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Review

Indoor air humidity, air quality, and health – An overview

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ABSTRACT

There is a long-standing dispute about indoor air humidity and perceived indoor air quality (IAQ) and associated health effects. Complaints about sensory irritation in eyes and upper airways are generally among top-two symptoms together with the perception "dry air" in office environments. This calls for an integrated analysis of indoor air humidity and eye and airway health effects. This overview has reviewed the literature about the effects of extended exposure to low humidity on perceived IAQ, sensory irritation symptoms in eyes and airways, work performance, sleep quality, virus survival, and voice disruption. Elevation of the indoor air humidity may positively impact perceived IAQ, eye symptomatology, and possibly work performance in the office environment; however, mice inhalation studies do not show exacerbation of sensory irritation in the airways by low humidity. Elevated humidified indoor air appears to reduce nasal symptoms in patients suffering from obstructive apnea syndrome, while no clear improvement on voice production has been identified, except for those with vocal fatigue. Both low and high RH, and perhaps even better absolute humidity (water vapor), favors transmission and survival of influenza virus in many studies, but the relationship between temperature, humidity, and the virus and aerosol dynamics is complex, which in the end depends on the individual virus type and its physical/chemical properties. Dry and humid air perception continues to be reported in offices and in residential areas, despite the IAQ parameter "dry air" (or "wet/humid air") is semantically misleading, because a sensory organ for humidity is non-existing in humans. This IAQ parameter appears to reflect different perceptions among other odor, dustiness, and possibly exacerbated by desiccation effect of low air humidity.

It is salient to distinguish between indoor air humidity (relative or absolute) near the breathing and ocular zone and phenomena caused by moisture-damage of the building construction and emissions therefrom. Further, residential versus public environments should be considered as separate entities with different characteristics and demands of humidity. Research is needed about particle, bacteria and virus dynamics indoors for improvement of quality of life and with more focus on the impact of absolute humidity. "Dry (or wet) air" should be redefined to become a meaningful IAQ descriptor.

1. Introduction

Yaglou (1937) concluded that "Artificial humidification, about which so much is heard on connection with winter air conditioning, was shown in the first part of this paper to be relatively unimportant from the standpoint of comfort and, so far is known, not essential from the standpoint of health. While a relative humidity of between 40 and 60 percent would probably be more normal and perhaps more healthful than between 20 and 30 percent, it is practically impossible to maintain this high range in cold weather because excessive condensation and freezing on the windows and sometimes inside the exposed walls".

Indoor air humidity, in terms of perceived dry air (dryness) and potentially associated health effects is an important parameter (relative (**RH**) or absolute (**AH**)) both in the aircraft and office environment. A long-standing dispute continues about the health relevance of RH and the cause(s) of perceived "dry air", a very common and abundant complaint about perceived indoor air quality (**IAQ**) in office-like environments. Further to this, causation of perceived sensory reactions in eyes and upper airways, among top-two reported symptoms in offices, continue to be a puzzle, despite several identified risk factors that influence the development of eye symptoms have been identified (Wolkoff, 2017); the risks of symptoms in the upper airways remain largely unexplained. Furthermore, there is an increasing recognition of the impact of humidity, e.g. on virus survival and transmission and sleep quality, regarding derivation of a safe limit for indoor air humidity (Derby et al., 2016).

Nagda and Hodgson (2001) reviewed the indoor air literature and concluded that slightly elevated RH would have a beneficial effect on perceived IAQ; in part based on the conclusion that experimental outcomes appeared to be strongly dependent upon the experimental

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Table 1
Studies in office environments, homes, schools, and hospitals.

Authors Environment	Study	Observation
Angelon-Gaetz et al. (2016) Schools	Teachers (n = 122) reported daily symptoms in 4–12 weeks diaries.	Modest, but not significant, increase in respiratory (asthma-like) symptoms over 5 days, both at low (< 30%) and high RH (> 50%) in comparison to referent teachers (30–50% RH). No effects of RH on cold/allergy symptoms.
Azuma et al. (2015, 2017) Offices	- Workers (n = 3335) in 320 offices responded to questionnaire.	Both studies showed strong correlation between perceived air dryness and report of eye irritation.
	- Workers (n = 3024) in 489 offices responded to questionnaire.	General symptoms were also associated with perceived humidity in the summer season.
Bakke et al. (2007,2008) Offices	Four university buildings, 2 complaint and 2 control buildings. Questionnaire and examination of the precorneal tear film (PTF) stability, nasal patency and inflammatory markers in nasal lavage fluid in university staff members.	Stuffy or dry air was significantly associated with low RH (15–35% RH). Otherwise no significant exposure differences between complaint and control buildings and no significant difference in objective signs.PTF stability (NBUT/SBUT) was improved at higher RH and perception of air dryness was reduced.
Brasche et al. (2005) Offices	Data from office workers (n = 814)	No clear conclusion about RH and reported eye symptoms or PTF stability. Indication that high RH might be protective, and particles associated with epithelial damage of the PTF.
Hashiguchi et al. (2008) Hospital	Temperature and RH measured for 3 months in hospital in sickrooms and wardens during winter. Symptoms and comfort was reported once a week by staff (n = 45) and patients (n = 36). Humidifiers were installed after 2 months in half of the rooms.	Humidification from 33 to 44% RH, on average, resulted in decrease of thermal discomfort and perceived air dryness among the staff, but not among the patients.
Lindgren et al. (2007) Aircraft	Cabin attendants (n = 58) and pilots (n = 22). Double blinded 3–10% increase of RH by ceramic humidifier during long-haul flights.	Significantly lower concentration of respirable particles at elevated RH from 6 to 1 $\mu g/m^3$; similar observation for mold and bacteria. Cabin air quality significantly improved at elevated RH by being perceived less dry and fresher.
Lukcso et al. (2016) Offices	Office workers (n = 7637; response rate 49%) in 12 buildings. Subset wore personal sampling equipment and underwent medical examination. Symptoms experienced over the last 4 weeks.	Low RH was significantly associated with lower respiratory and sick-building syndrome-type symptoms, thus suggesting that low RH may exacerbate upper and lower airway symptoms.
Nordström et al. (1994) Hospital	Blinded steam air humidification to 40–45% RH in two units and compared with two control units of 25–35% RH in a 4 months period. Air quality and symptoms were reported before and after intervention in hospital staff (n = 104).	Significant decrease of perceived air dryness and airway symptoms. Weekly sensation of air dryness was 24% in humidified units contrary to 73% in the non-humidified units. Perceived IAQ was unchanged in control unit.
Norbäck et al. (2000) See also Nordström et al. (1994) Hospital	Longitudinal 6 weeks study with blinded steam humidification in hospital with two units with independent ventilation systems, outside of pollen season. Staff (n = 26, 100% female; 14 in humidity group and 12 in non-humidity control group) were investigated before and after humidification applied in one of the units for a period of 6 weeks. Questionnaire and medical examination before and after.	The perception of air dryness was reduced significantly (p = 0.04) from 73 to 36% in the humidification unit by increase of RH from 35 to 43%, while only slightly reduced in the control group (90–81%). Perception of dustiness and stuffy air remained unchanged. No changes in the PTF stability (SBUT), nasal patency (rhinometry), and inflammatory markers in nasal lavage fluid. Cannot be excluded that outdoor RH may have influenced, also, although exposed subjects and controls were investigated on the same days.
Reinikainen et al. (1992) Offices	Office workers (n = 290) and cross-over trial, in two wings. Slight increase of temperature during humidification.	Dryness symptom score (dryness, irritation or itching of the skin and eyes; dry throat and nose) was significantly smaller ($p < 0.01$) during humidification (30–40% RH) compared with the non-humidification phase (20–30% RH). However, the perception of stuffy air increased significantly during humidification, which also included unpleasant odor and dustiness perceptions (not significant).
Reinikainen et al. (1997) Offices	Steam humidification up to 30–40% RH compared with non-humidified units. Cross-over trial, use of naïve panel (n = 20) to assess the perceived IAQ, weekly.	Humidification caused a decrease of the perceived IAQ, strongest among women.
Reinikainen and Jaakkola (2001) Offices	Same office workers as in 1992 study. Cross-over trial in two wings. One wing humidified and the other non-humidified for one week (constant temperature), then switch for a total of 6 weeks. Daily questionnaire.	High temperature conditions increased dryness symptoms and sick-building syndrome symptoms during non-humidified conditions. Increase of RH from about 25–35% resulted in fewer sick-building syndrome symptom complaints. Synthesis of studies: high temperature conditions increased sick-building syndrome symptoms in 4 out of 7 studies; high temperature resulted in an increase of perceived dryness. Humidification reportedly decreased sick-building syndrome symptoms or dryness in 5 out of 11 studies and in 3 studies an increase. Present study showed lower sick-building syndrome symptoms than in non-humidified conditions and alleviation of perceived dryness during humidification. Dryness increased more acutely under non-humidified conditions.
Reinikainen and Jaakkola (2003) Offices	Office workers (n = 368; 71%) returned baseline questionnaire and diaries with information about symptoms or perceptions; 342 diaries from non-humidified (25–26% RH) and 233 from humidified conditions (21–49% RH). Temperature from 21 to 26 °C.	Eye dryness was alleviated, but not significant. Humidification decreased nasal dryness. High temperature increased nasal congestion significantly (especially for AH). Odor perception increased at elevated RH; slightly stronger for AH. “Stuffiness seemed to be associated with humidification”. Humidification alleviated nasal congestion.
Sato et al. (2003) Factory	Comparison workers (n = 12) in ultra-low RH (2.5%) with workers (n = 143) at normal RH.	33% versus 18% reported eye symptoms in ultra-dry and normal RH, respectively, but not significantly. Skin complaints were significantly higher at ultra-low RH.
	Only two selected double-blind studies.	

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