Indoor air quality in low energy homes in Mexico City

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Abstract: This work looks into the indoor air quality at homes in Mexico City, and the use of the PassivHaus building certification as a way to improve it. For this purpose, monitoring in some homes in Mexico City is being carried out. Low-energy homes often address airtightness as a measurement to assure thermal comfort with the lowest energy consumption possible. But, it is known that air other problems might arise by addressing airtightness; such as ventilation, air pollution and mould. This paper focuses on IAQ and describes the possible implications of IAQ in low-energy homes in Mexico.

Key Words: Indoor Air Quality, Low-energy homes, Mexico, health and wellbeing on homes.

Introduction

In Mexico, housing accounts for around 16.7% of national energy consumption and 6% of CO_2 emissions (Fernandez Marinez et al., 2011). As part of policy to combat the effects of climate change Mexico has developed the *NAMA for Sustainable Housing in Mexico* (see (Feist, 2012; Kaineg et al., 2012)) and policies such as *Sustainable building - environmental criteria and minimum requirements* (NMX-AA-164-SCFI-2013) among many others. However, its implementation has not been successful. On one side governments initiatives are good, but on the other there is a lack of institutions that helps to control them (Lopez Silva et al., n.d.).

Building energy-efficiency has been an important issue in recent decades. Improving building envelope on pursuing energy savings and CO_2 emissions reductions has been widely studied. Much has been learned about the impact of buildings on the environment, reduction of energy consumption, and reduction of greenhouse gases associated with buildings (Emmerich and Persil, 2012). Airtightness is one of the most common practices to achieve energy savings and maintain a comfortable indoor environment. However, as we do airtightness and sealed buildings other problems arise. Indoor air quality (IAQ) can lead not only to health problems; it might as well increase or decrease energy performance. This has being widely discussed as mechanical ventilation in airtight-dwellings has proven inefficient for removing heat during warm seasons. IAQ controls rely on the capacity of systems to filter and ventilate indoor air. Crump et al., (2009) suggests that a lack of air infiltration could lead to poor indoor air quality as indoor air is not replaced, creating an environment where pollutants, humidity, and condensation become a high risk.

Recent studies have noted the importance of IAQ in low-energy buildings and the consequences of greater airtightness in the building envelope (Crump et al., 2009; Emmerich and Persil, 2012). Emmerich and Persil (2012) suggest that sealed buildings may raise pollution levels because air is not being replaced at a sufficient rate. Moreover, other studies suggest that construction materials, behaviour of residents and building maintenance play an important role in increasing contaminants (ASHRAE, 2007; Bernheim et al., 2015; Poppendieck, 2015).

If airtightness needs to be addressed in low-energy homes, one of the biggest challenges in the Mexican context is to move from passive and natural ventilation to sealed environments, relying on the use of mechanical ventilation.

Human health and IAQ in Mexico City

In Mexico City respiratory problems are often seasonal (Rosas, 2001), with the number of cases peaking in periods of rainfall (July-September). Rain causes a decrease in common air pollutants, suggesting that they may be found indoors rather than outdoors. Pollution problems increase mortality and illness[1]; as well as chronic obstructive pulmonary diseases (Rojas, n.d.; Rosas, 2001; Yip and Madl, 2000).

The lack of daily control and monitoring of air allergens and pollutants makes it difficult to understand this problem. However, some pollutants have been identified as particular sources of concern and studies are being carried out. Some of these chemical contaminants are carbon monoxide (CO), formaldehydes (HCHO), hydrocarbons (HC), nitrogen oxides (NO_x), ozone (O_3), $PM_{2.5}$ and PM_{10} particles, and sulphur dioxide (SO_2). Many of these have been found indoors and outdoors in residential areas, especially $PM_{2.5}$ and PM_{10}, and HCHO. This paper does not intend an exhaustive review of the IAQ on health's implications, but rather an explanation of the possible health effects and its sources in buildings.

Health effects of indoor air pollutants.

Intense and short exposure of CO can lead to loss of consciousness. Exposure to elevated levels can be associated with SBS symptoms: irritability, headaches, visual impairment, reduced work capacity and manual dexterity, poor learning ability, and difficulty performing complex tasks. Other effects are association with low birth weight, and an increase in perinatal deaths (Bruce et al., 2000; Mott et al., 1997).

Particles PM_{10} and $PM_{2.5}$, are airborne substances known or suspected to be causes of cancer, genetic mutations, birth defects, or other serious illnesses. Their effects are variable, from cataracts, strong irritation, reddening eyes, runny noses and respiratory irritations, to cancer and cardiovascular problems (Bernnan, 2015; Bruce et al., 2000) and hypertension (Holguín et al., 2003).

O_3 damages the cells that line the respiratory tract, causing irritation, burning, and breathing difficulty. It causes respiratory problems, aggravates asthma, causes inflammation of lung tissue, and inhibits the body's immune system. Other temporary effects include decreasing lung capacity from 15% to 20% (Mott et al., 1997) and hypertension (Holguín et al., 2003).

[1] cardiopulmonary, respiratory, cardiovascular, and even cancer

Effect of SO_2 may include wheezing, gasping, and shortness of breath, exacerbating asthma. It may exert corrosive effects on nasal lining, the trachea of the lungs and the alveolar tissue (Bruce et al., 2000; Mott et al., 1997).

Residential indoor air quality

The air quality is defined by its biological, chemical and physic characteristics (BRE, 2016). (ASHRAE, 2007) define *acceptable indoor air quality* as,

> *"…air in which there are no known contaminates at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction".*

This assumption may be suitable for highly occupied buildings, but might not be appropriate for low occupied buildings, such as homes. Other definitions discussed by Crump et al., (2009) express the importance of maintaining the comfort and health of occupants maintaining safe contaminants levels on breathable air.

Studies of indoor air pollution therefore involve examination of emission, accumulation, and assessment of pollutants regularly caused by poor ventilation. Hence, outdoor air pollution, whether chemical, physical or biological in origin, could lead to indoor contaminants (Crump et al., 2009). Of particular interest are issues involving air quality and human comfort within a building's interior. Recommendations for appropriate outdoor airflow rates to dilute polluted air indoors vary considerably (Pepper and Carrington, 2009), however a rate of 2.5 l/s*person is acceptable in residential buildings (ASHRAE, 2007). Residential indoor air pollution includes, but is not limited to, the following factors:

- allergens (mould spores),
- building materials and finishes,
- cleaning, maintenance, and personal care products,
- CO and NO_2 combustion,
- cooking, dry cleaning clothes, and human activities,
- O_3,
- Pesticides, and
- ETS.

Building sources of air pollution

There is an extensive collection of scientific literature on sources of air pollution (Coward et al., 2001; Crump et al., 2009, 2002; Dimitroulopoulou et al., 2005; WHO, 2010, 2000). Table 1 provides a summary of the main sources and types.

Table 1, Sources and types of indoor air pollution. Source: (Crump et al., 2009)

Source	Main Pollutants
Outdoor air	Benzene, biological particulates, NO_x, O_3, particulates, SO_2
Combustion of fuel	CO, NO_x, particulates, VOCs
Tobacco smoke	CO, particulates, VOCs
People	CO_2, organic compounds
Building materials	Ammonia, fibres, formaldehyde, other particles, radon, VOCs
Consumer products	Formaldehyde, pesticides, VOCs

Furniture	Formaldehyde, VOCs
Office equipment, including MVHR	O_3, particulates, VOCs
Bacteria and fungi	Biological particulates, VOCs
Contaminated land	Contaminated dust (i.e. metals), methane, VOCs
Ground	Moisture, radon
Washing and cleaning	Moisture
Animals	Allergens

The main sources of inorganic IA pollution are: combustion of fuel, outdoor air, and respiration. Therefore there is a strong relationship between IA pollution and human behaviour. Space heating, water heating and cooking are everyday activities that may cause fuel burning. Other sources may include ETS and vehicles.

Conclusions

Interest on IAQ in airtightness houses has been a topic of studies recently. Scientific evidence suggests that there is a high relationship between IAQ and the building environment. In Mexico airtightness homes are not common, however as we move into a more energy efficient homes, airtightness homes will become more common as suggested on the *NAMA for Sustainable Housing in Mexico*. Homes in Mexico are traditionally ventilated with natural techniques, this however opposed to the actual low-energy home ventilation techniques. Therefore, people need to adapt its behaviour to mechanical controlled environs and be aware of its implications.

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