Thermal environment, IAQ and sleep

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Thermal Environment, IAQ and Sleep

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Is sleep becoming so much scarcer than ever before because people do not realize the importance of sleep for health and well-being? All over the world, digital communications now mean that contact with work continues after hours and during weekends and that “friends” are no longer just the people we meet regularly, but the many more we contact regularly. These new contacts compete strongly for our time with online entertainment and news, our leisure activities and our immediate families, and there are still only 24 hours in each day.

The time available for sleep is thus under great pressure. There is widespread concern among health professionals that we are no longer getting enough sleep. It is important to know whether that matters, and if so, how we can efficiently use the time that we reluctantly make available for sleep. Sleep and its importance are briefly summarized in the sidebar, “Why Enough Sleep Is Vital for Well-Being.” This column focuses on what ASHRAE engineers can do to ensure efficient sleep.

Question 1 What current developments are affecting sleep?

Increasing work-life stress, social media, mobile communications and online entertainment have greatly reduced the time left over for sleep. The equipment tends to find its way into bedrooms and to be used after bedtime. In the tropics, and elsewhere as the planet warms, split-cooling is increasingly being installed in bedrooms. This reduces temperature and humidity, sometimes by more than is beneficial for sleep, leading to greatly reduced bedroom air quality, as windows are then kept closed. Increasing insulation levels to conserve energy is also causing bedrooms to be too warm even in cool summer weather.

Question 2 Which physical factors are likely to affect sleep?

Security (from intruders, predators and insects), privacy, noise, temperature, humidity, light levels, air quality and air velocity. Every one of these factors is determined by building design and operation. Architects determine security, privacy and light levels, but ASHRAE engineers determine the rest.

Question 3 What has research discovered about thermal effects on sleep?

1) Preferred bedroom air temperatures vary greatly between individuals, not least due to systematic differences in bed-wear insulation and in how the drape of the bedcovers is unconsciously manipulated during sleep;¹ 2) It is difficult to fall asleep and to stay asleep

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Why Enough Sleep Is Vital for Well-Being

In a recent article, Matthew Walker, Director of the Center for Human Sleep Science at the University of California, Berkeley, stated that although it is known that most people need to sleep for 7 to 9 hours every night to function well and remain healthy, more and more people are failing to do so. He explained that what we call “sleep” involves transitions between three different states: wakefulness, rapid eye movement (REM) sleep that is associated with dreaming, and non-rapid eye movement (N-REM) sleep.

He defined four different levels of N-REM sleep, from light to deep, and stated that a good night’s sleep involves successive sleep cycles lasting about 90 minutes, during each of which we should spend some time in each of these five states. During a night of poor sleep, we may never reach the deeper levels of sleep. In his article, he described research that convincingly links a lack of deep sleep to early-onset dementia and Alzheimer’s. This link involves the recently discovered glymphatic system in the brain, composed of glial cells positioned around our neurons, whose function is to collect and break down the harmful metabolic debris they generate.

During deep sleep, this system removes 10 to 20 times more metabolic debris than otherwise, and glial cells shrink in size by an astonishing 60% to make this possible. When adult subjects were deprived of deep sleep, there was a significant increase in Alzheimer-related amyloid in their cerebrospinal fluid, and when middle-aged and older subjects with sleep disorders were successfully treated, their rate of cognitive decline slowed, delaying the onset of Alzheimer’s by up to 10 years.

The National Sleep Foundation (NSF) website summarizes the more immediate benefits of sleep—how reduced total sleep duration causes next-day drowsiness and lack of concentration that have negative effects on all kinds of work and make accidents more likely; how a lack of N-REM sleep leads to overnight forgetting rather than remembering; and how a lack of REM-sleep deprives us of the dreams that are believed to be an important way of organizing our remembered experience.

Sleep is an essential part of the many changes that take place in the body in each 24-hour cycle. Levels of the hormone cortisol dip at bedtime and increase in the course of the night to promote alertness in the morning. Sleep also keeps us healthy by boosting our immune system, and helps to regulate levels of the hormones ghrelin and leptin, which play a role in our feelings of hunger and fullness; this means that when we are sleep-deprived, we may feel the need to eat more, which can lead to weight gain. We spend a third of our lives sleeping, a total of over 20 years for most people, and the NSF concludes that far from being unproductive, the time we spend sleeping plays a direct role in how full, energetic and successful the other two-thirds of our lives can be.
these abnormal conditions. Now that unobtrusive wrist-worn sensors can detect successive sleep stages, sleep research can move out of the laboratory and into the bedroom.

**Question 6** Which IEQ factors should be investigated regarding their effects on sleep?

1) Bedroom air temperature; 2) Bedroom air humidity; 3) Outdoor air supply rate; 4) Bedroom air velocity; 5) Background noise level from traffic and ventilation.

**Question 7** What do we know about current thermal and IAQ conditions in bedrooms?

Field measurements show that when two people sleep in a room with closed doors and windows, CO\(_2\) levels can quickly exceed 2,500 ppm; these high levels occur routinely in cold climates\(^{10}\) and when split-cooling is used in the tropics.\(^{11}\) Night-time CO\(_2\) levels remain particularly high if multi-use bedrooms are not aired out before sleep.\(^1\) Preferred bedroom temperatures vary widely between individuals (see Question 3). Occupants while asleep can do much less about a mismatch of the temperature with their requirements than they can while awake, and dissatisfaction with conditions in bedrooms is indeed often greater than with conditions elsewhere in the dwelling.\(^{12}\)

**Question 8** What are the energy implications?

If occupants are at work for 8 hours, over 50% of their time at home is spent asleep. In cold countries, night-time temperatures are usually much lower than daytime temperatures, and in tropical countries, air conditioning is currently being installed and run in bedrooms rather than living rooms. Thermal and indoor air quality requirements for sleep are thus expected to determine over 50% of energy use in dwellings.

**Question 9** What standards, guidelines or codes of practice apply to temperature & IAQ in bedrooms?

In the majority of countries, no standards or official guidelines apply specifically to bedrooms. Sleep is currently assumed to be optimal under conditions optimized for the activities in which occupants engage when awake.\(^{13–15}\)

**Question 10** What should ASHRAE’s current sleep research priorities be?

The main research priority is to determine whether an affordable and energy-efficient increase in the outdoor air supply rate to the breathing zone in bedrooms would improve sleep, in comparison with current bedroom ventilation. If so, the next priority is to develop such solutions and show that they work. The next priority is research that determines how to optimize air temperature, air humidity and air velocity in bedrooms for improved sleep.

**Question 11** What existing energy-efficient solutions could be used to enhance sleep?

Solutions that deliver clean air to the breathing zone in a bedroom, or remove heat and moisture from the bed at a controlled rate, would enhance sleep quality and be energy-efficient. The following solutions are of this kind: 1) Personal ventilation: a small flow of fresh air to the breathing zone of the sleeper, instead of to the room; 2) Contact cooling in beds: removal of heat directly from the body by contact with a cooled surface, for example, using the equipment that was developed to control body temperature during surgery; 3) Ventilated beds: removal of heat from the bed space by extracting a small flow of hot and humid air when sweating is detected; 4) Counter-current heat exchangers at the room level - “breathing outside walls” with balanced or alternating ebb and flow heat exchangers that avoid any effect on the ventilation of the rest of the dwelling.

**Question 12** How does occupant behavior affect sleep?

Occupants must decide whether to open windows to air out in bedrooms, causing energy loss, or to sleep in humid, warm and polluted air. House-dust mites thrive in poorly-ventilated bedrooms and in bedclothes and mattresses that are not adequately aired every day, causing allergic symptoms that negatively affect sleep. Occupants often leave electronic equipment running in bedrooms, contributing pollution to the air.

**Question 13** Why should ASHRAE engineers be interested in how sleep environments affect sleep quality?

It has been shown that sleep is important for health and productivity, especially for children.\(^{16,17}\) Recent research even shows that insufficient deep sleep leads to an earlier onset of dementia.\(^{18}\) Over 30% of the time we are indoors is spent asleep, yet the use of energy in dwellings has not been optimized for sleep.

**Question 14** How can ASHRAE promote good sleep?
First, by determining which IEQ factors are currently disturbing good sleep. This can be done by setting up field intervention experiments in which IEQ factors are changed, using blind crossover designs to prove causation and wrist-worn movement and heart-rate sensors for sleep-stage evaluation, sleep quality questionnaires and next-day performance as the dependent variables. Technical Committee 2.1, Physiology and Human Environment, is currently preparing a Work Statement for a research project of this kind, and related initiatives could be taken by other ASHRAE Technical Committees.

Second, by developing standards specifically for sleeping environments, and thirdly, by developing technical solutions that ensure that HVAC control and operation can reduce sleep disturbance. Bedroom windows that must be open for ventilation and thermal control admit external noise, pollution, insects and even intruders, while allowing heating and cooling energy to be dissipated outside the building. Bedroom doors that must be open for internal air circulation decrease privacy and admit internal noise.

The authors suggest ASHRAE should develop affordable and energy-efficient bedroom heating, cooling and ventilation technology that requires neither of these crude, wasteful and ineffective measures, together with bedroom thermostats that optimize the thermal environment for sleep throughout the night.

References