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Analysis of room acoustics in Danish Hospitals

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This project aims to compare room acoustic parameters and noise levels in various Danish hospitals: Odense, Gentofte, Bispebjerg, Hillerød and Aarhus Hospitals. Room acoustic conditions are measured in audiometric rooms at Odense, Gentofte, Bispebjerg and Aarhus hospitals. The noise levels in emergency rooms at Gentofte, Køge and Hillerød hospitals are measured over several days. The measurements are also compared with the requirements in the Danish Building Regulation, WHO guidelines and previous studies. The main parameters considered are the reverberation time parameters, e.g., Early decay time (EDT) and T_{20} , and the sound pressure level metrics, namely the equivalent level and peak level. In addition, the staff at the hospitals is asked about their personal perception of the acoustic and noise conditions and the correlation between their subjective disturbances/annoyance and the objective acoustic parameters is investigated.

1 Introduction

Room acoustics at hospitals has gotten an increasing amount of attention over the last years. Studies show that the acoustic environment can have tremendous effect on patients' recovery, working conditions of the staff, communication between patient and staff etc. [1-2] However, the requirements to room acoustics at Danish hospitals are very sparse. There are a few guidelines to the reverberation time, sound isolation and background noise. The Danish Building Regulation (BR18) divides hospital rooms into two categories: patient bedroom and examination/treatment room. [3]

For this project, it has been possible to measure 25 rooms at audiology departments, where room acoustics have been a key parameter when designing the rooms. Also the noise level at three doctors' and nurses' station in three different emergency rooms have been measured.

For this project reverberation time, T_{20} , and A-weighted equivalent sound pressure level are being considered.

2 Acoustic regulations for hospitals in Denmark

The Danish Building Regulation [3] has limited requirements to room acoustics at hospitals. The regulation recommends certain design values for the reverberation time – 0.6s for examination rooms and patient bedrooms in the frequency range

of 125-4000 Hz (with a liberation of 20 % for 125 Hz). Currently there's an overlap between the regulation of 2018 and the regulation of 2015 up until June 30th 2018.

BR18 also recommends an upper limit of 30 dB(A) from building services [3]. The regulation does not mention a limit for the noise level from other sources.

The World Health Organization has made the following guidelines for background noise at hospitals. The L_{Aeq} should not exceed 30 dB(A) and at night the L_{Amax} should not exceed 40 dB to avoid disturbing the patients' sleep [4].

The Danish standard DS/EN 15251:2007 [5] has made similar guidelines based on a typical range for the given room. This sets the recommended guideline for wards and bedrooms at 30 dB(A)

3 Method

The measurements have been made according to DS/EN ISO 3382-2 [6] as far as the particular room allowed it.

For measuring reverberation time, the rooms have to be in an unoccupied state (meaning up to two people in the room depending on the room size). It was assumed that the reverberation time at 2 kHz and 4 kHz respectively would not exceed 1.5s and 0.8s causing the air absorption to be negligible. Regarding placement of the microphone, it was endeavoured to place the microphone at least a quarter of a wavelength (1m) from any reflective surfaces. Some of the measured rooms were too small to meet the standard regarding this. The background noise was measured to ensure that the sound pressure level produced by the source would be at least 35 dB above this. The interrupted noise was made sure to be at least the double of the reverberation time.

For this project, three different types of measurements have been conducted.

For the audiology departments, impulse response measurements using the software programme DIRAC have been performed, since the data is part of another project where parameters like Early Decay Time and Impulse Response are required. The impulse response measurement was made with an exponential sweep and was repeated 10 times for each source-microphone combination. Depending on the size of the room, a sufficient number of combinations were made to reach an acceptable standard deviation. This meant 2-3 source positions and a total of 14-24 source-microphone combinations. Rooms at audiology departments have been measured at Gentofte, Bispebjerg, Odense and Aarhus Hospitals. Most rooms were audiometric rooms or offices being used for cochlear implant (CI) fittings and free field testing. A total of 25 rooms have been measured during the fall of 2017.

For the emergency rooms it has been decided to consider the staff and their exposure to noise. Therefore doctors' and nurses' stations in the emergency rooms have been analysed. In the emergency rooms it is not possible to measure reverberation time, since the room mostly is in an occupied and fully furnished state, which would interfere with the measurement. Therefore, an SPL meter is placed in the room over several days to get an overview of the noise levels that the nurses and doctors are exposed to. The emergency rooms at Gentofte, Køge and Hillerød Hospitals (the last one being the paediatric emergency room) have been measured.

Reverberation time is going to be measured in patients' bedrooms at Hillerød and Bispebjerg Hospital's departments of respiratory diseases during March 2018. The final number of rooms that will be analysed is uncertain since the departments at times are busy causing the number of empty rooms to be limited. These rooms will be measured by simpler means than the rooms at the audiology departments. For these measurements an SPL meter, amplifier and omnidirectional source were utilized. Following the ISO 3382, 2-3 source positions and a total of 12 source-microphone combinations are performed with pink noise as the interrupted noise with two decays of 3 seconds over the frequency range of 125-4000 Hz in 1/1 octave bands.

4 Results

The audiometric rooms and offices that have been measured are of different age and quality. Most rooms had a background noise of about 20 dB(A). However most of the measurements were made on holidays or outside opening hours, meaning that the offices with a door directly towards the hallway might be exposed to more noise during the day time.

All rooms had sound absorbing materials on several surfaces – carpets on the floor, acoustic ceilings and/or wall panels of varying materials.

Figure 1 and 2 show an office used for free field audiometry for infants at Odense Hospital and a room for CI fitting at Bispebjerg Hospital. The two rooms are examples of the diversity in the rooms' size, age and design.



Figure 1: Audiometri 5, Odense Hospital



Figure 2: Efterkontrol 2, Gentofte Hospital

Figure 5 displays the results of the measurements of the rooms at the audiology departments. They display the reverberation time, T_{20} [s] as a function of the volume of the room [m^3], at 125 Hz, 500 Hz, 1000 Hz and 4000 Hz respectively.

When visiting the emergency rooms the staff in general expressed that the doctors' and nurses' station is the room in the ward with the most significant problems with noise compared to rooms where patients are waiting or being treated. Many are daily annoyed due to the noise, which is most likely caused by the large number of working people in the relatively small rooms (up to 20 people at the handover). When retrieving the SPL staff at all three emergency rooms expressed how the noise level during the measurement duration had been normal.



Figure 3: Køge Hospital ER

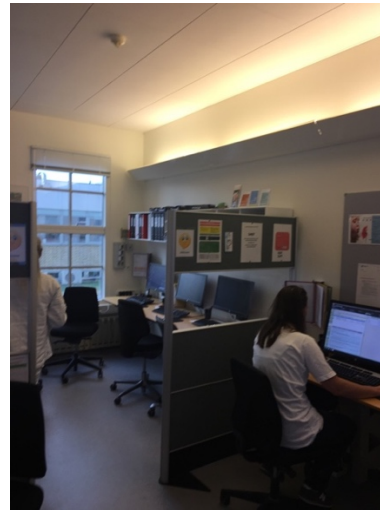


Figure 4: Hillerød Hospital paediatric ER

Results from the noise measurements at the emergency rooms are displayed in figure 6 and table 1. In the emergency rooms the data points in figure 6 represent measurements in 3,5 minute intervals. Since the logging period was set to 1s there's been made a minimum, maximum and average for each time interval. It appears that the sound pressure level fluctuates quite a lot.

Table 1: Volume, measurement duration and average L_{Aeq}

Hospital	Volume	Measurement duration	L_{Aeq}	L_{Cpeak}
Gentofte	63 m^3	5 days	57,0 dB	126,3 dB
Hillerød	67 m^3	4 days	56,2 dB	116,7 dB
Køge	38 m^3	4 days	58,3 dB	118,3 dB

5 Discussion

Figure 5 displaying the reverberation time in the different rooms are of varying length, but most meet the design value from BR18 of 0,6s. The figures also suggest a trend that the smaller rooms in general have shorter reverberation time – this trend is most likely caused by the fact that the audiometric rooms that in general had the lowest reverberation time were relatively small (~20m³).

As it appears from Figure 5, two rooms at Odense Hospital have the longest reverberation time. These two rooms were both used for CI fitting. Both rooms had an acoustic ceiling but hard surfaces on the walls and floor and therefore need to be acoustically treated further to improve the reverberation time.

As shown in Figure 6, the sound pressure level rarely goes below 35 dB(A) causing a possible problem in terms of the speech intelligibility [4] and thereby the communication between the staff. Long term exposure to levels above 70 dB(A) might cause hearing impairment on some and exposure to a peak sound pressure should never exceed 140 dB(A) for adults and 120 dB(A) for children according to WHO [4]. In table 1, the peak level at Gentofte exceeds the limit for children.

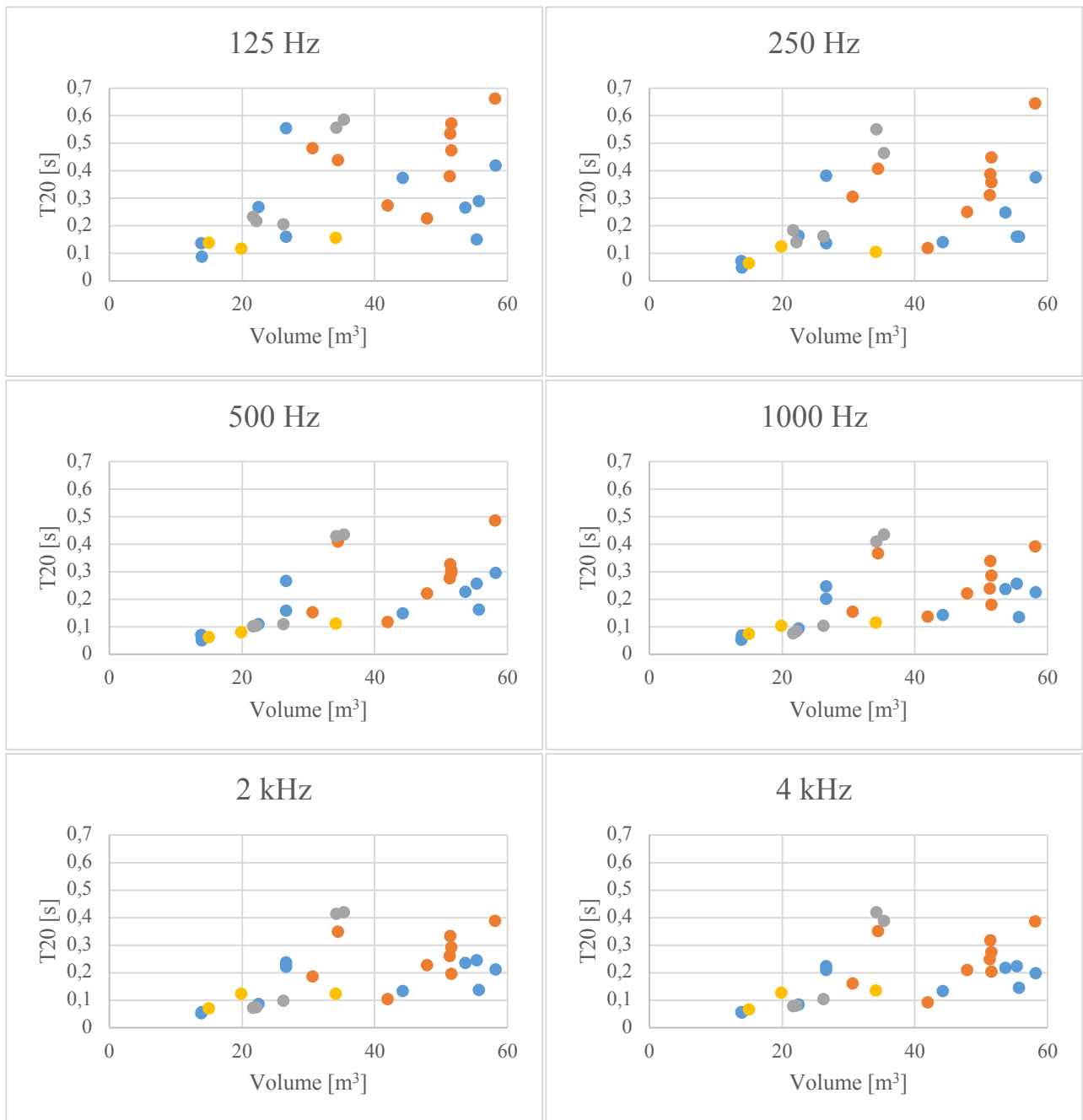
6 Conclusion

The reverberation times measured in three Danish hospitals' audiometric rooms complies with the regulations in BR18, as they are below 0.6 s. The noise levels in Danish emergency rooms are decent, as the average A-weighted levels are lower than 60 dB(A), but sometimes the peak level can reach up to 126 dB.

In the further study as many patient bedrooms will be measured to analyse the acoustic environment for the patients when they are hospitalized and need recovery. Also the data from the noise measurements at three emergency rooms will be analysed further.

References

- [1] Hsu, Ryherd, Ackerman, Persson Waye, "Noise pollution in hospitals: Impacts on patients", J. Clin. Out. Mgmt. 2012, Vol. 19, No. 7, page 301–309
- [2] Blomkvist V, Eriksen, CA, Theorell T, Ulrich R, Rasmains G, "Acoustics and psychosocial environment in intensive coronary care", Occup Environ Med, Mar 2005.
- [3] Danish Building Regulation 2018, § 368 - § 376
- [4] Berglund B, Lindvall T, Schwela DH, "Guidelines for community noise", Technical report 1999, World Health Organization
- [5] DE/EN 15251:2007, Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lightning and acoustics.
- [6] DS/EN ISO 3382-2:2008, Acoustics – Measurement of room acoustic parameters – Part 2: Reverberation time in ordinary rooms



● Bispebjerg ● Gentofte ● Odense ● Aarhus

Figure 5: Results from audiology departments at 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz

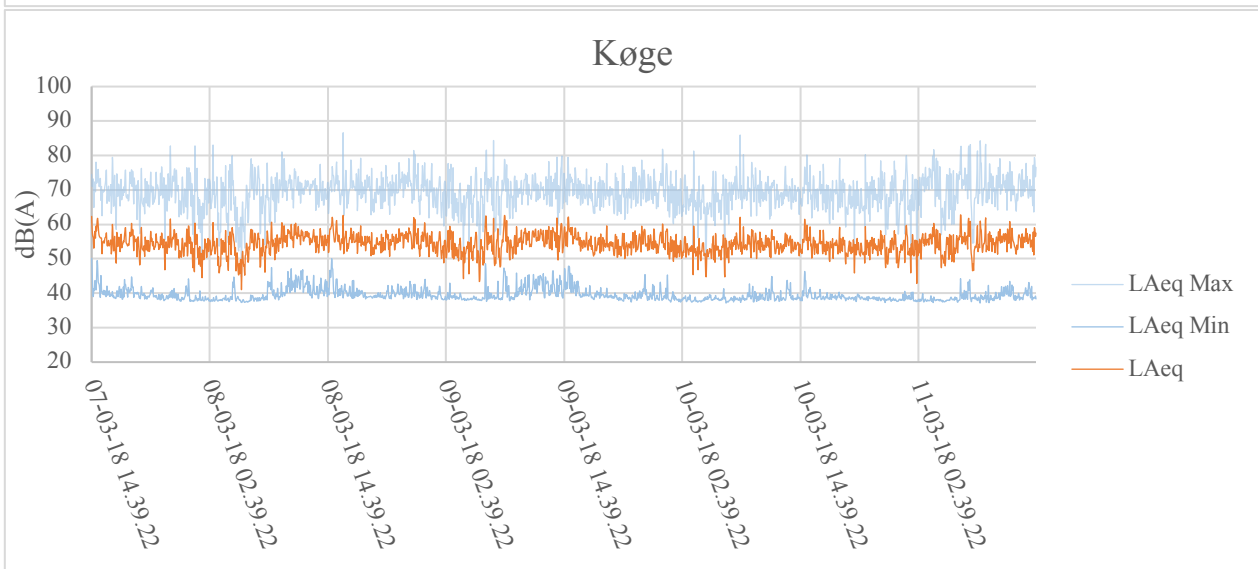
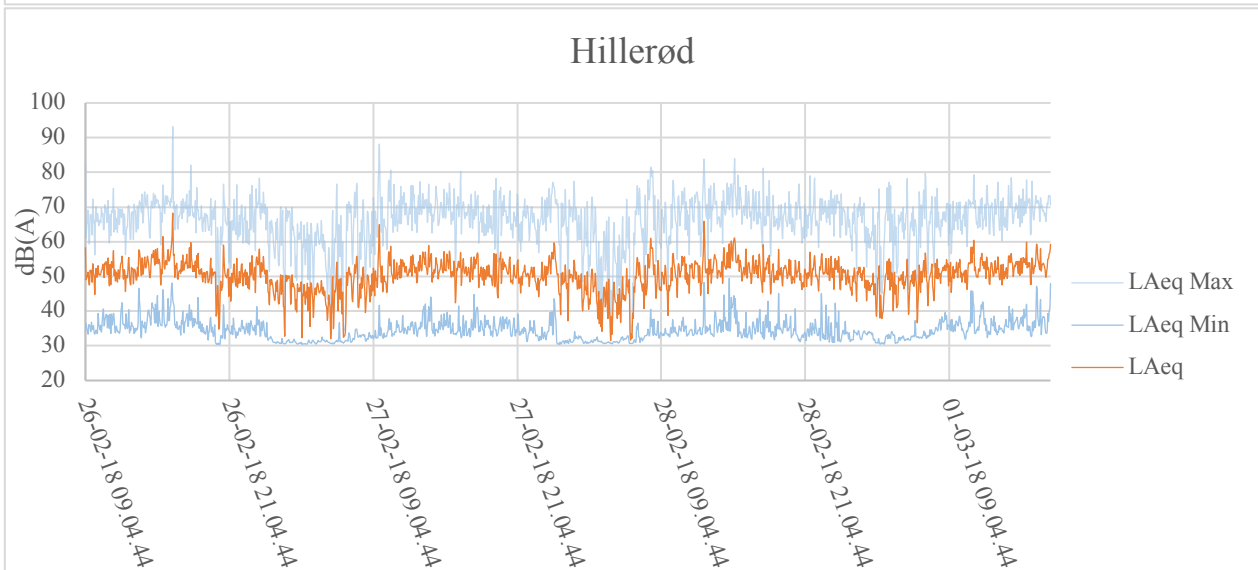
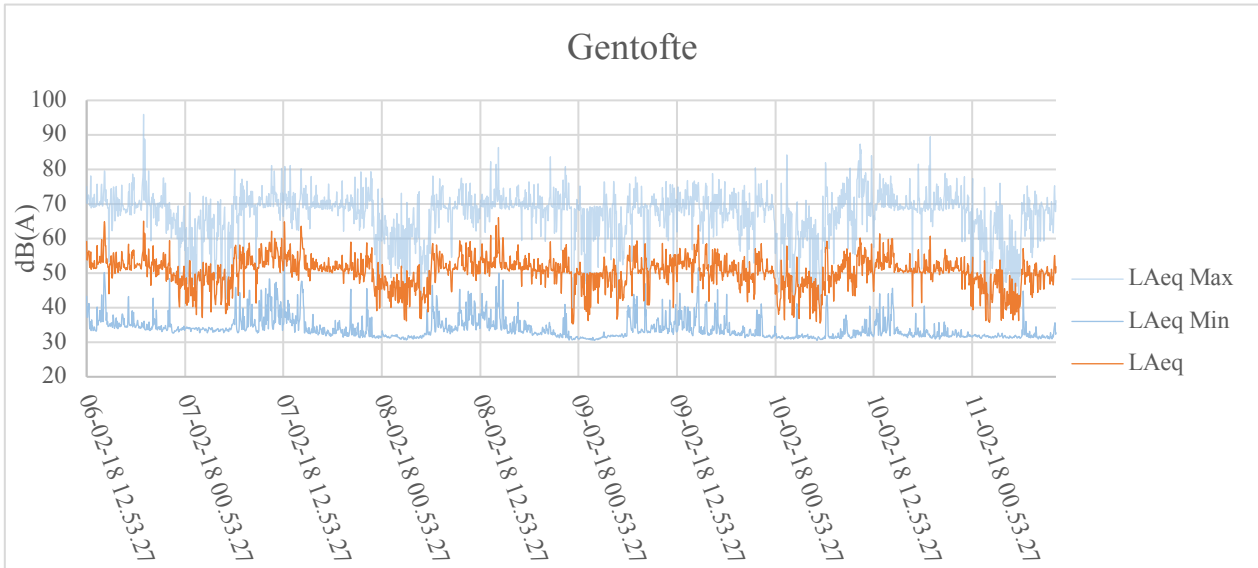


Figure 6: Results from doctors' and nurses' station at Emergency rooms