IMPACT ON IAQ OF BUILDING MATERIAL EMITTED POLLUTANTS THROUGH BUILDING LEAKS : STATE OF THE ART AND SAMPLE TESTING METHODOLOGY

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ABSTRACT

French authorities have launched an extensive thermal renovation program aiming at retrofitting 4M dwellings over 10 years, with priority given to the most energy consuming ones. Without specific focus on airtightness, retrofitting does not achieve very low airtightness levels, which means numerous leaks in the envelope. Added to the possibility of fungus development at the junction between ancient and new wall, the possibility of airflow conveying pollutants emitted in walls into indoor air is a major concern for public health. Although this concern might apply to all types of construction, this paper will only deal with retrofitted walls, proposing a state of the art and a methodology dealing with the following issue: what is the impact of leaky retrofitted walls on indoor air pollution?

Literature shows that VOCs are commonly emitted by building construction materials. Still, the proportion of pollutants due to air leakages is scarcely documented. Hayashi et al (2008) discussed however the influence of concealed pollution sources upon IAQ in Japanese houses.

The use of a test chamber will give some valuable answers to the question raised. The chamber's purpose is to pressurize a retrofitted wall sample in order to measure the amount of pollutants released by the induced airflow through purposely made building cracks. Temperature, relative humidity and airflow being controlled, TVOC and particles concentrations will be measured in the first place.

This project will quantify by extrapolation the amount of indoor pollutants due to air leakages. Results will however only partly be generalized, as the continuous pressurization methodology only accounts for mechanical exhaust ventilation.

KEYWORDS

Airtightness, IAQ, VOC measurements, retrofit

1 INTRODUCTION

French authorities have launched an extensive thermal renovation program aiming at retrofitting 4M dwellings over 10 years, with priority given to the most energy consuming ones. Considering indoor air quality (IAQ) as a major health issue, part of the retrofit efforts should deal with it too.

Without specific focus on airtightness, retrofitting does not achieve airtightness levels as low as newly built buildings, which means numerous leaks in the envelope. Added to the possibility of fungus development at the junction between ancient and new wall, retrofitting may become a threat to IAQ if not properly managed.
This paper identifies three impacts of poor airtightness on IAQ and focuses on the leaky retrofitted wall as a possible indoor air pollution source. The paper describes a laboratory and onsite methodology to quantify and qualify this impact. The paper aims thus at dealing with following issues: what is the impact on IAQ of a leaky retrofitted wall? From the IAQ point of view, what is the importance of airtightness treatment in the success of a retrofit operation?

2 LITERATURE AND STATE OF THE ART REVIEW

2.1 Airtightness in retrofit

Retrofitting works on a dwelling aims most of the time at improving the building's envelope to lower the energy consumption. If those works are often accompanied by improvement of the airtightness level (Chan et al, 2012), the levels reached are relatively high in comparison with what can be achieved in newly built buildings.

Table 1: Airtightness in retroditted and newly built single family dwellings, in $m^3/h/m^2$

French building's airtightness Database

	Recently retrofitted single family dwellings (2010, 2011 and 2012) n=28	**Newly built single family dwellings with certification (2010, 2011 and 2012) n=13544**	**Newly built single family dwellings without certification (2010, 2011 and 2012) n=2086**
Mean	1.13	0.42	0.43
25^{th} percentile	0.78	0.31	0.31
75^{th} percentile	2.07	0.53	0.58
95^{th} percentile	3.48	0.70	1.18
Standard deviation	1.19	0.21	0.42

Table 1 shows the mean values, the 25^{th}, 75^{th} and 95^{th} percentile and the standard deviation of airtightness levels of retrofitted and low energy-consumption certified newly built single family dwellings. Whereas most of the newly built dwellings with certification achieve airtightness levels lower than 0.53 $m^3/h/m^2$ (75%), most of the retrofitted dwellings achieve airtightness levels higher then 0.78 $m^3/h/m^2$ (75%). The standard deviation of the retrofitted dwellings shows very variable airtightness levels around the mean value. The particularly low results in the newly built dwellings with certification can partly be explained by the airtightness requirement of 0,6 $m^3/h/m^2$which is inherent to the certification. However, among non certified newly built buildings, the airtightness levels are very similar to certified newly built buildings. This is why we can consider that the differences between retrofitted dwellings and newly built dwellings are still relevant.
From this table can be inferred that low airtightness is not guaranteed after a retrofit. It is very dependent on the existing structure and the retrofit itself, whether it is heavy and how it is done. Retrofitted walls are hence expected to be leakier than newly built walls.
Furthermore, the progress of airflows through building cracks is unknown. It can follow direct paths through the wall or travel between two construction layers by indirect paths. In both cases, airflows progress nearby building construction materials.

Having leaky envelopes may lead to three problems regarding IAQ :
1) transportation of outdoor pollution indoors,
2) release of sealed pollution sources in the wall itself conveyed by airflow progressing through the wall and,
3) disorders of the ventilation due to pressure variations.

1) The transfer of outdoor pollution through building cracks has been documented in the past. Liu and Nazaroff (2003) as well as Olea et al (2007) studied particle penetration through building cracks. Both papers show different penetration factors depending on the size of the building crack and the size of the particles. This paper will therefore not deal further with pollution penetration through leaky walls.

2) Building materials in the wall itself may be a source of pollution of the indoor air as well. Indeed, building construction materials are known to emit pollutants. Jones (1999) listed these pollutants in a review of existing literature on the topic: aliphatic hydrocarbons, aromatic hydrocarbons, halogenated hydrocarbons, aldehydes, ketones, ethers and esters. The author also identified VOCs to be often used in construction.

Furthermore, airflows transferring through the wall as well as vapour may condense in the wall. Not only may it damage insulation materials but it may also result in fungus development, which represents another pollution source in the wall itself. In France particularly, internal insulation is used most of the time and as soon as vapour barriers are not precautiously fitted, this risk exists.

The wall as source of indoor air pollution has of course been known for a long time. The fact that leaky walls contribute all the way more to this pollution has however scarcely been studied.
Hayashi (2008) studied from cut models, prefabricated houses and simulation tools the impact of concealed pollution sources upon indoor air quality in Japanese housing. The principle was to study the impact of known pollutant sources in the crawl, the beam and the truss spaces on the concentration of the same pollutants indoors, with calculation of the infiltration rates from these spaces to the indoor. The author concluded that seeing the concentration measured indoors, one should consider the emissions from the materials in the concealed spaces, that it is important to have low infiltration rates between those spaces and finally that the ventilation systems has to be carefully designed to fit the ventilation purposes properly. However, this paper does not study pollutants emitted by the building materials themselves.

3) The pressure variations indoors caused by poor airtightness may result in disorders of the ventilation system.
Brogat (2003) identified in a guide to retrofitting several ventilation systems unsuitable with poor airtightness. When retrofitting multi-family housing, the guide recommends not using mechanical ventilation (inlet and outlet) and any system using hygrometric controlled inlet air grids.
The impact of airtightness on ventilation is to be dissociated from its proper functioning. As a hypothesis for this paper is understood that disturbances in the ventilation system are only due to pressure variations and that the ventilation system has been properly installed and maintained.

For the purpose of this paper, only the second impact, building materials source of pollution through building cracks, will be dealt with.

3 RETROFITTING: QUANTIFYING THE IMPACT OF POOR AIRTIGHTNESS ON IAQ

Considering that building materials are a pollution source that has an impact on IAQ through envelope leakages, the question is to quantify this impact. If the impact appears to be relevant, it will be all the more important to achieve good airtightness after retrofit. This paper focuses on two methodologies which feasibility is currently being studied.

3.1 Sample testing in laboratory conditions

3.1.1 Principle

The airflow is charged with pollutants by transferring through the building cracks. In buildings, these airflows are naturally induced by wind pressure, temperature or mechanical ventilation. A wall is thus submitted to various natural pressure differences, up to ± 10 Pa.
The idea is to artificially create an airflow through previously designed building cracks on wall samples in order to measure the concentrations of VOCs released by the wall sample.
Laboratory conditions allow fixing temperature and relative humidity, which have an impact on the emission of pollutants of building materials and allow making the pressure difference on the sample vary.

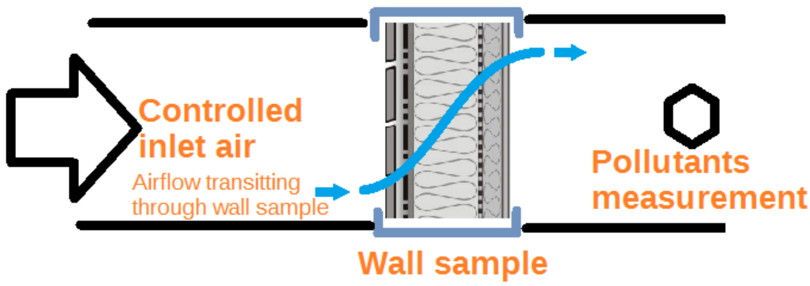

Figure 1 : Principles of the wall sample methodology. This figure does not account for the definitive design of the test chamber.

Figure 1 shows the principles of such a test. Two chambers are applied on a wall sample. The wall sample has been assembled on site specifically to have building cracks designed for the purpose of the test. Two major building cracks can be applied: direct and indirect. One chamber blows controlled air at a regulated pace, to apply various pressure differences. The sample is pressurized and air flows naturally from one side to the other. The other chamber contains pollutants measurement devices.

3.1.2 Testing methodology

The methodology has been built to be as close as possible to the ISO 16000 which describes an indoor air pollution sampling and testing methodology.

- The laboratory's air is characterised to assess the impact of indoor air pollution in the laboratory on the tests. In this case, VOCs measurements are performed before and after any test on a sample.
- The sample is tested with the following procedure. Several depressurization stages are applied to the sample. The 0 Pa measurement stage characterizes the sample emissions without any impact of poor airtightness. The following stages determine the amount and the nature of VOCs released depending on the pressure applied.

- The airtightness of the sample is determined by applying the NF EN 13829. The airtightness value is an essential parameter to understand the results of the VOCs measurements.

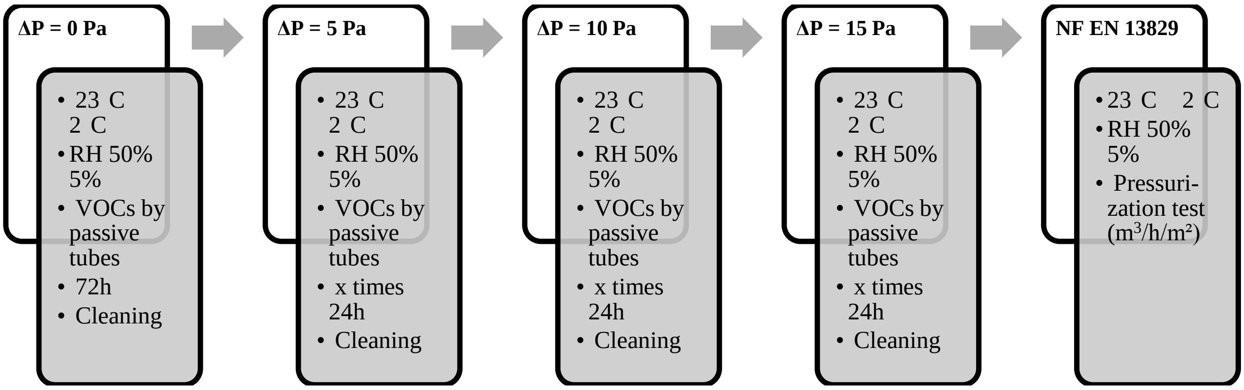

Figure 2: Test steps

3.1.3 Application to retrofit walls

The initial goal of setting up this procedure is to study the impact of retrofitting on IAQ, considering the retrofitted wall as a source of pollution when its airtightness is poor. For the need of the project, the influence of several parameters will be studied: nature of the crack, nature of the existing wall, nature of the retrofit.

The tests will focus on the most standard retrofitted walls among housing that will the most benefit from a retrofit. Indeed, this housing stock will probably be the target of the large governmental retrofit program. As for Burgundy, the housing stock which will benefit the most from retrofit is single-family dwellings, built before 1949 and which structure is stone. It represents almost 20% of the energy consumption in Burgundy and has a high potential of energy consumption savings. Furthermore, the hygro-thermal behaviour of this type of structure is particularly difficult to apprehend, because of scarce literature on the subject. Disorders due to retrofitting are even more to be expected.

The present project shall thus study the impact of retrofit, with different scenarios, of such retrofitted walls on IAQ.

3.2 On site measurements campaigns

To provide better insight on the pollution state in retrofitted dwellings, an onsite measurements campaign was considered.

In order to supplement the sample test methodology, the tests shall be performed in dwellings presenting the same construction type and the same retrofit program than the samples intended to be tested.

The goal of an onsite campaign is to quantify the VOCs pollution and compare the results with those obtained in laboratory conditions.

The campaign should deal with at least 10 dwellings. On each dwelling, three interventions are considered:

- before retrofit to provide a blank state of pollution on the dwelling,
- after retrofit to characterize the impact of the retrofit on indoor air,
- 6 months after retrofit to analyse the decrease in time of the pollutants emission.

These interventions should take place in either the living room or the bedrooms, the one that are the most impacted by the ventilation system in terms of depressurisation.

At each stage, several parameters shall be measured or controlled. Temperature and relative humidity are measured, which influence the emission rates. Ventilation system is controlled to assess the quality of its installation and the impact it could have on pollution removal. Ventilation airflows is measured, also to assess its influence on pollution removal. VOCs concentration when no depressurisation is applied, ventilation is stopped. VOCs concentrations when artificial depressurisation is applied, ventilation system still stopped. Finally, the airtightness level of the room is determined, on the basis of the NF EN 13829, which results are given in $m^3/h/m^2$, and a leakage analysis is performed.

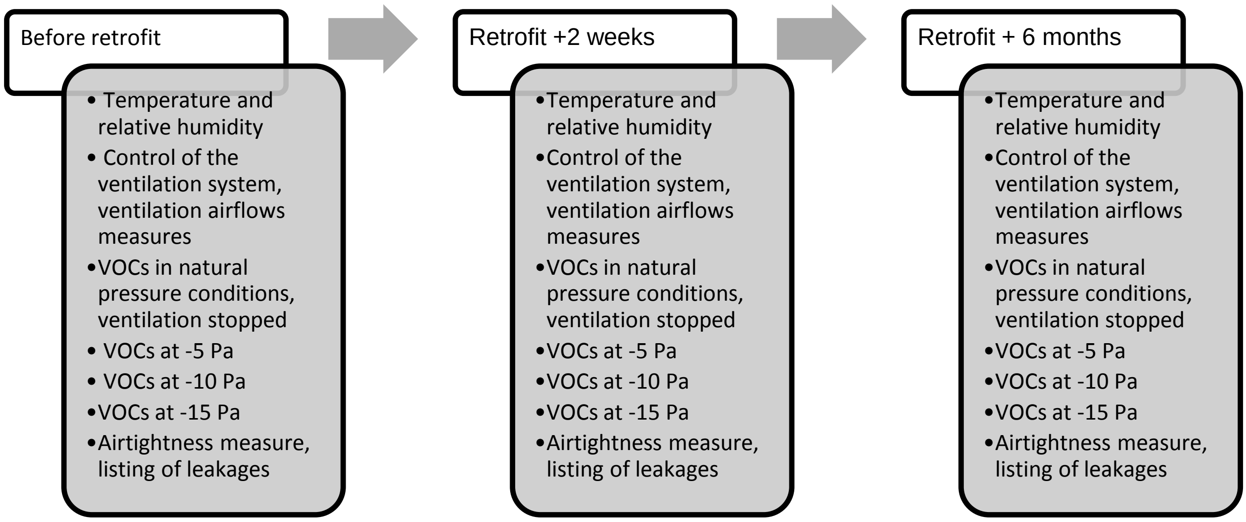

Figure 3: Steps of an onsite campaign

4 DISCUSSION AND PERSPECTIVES

4.1 Accountability of the results

This project should give valuable results on indoor air pollution by leaky retrofitted walls. Depending on the pertinence of the results, it is expected that attention should be brought to the emissions of all building materials. Moreover, an influence of the airtightness level is expected, which could show the need of treating airtightness properly during a retrofit program to avoid poor IAQ.
The results however will only account for retrofitted dwellings with ventilation systems that put the building in depression. Mechanical exhaust ventilation and natural ventilation working with stack effect are the main systems related to the results. Even so, the results are representative of the housing stock, since mechanical exhaust ventilation systems are often installed in France.

4.2 Perspectives

The tests described in this paper are part of a larger project lead by the CETE de Lyon aiming at identifying keys for retrofit strategies. Indeed, if a large set of buildings need to be retrofitted in the frame of the national retrofit program, a general reflection will have to be done on the regulatory frame of retrofitting. If energy consumption is the parameter dealt with in the current retrofit regulation, IAQ has been identified as a national public health issue by French policies and could be integrated as an important parameter if enough studies show its pertinence in a regulatory text.

Considering these challenges, the project aims at assessing the pertinence of the treatment of airtightness in retrofit programs from the IAQ point of view. Taking it further, the question to be answered is the following: from the IAQ point of view, is it relevant to set a regulatory requirement on airtightness and if so, what should it be?

5 CONCLUSIONS

In the frame of a project aiming at assessing the importance of airtightness treatment in retrofit programs, the CETE de Lyon (CEREMA) has developed a laboratory and onsite methodology to quantify and qualify COVs emissions from the building materials of leaky retrofitted walls by applying a depressurisation. The project will focus on the most energy consuming type of buildings.

The project takes place in a context of national retrofit programs and should give valuable keys to the revision of regulatory texts about retrofitting.

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ISO 16000-9 Indoor air – Part 9: Determination of the emission of volatile organic compounds from building products and furnishing – Emission test chamber method