The assessment of surface condensation risk in dwellings. The influence of climate in Spain

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ABSTRACT

Surface condensation risk is a fact that has to be dealt with when buildings are airtight. Airtight buildings with lower ventilation rates are the result of applying energy saving policies and criteria. Surface condensation risk depends greatly on the ventilation rates, as well as on another factors such as generation of water vapour, climate, envelope components and U value, etc. In order to assess the risk of condensation all these factors need to be taken into account.

Commonly used condensation assessment methods only study climate conditions in January, but in a relatively dry climate such as the Spanish one, other times of the year could present a higher risk of condensation due to the higher values of humidity.

This paper presents the research on the assessment of the surface condensation risk due to the higher outdoor humidity in two Spanish climates. The results of the surface condensation risk assessment are presented for four types of dwellings, according to the number of bedrooms and bathrooms and for two distinct Spanish climatic zones, both having an average high relative humidity. The study analyses the influence of the outdoor climate conditions into the risk and proposes a broader assessment during the whole year.

KEYWORDS

Ventilation, precipitations, IAQ, regulations, condensation, risk.

1 INTRODUCTION

As part of the research that has been carried out to support the modification of the Spanish IAQ regulations to accommodate the use of more efficient ventilation systems which are capable of adapting required ventilation rates to real needs, a study on the effect of lower ventilation rates on the surface condensation risk was conducted. In June 2017, the proposal came into force and became part of the Spanish Building Code (CTE – Código Técnico de la Edificación[1]). The results of this study has already been presented by the authors [2].

The use of optimized ventilation systems produces a reduction of the global ventilation rate and, consequently, a reduction of the heating and cooling energy demand[3]. The results of the optimized ventilation flow rates according to Spanish Building Code and the correspondent energy saving assessment have already been presented [4 5 6].

Whenever assessing condensation risk, the whole of the scenario[7] must be taken into account. Ventilation rates, climate, occupancy, generation of water vapour and dwelling type and size are the most important factors than configure the possible scenarios.

There are a number of international standards that study moisture control and provide condensation risk assessment in buildings and building envelopes, such as: ASHRAE

Standard 160-2009[8], British Standard BS 5250:2011[9], British Standard BS EN 15026:2007[10], and ISO 13788:2012[11]. The assessment methods are mostly based on multi-variable calculations. The Condensation in Buildings Handbook[12] describes the scope of some of these standards and outlines the nature of their content.

Condensation assessment is generally conducted for January conditions, but in relatively dry climates with rainy seasons, other times of the year could be more prone to condensation risk due to higher levels of moisture in air.

A method to assess the influence of variations in ventilation on surface condensation risk based on the one described in DA DB-HE/2[13] (derived from ISO 13788:2012) was used. As a consequence of a close look into the application of this method to the actual study cases, the method has been on one hand extended and adapted to the local climate conditions –mainly derived from relative humidity and precipitations - and on the other hand has been simplified taking into account that the U-values of the envelope components are small enough to be eliminated from the calculation process.

2 METHODOLOGY

Surface condensation risk depends on different factors related to indoor and outdoor climate such as temperature and absolute humidity[14]; and related to characteristics of the building envelope like the U-value. In order to analyse the influence of the outdoor humidity on the condensation risk, dwelling types, envelope characteristics and indoor conditions were stablished (these factors were studied in [2] by the authors) and simulated using two different climate zones.

The U-values of the building´s envelope, that have been estimated to fulfil the Building Code for each climatic zone, are provided in Table 1.

Table 1. U-values

	U ($W/m^2 \cdot K$)	
	D1	**A3**
Façade walls	0.26	0.32
Roof	0.23	0.32

2.1 Outdoor conditions: humidity and temperature. Climatic zones

Two Spanish climatic zones [15] [16] were chosen to conduct the study because of their supposed higher risk of condensation due to their higher absolute humidity content: A3 (Cádiz, south Atlantic coast, Mediterranean climate) and D1 (San Sebastián, north Atlantic coast, oceanic or highland climate) (See Figures 1 and 2). Absolute humidity is in general higher in zone A3 than in D1. Both climates are synthetic ones.

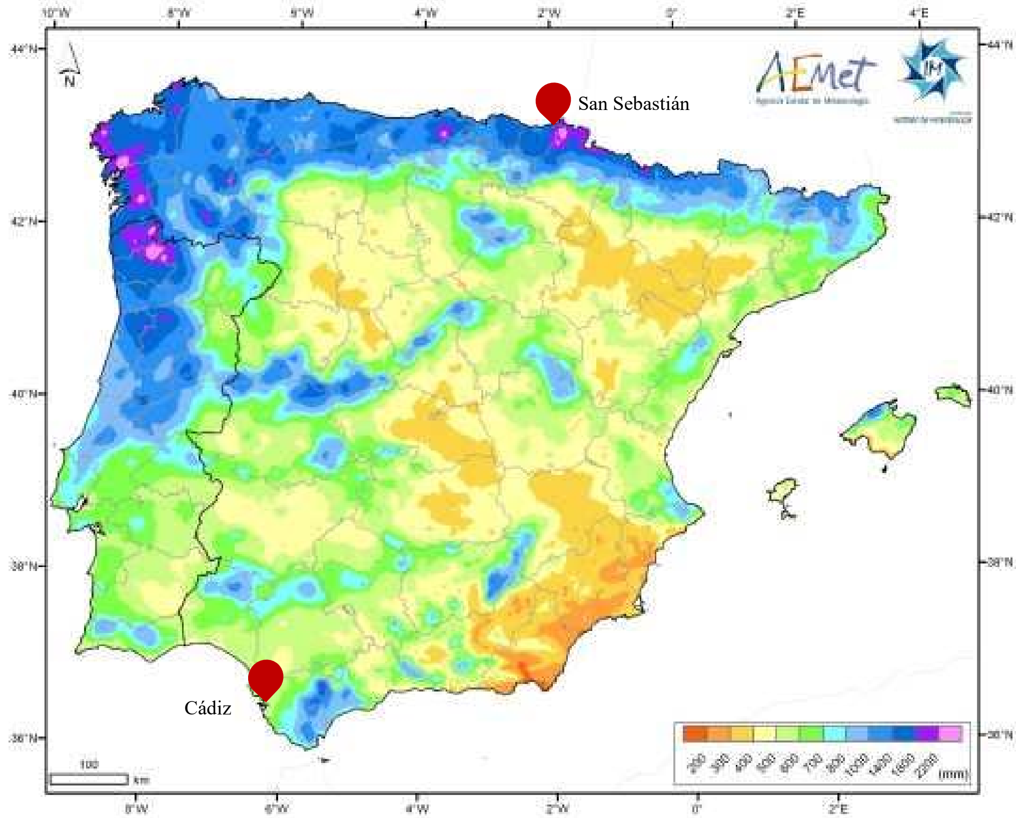

Figure 1. Map of average annual precipitation (mm). Source: AEMET

San Sebastián is the Spanish capital city with the highest number of days with rainfall. According to some studies[17], it rains an average of 141.1 days per year. On the other hand, Cádiz has a lower amount of precipitations, mostly occurring in Spring and Autumn. Figure 3 displays the precipitations measured in Cádiz‘observatory in 2017. Figure 4 depicts the average precipitations in San Sebastián. Both figures show a correlation to the data observed in figure 2 related to humidity.

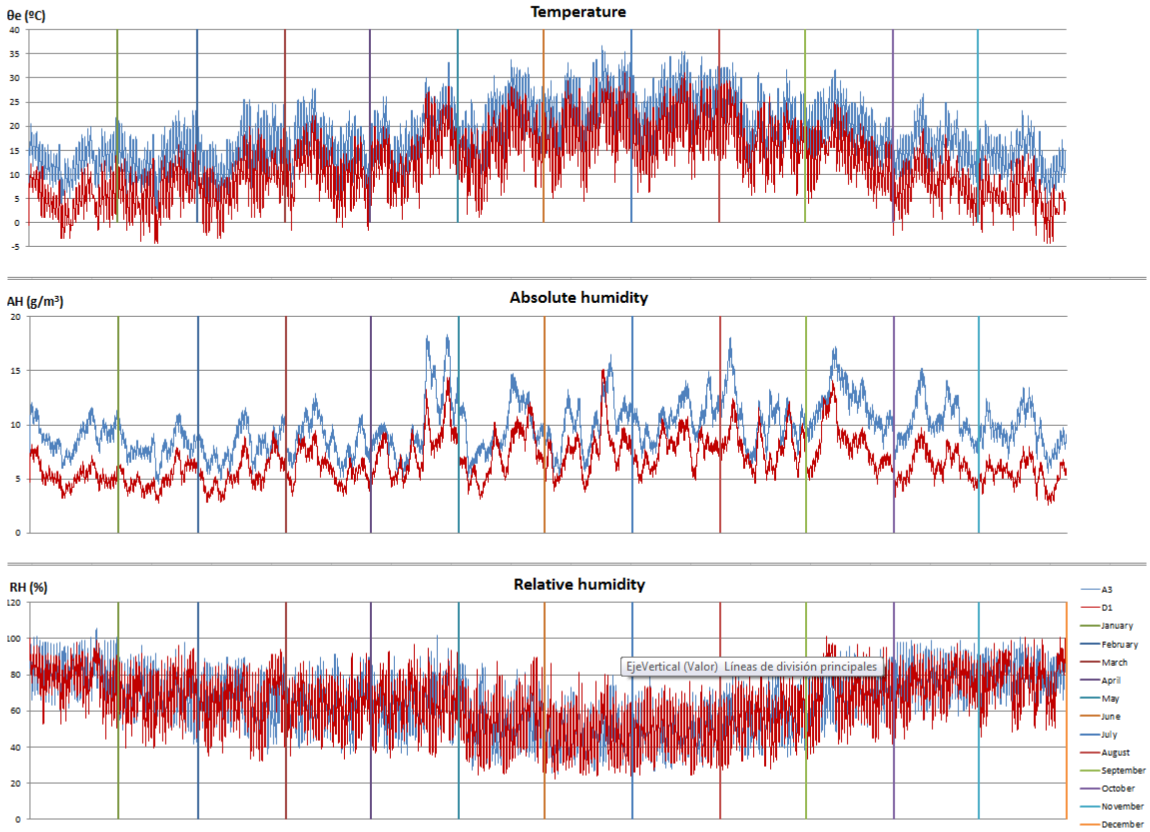

Figure 2. Climatic data of climatic zones A3 (blue) and D1 (red) for a year.

2.2 Indoor conditions: relative humidity and temperature

Indoor temperature values were set in 25ºC for the hot season (from June to September), 20ºC for the cold one (from November to April) and 23ºC for May and October.

Indoor humidity is a consequence of the outdoor humidity and the production of indoor water vapour due to human breathing, metabolism and activities (cooking, washing and others). It can be reduced with ventilation with outdoor fresh and dryer air.

The generation of H_2O was set it off based on CEN/TR 14788:2007 IN [18]. An occupancy scenario for each occupant was set to establish the H_2O generation in each room at any given time.

The ventilation rates were the minimum ones to fulfil the IAQ requirements (See Table 2). One way flow system was considered: fresh air was supplied in living room and bedrooms, and extracted from bathrooms and kitchen.

Table 2. Continuous ventilation rates values that fulfil the IAQ requirements

Case study	Total whole dwelling continuous ventilation rate (l/s)
1	14
2	24
3	33
4	33

CONTAM was used to simulate the concentration of vapour water (H_2O) and to obtain the indoor absolute humidity values (AH, g/m^3). CONTAM is a multi-zone airflow and contaminant transport analysis software application developed by the National Institute of Standards and Technology (NIST-US).

Indoor absolute humidity values were then converted into relative humidity (RH, %) by using the saturation value (SV, g/m^3) at each temperature:

$$RH = \frac{100 \cdot AH}{SV} \quad (1)$$

The saturation value was obtained from the indoor temperature (θ_i, ºC) using the following regression analysis expression:

$$SV = 5{,}015 + 0{,}32321 \cdot \theta i + 8{,}1847 \cdot 10^{-10} \cdot \theta_i^2 + 3{,}1243 \cdot 10^{-4} \cdot \theta_i^3 \quad (2)$$

2.3 Surface condensation risk assessment, basic method

The surface condensation risk requirement for dwellings established in the Spanish Building Code can be verified using a simplified calculation method described in DA DB-HE/2 based on ISO 13788:2001 method for the internal surface temperature of a building component or building element below which mould growth is likely, given the internal temperature and relative humidity.

The method compares the temperature factor of the surface (f_{RSi}) with a limit value ($f_{RSi,min}$) establishing that whenever $f_{RSi,min}$ is greater than f_{RSi} there a risk of surface condensation.

The limit value can be obtained from the following equation, depending on the indoor (θ_i) and outdoor temperatures (θ_e) and on the limit surface temperature ($\theta_{si,min}$) (ºC):

$$f_{Rsi,min} = \frac{\theta_{si,min} - \theta_e}{\theta_i - \theta_e} \quad (3)$$

Clearing up $\theta_{si,min}$:

$$\theta_{si,min} > f_{Rsi} \cdot \theta_i + (1 - f_{fRsi}) \cdot \theta_e \quad (4)$$

2.4 Surface condensation risk assessment, modified method

As a consequence of a close look into the application of this method to the actual study cases, the method was on one hand extended and adapted to the local climate conditions –mainly derived from relative humidity and precipitations - and on the other hand was simplified taking into account that the U-values of the envelope components are small enough to be eliminated from the calculation process.

Extended method to the whole year

The method described in DA DB-HE/2 (based on EN ISO 13788:2001) only studies the risk of condensation in January because assumes January is the month with the highest risk.

As it can be observed in Figure 2, there are times of the year in which relative humidity is higher, probably due to more frequent precipitations (See Figures 3 and 4), so it is understood that the risk of surface condensation could be bigger at these times of the year.

Due to this suspicion in this study the assessment has been extended to the whole year.

Simplified method removing factors

In the above described method, the temperature factor of the surface for each part of the envelope can be obtained from its U-value (W/m^2·K) (Table 1) using the following expression:

$$f_{Rsi} = 1 - U \cdot 0.25 \quad (5)$$

In the case studies, because the U-values of the envelope are low enough to fulfil Spanish energy saving regulations in each climatic zone, the factors f_{Rsi} and $1\text{-}f_{Rsi}$ are very close to 1 and 0 respectively. This means that the surface condensation risk expressed in (4) mostly depends on the direct comparison between $\theta_{si,min}$ and θ_i .

$$\theta_{si,min} > f_{Rsi} \cdot 1 + (0) \cdot \theta_e \tag{6}$$

Therefore, in order to simplify the calculation to qualitative assess the condensation risk, a simplified expression was used based on (4):

$$\theta_{si,min} > \theta_i \tag{7}$$

Both terms of equation (7) were calculated in five minutes´ intervals and the intervals in which there might be surface condensation risk were identified for all the case studies. The annual percentage of number of hours with a risk of condensation was used as the reference index to compare all the different scenarios.

3 RESULTS

The results of the surface condensation risk assessment are presented for four types of dwellings, according to the number of bedrooms and bathrooms and for two distinct Spanish climatic zones, both having an average high relative humidity. The study analyses the influence of the outdoor climate conditions into the risk and proposes a broader assessment during the whole year.

In each dwelling the living room and the master bedroom were studied, because they usually present walls that can be affected by growing mould when condensation (kitchen and bathroom usually have ceramic wall tiles), and were presumed to present a higher risk of condensation[19] due to their higher production of water vapour caused by the length of the stay and the number of occupants than the rest of rooms (we supposed master bedroom has two occupants, and the rest only one).

In order to be able to assess how the risk varies along the year influenced by the climatic factors, graphical representations were plotted. Both terms of equation (7) were graphed in 5 minutes' intervals.

The blue line represents the second term of the equation (7) and the red line the first term above the second term. The peaks of the red line above the blue line represent risks of surface condensation.

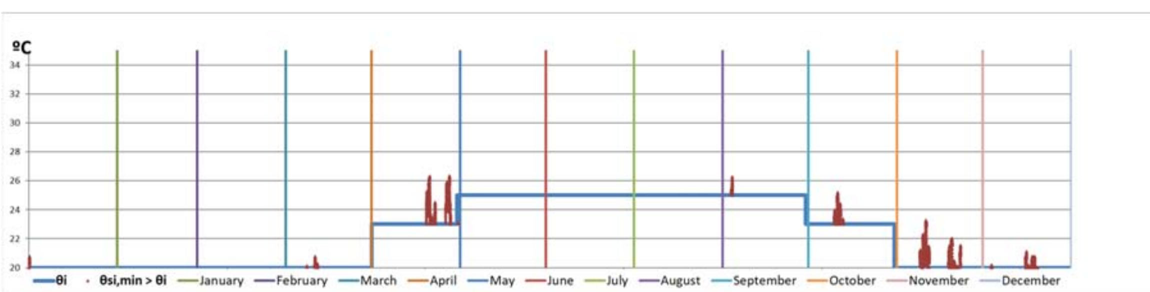

Figure 5. Case study 1, bedroom, climatic zone A3

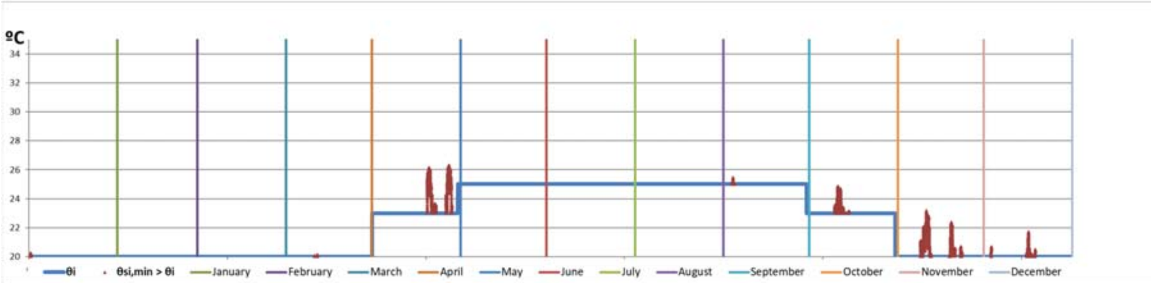

Figure 6. Case study 1, dining room, climatic zone A3

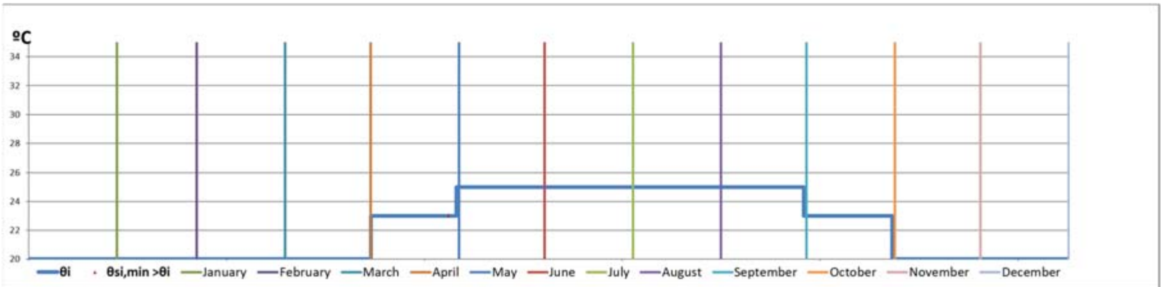

Figure 7. Case study 1, bedroom, climatic zone D1

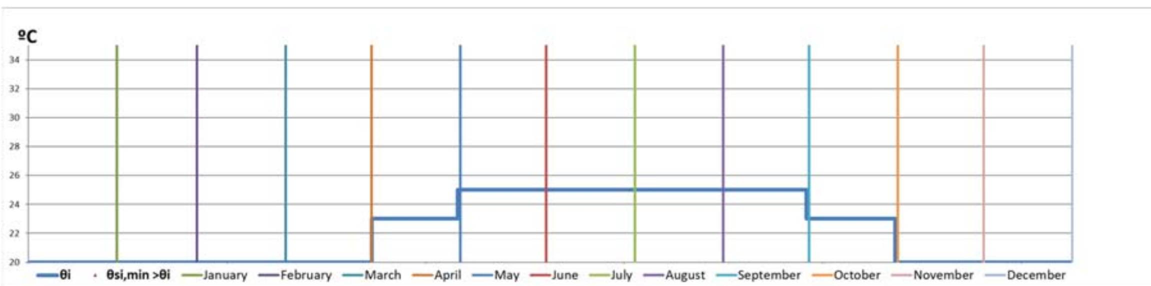

Figure 8. Case study 1, dining room, climatic zone D1

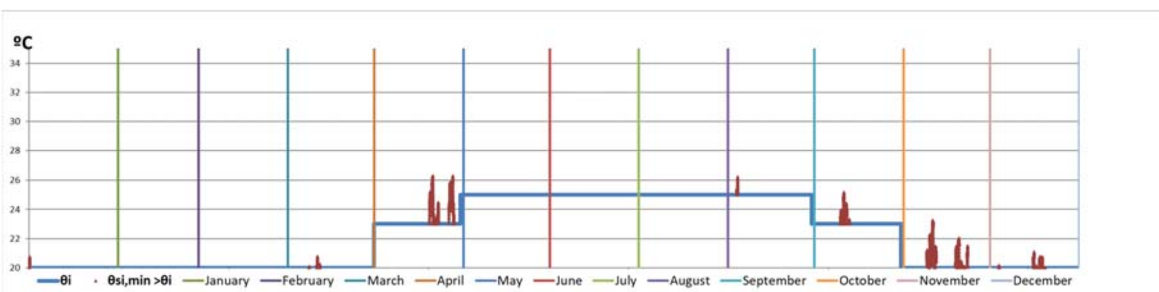

Figure 9. Case study 2, bedroom, climatic zone A3

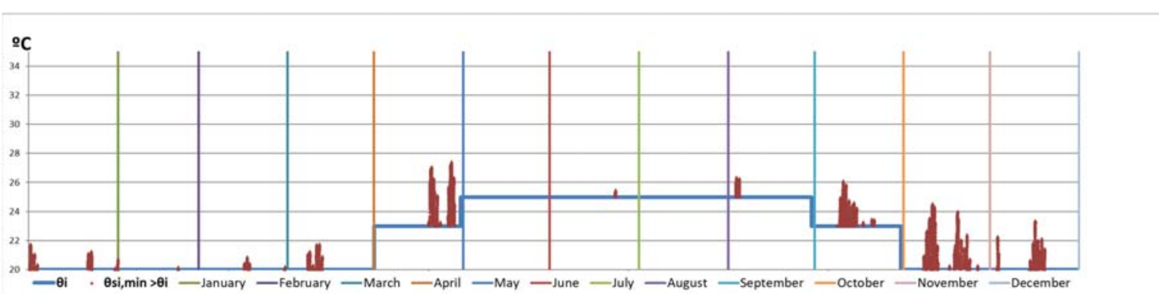

Figure 10. Case study 2, dining room, climatic zone A3

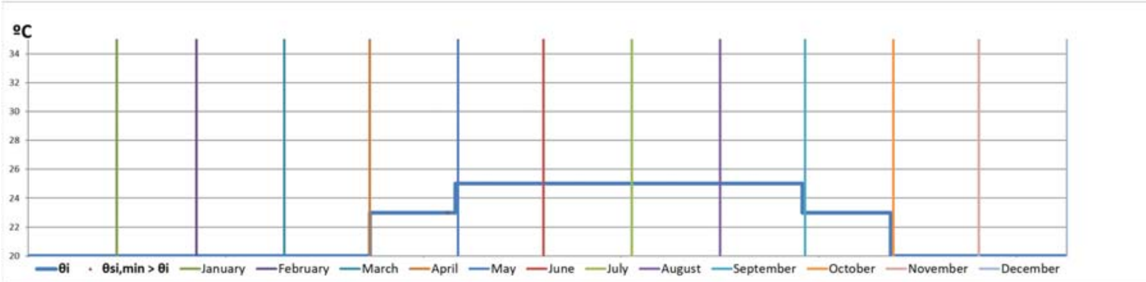

Figure 11. Case study 2, bedroom, climatic zone D1

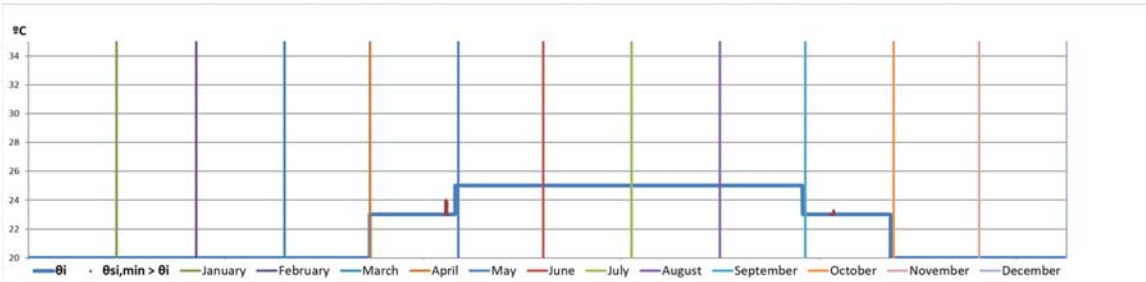

Figure 12. Case study 2, dining room, climatic zone D1

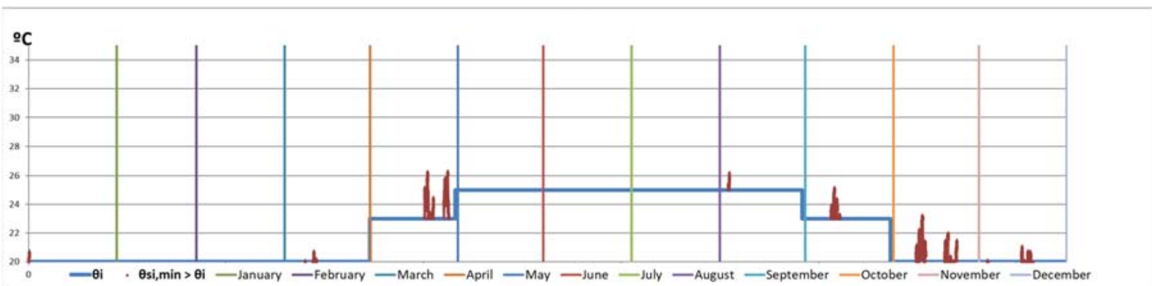

Figure 13. Case study 3, bedroom, climatic zone A3

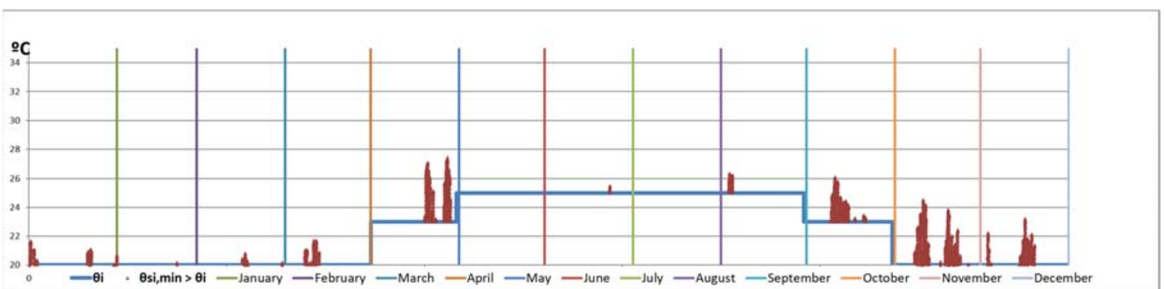

Figure 14. Case study 3, dining room, climatic zone A3

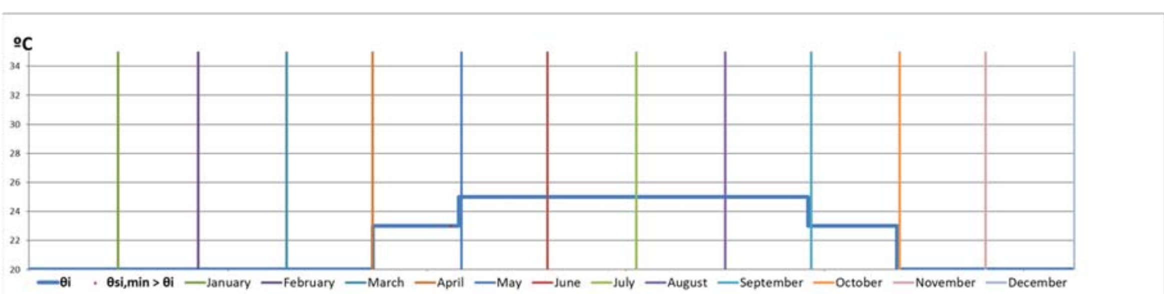

Figure 15. Case study 3, bedroom, climatic zone D1

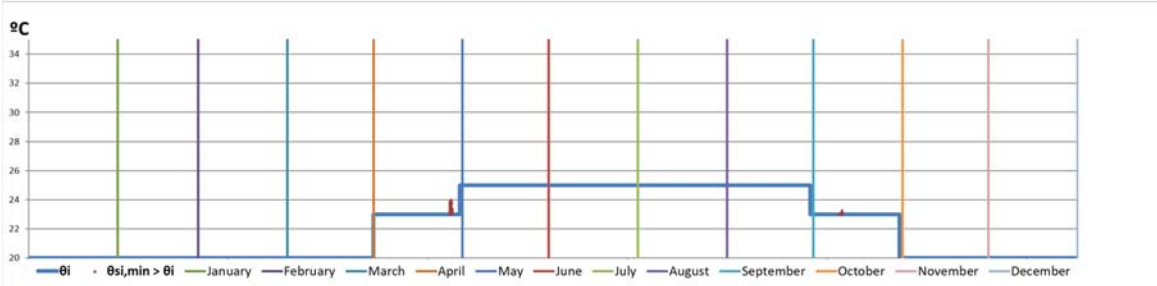

Figure 16. Case study 3, dining room, climatic zone D1

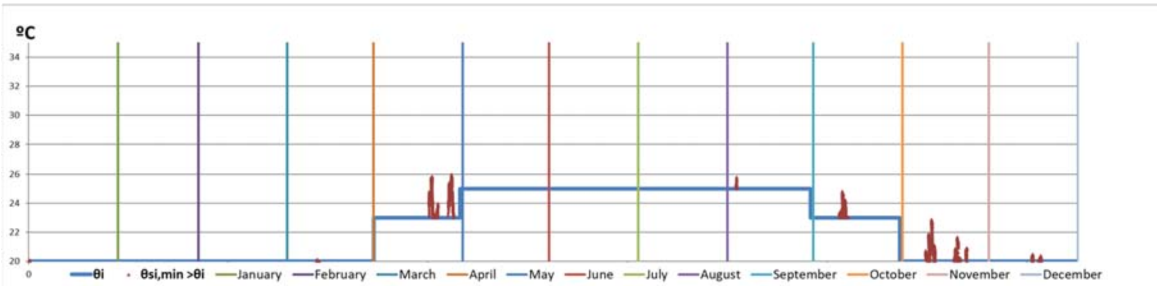

Figure 17. Case study 4, bedroom, climatic zone A3

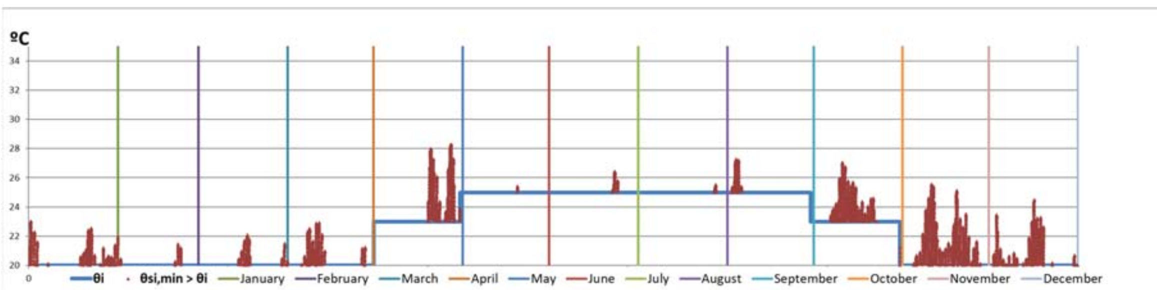

Figure 18. Case study 4, dining room, climatic zone A3

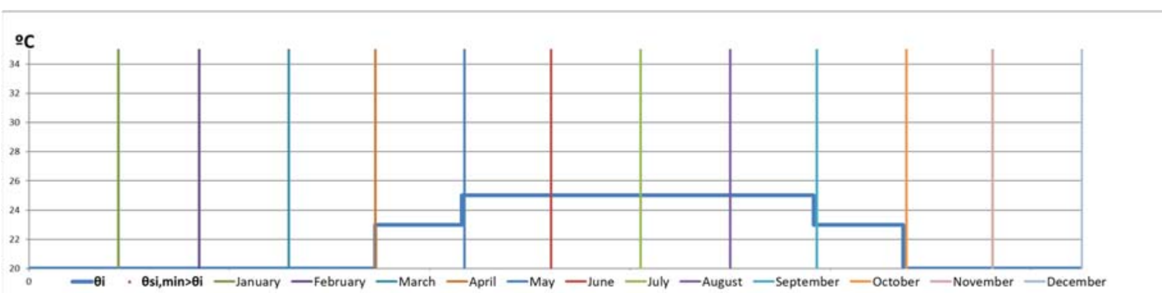

Figure 19. Case study 4, bedroom, climatic zone D1

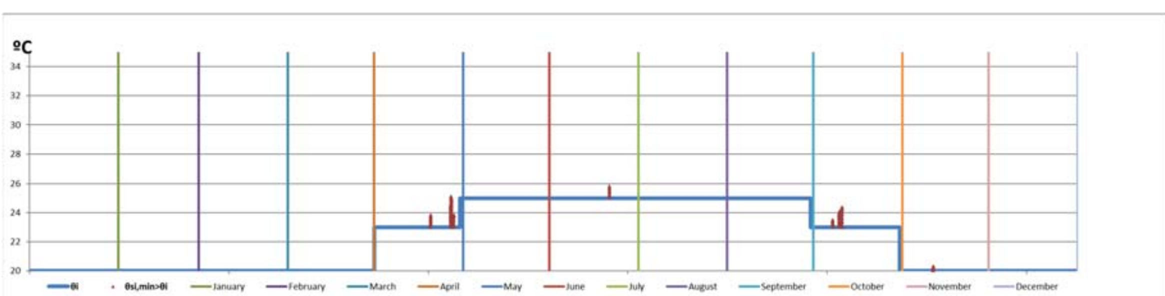

Figure 20. Case study 4, dining room, climatic zone D1

4 DISCUSSION

Results show that in all the case studies in climatic zone A3 the risk of surface condensation is quite variable around the year, with the highest peaks of risk happening in Spring and Autumn, much bigger than the ones in January. Being constant the factors that influence condensation, except the outdoor conditions and the indoor temperature, this fact is explained because the relation between outdoor absolute humidity and indoor temperature is higher at those times of the year.

In climatic zone D1, the risk is more homogeneous around the year, only being slightly higher in Spring and Autumn for case studies 2, 3 and 4 in the dining room.

5 CONCLUSIONS

Assessment of condensation risk must take into account multiple variables. The relation between outdoor absolute humidity and indoor temperature is a very important factor. Condensation risk may not only occur in January in all climatic zones, the month when usually the assessment is conducted.

In climatic zone A3 the bigger condensation risk happens in Spring and Autumn, but not in January how it can be derived from the method described in DA DB-HE/2. Therefore, it can be proposed that the condensation risk analysis should be carried out over a year instead of only in January in climatic zones where absolute humidity is high in certain times of the year.

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