The sound environment in healthcare facilities
**HOW DESIGN AFFECTS WELLBEING**

The architectural and functional design of hospitals can improve people’s wellbeing. Hospital design must ensure patient services can be provided by staff. In the long-term, it can also promote patient safety and care quality, reduce care costs, lower operating and construction costs as well as provide other significant business advantages.

Nowadays there is growing awareness amongst healthcare managers and architects about the importance of design in a healing environment. The environment should help staff perform to the absolute best of their ability and help patients cope with the considerable stress that illness involves. Supportive Healthcare Design is inevitably holistic and evidence-based: more than 700 research projects have analysed the effects of colour, lighting, temperature and sound on the wellbeing of patients, visitors and healthcare staff. Several investigations and research projects have pointed out clear links between sound levels and the quality of care.

**CARE ABOUT SOUND**

When people think of a place to recuperate from illness or medical treatment, most visualize places that are quiet and peaceful. This is in stark contrast to the typical modern hospital, where noise from beepers, alarms, equipment, telephones, voices and more fill the normal sound environment. Hospital noise - one of the biggest complaints of patients - should no longer be ignored. Especially as a good sound environment becomes indispensable in the context of intense, accurate communication while applying stricter rules regarding patient privacy and patient data security.

Ecophon’s system solutions are developed to combine acoustic, aesthetic, hygienic and other relevant requirements. The available solutions are not only decisive for the economics of a healthcare facility but also for recovery and personal health.
“Good design can reduce anxiety, lower blood pressure, improve the post-operative course, reduce the need for pain medication and shorten the hospital stay.”

Roger S. Ulrich, Professor
Center for Health Systems and Design Texas A&M University

PATIENT BENEFITS
- Less sleep deprivation, disturbance and annoyance
- Reduced need for pain medication
- Lowered readmission rates
- Improved healing, thereby reducing stays in hospital
- Improved patient satisfaction with services provided

CAREGIVER BENEFITS
- Decrease in stress, leading to reduced levels of burnout and depression
- Can decrease number of medical errors by improved speech intelligibility
- Prevents hearing loss for some medical professionals
- Improved team-spirit and work-satisfaction
Hospital noise is not only a primary cause of patient dissatisfaction at most hospitals. It can negatively impact patient outcomes, cause sleep deprivation and prolong the healing process.

**RISK TO PATIENT OUTCOMES**

Much research has documented the negative effects of hospital noise on patient outcomes. Several studies on infants in natal intensive care units, for instance, show that higher noise levels increase the need for oxygen support therapy, elevate blood pressure, increase heart and respiration rate, as well as negatively affect sleep\(^1\)\(^{-3}\).

Patients exposed to continuous extraneous noise can also experience memory alteration, increased agitation, less pain tolerance and feelings of isolation. Noise has been shown to contribute to patient falls, cause confusion and result in increased medication and use of restraint. These environmentally generated symptoms are often medicated or otherwise treated in ways unrelated to their cause. In addition, hospital noise increases a patient’s anxiety and decreases his confidence in the clinical competence of the staff, thus bringing into question the service levels provided. Furthermore, reducing noise has been associated with improved healing and lowered readmission rates\(^4\).

**MAIN CAUSE OF SLEEP DEPRIVATION**

Hospital noise is a stress factor that can cause sleep deprivation among patients. Research on adults and children clearly shows that noise is a major cause of waking and of sleep deprivation. When a person is deprived of sleep, there is a risk that this may be associated with a diminished protein synthesis and immune function, both important aspects of healing\(^5\).

What causes disturbance to patients’ sleep? According to a Finnish study that sought to clarify the sleep disturbance factors of patients, the cause is the hospital environment itself. Data from 177 patients at the Central Hospital of Northern Carelia’s two medical and two surgical wards was collected. The results indicated that hospital environment factors (noise from other patients, equipment, working nurses, and general hospital noise) were regarded as the main causes of sleep disturbance. In fact, 80% of patients regarded these factors as the cause of disturbed sleep. As a comparison, only about half of these patients reported that pain disturbed their sleep. Furthermore, it is generally accepted that enhancing sleep quality accelerates healing and recovery\(^6\).

**HOW NOISE LED TO INCREASED PAIN MEDICATION**

A study by Barbara Blake Minckley at the Sequoia Hospital in California looked at how noise effects post operative patients\(^7\). The head nurse at the post surgery recovery department, she suspected high noise levels could be associated with increased perception of pain amongst patients returning from surgery. A higher level of activation caused by an environmental stressor (e.g. noise) can make it more difficult to cope with pain. Her study showed that increased perception of pain caused by noise led to increased administration of pain medication.
CASE: SOUND SLEEP WITH ECOPHON

Studies conducted by sleep researcher and medical doctor Sören Berg of the University of Lund (Sweden) confirm that patients’ sleep quality is improved when Ecophon sound-absorbing ceilings are used in the wards.

Dr. Berg’s findings confirm that the sound-absorbing properties of a room affects a patient’s ability to maintain satisfactory sleep quality even when subjected to noise. In one study, 12 healthy people slept several nights in a ward in which the ceiling tiles were altered between those with sound-absorbing properties and others with sound-reflecting properties. Various environmental sounds were played during the night. Objective sleep quality was assessed by electroencephalograph (EEG). When the sound-absorbing ceiling was in place, the environmental sounds caused less disruption to sleep. Dr Berg’s study suggests that equipping a room with an Ecophon sound-absorbing ceiling, resulting in a short reverberation time, makes it possible to remove noise and promote good sleep quality.

The number of sound-induced instances of waking dropped from 42% to 25% when the ceiling was changed from a reflective ceiling to an Ecophon Absorption Class A ceiling. The research carried out by Dr. Berg was peer-reviewed and published in the leading medical journal Sleep.

References
1. Johnson, A. N.; Neonatal response to control of noise inside the incubator. Pediatric Nursing. 27(6), 600-605, (2001)
Not only is healthcare a physically and emotionally demanding service to deliver. Healthcare staff and hospital employees spend more time in the facilities than patients do. Healthcare design can help increase employee satisfaction and commitment. After all, the design of a healthcare facility tells a story about that premise and communicates a great deal about management’s concern for caregivers.

**STRESS, BURNOUT AND TURNOVER**

There is evidence that hospital employees perceive high levels of sound as stress-inducing\(^1\).\(^2\)\(^3\).

One such study, for instance, looked at the correlation between stress among registered nurses and hospital noise in a tertiary care paediatric intensive care unit. Eleven nurse volunteers took part in the study and were observed for a three-hour period of patient care. Heart rate and sound level were recorded continuously; saliva samples and stress/annoyance ratings were collected every 30 minutes. Variables assessed as potential confounders were the number of years of nursing experience, caffeine intake, patients' paediatric risk of mortality score, shift assignment, and room assignment. The average daytime sound level was 61 dB, night time 59 dB. Higher average sound levels significantly predicted higher heart rates. Higher average sound levels were also predictive of greater subjective stress and annoyance. Accordingly, the study reports that noise was shown to correlate with several measures of stress including tachycardia and annoyance ratings.

Other studies show that people who work long shifts in noisy environments, day in and day out, report effects from exhaustion to burnout, depression, and irritability expressed at home. Interfering and distracting sounds have been shown to contribute to medical and nursing errors. Importantly, noise-induced stress in nurses correlates with reported emotional exhaustion or burnout\(^4\)\(^5\).

**MEDICAL ERRORS AND NEGATIVE SPEECH INTELLIGIBILITY**

In a 2002 report entitled *Healthcare at the Crossroads: Strategies for Addressing the Evolving Nursing Crisis*, the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) found that physical working conditions are key contributors to staff turnover and burnout. JCAHO is a US-based non-profit organization whose aim is "to continuously improve the safety and quality of care provided to the public through the provision of healthcare accreditation and related services that support performance improvement in healthcare organizations". They mention noise as a potential risk factor related to medical and nursing errors, stating that the ambient sound environments should not exceed the level that would prohibit clinicians from clearly understanding each other.

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1. **Hospital Noise: Care for your Caregivers**

“We noticed a huge difference once we got the new acoustic ceilings. Noise is prevented from spreading from the source to other parts of the room. We are now able to hear each other more clearly when talking, which helps reduce stress. The beeps and alarms from monitoring devices have now been lowered to bearable levels. And the noise from ventilation is no longer a problem.”

Agneta Haglind
Head Nurse, post-surgery recovery room
Halmstad (Sweden) Hospital
CASH: ACOUSTIC DESIGN FOR HEALTH WITH ECOPHON SOUND-ABSORBING CEILINGS

The effects of higher versus lower noise levels on the same
group of coronary intensive-care nurses were examined
over a period of months. Lower noise levels were linked
to a number of positive effects on staff, including reduced
perceived work demands, increased social support in the
workplace, improved quality of care for patients and better
speech intelligibility6.

The ceiling tiles in the unit were periodically and
without anyone’s knowledge, changed from ones with
sound-reflecting properties to others with sound-absorbing
properties. When the sound-absorbing ceilings were
in place, patients slept better, were less stressed (lower
sympathetic arousal), and reported that nurses gave them
better care. The study was unique in that it was possible
to confirm the connection between the experiences
and spontaneous reactions of the staff to the acoustic
measurements.

The Ecophon sound-absorbing ceilings resulted in:

- Staff reported that it was easier to understand and
  communicate with each other
- Relaxed staff meant higher quality care; staff perceived
  the pace as slower and the amount of work as less
demanding during the day
- Staff perceived the atmosphere as being better, with less
  irritation towards each other
- Patients were less likely to be re-admitted (21% vs 48%)
- The need for aftercare was reduced when the acoustic
  environment was improved
- Most seriously ill patients experienced a difference in
  objective stress levels
- Quieter environment improved patient sleep quality and
  lowered patient stress levels

References
According to researchers at Johns Hopkins, noise levels in hospitals throughout the world have been increasing by about 0.4 decibels per year since 1960. Their findings indicate that average daytime hospital sound levels on a global basis have risen from 57 to 72 dB since 1960 and that hospital noise at night has gone up from 42 decibels to 60 dBs. According to the report from Johns Hopkins, current sound levels are now sufficiently high to be a concern to patient safety.

ABOUT THE STUDY
The sound pressure levels in various units of the Johns Hopkins Hospital were monitored using a precision sound level meter, producing sound levels as a function of location, time of day and frequency. Other highlights from the study include:

- The measurements vary little between different types of hospitals, indicating the problem is widespread,
- Much hospital noise falls into the human speech frequency range, making oral communication difficult. This can force doctors and nurses to speak louder to be heard, further boosting noise levels,
- Measurements indicated that noise levels remained high throughout the day and night.

CASE: NOISE REDUCTION STRATEGIES IMPLEMENTED
Initially, two improvements helped to lower noise levels in several patient care areas. Firstly, staff were equipped with hands-free personal communicators and the regularity of overhead paging dropped to about once an hour, from once every five minutes. Secondly, as many areas lacked sound-absorbing ceiling tiles, researchers wrapped fibreglass insulation inside anti-bacterial fabric and mounted the sound-absorbers onto ceilings and walls in an oncology unit. This reduced sound reverberation by a factor of almost three. After a number of weeks, the researchers’ own sound-absorbers were replaced with solutions from Ecophon.

“Unnecessary noise is the most cruel absence of care which can be inflicted upon either the sick or well.”

Florence Nightingale, 1859
WHAT THE WHO SAYS

The World Health Organization (WHO) guideline values for continuous background noise in hospital wards are 35 dB, with night-time peaks not to exceed 40 dB. However, many studies have shown that background noise levels in hospitals are much higher. Background noise levels are typically 45 dB to 68 dB, with peaks frequently exceeding 85 dB to 90 dB.1-7

References
The sound environment of modern hospitals typically contains very high noise levels, for example:

- Noise from alarms and certain equipment exceed 90 dB, which is comparable to walking next to a busy street when a large lorry passes. A study in a NICU measured peak levels once per minute and found that 31 percent of peaks exceed 90 dB.1
- Noise peaks in hospitals can be extraordinarily loud. A recent study recorded 113 dB during shift changes at a large hospital, which is painful and can even be harmful. This can be compared to a sports event.2
- Noises from surgical drills, saws and other equipment in the operating theatre are in the range of 100 dB to 110 dB (comparable to a lawnmower) and presents a significant risk for noise-induced hearing loss.3-5

Note: In judging these levels, it is worth noting that the decibel scale is logarithmic; each 10 dB increase represents approximately a doubling of the perceived sound level. A 60 dB sound, accordingly, is perceived as roughly four times as loud as a 40 dB sound.

REASONS FOR THE NOISE

A research team from The Center for Health Design recently looked at more than 130 references focusing on noise in hospitals in the published studies. They suggest two general reasons why hospitals are excessively noisy. First, the noise sources are numerous and they are loud. Second, the surfaces in hospitals (floors, walls and ceilings) are usually hard and reflect sound rather than absorb it. The design of many modern hospitals thus actually amplifies noise. For hygienic reasons, hospitals are built with hard, easy-to-clean surfaces. No carpets or sound-muffling panels are used. These hard surfaces affect sound as a mirror affects light. They simply reflect the sound. If sound is free to bounce around, it will do just that.

SPEAKING ABOVE THE NOISE

A large proportion of hospital noise falls within the frequency range for human speech. Hospital staff often need to express themselves loudly to compete with the background noise from medical equipment, paging systems, mechanical building elements, etc, in order to make themselves heard. Due to this, the sound level increases even more; this is referred to as the Lombard Effect.

References

Leaving the sound environment to chance means that patient outcomes are put at risk. In addition, though unintentional, hospital noise sends a signal from hospital management indicating a lack of care towards patients and caregivers. How can this be improved?

**SOUND ENVIRONMENT ASSESSMENT**

To reduce hospital noise and improve the sound environment, standards have to be set that are just as stringent as all others relating to patient safety. An assessment of the sound environment provides the basis for this. Many facility areas are dynamic, having peak periods of activity and noise. It is therefore important to profile the facility and list its different sound and functional zones. Identification of noise sources is another important aspect of managing the sound environment. However, many noise sources are not easy to resolve, such as mechanical and building noise. Defining the desired sound environment in a sound policy as well as involving acoustical engineers, architects and building experts is the best way of addressing the planning of renovations as well as the design of new facilities.

**ENSURING QUALITY SOUND ENVIRONMENTS**

In its key recommendations for reducing hospital noise, the Center for Health Design states that environmental interventions that have proven particularly effective for reducing noise and improving acoustics in hospital settings include:

- Installation of high-performance, sound-absorbing ceiling tiles
- Elimination or reduction of noise sources (for example, adopting a noise-free paging system)
- Provision of single-bed rather than multibedrooms

The organizational culture of the healthcare facility is of utmost importance in ensuring a high quality sound environment. In general, however, studies of the effectiveness of noise-reduction measures suggest that environmental or design interventions are more successful than organizational interventions, such as staff education or the introduction of quiet hours.
SOUND ENVIRONMENT PLANNING: SOME TIPS

Reduction of equipment noise: Alarms, signals, pumps, beepers, telephones, televisions, radios: the equipment used to facilitate healthcare work is procured in separate processes, with acoustic performance often being neglected in the brief. Ensure that equipment sound is taken into consideration and that it can be controlled.

Layout and zoning: The use of distance and layout to separate loud and quiet activities is an effective way of reducing disturbance. A well-planned, logistic flow of supplies and people reduces the noise level, allowing patients to rest and staff to focus on the tasks at hand.

Room acoustics: In rooms with hard surfaces, sounds build up and increase the general noise level. The use of sound-absorbing material reduces noise levels and increases comfort. In larger rooms, the amount of sound absorption will also affect sound propagation in the room and from the room to other areas as well as vice versa.

References
The quantity and placement of sound-absorbing material is the key factor for good room acoustics in healthcare facilities. Room acoustics relate to the sound environment in a restricted space. The most common measurement is reverberation time, but in many instances it is of even greater importance to measure the reduction in sound level. In rooms where transmission and communication of information is of great importance, other measurements can be used to gauge speech intelligibility or privacy.

**SPEECH PRIVACY**
Speech privacy is of increasing importance in everyday life, including healthcare facilities. The need to measure and rate a room’s performance is driven by both patient demand for the respect of privacy and by regulations. According to ISO, speech privacy is conversation that is not intelligible to casual listeners. It is defined by the Articulation Index (AI) and can be measured objectively.

**SOUND PROPAGATION**
When it comes to minimising sound disturbance between people and/or different areas, room layout is very important. Speech is the most disturbing factor because it is very difficult to ‘tune out’ and distracts people more due to the instinct to try to hear what is being said. However, in healthcare premises, individuals must be given as much privacy as possible. In order to prevent sound from being reflected and propagated via the ceiling, it is crucial that the acoustic ceiling has excellent sound absorption properties across the whole frequency range.

**BACKGROUND NOISE LEVEL**
This is weighted to correspond to the human ear, dB(A). The WHO recommends that the equivalent sound level should not exceed 35dB in areas where patients are being treated, observed or resting. Momentary sound during the night should not exceed 45dB. An effective acoustic ceiling reduces background noise.

**SPEECH INTELLIGIBILITY**
This indicates the extent to which a listener understands what is being said by the speaker. Various methods are used to quantify speech intelligibility. Speech intelligibility is directly dependent on the level of background noise, reverberation time and the shape of the room. Different methods are used to evaluate speech intelligibility. Effective acoustic ceilings improve speech intelligibility.

**SOUND PRESSURE LEVEL**
High noise levels due to activities or equipment are often the main disturbance in many surroundings. These make communication difficult and increase stress and the feeling of discomfort. To decrease the sound pressure level in an efficient manner it is important to use acoustical products with as high sound absorbing properties as possible.

**REVERBERATION TIME**
This indicates the time needed for a single sound to decrease by an interval of 60 dB. A short reverberation time is often considered to provide a more home-like acoustic environment with a lower echo. In healthcare buildings, room surfaces are often made from hard, sound-reflecting materials; these have a negative impact on room acoustics. A short reverberation time can be achieved by using sound-absorbing ceilings or wall panels.
Why sound absorbing materials?

- Increases privacy and confidentiality
- Reduces sound propagation
- Reduces noise
- Reduces sound levels
- Improves communication
- Reduces sound reflection and flutter echo
- Improves concentration
- Increases speech intelligibility
- Enhances overall sound quality.
Every room in a healthcare facility has specific quality requirements regarding building materials and solutions. The number and complexity of requirements increases as the level of care increases. Ceiling and wall solutions can offer other functional properties in addition to sound absorption. Ecophon offers a portfolio of sound-absorbing ceiling and wall solutions that meets all quality requirements while also offering all the functional properties relevant to healthcare facilities. Some of the major properties are listed on these pages.
SPECIFIC DEMANDS

SOUND ABSORPTION
Ecophon ceiling systems are classified according to EN ISO 11654, which ranges sound absorption from class A to E. The majority of Ecophon systems meet the highest class, Class A. The corresponding NRC/SAA value according to ASTM C 423, is between 0.85 and 1.0. The maximum value that can be achieved is 1.0.

CLEANABILITY/DISINFECTION
Ecophon ceiling systems are classified for different requirements. Smooth, glossy, hard materials are traditionally associated with a high level of cleanability and hygiene. On the other hand soft, porous materials are usually needed for efficient sound absorption. Ecophon Hygiene systems successfully combine acoustic performance with high cleanability. The materials used do not act as a breeding ground for bacteria.

PARTICLE EMISSION
Dust and emissions play a part in the increase in allergies. Ecophon offers products certified by the Indoor Climate Labelling (DIM), fulfilling the highest requirements, and also offers suitable solutions for environments that demand limitation of airborne particles. They are also recommended by the Swedish Asthma and Allergy Association.

MOISTURE RESISTANCE
Ecophon offers ceilings that are able to withstand a permanent ambient RH up to 95% at 30°C without sagging, warping or delaminating. A higher temperature/moisture is permissible during washing.

ENVIRONMENTAL INFLUENCE
A number of Ecophon’s sound absorbers are eco-labelled with the Nordic Swan showing that they fulfil the criteria and demands of the Nordic Eco-labelling council in respect of the product’s entire life cycle, from raw materials to reclamation. Demands relate to aspects that include discharges and emissions that are health hazards, the handling of waste and the use of energy and natural resources.

CE MARKING
CE marking is used to allow the free trade of products within the EU. The basic rule is that it should be possible for a product that is CE marked to move across Europe’s internal borders without any national marking requirements or control of what is covered by the CE marking. This means that all manufacturers on the European market must comply with the same standard, leading to the harmonisation of reporting on different product properties. This simplifies the comparison of acoustic solutions and many other products.

P MARKING
A P-labelled sound absorber secures that the absorption stated by the manufacturer is fulfilled. Ecophon has chosen to permit its sound absorbers to undergo an objective scrutiny at SP (Sweden’s Testing and Research Institute) regarding sound-absorbing ability in order for them to be P-labelled. This removes all uncertainty about incomplete or “home made” measurement values.
PUBLIC ZONES

The stress associated with having to go to hospital as a patient or visitor can be eased by creating an acoustic environment suitable for communication and orientation. Large, open areas/spaces make sound propagation an issue. Reception areas need to be designed with acoustic privacy and speech intelligibility in mind. With proper design and use of colors, patients can be eased to find the most logical way to their destination. The performance of the acoustic ceiling has a significant impact.

EXAMPLES: entrance hall, restaurant, corridor, waiting areas

NURSING ZONES

Different types of nursing zones are required depending on the needs of individual patients. Along with offering nurses with an effective work environment, the most important function for a nursing zone is to offer the patient an environment that promotes sleep and recovery.

The overall purpose of the nursing zone:

- Facilitate supervision, medication and instruction for nurses
- Ensure patients can rest and sleep
- Act as a place to recover and prepare for everyday life

EXAMPLES: wards, patient rooms, consulting rooms
**SUPPORTING ZONES**

Throughout a hospital there are many functional areas that support the facility’s operations. Laundries and kitchens generate extra humidity. Others, like laboratories, involve requirements for cleaning all surfaces or the need to regularly carry out a total decontamination using strong, disinfectant chemicals. Supporting areas also encompass in-house support functions, such as public and private businesses and hospital administration. Research in office environments confirms the positive impact low sound levels have on performance.

**EXAMPLES:** laboratory, laundry, kitchen, meeting and conference rooms, lecture rooms

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**CLINICAL ZONES**

Clinical zones should support effective use of medical equipment. Communication and function are of critical importance. Technological requirements involve the need for the frequent expansion of these areas. Ceilings should therefore allow flexibility, accessibility as well as durability. The clinical zone is the fastest growing area in the hospital. The cost of modern medical equipment makes it necessary to consolidate with central facilities for effective use.

The overall purpose of the clinical zone:

- Diagnostics and treatment
- To communicate and give instructions in sensitive matters
- To interpret and analyse medical data

**EXAMPLES:** operating theatre, pharmacy