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Measurements of moisture production caused by various sources

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ABSTRACT

To accurately predict indoor air moisture levels, the input data that includes the moisture production must be determined with high accuracy. The existing researches provide data about the estimated moisture generation rate by household activities but the data vary largely between the publications. Therefore, during this research, measurements of moisture generation from sources like cloth washing, emission by plants and human respiratory process were carried out. The moisture production in case of natural cloth washing and drying in indoors was performed in household environment at different mechanical washing machine drying revolution speeds and for five pieces of typical clothes. Also the influence of mechanical washing machine drying revolution speed as well as clothing fabric was determined. The moisture production from plants and humans was measured in climatic chamber with controlled environment by calculating it according to measured relative humidity. The overall results showed inconsistency with the ones provided in existing researches. The obtained moisture production values were lower for each of the source. This findings can be applied in future calculations when predicting indoor humidity.

1. Introduction

The indoor relative humidity can have large effect on both human health [13] as well as building materials [11]; therefore, it is important to control it in predetermined boundaries. To do this, it is necessary to predict the RH during design stage. For this task the sources of humidity must be correctly assumed. In general, there are several processes in household activities that generate moisture. Some of these include moisture generation from peoples due to respiratory process, moisture by preparing dishes, dish-washing, bathing or showering, cloth washing, and cloth drying. All these must be taken into account to precisely predict the indoor relative humidity. The moisture generation can be given for whole residential buildings like presented by TenWolde and Walker [15]. They account for several factors – the number of people in the family, their habits, building equipment, what type of cloth drying is used, plants, etc. Another approach is to calculate moisture generation by each source and sum them afterwards.

Moisture content, which is released from the people, depends on the working load, air temperature, as well as individual metabolic profile. The moisture generation by persons has been noted and reported for a long period, but different sources provide different results. According to a report [7], a family of four persons generates 0.20 kg/h of moisture at night and 0.21 kg/h during the day if there are three persons at home with a higher activity level. The same numbers are provided by Angell and Olson [2], while the IEA [9] quotes moisture release rates from 30 to 300 g/h per person, depending on level of activity. Values by Sanders [12] are in smaller range, as moisture generation by respiration is given from 0.9 to 1.25 kg/day which corresponds to 37.5–52.0 g/h. A bit different approach is mentioned in the Ref. [3] as it determines the moisture load by perspiration for men as loss in body weight. According to this source, at 21.1 °C, a man at rest loses about 90 g/h and at work loses 270 g/h. However for more accurate estimation the moisture release must be divided in two parts – by respiration and transpiration, and the surrounding air temperature and relative humidity. According to McCutchan and Taylor [10] the respiration moisture generation is estimated to be close to 240 L/h per m^2 of body surface area while the transpiration rates calculated by Ferguson and Martin [6] for ambient conditions of 20 °C at 50% RH are in the range of 0.5–1.4 kg/day per adult person at rest. Given that the people during they stay inside the residential building for the longest period of time spend in relative peace or low activity then it can be assumed that a person is responsible for moisture release with the sum of respiration and transpiration processes in the range of 0.8–1.7 kg/day or approximately 30–70 g/h according to existing researches. Similar values are presented in Ref. [4] which state that a person emits 40 g/h when sleeping and 55 g/h when active. In

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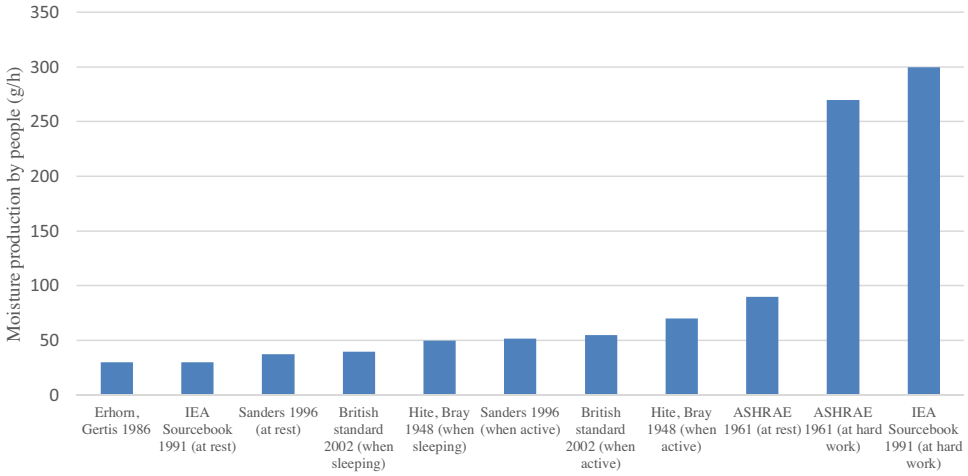

Fig. 1. Comparison of moisture production by people according to various sources.

general it can be assumed an average a person releases 50 g/h of water vapor.

Another source of moisture is indoor cloth drying. According to a source [4] due to cloth washing and drying indoors the total released moisture is estimated to be 1.5 kg/person per day. In comparison an outdated article Hite and Bray [7] reports that a load of laundry after wringing contains 11.9 of water. While Angell and Olson [2] present much lower number: 2.2–2.95 kg of water retained in a standard 3.6 kg load of laundry after dry spinning, indicating the advantages of spin dryers over wringers. Other sources for washing machine with 5 kg capacity suggest even 4.7–6.2 kg of moisture release. The number of cloth washing occurrences are dependent on the number of people in the household and their habits, in general it can be assumed that a five people household would need approximately one cloth washing process per day. According to Annex 27 [8] the frequency of cloth washing can vary from 20 times/month for 4 person household or about 5 times/week to every day.

The previously mentioned research [7] also describes the water vapor release from plants. According to their experimental data a plant releases from 39 to 101 g/day as measured of seven different house plants at normal winter indoor conditions. The exact amount released by each of plants varied depending on the size and species of given plants – the larger ones released more vapor. In general the average release rate was determined to be close to 2.5 g/h by each individual plant. According to the authors, major part of this released water vapor is due to transpiration from the plant itself and only small part is due to evaporation from the soil. In comparison the [9] present a lot higher evaporation rates for potted flowers: 5–10 g/h, for potted plants: 7–15 g/h and for medium-size rubber plant: 10–20 g/h. Similar results are given by several other researchers. According to Angell [1] a plant releases around 4.1 g/h but by Erhorn and Gertis [5] a small to medium plant releases 8.3 g/h. As seen, these rates are higher if compared to the other data and are even as high as moister released by pets, therefore seem a bit unrealistic. According to Yik et al. [17], moisture release by a plant is on average about 0.84 g/h. This on the other hand is a lot lower value, but, according to TenWolde and Pilon [14], it must be adjusted for room temperature, as these measurements were done at relatively low temperatures +15 °C. If this is done and we assume that the Hite and Bray did their experiments at 21.1 °C, then the two rates would be very similar. According to the same publication, the water vapor release of plants is dependent on the environments relative humidity. The plant respiration increases linearly with decreasing RH until RH goes below 25% to

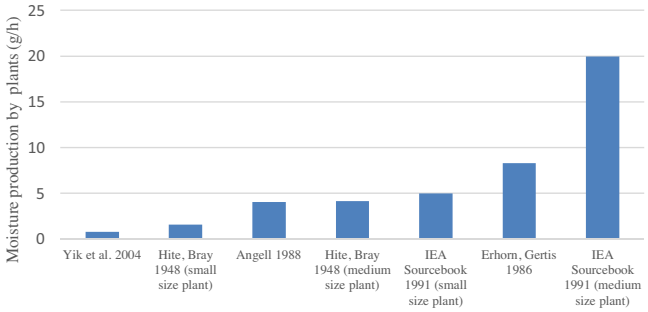

Fig. 2. Comparison of moisture production by plants according to various sources.

35%, as stated by experiments of West and Gaff [16]. If the relative humidity falls below 30%, then the moisture release remains constant due to closing of stomata.

The existing researches provide data about the estimated moisture generation rate by these activities, but the data vary largely between the publications (see Figs. 1 and 2) and some of them might be outdated. Therefore, during this research, measurements of moisture generation from household activity like cloth washing and plants were carried out.

2. Field measurements of moisture release by cloth drying

To measure the moisture generation caused by the natural drying indoors of clothes after washing them a field experiment was performed. The clothes at first were washed in electrical washing machine with different mechanical drying settings – 500, 800 and 1200 rpm. Afterwards the clothes were weighted and hanged in the apartments corridor to dry. The clothes were hanged in a freely chosen manner relatively close to each other but to make sure that they do not touch as this can influence the drying ratio. In general it was done to most naturally resemble the way in which people hang them as they do not apply scientific principles during this process. Afterwards the data of cloth weight with one hour intervals were obtained. The weighting was done on electronical scales with the maximal weighting capacity of 20 kg, precision class of 0,1 g and linearity of ±0.3 g.

To determine the moisture generation and release in indoor air by cloth drying after washing with automatic cloth washer field measurements were performed. Although the existing researches have dealt with similar task, the specific of Latvia is the common practice to use household not centralized washing machines and to