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Assessment of Humidity Effects in Algerian Residential Buildings: Case of Guelma

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This paper evaluates indoor air quality in residential buildings affected by humidity and investigates its impact and effects on hygienic comfort. Using a comparative methodology, we explored the negative impact of humidity in indoor air on hygienic comfort based on measurements of relative humidity (RH) during two periods (summer-winter) inside two apartments in residential buildings in theGahdourTahar neighborhood located in the city of Guelma(northeast Algeria). We also assessed the state of indoor air by observing the physical pathologies in the buildings studied. Indeed, the humidity level observed in the two apartments studied contributes strongly to pathogenic contamination through the production of mold and fungi, which directly affects the safety of the building. This study aims to remedy and correct the inadequacy of natural ventilation to facilitate the elimination of indoor humidity that can affect the hygienic condition of the building. Thus, the maintenance of an optimal RH must be sought to ensure the integrity of the building elements and the comfort of the inhabitants.

Keywords: Gahddour-Thar neighborhood, Hygienic comfort, Indoor air quality, Natural ventilation, Physical pathologies.

INTRODUCTION

Most people spend about 80-90% of their time indoors (Batagoda et al., 2010, P.02), or about 12-14 hours per day in the habitat (Mazzuoli, 2009). Therefore, designers and architects are challenged to design, develop, build, and maintain a habitat with a high quality of life that is safe and healthy for the inhabitants (Allaume-Bobe, 2017, P.12). To do so, they are involved in implementing protective measures against contaminated and polluted air and avoiding its risks, on the one hand. On the other hand, they are required to improve indoor air quality (IAQ), which has become a major issue for the quality of the living environment of inhabitants and healthy housing policies.

Today, stakeholders and policymakers are aware of the risk factors of polluted indoor air in all living spaces including allergens, humidity, and molds (WHO, 2009), caused by lack of adequate hygienic ventilation (Sundell et al., 2011). Therefore, ensuring good indoor air quality is not only about ensuring adequate outdoor air and controlling indoor air pollutants. It is also important to consider the effect of relative humidity in the air (Romana et al., 2016, P.12). The high concentration of water vapor and humidity leads to molds that are harmful to human health, damaging the construction and affecting the hygienic comfort of the building (Mandin, 2021, P.01; Juan Wang et al., 2021).

In this regard, several studies have been conducted. Researcher Wang in (Wang et al., 2013) conducted research in China, revealing that humidity inside the house (indicated by mold stains, damp stains, water damage, and condensation) can increase the perception of odors, humid, and dry air. Thus, the World Health Organization (WHO, 2018) report on air quality and environmental health estimates that about 90% of the world's inhabitants breathe polluted air. Poor air quality affects the health of residents. All these studies state that renovating the natural ventilation system would be useful, the main factor limiting humidity in residential buildings.

The sources of moisture in the residential building are related to physical conditions, mainly due to the existence of water vapor produced by the inhabitant. In this regard, Roulet (2012, P.88) mentions that "an adult evaporates between 40 and 60 grams of water per hour for quiet activity. The steam emitted increases proportionally to the activity, about 500 g/KWh".

Thus, domestic activities (cooking, bathing, etc.) can contribute to water vapor generation without sufficient natural air renewal. Roulet (2012) also mentioned that "cooking food produces about 2 kg of water vapor per day, to which must be added, if necessary, the water vapor produced by the combustion of cooking gases, or about 1 kg per day." Drying laundry indoors or with a dryer without steam exhaust produces an additional 1.5 kg/day. It is also noted that water in the building can come from damaged plumbing, cracks in the facades, or the roof.

For example, a study was conducted by the *Association* for the Prevention of Air Pollution) on 300 dwellings contaminated by mold. A habitat-health advisor also evaluated these buildings. The results show that in 60% of the cases, the main sources of increase in indoor humidity are insufficient insulation of the building marked by the presence of thermal bridges, a low indoor temperature with insufficient air renewal, water leaks at the level of pipes, and the outdoor temperature that influences the residential humidity rate.

Indeed, a low outdoor temperature associated with a relatively high humidity rate can cause condensation risks on cold walls (Rivière et al., 2011, P.02; Charpin et al., 2018, P.02).

The physical characteristics of indoor air humidity can help understand the air's hygrometric state. The value of the relative humidity of the air can be determined in relation to its absolute value. This parameter has two components "relative humidity and absolute humidity" (Zürcher et al, 2014, P.75). Relative humidity (RH) measures the amount of water vapor in the air compared to the amount the indoor air can hold at a given room temperature. The relative humidity value is expressed as a percentage of a given temperature.

According to Solec (2000), relative humidity is the ratio of the amount of water the air contains (absolute humidity) to the maximum amount of water it can hold at a given temperature before condensing. The temperature variability directly influences relative humidity, so it decreases when the temperature increases and increases when the temperature decreases. Absolute humidity (AH) is the amount in grams of water vapor present in a given volume of dry air. Its value remains constant even if the air temperature varies. Zürcher et al, (2014, P.77) highlighted that the absolute humidity we breathe could affect the quality of the air and our health because of the quantity and percentage present in the air.

Humidity problems in residential buildings are recognized as a major risk factor for their stability. In spaces with high water vapor production (kitchen, bathroom, powder room) and those with high occupancy, mold develops on the walls and ceiling, which degrades and damages the building structure, threatening its durability over time (Koffi, 2009, P.35). According to Roulet (2012, P.91), some molds, such as dry rot, attack and destroy building materials, especially wood. These microbial agents also affect the aesthetics of the building. Achieving good indoor air quality in residential buildings remains challenging. Therefore, do the effects of humidity resulting from poor ventilation in residential buildings in the GahddourTahar neighborhood threaten and cause physical damage to the building?

METHODS AND MATERIALS

In this study, we aim to evaluate the rate of humidity and the condensation of molds embedded in these poorly ventilated apartments. Therefore, we aim to assess its effects on the safety of residential buildings in the neighborhood GahddourTahar, detecting the problems of indoor air quality based on the variability of the humidity content in the air.

The investigation is based on an experimental-comparative methodology.

Presentation of the Study Context

The city of Guelma is located in the northeast of Algeria. According to the climatic parameters given by the metrological station of the city and the site OGIMET (professional information about meteorological conditions in the world) during the period (2010-2020), Guelmais characterized by a semi-humid climate, with short and very hot summers and long winters. It is characterized by a wet period that extends over five months of the year (January, February, March, November, and December) and a dry period for the remaining months. This study evaluates the collective buildings in the GuahddourTahar housing estate. This neighborhood is a program of "housing area with new urbanism" that was built in 1975. It is located in the middle of the southern area of the city of Guelma.

Test and Measurement Protocol of the Surveyed Dwellings

Two apartments (containing three rooms: a living room and two bedrooms) were chosen as case studies. They are located in two collective buildings of five floors in the GahdourTahar neighborhood (Guelma, Algeria).The first apartment oriented to the North-West / South-West is located on the top floor of building 28. It is a bar-shaped building with four apartments per floor. While the second oriented to the North-East is located on the first floor of building 08; it is a corner building containing three apartments per floor.

Figure 1. Gahdour Tahar neighborhood and apartments studies. (Source: Google Earth, modified by the Authors, 2021)

In-situ measurements of the relative humidity (RH) of the indoor air and temperature using the instrument Air Quality test JD-3002 were carried out. These measurements accompanied a deciphering based on observing physical pathologies in these buildings.

Two days of the experimental design, DD1 and DD2, were selected for the measurements. Their selection was based only on the daily averages of the temperature and humidity parameters, so the selected day is the day with the maximum temperature (t) and the maximum humidity value (RH) (in warm period), and the minimum temperature (t) and the minimum humidity value (RH) (in cold period). In this context, the problem is defined as finding, from the search space (set of 365 days), the days DD1 and DD2 that return these two criteria in their maximum and minimum values, respectively (Khelil, 2019).

To simultaneously optimize (maximize or minimize) these criteria, multi-objective optimization (MO) techniques are used in the design day selection problem. The first design day, DD1, was July 28. It represents the least humid day and the warmest day. The second design day, DD2, was January 2. It represents the wettest day and the coldest day. The measurements were made in summer on July 28, 2021, respectively. Also, in winter, on January 2, 2022. Measurements were taken three times a day: 9 am, 1 pm, and 7 pm.

The variation of the measured parameters (RH, Temp) is based on the following conditions:

-Opening and closing of windows

-Indoor environment (air conditioner, heater, fan)

RESULTS AND DISCUSSION

We can note that the dwellings studied are badly ventilated based on the field investigation. This refers to the absence of openings in the sanitary, the small surface of the openings, particularly those of the kitchens, and the absence of airflow inside these dwellings.

Indoor Air Quality of the Studied Dwellings

This air velocity is measured by a propeller anemometer (BA16 Trotec) in the case of closed and open windows. It is very weak, varying between 0 and 0.2 m/s throughout the measurement campaign. This observation is reinforced by the words of inhabitants who perceived that the air inside their dwellings is of poor quality.

Observation of Physical Pathologies

From our observation, we found damp stains (black stains, visible traces, flaking coating, etc.) on the walls, ceilings, and behind the cupboards of the apartments studied. At the same time, we found cracks in several places in these dwellings (Figure 2). These signs are due to the increase in humidity inside the apartment and the accumulation of mold, fungi, and bacteria. These harmful agents cause the degradation of certain materials, the degradation of pipes, cracks, and other damage to the building (Psomas 2021). It is noted that the bathrooms and cold walls poorly oriented that do not have sufficient sunlight or adequate ventilation are the places most threatened by traces of humidity. To understand the sanitary condition of the apartments studied from the observations on the surveyed apartments, we can say that these apartments are degraded; they suffer from the development of significant mold caused by the increase in the degree of humidity. This situation threatens the integrity of the building and the well-being of the inhabitant.

Figure 2. Damp stains observed in the apartment. (Source: Authors, 2021)

Evaluation of Summer Measures

Figures 3 and 4 show the variations in relative humidity inside the different spaces of the studied apartments during the summer period, while Tables 1 and 2 illustrate the temperature measurements.

According to the literature, the optimal relative humidity is between 30 and 50%. Depending on the time of year and the indoor/outdoor temperature (Levasseur et al., 2017). According to ASHRAE 55-81, the relative humidity should not exceed 70% at an ambient temperature of 22.6°C and 60% at 26°C. Specifically, Tsutsumia et al. (2006) noted the relative humidity in the apartment should be between 35% and 60%, which can maintain comfortable conditions (Romana et al., 2016). By adhering to this range, it appears that in the first apartment on the fourth floor, the humidity levels measured in the summer remained in the comfortable range. On the other hand, in the second apartment on the first floor, the humidity values measured in the same period exceeded the recommended values, especially in the bathroom and living room, where they were 56% and 58%, respectively, in the evening.

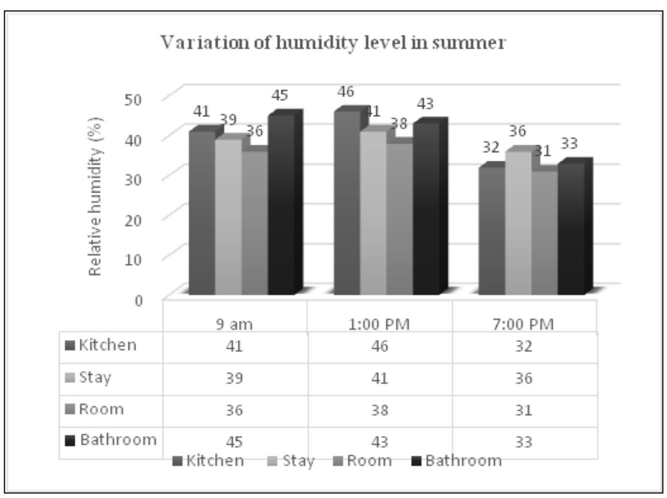

Figure 3. Variation of humidity in different zones of apartment 1. (Source: Authors, 2021)

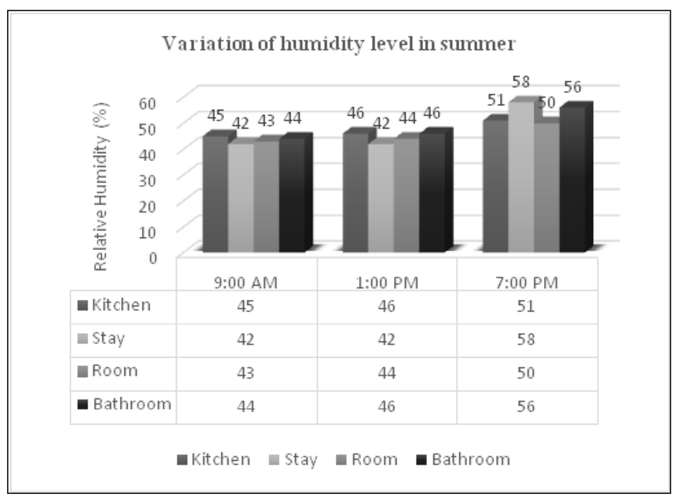

Figure 4. Variation of humidity in different zones of apartment 2. (Source: Authors, 2021)

Table 1. Recording of temperature measurements in apartment 1 during the summer period.

Temperature	Outdoor temperature	Indoor temperature
9 am	43°C	34°C
1 pm	45°C	37°C
7 pm	37°C	30°C

Table 2. Recording of temperature measurements in apartment 2 during the summer period.

Temperature	Outdoor temperature	Indoor temperature
9 am	43°C	30°C
1 pm	45°C	32°C
7 pm	37°C	32°C

Evaluation of Winter Measures

Figures 5 and 6 show relative humidity variations inside the different spaces of the studied apartment during the winter period, while Tables 3 and 4 illustrate the temperature measurements.

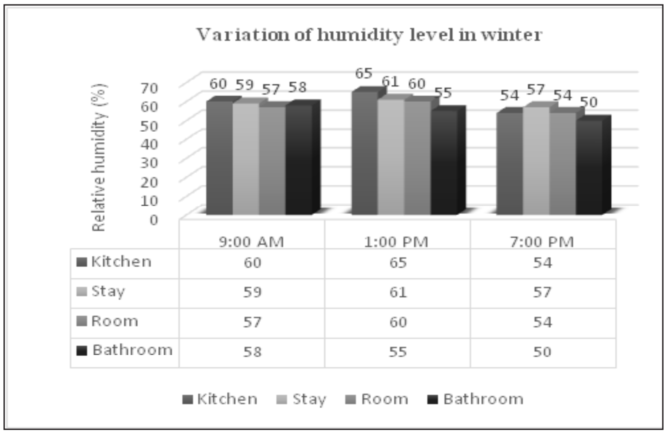

Figure 5. Variation of humidity in different zones of apartment 1.(Source: Authors, 2021)

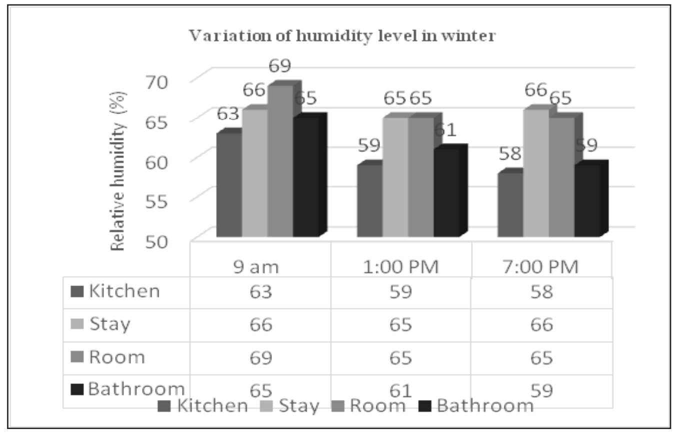

Figure 6. Variation of humidity in different zones of apartment 2. (Source: Authors, 2021)

Table 3. Recording of temperature measurements in apartment 1 during the winter period.

Temperature	Outdoor temperature	Indoor temperature
9 am	15°C	18°C
1 pm	16°C	19°C
7 pm	13°C	18°C

Table 4. Recording of temperature measurements in apartment 2 during the winter period.

Temperature	Outdoor temperature	Indoor temperature
9 am	15°C	16°C
1 pm	16°C	17°C
7 pm	13°C	16°C

Unlike in the summer, the humidity levels measured on the device are very high in winter. They exceed the regulatory values, which vary from 50% to 65%, including in different spaces of the first housing. The humidity level peaks at 65% at noon in the kitchen.

The measuring device mentioned that the highest humidity values are in the bedroom and living room in the second apartment (66% and 69% in the morning). These spaces are oriented to the north, and they are not very sunny with cold walls, whose heating is on, and the windows are closed to avoid cold penetration.

Relative humidity is one of the most detrimental components of comfort and indoor air quality (Romana et al., 2016). Our measurements show that the humidity variations in the studied apartments exceeded the limits considerably during the winter period, especially in the dwelling located on the first floor. These high values are due to domestic activities, the practices of the inhabitants (use of heating, the closing of windows), and partly to the poor ventilation of the apartment. On the other hand, the relative humidity measured in the apartment located on the fourth floor is acceptable, especially in summer.

By comparing the humidity level measured with the Air Quality tester JD-3002 instrument with the observations made on the buildings studied, we found a balance between the answers of the inhabitants and the measurements made. Our investigations show that the humidity levels are very high during the winter compared to the summer period. They exceed the regulatory values, especially in the apartment located on the first floor. It should be noted that the highest humidity values are found in spaces that do not have sufficient sunlight or adequate ventilation. In these same spaces, we observed the presence of traces of humidity represented by black spots, detachment of coating, etc. They give off unpleasant odors affecting the comfort and well-being of the inhabitant.

CONCLUSION

This empirical study evaluated the effects of residential humidity in collective housing in the GahdourTahar neighborhood (Guelma, Algeria). The need to improve the natural ventilation system inside these apartments to achieve hygienic comfort in the building was highlighted. The results obtained show that the lack of adequate natural ventilation could increase indoor humidity. Analyzing the results obtained from the measurement campaign and the observations made on these apartments,it can be noted that the high humidity level can promote the proliferation of condensation and visible mold on the surfaces and the perceptible bad smell of mold.

Therefore, these microbial agents in the building are associated with the perception of stale air and an unpleasant odor. They can also lead to contamination of interior spaces and threaten the health and stability of the building by causing degradation (cracks, peeling paint, etc.). The problem concerns the apartments on the lower floors, which are poorly ventilated, especially in winter when the openings are closed. However, the presence of humidity inside the dwelling requires the improvement of the interior air quality to guarantee the perenniality of the building in time. We recommend correcting the defect at the source to ensure a good quality of the interior air necessary to preserve the well-being of the inhabitant.

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