first report on the GBD concept in 1996. In a 2006 report by the WHO, they "estimated 24% of the disease burden (healthy life years lost) and an estimated 23% of all deaths (premature mortality) was attributable to environmental factors. Among children 0–14 years of age, the proportion of deaths attributed to the environment was as high as 36%."[11]

Beginning in the spring of 2007, a new GBD project was initiated. The new Global Burden of Diseases, Injuries, and Risk Factors Study (the GBD 2010 Study) "is the first major effort since the original GBD 1990 Study to carry out a complete systematic assessment of global data on all diseases and injuries.

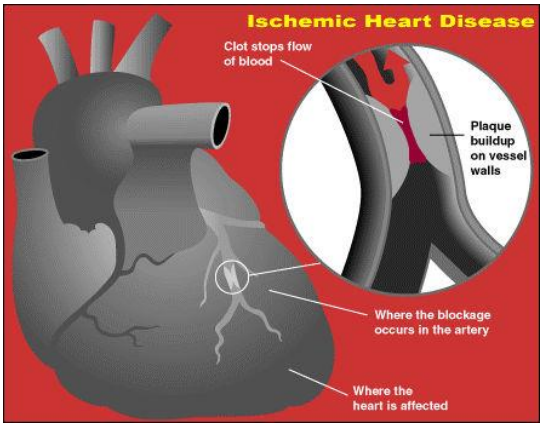
The GBD 2010 Study brings together a community of experts and leaders in epidemiology and other areas of public health research from around the world to measure current levels and recent trends in all major diseases, injuries, and risk factors, and to produce new and comprehensive sets of estimates and easy-to-use tools for research and teaching."[10]

The results of the GBD 2010 study were announced on December 14, 2012. The study was presented as seven articles.

We would have expected that this study (GBD 2010) would include a discussion on indoor microbial contamination. Unfortunately, there was nary a reference to mold, mould, fungi, microbial or biological contaminants in any of the seven articles. This is a glaring omission. It's very disappointing that they neglected to address this important public health issue in the study, and it makes it even more important that we address the global burden of disease from indoor air contaminants in this paper.

Even though the GBD 2010 study did not address those specific indoor air contaminants, they did mention a few other types of indoor air pollutants. In the article titled "A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions,"[12] they mentioned other indoor pollutants such as solid fuels, residential

radon, lead exposure and several occupational exposures (i.e., asbestos, arsenic, benzene, cadmium, chromium, diesel exhaust, second-hand smoke, formaldehyde, nickel, polycyclic aromatic hydrocarbons, silica, and sulfuric acid) and occupational asthmagens and occupational particulate matter, gases and fumes.



In the table shown on page 2236 of the article titled "A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions," they list "the proportion of ischaemic (ischemic) heart disease disability-adjusted life-years (DALYs) attributable to individual risk factors."[12]

Keeping in mind that these percentages only consider a single health effect (ischaemic heart disease), here are a few of the results relating to these three indoor air pollutants:

Ambient particulate matter pollution	22%
Household air pollution from solid fuels	18%
Lead exposure	4%

On pages 2238-2240 of that same article, they provide the number of deaths in 2010 for specific risk factors.[12] The five statistics in the table that relate to air pollutants are:

Ambient particulate matter pollution	3,223,540
Household air pollution from solid fuels	3,546,399
Residential radon	98,992
Lead exposure	674,038
Second-hand smoke	601,938

In another article included in the GBD 2010 study titled "Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010,"[13] they say that "annual updates of the GBD study will now be feasible," so we will not have to wait a decade for the next update.

> Public health priorities everywhere are changing, or soon will be, as large and avoidable causes of disease burden become more common with development.[13]
>
> Rather than huge periodic revisions of the GBD every decade, it is now feasible to conduct annual updates so that the consumers of health intelligence have the most recent and comprehensive information on comparative causes of disease burden available where and when it is required to help guide public health decision making.[13]

Global Burden of Disease (2013 and 2015)

They provided updated numbers in 2013 and 2015, but there was still no mention of mold, mould, fungi, microbial or other biological contaminants.

The 2013 GBD report an update on statistics for 240 causes of death and individual reports that focused on specific health issues (i.e., viral hepatitis, stroke, HIV, tuberculosis, malaria and infant deaths and maternal mortality).

The 2015 GBD report had an update on statistics for 249 causes of death and individual reports that updated the statistics for the same health issues included in the previous reports.

We will continue to monitor the research being conducted by the WHO and will actively participate in the advancement of these important public health issues. The following discussion will provide additional information about other research papers that have been published by the WHO on the topic of indoor air contaminants.

World Health Organization (WHO)

The World Health Organization has discussed the health issues resulting from indoor air pollution and environmental exposures in several reports, including the following five publications.

- World Health Organization: Indoor Air Pollutants: Exposure and Health Effects (1982)[14]
- World Health Organization: Preventing disease through healthy environments: Towards an estimate of the environmental burden of disease (2006)[10]
- World Health Organization: Guidelines for Indoor Air Quality--Dampness and Mould (2009)[2]
- World Health Organization: Guidelines for Indoor Air Quality: Selected Pollutants (2010)[3]
- World Health Organization: Worldwide burden of disease from exposure to second-hand smoke: a retrospective analysis of data from 192 countries (2010)[15]
- World Health Organization: Environmental Burden of Disease Associated with Inadequate Housing (2011)[16]
- World Health Organization: Ambient Air Pollution: A Global Assessment of Exposure and Burden of Disease (2016)[17]
- World Health Organization, Ten Years in Public Health (2017)[18]

Each of these reports discusses the health effects, illnesses and deaths caused by indoor air pollutants. We are providing a few key excerpts from each of these reports, as follows:

1982 WHO report (indoor air pollutants)

> With the growing recognition that air pollutant concentrations often vary considerably according to location and time, and that people often spend 80-90% of the whole day within enclosed spaces, it is necessary to determine the total exposure of individuals and populations to different air pollutants in order to assess the adverse health effects associated with them.[14]
>
> Epidemiological studies of the health effects of air pollution should ideally be based on personal total exposure, although in practice this is not always possible and personal passive monitoring is often the only feasible way of acquiring such exposure data.[14]

2006 WHO report (preventing disease through healthy environments)

The World Health Organization published a 2006 report titled "Preventing disease through healthy environments: Towards an estimate of the environmental burden of disease."[10]

This report includes several environmental factors in its analysis, but it is important to note that it excludes many of the indoor air pollutants that are addressed in the GIHN papers on "Indoor Air Contaminants" and "Molds, Mycotoxins and Related Contaminants in Water-Damaged Buildings."

As a result, the statistics included in this 2006 WHO report do not relate directly to GIHN's definition of indoor air pollution, but it does provide some valuable information regarding the health effects of a variety of environmental exposures.

The following is a list of environmental factors included in the 2006 WHO report:[10]

- pollution of air, water, or soil with chemical or biological agents;
- UV and ionizing radiation;
- noise, electromagnetic fields;
- occupational risks;
- built environments, including housing, land use patterns, roads;
- agricultural methods, irrigation schemes;
- man-made climate change, ecosystem change;
- behaviour related to the availability of safe water and sanitation facilities,
- such as washing hands, and contaminating food with unsafe water or unclean hands.

> The evidence shows that environmental risk factors play a role in more than 80% of the diseases regularly reported by the World Health Organization. Globally, nearly one quarter of all deaths and of the total disease burden can be attributed to the environment. In children, however, environmental risk factors can account for slightly more than one-third of the disease burden.[10]

Globally, an estimated 24% of the disease burden (healthy life years lost) and an estimated 23% of all deaths (premature mortality) was attributable to environmental factors. Among children 0–14 years of age, the proportion of deaths attributed to the environment was as high as 36%. There were large regional differences in the environmental contribution to various disease conditions – due to differences in environmental exposures and access to health care across the regions. For example, although 25% of all deaths in developing regions were attributable to environmental causes, only 17% of deaths were attributed to such causes in developed regions. Although this represents a significant contribution to the overall disease burden, it is a conservative estimate because there is as yet no evidence for many diseases.[10]

Also, in many cases, the causal pathway between environmental hazard and disease outcome is complex. Where possible, attempts were made to capture such indirect health effects. For instance, malnutrition associated with waterborne diseases was quantified, as was disease burden related to aspects of physical inactivity attributable to environmental factors (e.g. urban design). But in other cases, disease burden was not quantifiable even though the health impacts are readily apparent.[10]

Lower respiratory infections. These are associated with indoor air pollution related largely to household solid fuel use and possibly to second-hand tobacco smoke, as well as to outdoor air pollution. In developed countries, an estimated 20% of such infections are attributable to environmental causes, rising to 42% in developing countries.[10]

An estimated 42% of chronic obstructive pulmonary disease (COPD), a gradual loss of lung function, is attributable to environmental risk factors such as occupational exposures to dust and chemicals, as well as indoor air pollution from household solid fuel use. Other forms of indoor and outdoor air pollution – ranging from transport to second-hand tobacco smoke – also play a role.[10]

2009 WHO report (dampness and mould)

Indoor air pollution – such as from dampness and mould, chemicals and other biological agents – is a major cause of morbidity and mortality worldwide.[2]

The prevalence of indoor dampness varies widely within and among countries, continents and climate zones. It is estimated to affect 10–50% of indoor environments in Australia, Europe, India, Japan and North America. In certain settings, such as river valleys and coastal areas, the conditions of dampness are substantially more severe than the national average.[2]

The prevalence of indoor dampness varies widely within and among countries, continents and climate zones. It is estimated to affect 10–50% of indoor environments in Australia, Europe, India, Japan and North America.

2010 WHO report (selected pollutants)

> Indoor exposure to air pollutants causes very significant damage to health globally – especially in developing countries. The chemicals reviewed in this volume are common indoor air pollutants in all regions of the world. Despite this, public health awareness on indoor air pollution has lagged behind that on outdoor air pollution.[3]

2010 WHO report (second-hand smoke)

> Worldwide, 40% of children, 33% of male non-smokers, and 35% of female non-smokers were exposed to second-hand smoke in 2004. This exposure was estimated to have caused 379,000 deaths from ischaemic heart disease, 165,000 from lower respiratory infections, 36,900 from asthma, and 21,400 from lung cancer.
>
> 603,000 deaths were attributable to second-hand smoke in 2004, which was about 1.0% of worldwide mortality.
>
> 47% of deaths from second-hand smoke occurred in women, 28% in children, and 26% in men.[15]

2011 WHO report (environmental burden of disease associated with inadequate housing)

> The findings confirm that housing is a significant public health issue and that policy-makers need to address it as a priority. Furthermore, they show the potential for primary prevention of a wide range of diseases and injuries through the improvement of housing conditions. However, public health workers cannot tackle the challenge alone.[16]
>
> Healthy housing is a multisectoral responsibility, achievable only if all relevant players contribute to it, including not only public health, but also housing, engineering and construction, environment, social welfare, urban planning, and building management. The combination of actions from all these sectors shows the complexity of the subject as well as its great potential to increase the health status of our populations through providing adequate, safe and healthy homes.[16]

2016 WHO report (ambient air pollution: a global assessment of exposure and burden of disease)

The WHO issued a report in 2016 that provides estimates by country on the impact of exposure to air pollution. In a startling new statistic, the WHO stated that "92% of the world's population lives in places where air quality levels exceed WHO limits."[17]

They repeat one of the key statistics from the 2012 Global Burden of Disease report:

Some 3 million deaths a year are linked to exposure to outdoor air pollution. Indoor air pollution can be just as deadly. In 2012, an estimated 6.5 million deaths (11.6% of all global deaths) were associated with indoor and outdoor air pollution together.[17] [The 11.6% statistic relates to only five types of pollutants.]

They go on to say:

"Air pollution continues to take a toll on the health of the most vulnerable populations – women, children and the older adults," adds Dr. Bustreo. **"For people to be healthy, they must breathe clean air from their first breath to their last."**[17]

As a reminder, pollution affects the air outside and inside our homes, schools and businesses.

<u>2016 WHO report (preventing disease through healthy environments)</u>

The WHO published a 2016 report titled "Preventing Disease through Healthy Environments: A Global Assessment of the Burden of Disease from Environmental Risks."[18] This is an update to the 2006 report. It is good they published another report on environmental health issues. However, they only briefly mention mould in regard to asthma, allergies and respiratory symptoms. Their list of references includes only three research papers relating to mould, and no research papers relating to mycotoxins or biological contaminants.

This report is focused primarily on environmental risks due to climate change, fossil fuel consumption, safe water and sanitation.

The report includes the following statistics for deaths attributable to the environment:

- 26% of all deaths in children under age five
- 24-26% of all deaths in adults age 50 to 75 (which includes the risk of falls)
- 23% of total deaths worldwide[18]

They point out in the paper that statistics are not available for deaths due to each of these specific causes, so the estimates are largely based on surveys of expert opinion.

Although these estimates reflect only a limited selection of environmental causes, imagine how large the percentage might be if they include all environmental factors.

2017 WHO report (ten years in public health, 2007-2017)

In a final report by the outgoing WHO Director-General, Dr. Margaret Chan, she discusses the evolution of global public health during her administration over the past ten years.

This report makes a few good comments about indoor and outdoor air pollution. However, it is disappointing to see that this "ten-year review" does not discuss specific types of indoor contaminants (e.g., radon, lead, asbestos, mold, fungi, biological contaminants, etc.) except for tobacco smoke. Here are a few excerpts from the report:

> WHO estimates that 17.5 million people die each year from cardiovascular disease, accounting for around 31% of all deaths worldwide and making this disease the world's biggest killer. Some 80% of these deaths are caused by heart attacks and stroke.[19]
>
> The risk of cancer increases with exposure to indoor and outdoor air pollution, radiation, environmental chemicals, and occupational exposures.[19]
>
> Abundant evidence shows that exposure to air pollution, either indoors or outdoors, is a significant cause of respiratory disease, including lung cancer.
>
> Air pollution, with its multiple toxic compounds, penetrates deep into the lungs, but it also penetrates the bloodstream, causing inflammation and a gradual narrowing of the arteries.[19]

The risk of cancer increases with exposure to indoor and outdoor air pollution, radiation, environmental chemicals, and occupational exposures.

How many of these deaths and how many cases of cancer are caused by environmental exposures? In addition to cardiovascular and respiratory disease, what are the statistics for other illnesses caused by environmental exposures?

The report also makes the following comment about the dangers of air pollution:

> Air pollution is one of the most pernicious threats to health because it is so pervasive. No one can escape it. Everyone has to breathe. When breathing becomes deadly, entire cities become a hazard to health.[19]

It is unfortunate that the WHO missed another opportunity to raise awareness about the serious health effects of contaminants found in water-damaged buildings.

The new Director-General, Dr. Tedros Adhanom Ghebreyesus, took over as head of the WHO on July 1, 2017. He plans to focus on five main areas, including "addressing the health impacts of climate and environmental change."[19]

European Union

The following information is from a 2017 report from the European Union titled "Healthy Homes Barometer, Buildings and Their Impact on the Health of Europeans."

> Today, one out of six Europeans – or the equivalent of Germany's population – reports living in unhealthy buildings, i.e., buildings that have damp (leaking roof or damp floor, walls or foundation), a lack of daylight, inadequate heating during the winter or overheating problems. In some countries, that number is as high as one out of three.[6]

> The entire respiratory system becomes vulnerable when exposed to poor indoor air quality, which can provoke the onset of various respiratory illnesses and even raise the risk of developing non-respiratory diseases. In fact, people are 40% more likely to have asthma when living in a damp or mouldy home.[6]

A 2012 report estimated the percentage of homes in 31 European countries that are affected by damp, mold or water damage. This report concluded that 12.1% of homes had damp, 10.3% had mold and 10.0% had water damage, giving a result of 16.5% for a combination of these indicators.[20]

> Significant (up to 18%) differences were observed for dampness and mold prevalence estimates depending on survey factors, region, and climate. In conclusion, dampness and/or mold problems could be expected to occur in one of every six of the dwellings in Europe.[20]

United Kingdom

A workshop was held in the United Kingdom on April 12, 2017, which brought together environment and medical professionals to discuss the impact of poor indoor air quality in homes in the United Kingdom (U.K.). After the workshop, several groups joined together to write a report.

These groups included the Royal College of Physicians, the Royal College of Paediatrics and Child Health, BRE (Building Research Establishment that carries out research, consultancy and testing for the construction and built environment) and the ARCC network (Adaptation and Resilience in the Context of Change network that supports the creation of robust built environment and infrastructure sectors in the U.K.).

According to the report, they estimate poor IAQ in homes is causing 40,000 fatalities per year in the U.K.[21]

Professor Stephen Holgate, special advisor on air quality to the Royal College of Physicians, said:

> There is a growing body of evidence that suggests volatile organic compounds (VOCs) are also being produced by synthetic building and furnishing materials. At the same time, insulating homes without adequate ventilation can trap a potentially toxic cloud coming from everyday household products such as air fresheners and cleaning products.[21]

Professor Jonathan Grigg, Royal College of Paediatrics and Child Health, said:

> Air pollution is already considered one of the leading dangers to children's health, and is known to effect people chronically over the life-course. It is therefore imperative that we strengthen the understanding of the relationship between indoor air pollution, exposure and health impacts and to be able to define the economic impact of poor indoor air quality and the health benefits of healthy homes.[21]

The report made several recommendations,[21] including:

- Reducing outdoor pollution through changes in private and public transportation
- Improving urban design and planning (separating homes from busy roads, etc.)
- Offering incentives that would stimulate production of indoor air quality enhancing materials
- Creating public health campaigns for greater public awareness and education
- Installing air filtration systems
- Educating the building supply chain (home builders, building inspectors, landlords, etc.) about the impact of indoor air pollutants and how to improve IAQ
- Consider ways to control pollutants in materials and household products (e.g., emissions labeling that is being done in some EU countries)
    - One example is the Allergy UK's voluntary Seal of Approval label for appliances and products in the home. This idea is now used in over 70 countries and is being expanded to cover building products and other items.[21]

<u>United Kingdom's Royal College of Physicians (2016)</u>

The United Kingdom's Royal College of Physicians issued a study in 2016 about indoor air pollutants. In addition to the pollutants that are already well known, they also discussed new indoor air pollutants that need to be considered such as advanced materials and three-dimensional printing.

> The multiplicity of contaminants can make it more problematic to determine the precise source of an exposure-triggered illness and more difficult for epidemiologists to quantify cases. However, the report estimates indoor air pollutants "cause, at a minimum, several

thousands of deaths per year in the U.K., and associated with healthcare costs in the order of tens of millions of pounds."[22]

In the report, they estimate that 40,000 deaths per year are attributable to outdoor air pollution, with an annual cost of 20 billion pounds. And, they also include information about indoor air pollutants (including radon, tobacco smoke, carbon monoxide, lead, nitrogen dioxide, particulate matter, PCBs, VOCs, formaldehyde, asbestos, kitchen products, faulty boilers, open fires, fly sprays, air fresheners, biological materials, mould, etc.).[22]

When our patients are exposed to such a clear and avoidable cause of death, illness and disability, it is our duty as doctors to speak out.[22]

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United Kingdom: National Institute for Health and Welfare (2015)

A 2015 pan-European study by the National Institute for Health and Welfare highlighted the impact of indoor pollutants on disease and life expectancy. The study concludes that indoor air pollution is potentially responsible for the annual loss of over 200,000 healthy life years in the U.K.[23,24]

Professor Peter Howarth, at Southampton University, and other researchers in the U.K. are using the term "Toxic Home Syndrome" to describe the condition where "a person's health deteriorates because of the air circulating in their home."[23,24]

Air circulating inside (the home) contains more than 900 chemicals, particles and biological materials with potential health effects. [23,24]

Mould spores, pollen, radon, carbon monoxide and dander all lurk within homes, seeping through cracks in walls and floorboards, brought in on clothing or produced by wood burners, gas hobs and detergents used in cleaning. [23,24]

Experts in the U.K. have urged authorities to make it mandatory for new homes to come with a "Healthy Home Mark," indicating that a good ventilation system was installed.

The annual burden of disease caused by inadequate indoor air quality is estimated to correspond to a loss of more than two million healthy life years in the EU. [23,24]

Fifty-seven per cent of the total burden relates to cardiovascular diseases, 23 per cent to lung cancer, 12 per cent to asthma and the remaining eight per cent is linked to other respiratory conditions. [23,24]

Professor Howarth says he has seen many patients with serious health conditions due to pollutants within the home.

United Kingdom's National Clean Air Day (June 15, 2017)

On June 15, 2017, the United Kingdom held its first ever National Clean Air Day. Experts from industry gathered at BESA's head office in London to discuss indoor air quality (IAQ) and to begin work on a new comprehensive standard for IAQ. Proper ventilation is key to improving IAQ.

Emeritus Professor Derek Clements-Croome of Reading University shared the results of a BESA 2016 survey that showed 70% of office workers were concerned with the impact of poor IAQ. The results of the survey also showed:

- 68% of office workers experience lapses in concentration on a monthly or more frequent basis
- Over two thirds (67%) of recipients reported suffering from fatigue while at work on a monthly or more frequent basis
- Over half (54%) of office workers surveyed experience decreased productivity on a monthly or more frequent basis
- Over a third (41%) of people experience watery or irritated eyes when in the office on a monthly or more frequent basis[25]

As a result of the survey, BESA has called on "industry, building managers and the general public to ensure proper, effective, well maintained ventilation systems are operating all offices across the U.K."[26]

BESA is collaborating with a number of industry bodies including the Chartered Institution of Building Services Engineers (CIBSE) and Institute of Healthcare Engineering & Estate Management (IHEEM) to raise awareness about IAQ and produce detailed guidance for contractors, designers and facilities managers.[26]

In addition, BESA is partnering with Foobot (an IAQ measuring technology company) on a project "to measure, monitor and analyse air quality data from a number of locations across London establishing a link between outdoor pollution 'events' and corresponding impacts on building occupants."[26]

United Kingdom: House of Commons, Environmental Audit Committee (2014)

This 2014 report references an earlier estimate by the Committee on the Medical Effects of Air Pollutants that says approximately 29,000 deaths per year in the UK could be attributable to man-made particulate matter pollution, equivalent to a loss of 340,000 life-years, with a cost to the economy of £16 billion per year.[27]

As noted in the report, this was the Committee's third report on air quality in five years. Since their recommendations from 2010 and 2011 were not implemented, they issued this third

report. Some of the notable recommendations relate to houses, schools, hospitals and care homes. They recommend that all new facilities should not be built near air pollution hotspots (such as major roadways and other hotspots). In addition, any redevelopment of these buildings should only be approved if they reduce pollution exposure for the occupants, and schools that are currently sited near pollution hotspots should be fitted with air filtration systems.[27]

China

China passed a new law on January 1, 2015, (called the Law on Environmental Protection) that was created for the purpose of safeguarding public health.

> Article 39 says "the State shall establish and improve environment and health monitoring, investigation and risk assessment systems, encourage and organize research on environmental quality impacts to public health, and adopt measures to prevent and control diseases related to environmental pollution."[28]

In 2016, the Chinese Environmental Protection Ministry conducted its first nationwide survey on children's pollution exposure patterns. The survey assessed pollution exposure patterns in 75,500 children and teenagers.

According to the survey results: "As many as 26.8 percent of Chinese children are exposed to polluted indoor air at home."[29] Although this was a limited survey that focused only on indoor air pollution from cooking and heating through the use of solid biomass, it is startling to know that more than a quarter of the children are being harmed by just this one type of indoor pollutant.

As a result of this July 2016 report, the International Ecological Economy Promotion Association (IEEPA) launched a research project to evaluate the health impact of indoor air pollution in urban public spaces. The initial project will focus on the Beijing-Tianjin-Hebei region.[29]

Finland

According to a 2012 report ordered by a Parliamentary Committee in Finland, mould and damp problems affect up to 337,000 people in houses, 154,000 in apartments and 260,000 children attend schools or day care centres affected by mould problems.[7]

In Finland, mould and damp problems affect up to 337,000 people in houses, 154,000 in apartments and 260,000 children attend schools or day care centres affected by mould problems.

An April 2017 report from Finland highlights the statistical impact of mold in houses, apartments, schools, nursing homes, hospitals, outpatient departments and offices.

Here are excerpts from the report:

The recent publication of the Audit Committee of the Finnish Parliament indicated that approximately 7–9% of terraced houses; 6–9% of apartment buildings; 12–18% of schools and kindergartens; 20–26% of nursing homes, hospitals, and outpatient departments; and 2.5–5% of offices have been significantly damaged with dampness and are infested with indoor molds.[30]

It has been estimated that approximately 800,000 or every seventh Finnish citizen has been exposed to some extent and become sensitized to compounds present in poor quality indoor air. However, since there is no ICD-10 coding system for mold-related illness, its exact incidence is unknown. If one extrapolates from the above presented figures, one could argue that the incidence of mold-related illness may be much higher than the incidences for cardiovascular conditions, cancers, and accident-induced traumas.[30]

United Arab Emirates

Researchers at the British University of Dubai investigated indoor environmental quality (IEQ) in elementary schools in the United Arab Emirates (UAE). This study showed that children in these classrooms were exposed to poor IEQ conditions. The researchers examined several IAQ conditions including TVOC, CO2, O3, CO, and particulates levels.[31]

In June 2016, Saeed Al Abbar, Chairman of the Emirates Green Building Council, gave a presentation where he reminded building managers of the importance of good indoor air quality. He said:

> As our experts reminded during the event, even if design and construction can make a building 'green,' the wrong usage of products and poor maintenance of ventilation systems can reverse the effect and make buildings unhealthy.[32]

As our experts reminded during the event, even if design and construction can make a building 'green,' the wrong usage of products and poor maintenance of ventilation systems can reverse the effect and make buildings unhealthy.

India

In May 2017, there was a major change in India regarding the recognition of the effects of air pollution.

> An environment ministry draft note has acknowledged a "rise" in the number of deaths due to air pollution in the country, which contradicts its long-standing position on the "absence" of credible data to link morbidity to pollution.[33]

This change in position was announced was one week after the previous minister passed away.

The previous environment minister had rejected the findings of the State of Global Air Report 2017 that had "painted a grim picture of India in terms of alleged deaths due to PM 2.5 (ultrafine pollutant measuring less than 2.5 microns in diameter) and ozone pollution."

The note from the new minister said:

Studies across the world and also in India prove that outdoor and indoor air pollution is a serious environmental risk factor that causes or aggravates acute and chronic diseases and has been identified as the fifth highest cause of morbidity in India.

The following statistics about India were quoted from the 2016 report by UNICEF:

Four kids could be dying every hour in UP (Uttar Pradesh) of pneumonia caused by respirable suspended particulate matter (PM) 1, 2.5 and 10, which form a large part of the air we breathe. Alarmingly, the number adds up to 104 deaths per day and 38,000 a year.[1,34]

In the article, Professor Shally Awasthi, paediatrician at King George's Medical University said, "Scientific evidence is available to prove that about 50% of pneumonia deaths could be attributed to indoor air pollution which holds true for outdoor pollution too."[34]

Official data reveals that pneumonia affects 1.5 crore (150,000) children in a year in UP of whom 76,000 die.

Pulmonary medicine expert Dr. B.P. Singh explained why children were more susceptible to air pollution:

"Children's lungs, their brains and immune systems are more permeable than of adults which makes them more vulnerable to indoor and outdoor pollution. Also, they breathe in more than their relative body weight which makes them inhale more toxins than grownups."[34]

UNICEF, which recently released the Clear the Air for Children report, noted:

"Pollutants don't only harm children's developing lungs, they can actually cross the blood brain barrier and permanently damage their developing brains and, thus, their futures. No society can afford to ignore air pollution."[1]

In 2015, the Centre for Science and Environment (CSE) in India issued the Body Burden 2015 report that stated:

Air pollution is responsible for 10,000-30,000 deaths in Delhi annually and is the fifth largest cause of death in the country.[35,36]

Outdoor air pollution kills 620,000 people, and indoor air pollution kills 1.5 million people in India annually.[35,36]

Africa

Carlos Dora of the World Health Organization gave a presentation in February 2017 at a conference sponsored by the Novartis Foundation. The rapid urbanization in Africa is causing significant increases in indoor and outdoor pollution.

Some of the unique causes of pollution in Africa include using kerosene to cook, coal fires and the burning of waste.

According to a report by the OECD (Organisation for Economic Co-operation and Development), the annual number of deaths from outdoor pollution rose 36% from 1990 to 2013. Deaths from indoor air pollution rose 18% during that same time period.[37,38]

Dirty air has led to the premature deaths of 712,000 Africans each year, more than the toll of unsafe water, malnutrition and unsafe sanitation. In September last year, researchers calculated the monetary cost of air pollution in Africa for the first time: $215 billion from outdoor pollution and $232 billion from indoor pollution (based on 2013 figures).[37,38] These cost estimates are based on the economic cost of premature deaths.

Canada

Estimates of the environmental burden of disease in Canada were provided in a 2008 report. The researchers used the World Health Organization's previous estimates along with data from Canadian public health institutions. They focused on four major categories of disease (i.e., respiratory disease, cardiovascular illness, cancer and congenital affliction). They presented the following estimates:

- 10,000-25,000 deaths
- 78,000-194,000 hospitalizations
- 600,000 to 1.5 million days spent in hospital
- 1.1 to 1.8 million restricted activity days for asthma sufferers
- 8,000-24,000 new cases of cancer
- 500-2,500 low birth weight babies[39]

Their estimates show that the burden of illness in Canada from environmental exposures is significant -- with an annual cost of $3.6 to $9.1 billion each year due to those four categories of disease. They recommend stronger efforts to prevent adverse environmental exposures including research, education and regulation.[39]

United States

There are several reports that mention various statistics and costs relating to the impact of indoor air pollution in the United States. We are including only five of those reports in this section. For additional statistics reported by federal agencies, go to the next section on U.S. Federal Government Agencies.

Valuing the Economic Costs of Allergic Rhinitis, Acute Bronchitis, and Asthma from Exposure to Indoor Dampness and Mold in the U.S. (2016)

In a 2016 report, Dr. Mudarri estimated the costs of allergic rhinitis, acute bronchitis and asthma caused by exposure to indoor dampness and mold in the U.S.[40] He used two methods—cost of illness (COI) and willingness to pay (WTP).

> WTP measures the full cost to society, but WTP estimates are difficult to compute and rarely available. COI methods are more often used but less likely to reflect full costs.

> Based on the data available, he estimates the total annual costs[40] as follows:

Allergic Rhinitis	$3.7 billion
Acute Bronchitis	$1.9 billion
Asthma Morbidity	$15.1 billion
Asthma Mortality	$1.7 billion

Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments (2016)

A 2016 study, conducted by researchers at Harvard University, Chan School of Public Health, SUNY-Upstate Medical School and Syracuse University, shows the significant improvement in office workers in Green and Green+ environments (compared to Conventional working environments). They tested low-VOC (Green) and high-VOC (Conventional) building conditions at standard ventilation rates. The third category (Green+) used low-VOC conditions with higher ventilation rates.

> The researchers found:

> Cognitive function scores were higher under the Green building condition than under the Conventional building condition for all nine functional domains.[41]

> On average, cognitive scores were 61% higher on the Green building day and 101% higher on the two Green+ building days than on the Conventional building day. The

largest effects were seen for Crisis Response, Information Usage, and Strategy, all of which are indicators of higher-level cognitive function and decision making (Streufert and Swezey 1986).[41]

For Crisis Response, scores were 97% higher during the Green condition than during the Conventional condition, and 131% higher during the Green+ condition than during the Conventional condition.[41]

For Information Usage, scores obtained under the Green and Green+ conditions were 172% and 299% higher than under the Conventional condition, respectively.[41]

Finally, for Strategy, which tested the participants' ability to plan, prioritize, and sequence actions, the Green and Green+ day scores were 183% and 288% higher than on the Conventional day, respectively.[41]

The Impact of Working in a Green Certified Building on Cognitive Function and Health, Building and Environment, (March 2017)

A March 2017 study compared cognitive function in green certified buildings versus non-certified buildings. They said:

Thirty years of public health research have demonstrated that improved indoor environmental quality is associated with better health outcomes. Recent research has demonstrated an impact of the indoor environment on cognitive function.[42]

Workers in green certified buildings scored 26.4% (95% CI: [12.8%, 39.7%]) higher on cognitive function tests and had 30% fewer sick building symptoms than those in non-certified buildings.[42]

A review of leading, global green-building standards - LEED New Construction 2009, Green Star Office v3, BREEAM New Construction 2012, BCA Green mark for new non-residential buildings v4.1 2013, and DGNB New Office v2012 - demonstrates the approach of these certification standards toward IEQ.[42]

All of the rating systems offer credits for thermal comfort, indoor air quality (IAQ) and lighting; all but LEED NC 2009 (NC = new construction) have credits for acoustics; and Green STAR v3 and LEED NC 2009 have credits specifically for ventilation. However, building owners and developers can opt for certain credits, and IEQ represents only 4–20% of the total score a building can obtain.[42]

Of the reviewed rating systems, only LEED NC 2009 has mandatory IEQ credits, for minimum IAQ performance and environmental tobacco smoke control.[42]

It is important to acknowledge that Green building standards have improved working conditions inside LEED-certified buildings. However, there is more that can be done.

LEED: A Set-Up for Sick Buildings? Is LEED Diamond the Answer? (2012)

Dr. Claudia Miller offers suggestions in a 2012 paper. She proposes a new LEED category called "LEED Diamond" which would require additional measures be taken to improve indoor air quality.[43]

> Although Indoor Environmental Quality requirements are part of LEED and points can be earned by taking additional measures that can improve Indoor Air Quality (IAQ), the designation of LEED (silver, gold, or platinum) is, in and of itself, insufficient to protect the most vulnerable building occupants.[43]
>
> A new designation, perhaps "LEED Diamond," should be introduced with mandatory criteria to ensure excellent IAQ and protect all building occupants.[43]
>
> Why should architects design buildings for the most vulnerable individuals?
>
> If you protect the most vulnerable people, you will protect everyone. Regrettably, because LEED designations are not designed to ensure excellent IAQ, susceptible individuals may get sick when they live, work or go to school in a LEED building.[43]

Why should architects design buildings for the most vulnerable individuals?
If you protect the most vulnerable people, you will protect everyone.

In May 2013, the U.S. Green Building Council (USGBC) introduced LEED v4 which has several changes and reclassifies many items to other categories. LEED v4 encourages the incorporation of the smart grid program and includes an expanded focus on water usage and the impact of materials on human health and the environment. Effective October 31, 2016, new projects registering for LEED certification must comply with LEED v4. A few of the changes relating to indoor environmental quality include:

- Added requirements for outside air delivery monitoring
- Added requirements for residential projects addressing combustion appliances, CO (carbon monoxide) monitors and radon
- Prohibited smoking on the entire site for school projects
- Added requirement for TVOC (total volatile organic compounds) disclosure[44-47]

On July 8, 2017, an updated version of LEED v4 was released. It includes the following statement relating to mold and microbial growth.

> Under the section on Healthcare: Develop and implement a moisture control plan to protect stored on-site and installed absorptive materials from moisture damage. Immediately remove from site and properly dispose of any materials susceptible to microbial growth and replace with new, undamaged materials. Also include strategies for protecting the building from moisture intrusion and preventing occupants' exposure to mold spores.[44-47]

Ten Questions Concerning Green Buildings and Indoor Air Quality (2017)

A 2017 paper by Steinemann, et al, provides additional discussion about green building standards and the impact on indoor air quality (IAQ). They reviewed numerous studies and found that the majority of available measurements in green buildings do show that IAQ, as perceived by occupants, is improved. However, the studies do not make sufficient connection between these results and the physical and chemical measurements of actual exposure levels.

In this paper, they explain how some green practices can compromise IAQ in green buildings. For example, products marketed as "green" often emit and generate harmful compounds (such as low VOC paints or home furnishings). Two more examples from the paper include the following:

> One example of green practices having potentially negative consequences for IAQ is the use of waste-based materials, recycled materials, or reused materials. For instance, application of fly ash as an additive to building materials can increase the exposure of building occupants to a suite of heavy metals that may have toxic properties.[48]

> Another example are actions to keep outdoor air supply at minimum rates and reduce the need for cooling and air conditioning, and supplement them with other less energy demanding solutions. These actions comprise the use of air purification methods and flushing or enhanced ventilation. Although it may be expected that air purification systems would benefit IAQ, two major problems have been related with this technology. One problem is that the air cleaners may not be as effective as they are claimed to be, or they may selectively remove only some pollutants and be ineffective for the others. The other problem is that some air cleaners during the process of cleaning will generate unwanted products, some even more harmful than the pollutants that are removed. Additionally, some air cleaning and filtration techniques can become the source of pollution if not properly serviced or maintained.[48]

They offer solutions for improving IAQ in green buildings including adding credits that focus on reducing harmful exposures (e.g., reducing or eliminating VOCs and fragrances, using alternative pest control and safer cleaning products).

In summary, the USGBC made several changes and improvements to the previous LEED NC 2009. However, the new credits relating to incorporation of the smart grid program will

result in a significant increase in harmful EMF/RF radiation. As noted above, there is still more work to be done to improve indoor environments in our homes, schools and businesses and solutions have been presented.

U.S. Federal Government Agencies

This section provides information and statistics from U.S. federal government agencies. As you read through this section, you will see how they took a much stronger position during the late 1980s. As time went on and Big Business implemented their campaign of misinformation, these agencies downplayed the serious health threats posed by indoor air pollutants.

For more information the role of Big Business, see our paper on "Discussion of Naysayers and Deniers."

U.S. EPA report "The Inside Story: A Guide to Indoor Air Quality" (1988)

In a 1988 report titled "The Inside Story: A Guide to Indoor Air Quality,"[49] the U.S. Environmental Protection Agency (EPA) and the U.S. Consumer Product Safety Commission (CPSC) provide additional details on select indoor air pollutants. This report also describes the significant risks to health caused by indoor air pollution, as follows:

> In the last several years, a growing body of scientific evidence has indicated that the air within homes and other buildings can be more seriously polluted than the outdoor air in even the largest and most industrialized cities. Other research indicates that people spend approximately 90 percent of their time indoors. Thus, for many people, the risks to health may be greater due to exposure to air pollution indoors than outdoors.[49]
>
> In the opinion of some World Health Organization experts, up to 30 percent of new or remodeled commercial buildings may have unusually high rates of health and comfort complaints from occupants that may potentially be related to indoor air quality.[49]

U.S. EPA Report to Congress on Indoor Air Quality (1989)

In 1989, the U.S. EPA prepared a report for Congress on Indoor Air Quality. Volume II of the report was titled "Assessment and Control of Indoor Air Pollution."[4]

> Health effects from indoor air pollution cover the range of acute and chronic effects, and include eye, nose, and throat irritation, respiratory effects, neurotoxicity, kidney and liver effects, heart functions, allergic and infectious diseases, developmental effects, mutagenicity, and carcinogenicity.[4]
>
> Building sicknesses, such as sick building syndrome, building related illness, and multiple chemical sensitivity are issues of potentially great significance but are

poorly understood. Additive or synergistic effects from pollutant mixtures, where concentrations of each individual compound are below its known health effect threshold, may help to explain some sick building syndrome complaints.[4]

Biological contaminants are a principal cause of building related illness, and can be the principal problem in some buildings. Building related illness can result in death, as in Legionnaire's disease, or serious infectious or allergic diseases.[4]

The population health risks posed by exposure to indoor air pollutants appear to be significantly greater than the health risks posed by some of the environmental problems that receive the most public concern and governmental funding, including hazardous and non-hazardous waste sites, and contaminated sludge.[4]

It is known that microbial contamination can cause significant damage to buildings and equipment, and there is anecdotal evidence that damage can be so severe as to make a building unfit for human occupation.[4]

U.S. Government Accountability Office (1991)

In 1991, the U.S. Government Accountability Office (GAO) issued a report to Congress titled: "Indoor Air Pollution: Federal Efforts are Not Effectively Addressing a Growing Problem." Here are a few excerpts:

In the 1970s increased emphasis on energy conservation measures, such as using more energy-efficient building materials and reducing the air exchange rates of ventilation systems, resulted in increases in indoor air pollution in offices and homes. For example, energy efficiency measures sometimes result in lower air exchange rates for ventilation systems and cause pollutants, such as second-hand tobacco smoke, dust mites, carbon monoxide, benzene, and pesticides, to remain indoors and contribute to indoor air problems. Additionally, certain materials used in carpets, insulation, and home and office furniture contribute to the overall indoor air problem by giving off chemical emissions. Therefore, the elevated levels of such pollutants increase the health risks--headaches, fatigue, respiratory diseases, and cancer--for building occupants when such materials, along with air exchange rate reductions, are employed.[50]

In 1989 and 1990 indoor air legislation was introduced in the Congress that called for more direct focus on indoor air by establishing a national program to reduce the human health threat caused by such pollution. Although the Senate passed its indoor air bill, the Congress did not enact any of the proposed legislation. Similar legislative proposals were introduced in both houses of the Congress in 1991. These legislative proposals go beyond research and require more emphasis on source control and mitigation of indoor air pollution.[50]

More than 10 years later, in 2002 and 2005, proposed legislation about the health effects of indoor mold was again presented to Congress. It has now been more than 25 years since that original legislation was presented, and we are still waiting for Congress to take action.

> Even though EPA recognizes that indoor air pollution represents a serious health risk with symptoms ranging from eye irritation, headaches, and fatigue to respiratory diseases and cancer, funding levels have not been commensurate with these health risks. In its Unfinished Business report, EPA ranked indoor air pollution fourth among thirty-one environmental problems in terms of the risk it poses to human health and the environment based on the opinions of a task force of 75 EPA scientists, engineers, and managers.[50]

In 2008, the GAO issued another report that was very similar to the 1991 report. The 2008 report is titled "Indoor Mold: Better Coordination of Research on Health Effects and More Consistent Guidance Would Improve Federal Efforts."[51]

The 2008 report focused primarily on the need for "better coordination of research activities among government agencies." However, they did admit that inhalation is generally the most common route of exposure for mold in indoor environments, but they downplayed the impact of inhalation by saying that "the roles of these routes of exposures in causing illness are unclear."[51]

The GAO also said that health effects from these exposures can arise due to allergic, infectious and toxic mechanisms. The report stated:

> Mold may affect human health through a number of routes and mechanisms. While inhalation is generally the most common route of exposure for mold in indoor environments, exposure can also occur through ingestion (for example, hand-to-mouth contact) and contact with the skin. The roles of these routes of exposure in causing illness are unclear. Once exposure occurs, health effects may arise through several potential mechanisms, including allergic (or immune-mediated), infectious, and toxic.[51]

Mold may affect human health through a number of routes and mechanisms. While inhalation is generally the most common route of exposure for mold in indoor environments, exposure can also occur through ingestion and contact with the skin.

U.S. EPA and U.S. GAO (1995)

According to the Healthy School Environment Resources page on the EPA website:

> Twenty percent of the U.S. population, nearly 55 million people, spend their days in our elementary and secondary schools. Studies show that one-half of our nation's 115,000 schools have problems linked to indoor air quality.[52]

These statistics were tied to a 1995 report by the U.S. Government Accountability Office (GAO) titled "School Facilities: Condition of America's Schools."[52]

National Institute of Environmental Health Services (NIEHS) and National Toxicology Program (NTP)

One estimate of illness caused by environmental exposures is included in a 2012 interview with Dr. Linda Birnbaum, National Institute of Environmental Health Services (NIEHS) and National Toxicology Program (NTP) (footnote 1a). The interview is included in a Scientific American article dated November 23, 2012.

Dr. Birnbaum states that human disease due to environmental exposures is "much more than 30%."[53] Here's an excerpt of Dr. Birnbaum's comments from the interview:

> How much of human disease is due to environmental exposures? The estimates vary, and it depends on how you define environment. People often say it's about 30 percent. I think that's defining environment fairly narrowly, considering only environmental chemical exposures, but your environment includes the food you eat, the drugs you take, the psychosocial stress you're exposed to and so forth. After all, what's the difference between a drug and an environmental chemical? One you intentionally take and the other one you don't. Considering all that, I would say then the environment is much more than 30 percent.[53]

National Institute of Occupational Safety and Health (NIOSH)

The National Institute of Occupational Safety and Health (NIOSH) just released a new report in November 2012 titled "NIOSH Alert: Preventing Occupational Respiratory Disease from Exposures Caused by Dampness in Office Buildings, Schools, and Other Nonindustrial Buildings."[54]

The report focuses on (only) the respiratory effects of indoor dampness. The report starts with the following warning:

> Occupants within damp office buildings, schools, and other nonindustrial buildings may develop respiratory symptoms and disease.[54]

Here is an excerpt from the report:

> NIOSH has estimated that 29% to 33% of new-onset adult asthma is attributable to work-related exposures and 23% of existing adult asthma is exacerbated by work. If occupants develop asthma or asthma exacerbation while working in damp buildings, medical treatment may not be effective if the occupant continues to be exposed. An occupant in damp buildings with allergic asthma may experience symptoms after exposure to very

low levels of a sensitizing agent that may still be present after remediation; in such cases, an occupant may require relocation to another area.[54]

Other Government Agencies

The Commonwealth of Massachusetts, Special Legislative Commission on Indoor Air Pollution (1989)

The 1989 report by a Special Legislative Commission in Massachusetts is also noteworthy because of the parties involved in the process and because it confirmed the growing concerns about indoor air pollution.

This Special Legislative Commission brought together numerous elected officials, individuals from several government and private entities, and representatives from industry, including:[55]

Several U.S. Congressmen and Senators
U.S. Environmental Protection Agency (EPA)
American Lung Association
Harvard School of Public Health

Massachusetts:

Department of Public Health
Department of Environmental Quality Engineering
Department of Labor and Industries
State Board of Building Regulations
Association of Health Boards
Health Officers Association
Bingham, Dana and Gould (representative of the building materials industry)
AIRXCHANGE, Inc. (representative of the heating and ventilation industry)
Life Energy Associates (expertise in indoor air pollution mitigation)[55]

There is a lot of good historical information in this report, and it explains in detail that the health impact of indoor air pollution has been known for decades. For example, the report states that sick building syndrome has been known since World War I, but the first published research paper on the topic did not happen until 1948 in England.

The report also acknowledged that health effects of biological contaminants can be due to allergenic, infectious or toxicogenic properties.

The following statements are excerpts from the Massachusetts report:

Indoor air pollution is a growing problem in the United States and accounts for up to 50% of all illnesses.[55]

The indoor air we breathe often contains pollutants which may have health effects ranging from annoying to deadly. Major pollutant types found in indoor environments include tobacco smoke, radon gas, formaldehyde, asbestos, volatile organic compounds, pesticides, combustion products and biological contaminants.[55]

For most of these pollutants, concentrations measured indoors exceed levels found outdoors yet current environmental air pollution laws and regulations are not protective of these indoor environments. They focus instead on the outdoor environment even though individuals spend about ninety percent (90%) of their time indoors.[55]

Biological contamination of indoor environments ranks third in NIOSH's list of indoor air health threats after poor ventilation and building fabric contaminants. Types of biological contamination range from animal dander, pollen and dust to bacteria, fungi and viruses. Poor ventilation, stagnant water in ventilation systems, and relative humidity levels falling outside the 40-60% range have been implicated as causes of high indoor air concentrations of these biological contaminants. High humidity and moisture concentrations support proliferation of biologicals in ventilation systems.[55]

The Commission's efforts confirm the seriousness of the indoor air pollution health threat, which worsened with the energy conservation efforts of the 1970s. More insulation and tighter construction led to lower ventilation rates and build-up of contaminants.[55]

Many 'sick' buildings have been identified where occupants suffer severe or recurring discomforts such as headaches, dizziness, fatigue, eye irritation, and respiratory problems. Other conditions attributable to indoor air contaminants include: cancer; bronchitis; pneumonia; heart, circulatory and respiratory problems; impaired vision; skin rash; chemical sensitivity; birth defects; and mental, nervous and immunological disorders.[55]

The Commission's efforts confirm the seriousness of the indoor air pollution health threat, which worsened with the energy conservation efforts of the 1970s. More insulation and tighter construction led to lower ventilation rates and build-up of contaminants.

In our 2012 position statement (and again in this paper), we included statistics from several different sources to help illustrate the impact of indoor air pollutants. Although a couple readers felt the 50% estimate in the Massachusetts report was too high (i.e., "indoor air pollution accounts for up to 50% of all illnesses"), it is important to note that we included this as just one of many statistics in our discussion of the global burden of indoor air contaminants. It is also important to note that the 244-page Massachusetts report was prepared by a large and diverse group that included government agencies, elected officials, medical organizations, IAQ experts, representatives from industry and others (see the list of names on page 33).

It would be interesting to hear from the large group of experts who were involved with writing the Massachusetts paper 28 years ago (in 1989). How did they come up with the number to support their statistic of "up to 50% of all illnesses" that was cited in their paper?

We do not have a current, combined statistic that covers all types of indoor air pollutants due to several factors including:

- There are many different types of indoor air pollutants (chemicals, molds, mycotoxins, lead, radon, asbestos, bacteria, formaldehyde, electromagnetic fields, fragrances, products of combustion, VOCs, carbon monoxide, air fresheners, pesticides, solid fuels, tobacco smoke and many others).

- The vast number of health effects caused by indoor air pollutants and the multi-symptom, multi-system nature of these illnesses.

- These numbers are not being tracked by the medical community.

However, as noted throughout this paper, there are some statistics available relating to individual pollutants, such as lead, asbestos and radon.

In order to determine the full impact of indoor air pollution, we would need a tracking system that identifies the number of deaths and illnesses caused by all types of indoor air pollutants.

Worldwide death statistics

Another approach is to look at the number of deaths worldwide. According to the World Health Organization, of the 56.4 million deaths in 2015, more than half (54%) were due to the top 10 causes.

> Ischaemic heart disease and stroke are the world's biggest killers, accounting for a combined 15 million deaths (27% of total deaths) in 2015.[18]
>
> Chronic obstructive pulmonary disease claimed 3.2 million lives in 2015, while lung cancer (along with trachea and bronchus cancers) caused 1.7 million deaths.
>
> Diabetes killed 1.6 million people in 2015, up from less than 1 million in 2000.[18]
>
> Deaths due to dementias more than doubled between 2000 and 2015, making it the 7th leading cause of global deaths in 2015.[18]

However, this approach is not sufficient because these statistics refer only to the number of deaths (not illnesses) due to specific health problems, and they do not identify the cause/source of these health conditions.

How many of these deaths from heart disease, stroke, etc. were caused by indoor air pollutants? How many illnesses are caused by indoor air pollutants? The definitive answers are currently unknown.

In contrast, if you look at the number of deaths in the 2010 GBD Study, there were more than 8 million deaths from five sources (i.e., ambient particulate matter, household air pollution from solid fuels, residential radon, lead exposure and second-hand smoke).

Another set of statistics was provided in the WHO 2016 report. They said an estimated 23% of total worldwide deaths are attributable to the environment. However, they were focused primarily on climate change, fossil fuel consumption, safe water and sanitation.

In summary:

- The WHO 2015 numbers looked at specific health issues that caused 56 million deaths worldwide.
- The GBD study looked at environmental causes of 8 million deaths (from only five environmental sources). Heart disease, stroke and pulmonary diseases account for almost 20 million deaths (36% of the total).
- The WHO 2016 report says 23% of total worldwide deaths are attributable to the environment but they focused primarily on four environmental sources.

Even though the GBD report discusses deaths from only five sources**,** the total is more than 14% of the worldwide total deaths. The WHO 2016 report focused on four sources and provided an estimate of 23% of worldwide deaths.

These numbers are not conclusive because they represent only a limited scope of environmental causes and include only deaths (not illnesses). In addition, their estimates leave out many other types of environmental causes. However, these numbers add to the discussion and raise many interesting questions.

The big question: If 23% of total worldwide deaths are attributable to only four environmental sources, what is the total burden of deaths and illnesses caused by all types of indoor and outdoor environmental pollutants?

A 2016 report from New Zealand echoed our concern about the "missing causes." They refer to international reports on the percentage of deaths due to non-communicable diseases (NCDs). Those reports from the United Nations and the World Health Assembly focus primarily on only four diseases (cardiovascular disease, diabetes, cancer, and chronic respiratory disease) and four key risk factors (tobacco use, unhealthy diet, lack of physical activity, and overuse of alcohol). As such, they are missing many other significant causes and are also missing the burden of morbidity (illness).

> These "missing causes" likely include adverse health exposures caused by our built environment, which could be occupational exposures and residential exposures. Infections and occupational and environmental exposures may be other key missing causes.[56]
>
> We further develop this view by suggesting that some more micro aspects of our built environment may themselves be important factors contributing to NCDs. These may include the influence of the outdoor contaminants on indoor environments like particulate matter from combustion processes (vehicle, industry), hazardous building materials, and include potential adverse health concerns like exposure to particulate matter, by-products of burning fossil fuels, fiberglass, asbestos, high/low humidity, radon, heavy metals, chemicals like formaldehyde, hormones and endocrine-disrupting chemicals (EDCs) and copper in water supplies.[56]

To help illustrate the magnitude of this issue, we have presented several of the relevant statistics in Table 1.

Table 1

Statistics on the Global Burden of Indoor Air Contaminants

Statistic	Pollutant	Year	Source of Statistic
300 million children live in areas with extremely toxic levels of air pollution	Air pollution	2016	UNICEF
300 million children live in areas where pollution levels exceed the minimum air quality standards set by the World Health Organization	Air pollution	2016	UNICEF
600,000 children under the age of five die from diseases caused or exacerbated by the effects of indoor and outdoor pollution	Indoor and outdoor air pollution	2016	UNICEF
3,223,540 deaths in 2010	Ambient particulate matter pollution	2012	GBD 2010 Study
3,546,399 deaths in 2010	Household air pollution from solid fuels	2012	GBD 2010 Study
98,992 deaths in 2010	Residential radon	2012	GBD 2010 Study
674,038 deaths in 2010	Lead exposure	2012	GBD 2010 Study
601,938 deaths in 2010	Second-hand smoke	2012	GBD 2010 Study
More than 80% of the diseases regularly reported by the World Health Organization	Environmental risk factors	2006	World Health Organization
24% of the global burden of disease; 23% of all deaths	Environmental factors	2006	World Health Organization
For children 0–14 years of age, the proportion of deaths attributed to the environment was as high as 36%.	Environmental factors	2006	World Health Organization

In developed countries, an estimated 20% of lower respiratory infections are attributable to environmental causes, rising to 42% in developing countries.	Indoor air pollution	2006	World Health Organization
42% of chronic obstructive pulmonary disease (COPD	Environmental risk factors including occupational exposures to dust and chemicals, as well as indoor air pollution from household solid fuel use. Other forms of indoor and outdoor air pollution – ranging from transport to second-hand tobacco smoke – also play a role.	2006	World Health Organization
10-50% of indoor environments in Australia, Europe, India, Japan and North America are affected (in certain settings, such as river valleys and coastal areas, the conditions of dampness are substantially more severe than the national average)	Indoor dampness	2009	World Health Organization
Worldwide, 40% of children, 33% of male non-smokers, and 35% of female non-smokers were exposed to second-hand smoke in 2004. This exposure was estimated to have caused 379,000 deaths from ischaemic heart disease, 165,000 from lower respiratory infections, 36,900 from asthma, and 21,400 from lung cancer. 603,000 deaths were attributable to second-hand smoke in 2004, which was about 1.0% of worldwide mortality. 47% of deaths from second-hand smoke	Second-hand smoke	2010	World Health Organization

occurred in women, 28% in children, and 26% in men.			
92% of the world's population lives in places where air quality levels exceed WHO limits	Air pollution	2016	World Health Organization
23% of total worldwide deaths are attributable to the environment 26% of worldwide deaths of children under age 5 are attributable to the environment 24-26% of worldwide deaths of adults age 50 to 75 are attributable to the environment		2016	World Health Organization
Estimates that 17.5 million people die each year from cardiovascular disease	Cause not identified	2017	World Health Organization
40% of people are more likely to have asthma	Damp or mouldy homes	2017	European Union
12.1% of homes have damp, 10.3% have mould, and 16.5% have a combination of these indicators	Damp or mouldy homes	2012	European Union
40,000 deaths per year	Indoor air pollution	2017	United Kingdom
Annual loss of over 200,000 healthy life years	Indoor air pollution	2015	United Kingdom
57% of healthy life years relate to cardiovascular diseases, 23% to lung cancer, 12% to asthma	Indoor air pollution	2015	United Kingdom
70% of office workers concerned with IAQ; 68% had lapses in concentration; 67% suffered from fatigue; 54% had decreased productivity; 41% had watery or irritated eyes	Indoor air quality	2017	United Kingdom

29,000 deaths per year and 340,000 life-years	Man-made particulate matter	2014	United Kingdom
26.8% of children exposed	Indoor air pollution	2016	China
337,000 people exposed in homes; 154,000 in apartments; 260,000 in schools or day care centres	Mould and damp	2012	Finland
800,000 (or 1 out of 7) people exposed to indoor air pollution	Indoor air pollution	2017	Finland
Four kids could be dying every hour in UP (Uttar Pradesh) 104 deaths per day or 38,000 per year	Respirable suspended particulate matter	2016	India
76,000 (50%) of pneumonia deaths in children	Indoor air pollution	2016	India
1.5 million people killed by indoor air pollution; 620,000 killed by outdoor air pollution	Indoor and outdoor pollution	2015	India
Deaths from indoor air pollution rose 18% from 1990 to 2013; deaths from outdoor pollution rose 36%	Indoor and outdoor pollution	2017	Africa
712,000 deaths each year	Indoor and outdoor pollution	2017	Africa
Environmental burden of disease for four major disease categories: 10,000-25,000 deaths 78,000-194,000 hospitalizations 600,000 to 1.5 million days spent in hospital 1.1 to 1.8 million restricted activity days for asthma sufferers	Environmental exposures	2008	Canada

8,000-24,000 new cases of cancer			
Cognitive scores were 61% higher in Green buildings and 101% higher in Green+ buildings	Green vs conventional buildings	2016	United States
Strategy scores were 183% higher in Green buildings and 288% higher in Green+ buildings	Green vs conventional buildings	2016	United States
30% fewer had sick building symptoms	Green vs conventional buildings	2016	United States
1/2 of U.S. schools have problems linked to indoor air quality	Indoor air pollution	1995	United States
30% of illnesses	Environmental exposures (includes only environmental chemical exposures)	2012	Dr. Linda Birnbaum, NIEHS and NTP
Up to 50% of all illnesses in the U.S	Indoor air pollution	1989	The Commonwealth of Massachusetts

These statistics should catch the attention of every physician, every lawmaker and every layperson reading this paper. It is time we started to pay more attention to the indoor air we breathe.

It is time for our national and world leaders to develop a comprehensive public health response to this devastating epidemic that has the potential to cripple our individual and collective futures.

Section III. Financial Impact of Poor Indoor Air Quality

If you look at the other side of the equation, billions of dollars could be saved if we implemented specific steps aimed at improving indoor air quality.

European Union

The World Health Organization issued the results of a ground-breaking study in 2015. They concluded that the economic cost of air pollution in 53 countries in the European Region of at $1.6 trillion. This is nearly 1/10 of the gross domestic product of the entire European Union.[8]

As they point out, outdoor air is used as supply air for ventilation systems of commercial, public and residential buildings. As a result, indoor air is contaminated by smog and other outdoor pollutants.

The WHO recommends the use of effective air filters and room air purifiers in homes and businesses.

In a 2017 report published by the Velux Group in Europe, they reported the annual cost of asthma and chronic obstructive pulmonary disease at €82 billion.

The economic cost of air pollution in 53 countries in the European Region is $1.6 trillion. Indoor and outdoor air pollution has a significant human cost and economic impact.

> Unhealthy buildings affect not only Europeans' health, but their wallets. The cost to European societies of asthma and chronic obstructive pulmonary disease is €82 billion per year. Half of that amount goes to direct costs such as medicine and care. The other half, almost €40 billion, is calculated as indirect costs such as loss of work productivity.[6]

As they state, "This should put a good indoor environment at the top of every employer's agenda."

United Kingdom

As noted above in the statistics section, approximately 29,000 deaths per year in the UK could be attributable to man-made particulate matter pollution, equivalent to a loss of 340,000 life-years, with a cost to the economy of £16 billion per year.[27]

A 2011 report by the World Health Organization estimates that unhealthy housing in England represents 22% of the 22 million dwellings at a cost of £17.6 billion.[16]

Unhealthy housing in England represents 22% of the 22 million dwellings at a cost of £17.6 billion.

About 12% of new childhood asthma in Europe is attributed to indoor mould exposure.[16]

New Zealand

A June 18, 2017, article titled "The cause of the billion dollar price tag for NZ's next big health epidemic: Leaky buildings and hidden mould" provides an estimate of the problem in New Zealand.

> New Zealand's leaky buildings, which have been widely attributed to lax building regulations and sub-standard materials, include schools, prisons, and government buildings, as well as an estimated 100,000 New Zealand homes.[57]
>
> Experts agree that leaky homes are still being built in New Zealand, and the health costs from them could reach into the billions.[57]

The full cost of the leaky building saga, sometimes estimated at $11 billion, was probably much higher than that – while the ongoing health costs were expected to be higher still.[57]

Finland

As noted above in the statistics section, a 2012 report ordered by a Parliamentary Committee in Finland, found that mould and damp problems affect up to 337,000 people in houses, 154,000 in apartments and 260,000 children attend schools or day care centres affected by mould problems.[7]

The cost of health problems associated with mould and damp is 450 million euros each year. If you add the cost of repairing the problems, the total reaches 1.4 billion euros.[7]

Africa

A 2016 report provided an estimate, for the first time, of the monetary costs of outdoor and indoor pollution. Researchers concluded that costs of outdoor pollution in Africa are $215 billion and indoor pollution is $232 billion.[37] These cost estimates are based on the economic cost of premature deaths. They stated the following conclusions:

- First, air pollution is of significant and increasing concern for the continent.[37]
- Second, the human and economic costs of air pollution might explode without bold policy changes in Africa's urbanisation policies.[37]

The costs of outdoor pollution in Africa are $215 billion and indoor pollution is $232 billion.

- Finally, no blueprint exists for the trade-offs African policy-makers face as they strive to balance human and economic development objectives. Instead, they will have to innovate.[37]

Canada

A 2008 report looked at information relating to four major categories of diseases. They estimated an annual cost of $3.6 to $9.1 billion for illness from environmental exposures.[39]

The researchers recommend stronger efforts to prevent adverse environmental exposures including research, education and regulation.

United States

As discussed in our paper on Indoor Air Contaminants, chemicals are another source of indoor air pollution and cause significant harm. In a 2016 report, they estimated the cost of healthcare and lost earnings due to illness caused by endocrine-disrupting chemicals at $340 billion.[5,58]

The vast majority of that annual $340 billion comes from the effects of neurological problems like intellectual disability. Other conditions caused by chemicals include autism, ADHD, diabetes, obesity, uterine disorders, male reproductive problems, heart disease and early death.

They also provided an estimate of these same costs for Europe, showing an annual cost of $217 billion.[5,58]

They estimated the cost of healthcare and lost earnings due to illness caused by endocrine-disrupting chemicals at $340 billion in the U.S. and $217 billion in Europe.

A 2008 report estimates the cost of environmental disease in children at $76.6 billion. This was a significant increase (39.5%) over a previous estimate of $54.9 billion in 2002. As the authorities of this study stated, a new estimate was needed because "few important changes in federal policy have been implemented to prevent exposures to toxic chemicals."[59]

This estimate includes only the costs of lead poisoning, prenatal methylmercury exposure, childhood cancer, asthma, intellectual disability, autism, and attention deficit hyperactivity disorder.

Imagine how large these numbers would be if you consider the health effects of all types of environmental pollutants.

United States (Government Agencies)

The following information provides statistics from a few reports issued by government agencies in the United States.

According to the Healthy School Environment Resources page on the EPA website:

Twenty percent of the U.S. population, nearly 55 million people, spend their days in our elementary and secondary schools. Studies show that one-half of our nation's 115,000 schools have problems linked to indoor air quality.[60]

These statistics were tied to a 1995 report by the U.S. Government Accountability Office (GAO) titled "School Facilities: Condition of America's Schools."

The 1995 GAO report gave an estimated cost of $112 billion "to repair or upgrade America's multi-billion-dollar investment in schools to good overall condition."[52]

With respect to lead in U.S. housing, it has been estimated that remediation of lead paint hazards in housing would have a benefit of $67 billion.[61]

In the 1989 U.S. EPA report to Congress on Indoor Air Quality:

> Many costs of indoor air pollution have not been calculated. Nevertheless, because of the large numbers of people and buildings potentially affected, as well as the wide range of effects for which there is an economic cost component, it is reasonable to conclude the aggregate costs of indoor air pollution amount to tens of billions of dollars per year.[4]

In its 1989 report, The Commonwealth of Massachusetts states:

> Indoor air pollution seriously threatens public health. Scientific testimony and information provided to the Commission shows that many diseases and symptoms are attributable to indoor air pollution: irritation of the eyes, nose and throat, headaches, fatigue, nausea, asthma, emphysema, pneumonia, lung cancer, heart disease, chemical sensitivity, liver and central nervous system damage and many other ailments. As a result, billions of dollars are spent annually on pollution abatement and health care costs resulting from indoor air pollution.[55]

Indoor air pollution seriously threatens public health. Scientific testimony and information provided to the Commission shows that many diseases and symptoms are attributable to indoor air pollution: irritation of the eyes, nose and throat, headaches, fatigue, nausea, asthma, emphysema, pneumonia, lung cancer, heart disease, chemical sensitivity, liver and central nervous system damage and many other ailments.

In one of the early naysayer reports (in 1992), they also admit the huge financial burden of poor indoor air quality. They cited the EPA, as follows:

> The EPA estimates that sick buildings cost the U.S. economy $60 billion a year in medical expenses, absenteeism, lost revenue, reduced productivity and property damage.[62]

In a 2007 joint study by the U.S. EPA and Berkeley Lab, "The national annual cost of asthma that is attributable to dampness and mold exposure in the home is $3.5 billion."[63]

According to a 2011 report by Fisk and the Lawrence Berkeley Lab:

> Estimates were calculated on the benefits and costs of implementing the following scenarios in U.S. office buildings:

- Increasing ventilation rates when they are below 10 or 15 l/s per person
- Adding outdoor air economizers and controls when absent, eliminating winter indoor temperatures >23°C
- Reducing dampness and mold problems[64]

> The estimated benefits of the scenarios analyzed are substantial in magnitude, including increased work performance, reduced Sick Building Syndrome symptoms, reduced absence, and improved thermal comfort for millions of office workers. The combined potential annual economic benefit of a set of nonoverlapping scenarios is approximately $20 billion.[64]

A 2000 report titled "Health and Productivity Gains from Better Indoor Environments and Their Relationship with Building Energy Efficiency" by William J. Fisk with the Lawrence Berkeley National Laboratory estimated the potential productivity gains.

> For the United States, the estimated potential annual economic savings plus productivity gains, in 1996 dollars, are approximately $40 to $200 billion" if we would implement specific scenarios to improve indoor environmental quality in U.S. office buildings.[9]

Imagine how big those savings would be if we also made these changes in schools, homes and other structures around the world. Other interesting cost estimates resulting from indoor air pollution and unhealthy housing have been made.

In 2000, William Fisk from Lawrence Berkeley National Laboratory in California established a baseline for quantifying benefits from improved IAQ and demonstrated the economic impacts of increased productivity. As stated in the report:

> The existing literature contains moderate to strong evidence that characteristics of buildings and indoor environments significantly influence rates of communicable respiratory illness, allergy and asthma symptoms, sick building symptoms, and worker performance.[9]

Some of the findings in the Fisk report are presented in Table 2.

Table 2

Potential U.S. Annual Savings or Productivity Gains

(If specific scenarios are implemented to improve indoor air quality in U.S. office buildings)

Source of Productivity Gain	Potential Annual Health or Productivity Benefits	Potential U.S. Annual Savings or Productivity Gain (1996 $US)
Reduced respiratory illness	15% to 76% decrease (16 to 37 million cases of common cold and influenza avoided)	$6-$14 billion

Reduced allergies and asthma	8% to 25% decrease in symptoms for 53 million allergy sufferers and 16 million asthmatics	$1-$4 billion
Reduced sick building syndrome symptoms	20% to 50% reduction in sick building syndrome health symptoms	$10-$30 billion
Improved worker performance from changes in thermal environment and lighting	0.5% to 5% improvement in office worker productivity	$20-$160 billion

Section IV. Businesses Making Money on Indoor Air Quality

Although many government agencies, lawmakers and businesses (e.g., insurance companies, builders, product defense firms, medical organizations, allopathic physicians and others) continue to downplay and deny the health effects of indoor air pollutants, other businesses are making billions of dollars by offering products aimed at improving indoor air quality.

Of note, the insurance companies also make billions of dollars by taking in billions of dollars in premiums from their policyholders, then refusing to pay claims and refusing to honor the terms of their insurance policies. The topic of "bad faith insurance companies" is another important and significant component of this issue, but we will not be discussing it in this paper.

In addition to the vast industry of experts who investigate, evaluate and remediate indoor air problems and those involved in the home renovation business, there are other businesses that have acknowledged the detrimental effects of indoor air pollutants and are offering products to remove or improve those conditions.

Air Cleaners and Air Purifiers

One example is the rapidly growing market for air cleaners and air purifiers.

<u>China</u>

A 2016 report provides statistics on the air purifier market in China. As seen in the news, smog is a significant problem in China, and the pollution from smog effects indoor air quality. The report cites several sources of air pollutants including automobile exhaust, road dust, construction, factories, coal, smoke dust, and home furnishings. Here are a few excerpts from the report:

With the development of economy, the increasing consumption of coal and petroleum as well as lack of environmental protection measures worsens the air pollution.[65]

In terms of PM2.5, 800 million people accounting for half of the population of China suffer from the haze namely high concentration PM2.5.[65]

In China, major indoor pollution sources come from construction, decoration, furniture, as well as the haze (PM2.5). The excessive VOCs pollution seriously damaged people's health. Smog can enter the room through open windows and the use of scavenger fans. Therefore, it is of vital importance to choose a suitable household air purifier for health.[65]

Smog can enter the room through open windows and the use of scavenger fans. Therefore, it is of vital importance to choose a suitable household air purifier for health.[65]

In 2015, there were more than 500 household air purifier brands in Chinese market, and the quantity of China's household air purifiers exceeded 3.5 million, of which the market size surpassed CNY 10 billion.[65]

United States

A recent report on the indoor air quality market in the United States focused on IAQ issues in residential homes, commercial buildings and light industrial properties, schools and hospitals. It discussed market trends for the overall IAQ market, as well as equipment and services affecting indoor air quality in these settings, including air cleaners, HVAC equipment, HVAC replacement filters and IAQ instrumentation.

The indoor air quality market in the U.S. totaled $7.8 billion in 2015. The market should total $8.3 billion in 2016 and $10.8 billion by 2021, increasing at a compound annual growth rate (CAGR) of 5.3% from 2016 to 2021.[66,67]

The report provides information on several key topics relating to indoor air quality, including:

Information about indoor air contaminants that are of the highest concern in end-use markets, including mold and other biological contaminants, allergens, airborne pollutants, and radon.[66,67]

In-depth analysis of the settings and end-use markets of IAQ, including homes, commercial buildings, schools and hospitals, as well as the reasons why IAQ is of great concern in each of these settings.[66,67]

Their report analyzed the trends in sales of "residential air purifiers." They found that sales in 2015 were $2.02 billion, and they are expected to reach $2.72 billion by 2012 (giving it a compound annual growth rate of 5.07%).

Interesting note: An executive from the 3M Company, one of the global leaders in this industry, recently quoted the statistic that "50% of all illness is caused or aggravated by polluted indoor air."[68] (See above for our discussion about this statistic in the report from the Commonwealth of Massachusetts.)

An executive from the 3M Company, one of the global leaders in this industry, recently quoted the statistic that "50% of all illness is caused or aggravated by polluted indoor air."

The executive, Adnan Ahmed Khan, a General Sales and Marketing Manager in the 3M Consumer Business Group – Gulf Region, goes on to say:

> Modern day homes and apartments are built with central air-conditioning. Usually, most households have carpets, foam cushions, furniture and painted goods. They are all a source of contaminated indoor air because of dust mites, gases and vapours emanating from household items and microbial contaminants.[68]
>
> A research has thrown up that a baby crawling on the floor inhales an equivalent of four cigarettes a day as a result of the outgassing of carpets, moulds, mildew, fungi and dust mites and unclean AC vents.[68]
>
> In the UAE (United Arab Emirates), indoor air pollution is a growing threat due to constant construction. Today, buildings are built airtight and they contain a long list of pollution sources.[68]
>
> Dust, fibreglass, asbestos and gases including formaldehyde from building materials are a concern. Dust mites from carpets at home or office, emissions from furniture and paints and other microbial contaminants are something that we should be careful of.[68]

Air Quality Monitoring

BCC Research issued a new report in April 2017 regarding trends in the "outdoor" air quality monitoring market. They predict a compound annual growth of 8.8 percent worldwide, with sales of $5.9 billion by 2021.[69,70]

Some of the companies leading this market are Emerson Electric Co., 3M Corp. and Merck. In addition, Oizom in India and EON Products, Inc. in the U.S. are developing new technologies in handheld personal air monitoring devices.

A 2015 article discussed some of the new "indoor" air quality monitoring devices being developed. Bitfinder was preparing to release its Awair indoor air quality monitor.

The speaker-sized units will share the market with existing smart indoor-outdoor weather stations from French firm NetAtMo, and ultimately with wearable environmental trackers from Vancouver-based TZOA, also slated for release later this year.[71]

The Awair will monitor air temperature and humidity, along with levels of dust particles, carbon dioxide, and a class of chemicals called volatile organic compounds, which includes solvents like acetone and benzene and a range of various other substances of varying toxicity.[71]

Other consumer air quality monitors in this market include Foobot, Speck, Air Mentor 6 in 1, Dylos DC1100 and Hobo MX1101. (Note: GIHN does not endorse products or service providers. This information is provided solely to illustrate the marketplace.)

Building Industry

Advances are being made by the building industry in regard to indoor air quality. In 2015, the "du Company" in the UAE received the first Building Indoor Air Quality (IAQ) Certification from Underwriters Laboratory (UL).[72]

UL's building IAQ certification program is the world's first comprehensive IAQ certification and preventative maintenance program for buildings. Under this program, buildings are evaluated for several indoor air pollutants including VOCs, formaldehyde, CO2, CO, moisture and dust. Annual inspections are required in order to maintain the certification.

Abdulhadi Alalyak, Vice President of Asset Management at du, said:

Over the years, we have cultivated a powerful culture of well-being -- one that staunchly values employee safety, work/life balance, and engagement. It is in line with this that du has, in recent years, emerged as an employer of choice here in the UAE. The UL IAQ Certification serves as a strong testament to our commitment to providing a safe workplace where our employees can thrive.[72]

We aim to serve as a role model for companies in the UAE and across the world when it comes to employee safety and welfare.[72]

Another expanding field is in the home building industry. Many companies are taking the lead and designing homes that offer improved air quality. There are many examples, but we will mention just a few.

Japan

In Japan, new ideas are being implemented to improve air quality inside homes. They are creating designs that combine IAQ features with sustainability and energy efficiency.

> Currently, about 10% of Japanese population is reported to have sensitivities or actually showing some symptoms induced by chemicals indoor air, that is called 'Sick-building syndrome' (MLIT 2003,Research group on "Sensitivity difference among people and among animals" 2005, MLIT 2002). It is a series of symptoms such as dizzy, headache, asthma, throat ache, caused by volatile organic compounds (VOCs) in newly constructed or reformed buildings. It is called "Sick-house syndrome" in Japan, and if it happens in school, it is called "Sick-school syndrome."[73]

The abstract of the paper provides the following summary of this project:

> There is increasing number of people suffering from "Sick-building Syndrome" in Japan. Therefore, we started "Chemi-less Town Project," building a model town in which buildings are constructed with fewer chemicals. In this paper, we introduce the background, concept and current situation of the project. We made the key word, "Chemi-less," which means "fewer" chemicals. In the model town, there are houses, clinic, school, library and park. At the clinic, we will practice the environmental preventive medicine. While decreasing the harmful chemicals in the town, we will carry out to create better environment in order to prevent possible adverse health effects, and to increase the quality of life of future generations. In five years, we would like to suggest new standards of houses and buildings, so that people can choose materials and technique to make towns according to the target level. Using Chemi-less Town project, we will spread our idea worldwide, about the necessity of sustainable health town for future generations from the view of the environmental preventive medicine.[73]

Sekisui House is a home building company in Japan, founded in 1960. They announced their new Sustainable Vision in 2005 which focuses on four key values—the environment, society, economy and residential homeowner needs. This new vision led to their "Green First" line of eco-friendly homes and their involvement in 2007 with the Chemi-Less Town Project.[74]

In Sekisui's 2011 report, they discuss their involvement with the Project and talk about building the test house, as follows:

> In building the test home, we examined chemical substance emissions from interior finishing materials as well as more than 200 types of building materials, including branderings, adhesives and heat insulation materials, and selected materials that met strict standards.[73]

Their design caused a significant reduction in VOCs which led to the company receiving the Chemi-less Certification award from the Association for Promotion of Chemi-Less Town in October 2009. This was the first prototype detached house with sick building syndrome preventive measures to receive this award.[73]

Sekisui House launched their "Green First" line of houses in 2009. These eco-friendly homes give residents a "high level of comfort, economic efficiency and environmental friendliness."

During 2010, we successfully reduced CO2 emissions from houses, which is mainly attributable to our "Green First" eco-friendly home characterized by outstanding comfort, economic efficiency and environmental friendliness.[74]

To be specific, we achieved a 49.4% reduction in CO2 emissions from the 1990 level. The Green First home is not only energy-efficient, but also capable of producing energy with its photovoltaic power generation and fuel cell systems.[74]

Orders for the Green First houses account for 70.6% of all the orders received for new build detached houses. As well, 19% of the orders for low-rise apartments for leasing are for the "Sha-Maison Green First" model that is also equipped with photovoltaic power generation system.[74]

Since the introduction of their Green First houses in 2009, they have been experiencing significant growth in sales and revenue. In 2011, 70.6% of all orders for new houses requested the Green First designs.[74]

Sekisui House is sharing their expertise with other countries and is partnering on projects in Australia, China and the United States.

Canada

Superkül, an architectural firm in Canada, designed a house for a client with environmental sensitivities. A great deal of research, planning, testing and collaboration went into the design process.

All materials were tested to see if the client had a reaction, and natural, virgin materials fared best. Recycled materials often caused a reaction, as did many plastics. So where plastics had to be used for technical reasons, they were put on the outside of the assemblies.[75]

Inside there is no drywall, which seems to provoke quite a reaction; all the walls are wood or American clay plaster, 100% all-natural, is VOC-free, and is made of a proprietary blend of sand aggregates and clays sourced entirely from the United States.[75]

Structural walls are made of one of our favourite materials, Durisol, inert cementitious blocks that inhibit the growth of fungi and molds.[75]

United States

Several builders in the U.S. are paying attention to indoor air quality as customers are asking for "greener" homes with improved air quality.

In order to meet consumer demand, these companies are making changes to their home building processes and materials. Here are four examples:

- Clarum Homes has a strong focus on indoor air quality with special attention toward eliminating chemicals, controlling moisture and proper air ventilation. They also incorporate the principles of "high-performing homes" which includes reducing the environmental impact of the home.[76]

- Pardee Homes also uses low-VOC paint, along with low-formaldehyde attic insulation, UV-blocking windows, and radiant barrier roof sheathing, and homebuyers can add a high-efficiency electronic air filtration system and central vacuum system. They also offer customers tips on how to reduce pollutants inside their home (e.g., use a HEPA-filtered vacuum, avoid synthetic fragrances, purchase cleaning products with safer ingredients, etc.)[77]

- C&B Construction, also known as Grey Fox Ridge, is the first Indoor airPLUS partner to earn the Leader Award three years in a row. They have built 100% of their homes as Indoor airPLUS since 2014.[78]

- Mandalay Homes was only one of eight homebuilders honored with a 2015 Indoor airPLUS Leader Award (and they were honored again in 2016) because of their focus on building homes with improved indoor air quality. The CEO of Mandalay Homes, Dave Everson, said:

  Energy efficiency and environmental quality isn't just a goal, it's a responsibility. We're proud of our homes and it's always wonderful to be recognized for hard work.[79]

To qualify for the Indoor airPLUS designation, homebuilders must first design a house to meet the criteria for the Energy Star certification. Then, they must build the house in compliance with all requirements on the Indoor airPLUS checklist.

Information on specific ideas for building mold-free homes can be found in a paper titled "Proactive Approaches for Mold-Free Interior Environments." The authors discuss several issues that need to be considered when building a mold-free home including site location, architectural

shell, space planning, selection of interior finishes, furnishings and equipment, ventilation techniques, and strategies for removing or reducing moisture and nutrient matter.[80]

There are many other businesses who have acknowledged the importance of good indoor air quality, and they are developing products and services in this rapidly expanding market.

Section V. Conclusion

In short, poor indoor air quality has a tremendous impact on our health, our individual financial well-being and the global economy. Millions of people are being harmed by indoor air contaminants in their homes, schools and business in countries around the world, and hundreds of billions of dollars are in the balance.

These statistics should catch the attention of every business, every physician, every lawmaker and every layperson reading this paper.

It is time we pay more attention to the indoor air we breathe.

It is time for our government agencies and medical organizations to acknowledge and share the truth about the health effects of molds, mycotoxins and other contaminants in water-damaged buildings.

It is time for our world leaders to address this important, and costly, public health issue.

Imagine how different things could be if the truth came to light and all vested parties worked together to improve our indoor air. Imagine the impact on future generations.

Global Indoor Health Network

The Global Indoor Health Network (GIHN) is a 501(c)(3) nonprofit organization dedicated to providing education and awareness of the health effects of mold and other indoor contaminants. We are uniting experts and laypersons from the world, with members throughout the United States and in eleven other countries. GIHN's vision is a global community of individuals and organizations working together to ensure that comprehensive information and guidance concerning medical treatment, investigative techniques and solutions are available to address the effects of contaminants in the indoor environment of homes, schools and businesses.

Visit our website at: https://www.globalindoorhealthnetwork.com.

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