

Assessment of acoustic comfort in Algerian hospitals with reference to national and international standards. The case study of the Urology Department in Abderrezak Bouharra Hospital, Skikda

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Abstract

Noise is one of the main issues that can impact both the environment and human health. In hospitals, which accommodate individuals more susceptible to noise, namely patients, workers, and often demoralized visitors, the sensitivity to noise is even greater. This study aims to evaluate acoustic comfort in hospitals through in-situ acoustic measurements conducted in the Urology Department of Abderezzak Bouharra Hospital in Skikda, Algeria. The results indicate that sound pressure levels exceed the majority of international and national standards analysed in this study, including Algerian regulations, which only regulate noise in the immediate vicinity of hospitals. This surpassing of permissible levels by standards is evident whether the noise occurs inside occupied rooms, unoccupied rooms, corridors, or outdoors.

Additionally, the analysis of measured sound pressure levels detected a significant number of peaks during the night, which can deteriorate patients' sleep quality and cause awakenings, making patients' recovery more difficult. Furthermore, these analyses also suggest that interior activities generate more noise compared to exterior sources.

Keywords: *Acoustics - Noise - Urology Department - Hospital – Standards - Skikda*

 https://doi.org/10.37896/pd92.6/92611

List of abbreviations

WHO	World Health Organization
UE	European Union
USEPA	United States Environmental Protection Agency
EHU	University Hospital
CHU	University Hospital Centre
EHS	Specialized Hospital Establishment
EPSP	Local Public Health Facilities
EPH	Public Hospital establishment
ISO	International Organization for Standardization
SPL	Sound pressure level
L_{Aeq}	A-Weighted Equivalent Sound Pressure Level
$L_{AFmax.}$	Maximum A-Weighted Sound Pressure Level with “fast” time weighting

1- Introduction

Since 1980, the World Health Organization (WHO) has been concerned about the problem of noise; its work began in 1992, arriving at the first publication in 1995, which explains the phenomenon and its risks to humans and the environment. Moreover, this publication also explains the quantification of noise with limit values for each environment in the form of guidelines (WHO, 1999). Seven years later, the European Parliament published Directive 2002/49/EC, which is a very important reference for the UE member states to limit the problem of noise. This Directive provides for a periodic report on the noise situation every five years, however, the last report of 2023 highlights how the number of people exposed to noise levels above the recommendations, in road, railway, aircraft and industry noise, has not stopped increasing from 2007 until 2021.

Noise disturbance is directly related to health. Many researches have proven the negative effects of noise on human health, especially on the health and rehabilitation of more vulnerable people such as patients, considering the hospital as a specific environment. These studies state the critical effect of noise on people, in particular, sleep disturbance, impairment hearing, cardiovascular and psychophysiological effects, discomfort and interference of communications (Nassur, 2018; Münzel et al., 2018; Basner & McGuire, 2018; Lin et al., 2020). Additionally, others researches have highlighted the harmful effects of noise on high blood pressure (Mahdjoub & Assaad, 2018) and

 https://doi.org/10.37896/pd92.6/92611

mental balance (Jensen et Al., 2019). However, WHO in 2018 reported that only 4% of noise studies and interventions in Europe were based in hospitals (WHO EUROPE NOISE, 2018).

Other researchers have highlighted the harmful effects of noise in the work environment which requires a lot of cognitive activities, indicating that noise in hospitals increases medical errors and lowers staff productivity (Waye & Ryherd, 2013; Loupa, 2020). In a study on hospitals carried out in the Netherlands using a questionnaire on worker comfort, 38% had headaches, with 32% of staff being dissatisfied with the quality sound of their work environment and with 36% reporting a lack of privacy (Eijkelenboom et Al., 2020). Additionally, other researchers have also reported the effects of noise on the well-being of visitors (Paiva et al., 2019), which has led many researchers to vary the field of application of their studies. In a review article on noise in hospitals, 82% of the studies analyzed were carried out inside hospitals, including 48% for intensive care units and 19% in several locations inside hospitals. In addition, 22% of studies were carried out in private rooms and waiting rooms and 11% in emergency rooms and indoor common areas, based on the idea of patient priority. However, 15% of studies were conducted externally with only 3% studying both environments at the same time (Andrade et Al., 2021). Finally, other research has indicated the importance of combined studies which serves to better describe the hospital situation and the seriousness of the problem, and also to properly determine the different sources of noise, either internal and/or external (Althahab et Al., 2022).

However, noise levels in hospitals continue to increase over time. Since 1960 noise in hospitals has increased from 57 dBA to 72 dBA during the day in 2007 to arrive in 2015 at levels which reach 106 dBA in L_{AFmax} , and from 42 dBA to 60 dBA during the night in 2007 to levels which reach 106 dBA in L_{AFmax} in 2015 (Vishniac et Al., 2005; Anjali, 2007; Fredriksson, 2015). Another study conducted in seven hospitals located in the city of Isparta in Turkey found that sound levels in L_{eq} measured at all points in outdoor exceeded the national standards for road traffic noise in sensitive areas, which require sound levels of 60 dBA during the day and 55 dBA at night, the measured levels also exceeded recommended levels set by international standards such as the WHO and the USEPA. However, the study demonstrated that private hospitals in Isparta, situated in a complex urban fabric with narrow streets and sidewalks, exhibited lower levels compared to other hospitals located at major intersections (Coşkun et al., 2022).

A study carried out in the Netherlands with a questionnaire validated and tested on staff, which is the category that uses the hospital on a permanent basis, highlighted how noise from the interior was the main complaint. Specifically, the 556 responses showed that 40% of this indoor noise was due to other people and 25% to devices (Eijkelenboom et Al., 2020).

 https://doi.org/10.37896/pd92.6/92611

With technological advancement, several electronic devices have been introduced into the field of medicine as decision support and monitoring tools. Therefore, considering the various activities taking place inside and outside the hospital, a large amount of noise will be produced. To better understand a sensitive and complex environment like hospitals, research in Italy was carried out in 2023 using quantitative and qualitative methods combined with acoustic simulations and concluding that the weakest element in noise transmission between the corridor and the room is the door. According to this study, intervening in the configuration of the corridor and in the characteristics of the door, make possible to obtain more than 10 dB of improvement of sound insultation between the corridor and the patient's room (Secchi et Al, 2023).

In Africa, the WHO has only addressed the issue of noise in the Southern African country, concerning the avoidance of hospital placement in so-called controlled zones where the average noise level exceeds 65 dBA over 24 hours. Additionally, several researchers have highlighted the scarcity of acoustic studies for hospitals on this continent in 2018 (Okokon et al., 2018; Sieber et al., 2018). Three years later, the results of a review study on hospital noise have confirmed that this phenomenon has only been studied in 2% of cases in Africa (Andrade et al., 2021).

In Algeria, a quantitative study carried out on dwellings revealed that the insulation of interior partitions, the insulation between adjoining dwellings and the insulation from impact noise have all poor values reference to the recommendations and international classifications schemes, in the absence of a national recommendation for the sound insulation, while the façade sound insulation is acceptable (Gramez et Al., 2021). Another study conducted in residential neighborhoods in Guelma, used a quantitative approach with measurements at 17 points along Champs de Manœuvre street and a qualitative approach involving a structured questionnaire distributed to a sample of 80 dwellings to assess noise perception. The results revealed that 70% of the participants live in an unpleasant acoustic environment. Additionally, 50% of them are disturbed by road noise, and 47% have lodged complaints about neighbour noise (Boulemaredj et al., 2022). However, noise in hospitals is rarely studied, probably as a consequence of the difficulty and complexity of the evaluation, whether quantitative or qualitative methods.

The healthcare system in Algeria includes both private and public sectors. In other countries like Jordan, there is a third sector referred to as the donor sector (Alzoubi & Attia, 2019). The Algerian system emphasizes the priority and dominance of the public sector, which ensures free public healthcare. Algeria has adopted a healthcare infrastructure composed of several types of hospitals, including one EHU, 14 CHUs, 65 EHSs, 261 EPSPs and 219 EPHs (Ould-Kada, 2010 ; Hadef et Al., 2015).

The Skikda Province has three types of hospitals: EPH, EPSP and EHS. Concerning the EPH, there are six in this province, distributed its various cities. The city center is equipped with two EPH, the first being older and located in the historical part of the city center, while the second is situated on the immediate outskirts of the city center (http://www.dsp-skikda.dz/, Consulted on November 10, 2023).

2- Normative Context

Numerous studies have highlighted the international and European variety concerning the divergence in descriptors, requirements, and limit values. Notably, the scientific works of Birgit Rasmussen (Rasmussen, 2010; Rasmussen, 2012) and Maria Machimbarenna (Machimbarenna, 2014) focused on housing. They described the diversity and variety of descriptors, classification schemes and limit values used for assessing acoustic insulation. Simultaneously, the COST TU0901 initiative, chaired by them, aimed at a common and harmonized international approach to building acoustic insulation. It involved the participation of 35 countries with the possibility of expanding to others. Initiated in 2009 and published in 2014, this initiative depicted the chaotic situation regarding building acoustic insulation requirements. It proposed harmonized acoustic insulation descriptors based on existing ones through statistical or theoretical translation. It also suggested a classification scheme from Class A to Class F for airborne noise insulation, impact insulation, facade insulation. This work was the basis for the definition of the international standard ISO 19488 (Acoustics – acoustic classification of dwellings) published in 2021.

Another study by Birgit Rasmussen in 2018 indicated that among the 12 European countries with acoustic classification schemes, seven countries included hospitals, including Turkey, and four Nordic countries with a wide range of included buildings (Rasmussen, 2018).

However, to combat noise in hospitals, the WHO recommends average daytime sound levels below 35 dBA L_{Aeq}, in areas with patient contact, and average nighttime levels of 30 dBA L_{Aeq} and a maximum level of 40 dBA L_{AFmax}, respectively. These recommendations aim to ensure both health prevention and patient well-being in terms of calm and tranquillity (WHO, 1999). This motivated 45% of the articles studied to use these WHO recommendations as reference values. Other authors used different standards in their studies, including 15% referencing the U.S. Environmental Protection Agency (USEPA 1974) standard, which recommends an indoor level of 45 dBA during the day and 35 dBA at night, with an outdoor level of 55 dBA for both day and night. Additionally, 12% used values from the American Academy of Pediatrics (USAAP), recommending a fixed indoor level of 45 dBA during both day and night, similar to the Australian standard. Other standards used to assess noise in hospitals include values indicated by the National Institute for Occupational Safety and

 https://doi.org/10.37896/pd92.6/92611

Health (NIOSH), recommending indoor levels of 40 dBA during the day and 35 dBA at night, and the Noise Council (NIC), recommending levels of 45 dBA during the day, 40 dBA during the evening, and 20 dBA at night. There are also less stringent international standards for limit values, such as the Chinese standard recommending an indoor level of 55 dBA during the day (Andrade et Al., 2021; Althahab et Al., 2022). The table 1 shows other international recommendations standards used to study noise in hospitals.

Recommendations Standards	W	NIOSH	NIC	CC	E	AA	UK	AUS	GB	IR	ECU	ZA
Indoor / daytime	35	40	45	65	45	45	45	45	55	45	45	
Indoor / nighttime	30	35	20	65	35	45	35	45		35	45	
Outdoor / daytime		50			55		55			55		65
Outdoor / nighttime		55			35		55			45		65

__W:__ World Health Organization; __NIOSH:__ National Institute for Occupational Safety and Health; __NIC:__ International Noise Council; __CC:__ Consensus Committee for Neonatal Intensive Care Unit Design; __E:__ United States Environmental Protection Agency; __AA:__ American Academy of Paediatrics; __UK:__ United Kingdom, Department of Health. Health Technical Memorandum, 2013; __AUS:__ Australian Standards; __GB:__ Chinese GB/T 51153-2015 standard; __IR:__ Iranian Standards; __ECU:__ Ecuadorian Construction Standard -NEC 11, 2011; __ZA:__ South Africa, WHO 1999 (Source: Andrade et Al., 2021, Althahab et Al.; 2022).

Table 1 : The recommendations standards used in the bibliography for assessing noise in hospitals.

In Algeria, several studies have indicated the limitations of building acoustic standards and regulations, leading researchers to refer to foreign and international experiences (Gramez, 2010; Gramez, 2021; Boulemaredj, 2022). For hospitals, Algerian acoustic regulations through Article 03 of Executive Decree No. 93-184 of 1993 set the A-weighed equivalent sound level limit values during the daytime (6 am to 10 pm) at 45 dBA and (10 pm to 6 am) at 40 dBA during the nighttime in the immediate surroundings of healthcare facilities. Table 2 presents the mandatory standards used in certain countries to assess noise levels in hospitals. These standards are established by institutions and legal authorities, founded on laws and official texts, and are obligatory to implement, unlike recommendations, which are optional to follow.

Mandatory standards	DZA	TN	IT	RD	PT	TR	BR	CL	CO	PR
Indoor /daytime				40	55	34			55	
Indoor / nighttime				30	55	34	35		55	
Outdoor / daytime	45	45	50					55		50
Outdoor / nighttime	40	35	40					45		

__DZA:__ Article 03 of Executive Decree No. 93-184 of 1993 of the Algerian regulations; __TN:__ The decree of the President of the commune, Mayor of Tunis, of August 22, 2000; __IT__ Ministerial Decree November 14, 1997; __RD:__ Spanish Royal Decree 1367/2007; __PT:__ Portuguese Decree-Law No. 9/2007; __TR:__ Turkish Ministry of Environment and Urbanization, 2017; __BR:__ Brazilian Standards (NBR 10152/1987): __CL:__ Curitiba Municipal Law no. 10625/2002; __CO:__ Resolution 8321 of August 4, 1983. Ministry of Health, Colombia; __UY:__ Uruguay standards; __PR:__ Peruvian National Environmental Standards for Noise.

Table 2 : The mandatory standards used for assessing noise in hospitals.

 https://doi.org/10.37896/pd92.6/92611

3- Methods

3-1- Presentation of the case study "EPH ABDEREZZAK BOUHARRA"

The EPH Abderezzak Bouharra is a public hospital establishment in CICEL, southwest of Skikda city center, created in April 2006 and intended for prevention, diagnosis, study, care and surgical vocations. Its theoretical capacity is 240 beds, with a current capacity of 295 beds, and has 18 departments and 6 technical platforms. It was put into service on 1st December, 2007 with specialized medical consultations, and in 2008, with its first hospitalization service; in 2017, the EPH had 25,018 hospitalized patients distributed as shown in the figure 1 (https://www. ehskikda-dz.com/, accessed 10/28/2023).

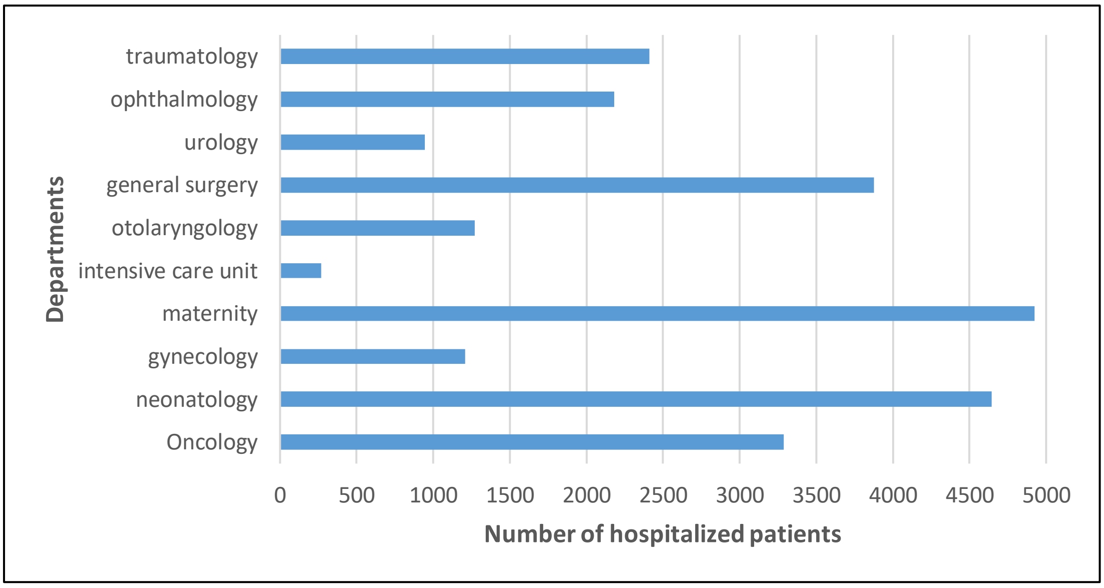

Figure 1 : The number of hospitalized patients in each hospital department at EPH ABDEREZZAK BOUHARRA according to the latest activity report in 2017 (Source: https://www. ehskikda-dz.com/ ;accessed 10/28/2023).

The EPH Abderezzak Bouharra is essentially composed of two blocks at different levels (see figure 2). The 1st is a single-level block that houses both the emergency and oncological consultation departments, represented with hatching in yellow, while the 2nd block of six levels, which houses the other existing hospitalization departments in the hospital, is represented with brown hatching. The connection between these two blocks is ensured by an overhang represented with magenta hatching. Access to the EPH blocks is mainly via emergency access for patients, administrative access for staff; the visitor access is open only during official visiting hours between 1 p.m. and 3 p.m. Interior mechanical circulation is done by one-way axes with a steep slope (≈ 11%) for the east-west direction in a loop from the entrance to the exit. There are four types of parking: emergency, administration, ambulance, and visitor parking. The technical rooms are located close to the visitor parking lot to the south of the hospitalization services, and the oxygen generator is placed close to the visitor access

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and to the north of the hospitalization services. The technical and maintenance services are housed in a block adjacent to the east of the hospitalization services.

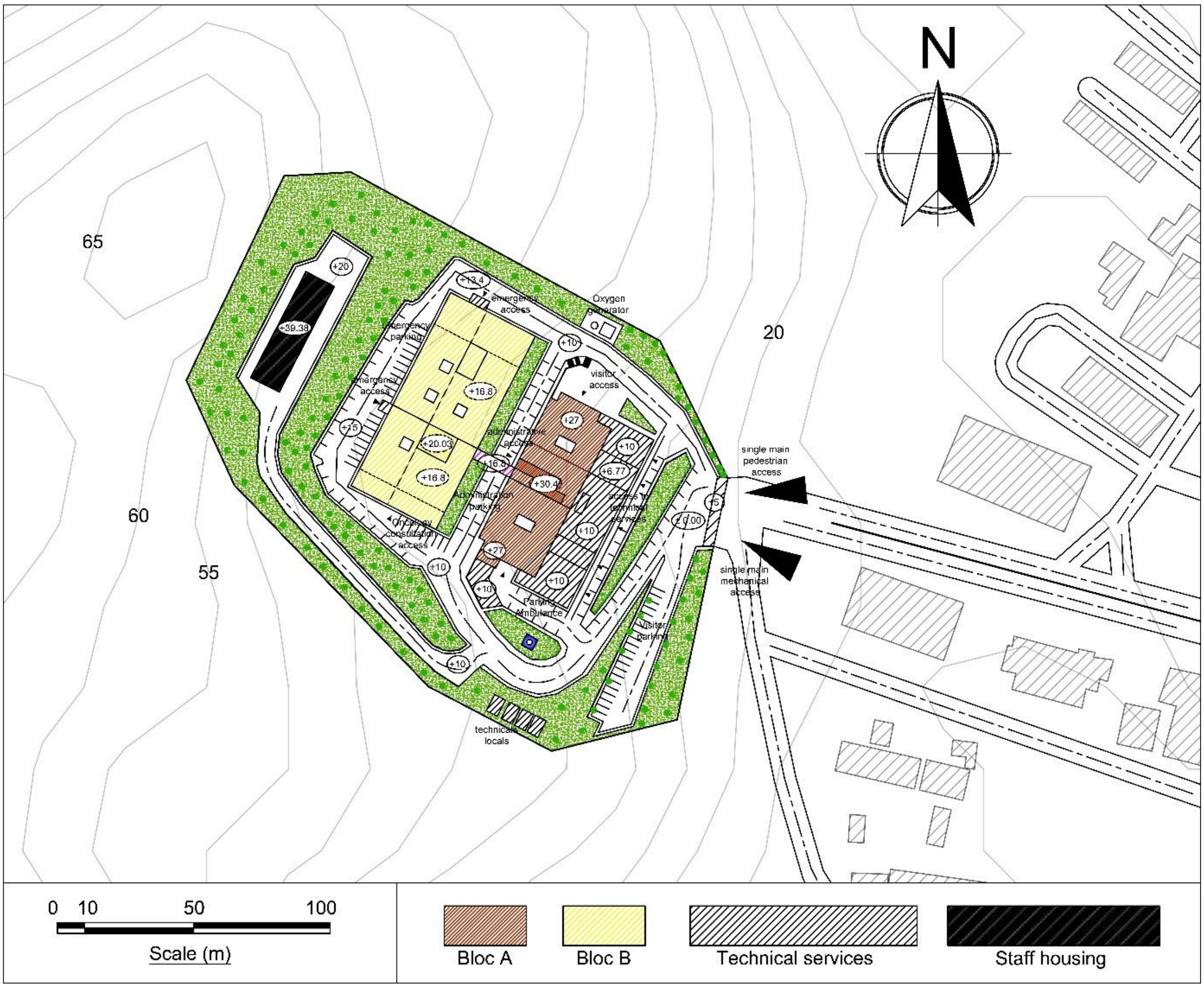

Figure 2 : Ground plan of EPH ABDEREZZAK BOUHARRA (Source: author; 2023)

This study was carried out in the Urology Department, which is located on the 1st floor in the 2nd block that houses the hospitalization services. The Department is divided into two sides (see figure 3), the men's side on the left and the women's side on the right. This division is ensured by a central space and two corridors with a width of 2.0 m each. Furthermore, in each side, this central space is itself divided by the patio into two parts: a wet sanitary part and a dry medical part. This composition allows for providing medical services to patients on both sides. This department has a current capacity of 12 beds for the men's side and of 8 beds for the women's side. It can be expanded toward its planned theoretical capacity of 15 men's beds and 15 women's beds.

Within the ward, there are two typologies of patient rooms in relation to size and capacity: rooms with three beds measuring 20.3 m² and rooms with two beds measuring 17.5 m².

However, all the rooms occupy the façade sides of the department. Specifically, there are rooms with a South-East orientation, which overlook the main and only entrance to the EPH and have an

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expansive view of the city. Additionally, there are rooms with a North-West orientation, which overlook the car park and the entrance to the administration and the emergency services.

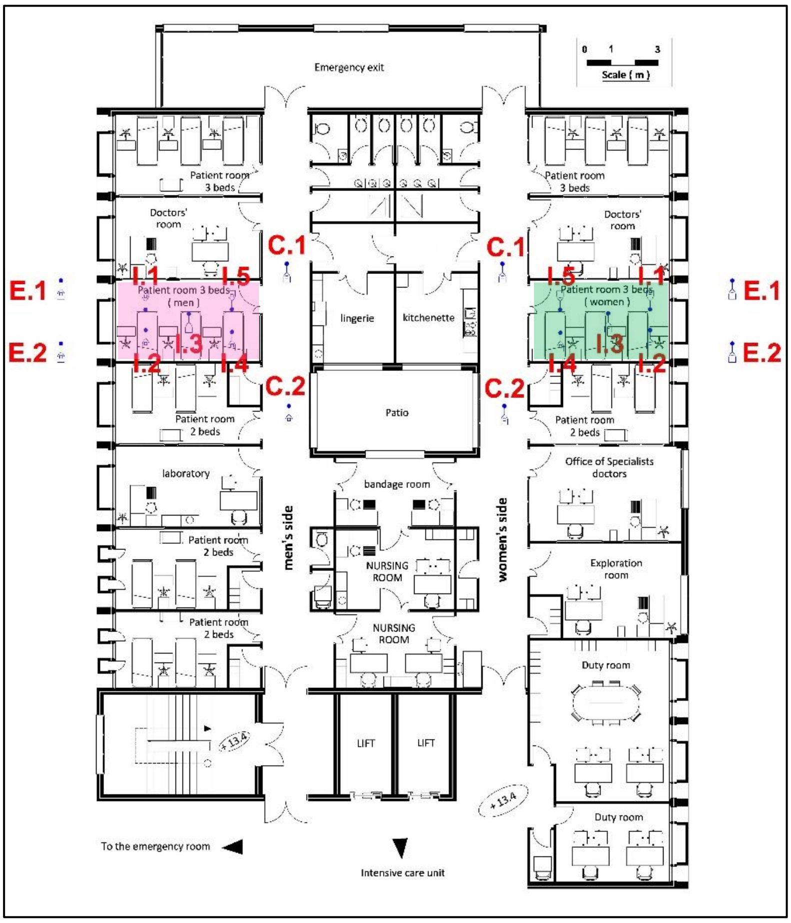

Figure 3 : Plan of the urology department with the positions of various noise measurement points (Source: Author; 2023)

3-2- In situ acoustic measurements

Due to the challenging and complex survey context of hospital, and based on interviews with workers and the latest statistics provided by the healthcare facility EPH Abderezzak Bouharra (see figure 1), noise measurements were conducted in a quieter and less frequented department, either by hospitalized patients or visitors. This approach ensures the smooth progress of the measurements and aims to avoid hindering the patients' healing process. The chosen department for these measurements was the Urology Department.

In accordance with ISO 16283-1:2014 standards, acoustic measurements were conducted using a class 2 integrating sound level meter Sauter Sw-2000 (see Figure 4). The sound level meter was equipped with a calibration certificate issued on 06/09/2021. To enhance precision, the sound level meter was calibrated before each series of measurements using the class 1 calibrator PCE-SC 42, following the calibration procedures outlined in IEC 942.

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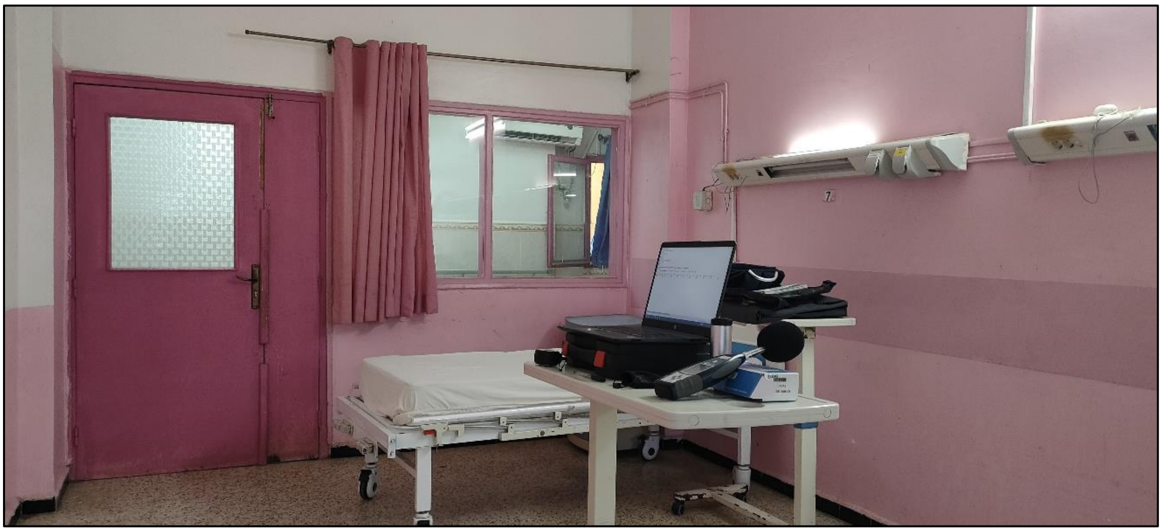

Figure 4 : The Sauter SW-2000 Class 2 integrating sound level meter and the PCE-SC 42 Class 1 calibrator used for noise measurements. (Source: author; 2023)

For measurements inside patient rooms, the sound level meter was positioned at a height of 1.5 m (see figure 5), and 1m from reflective surfaces such as walls. In the corridor, the sound level meter was also placed at a height of 1.5 m from the ground to simulate the position of a standing person, and in the centre of the corridor, 1m from reflective surfaces. Exterior measurements were taken through the window, with the sound level meter fixed on a stick at a height of 1.5 m from the ground and 1 m from the facade to capture external noise incidents on the facade.

For each period, sound pressure levels in L_{Aeq} were measured at five points inside the room, two points in the corridor, and two outside on the façade (see figure 3). Each point was measured for 2 minutes, and the results were averaged to obtain the L_{Aeq} of 10 minutes inside the room, the L_{Aeq} of 4 minutes in the corridor and the L_{Aeq} of 4 minutes on the façade.

Figure 5 : A photo of measurements taken in the patient room of the urology department when it is unoccupied on Fridays. (Source: author; 2023)

https://doi.org/10.37896/pd92.6/92611

ISSN: 0369-8963

The measurements were carried out in May 2023 in two rooms, each with three beds, and identical in size at 20.3 m² (see figure 3). The first room on the men's side (left, in magenta) was occupied, while the second room on the women's side (right, in green) was unoccupied. Additional measurements were taken in the corridor and outside on each side.

Each room, along with its corridor and exterior, was measured for a week on two weekend days (Friday and Saturday) and two weekdays (Monday and Tuesday). Measurements were taken at four time slots each day: in the morning (between 9 a.m. and 11 a.m.), at noon (between 1 p.m. and 2 p.m.), in the evening (between 7 p.m. and 8 p.m.), and during the night period (between 11 p.m. and 12 a.m.).

To obtain L_{Aeq}/daytime and L_{Aeq}/nighttime levels, measurements in the morning and noon, evening and night were averaged, respectively. This resulted in a daytime measurement of 20 minutes inside the room, 8 minutes in the corridor, and 8 minutes on the façade for each day, and a nighttime measurement of 20 minutes inside the room, 8 minutes in the corridor, and 8 minutes outside for each day.

To calculate overall L_{Aeq}/daytime and L_{Aeq}/nighttime levels for the four days of measurements for each case, the levels of L_{Aeq}/daytime and L_{Aeq}/nighttime were averaged. This resulted in a daytime measurement of 80 minutes inside the room, 32 minutes in the corridor, and 32 minutes outside for each day, and a nighttime measurement of 80 minutes inside the room, 32 minutes in the corridor, and 32 minutes outside for each day.

For corridor and exterior measurements, overall L_{Aeq}/daytime and L_{Aeq}/nighttime levels for the four days of measurements for each case were averaged. This resulted in 64 minutes of corridor noise monitoring and 64 minutes of outdoor noise monitoring.

For measurements inside the room, the original measurements were retained to calculate global L_{Aeq}/daytime and L_{Aeq}/nighttime levels for the four days of measurements for each case, for both the occupied and unoccupied room.

Additionally, a time history measurement in L_{Aeq} with steps of 0.1 seconds was recorded on Tuesday inside the occupied room for 10 minutes in each of the four periods of the day. This allowed for a detailed history of acoustic pressure levels, facilitating the analysis of peaks and sound events.

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4- Results and discussions

According to the recordings on Tuesday of the sound pressure level at intervals of 0.1 seconds inside the rooms of the urology department for four periods of the day, each lasting 10 minutes, the results of the measurements presented in Figure 6 show that the central periods of the day, midday and evening, represent the times when noise reaches the highest levels compared to morning and night periods in the men's rooms, which were occupied during the measurements. This is due to the large number of visitors during these periods, as they are open for unrestricted visits. For the women's room, which was unoccupied during the measurements, the results indicate that the morning, noon and evening periods follow the same trend in sound pressure level, which is higher than the levels measured during the night. This is due to variations in road noise, which is significant during rush hours and less pronounced at night. The comparison between the results of the occupied and unoccupied rooms reveals that the sound pressure levels in the occupied room are higher than those in the unoccupied room. However, the difference is more pronounced and significant during the central periods of the day, noon and evening, where the number of visitors and noise-emitting activities, such as oral discussions, telephone calls, and moving objects, is higher.

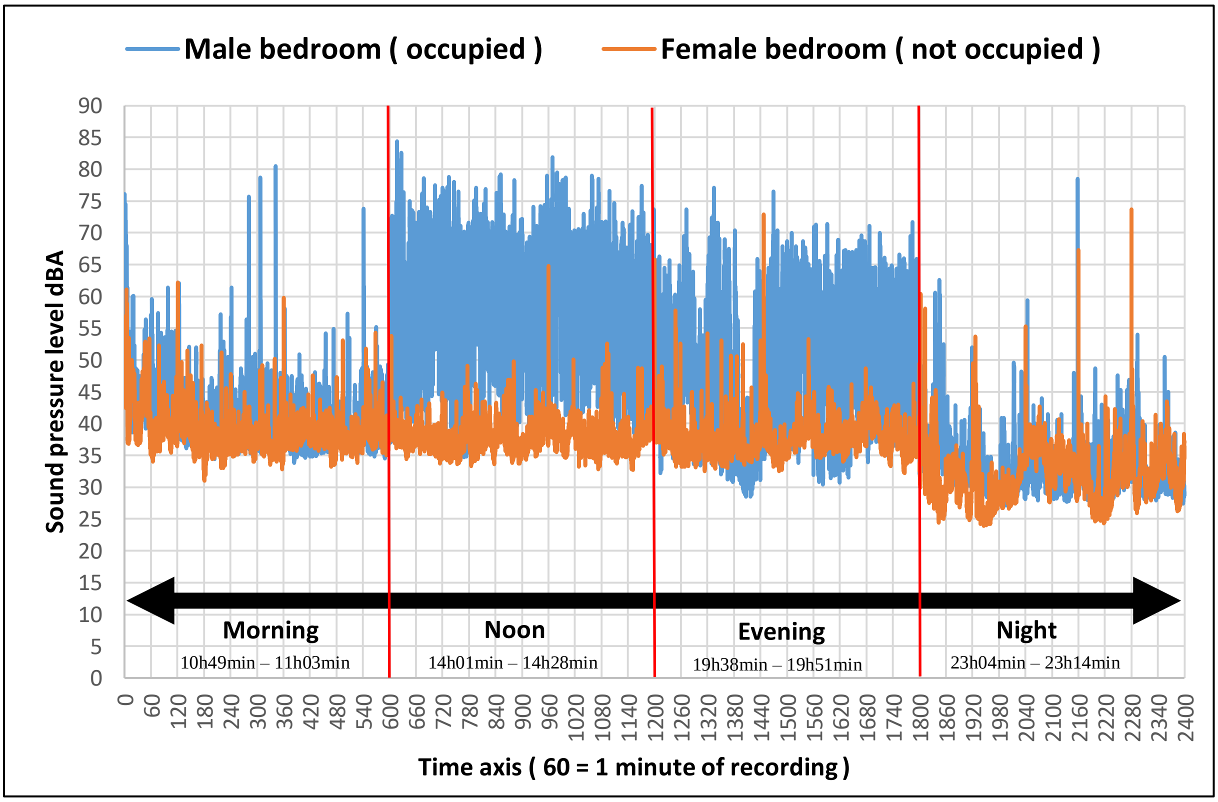

Figure 6 : Time history of sound pressure levels on Tuesday morning, noon, evening and night, (Source: author; 2023)

The results of the sound pressure level measurements during the night are the lowest compared to other periods of the day (see Figure 7). However, the analysis of SPL variations during the night indicates that there are a significant number of sound peaks, probably due to impact and shock noise.

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The high levels associated with these peaks, which exceed the background noise by more than 10 dB, may disrupt the sleep and rest of patients.

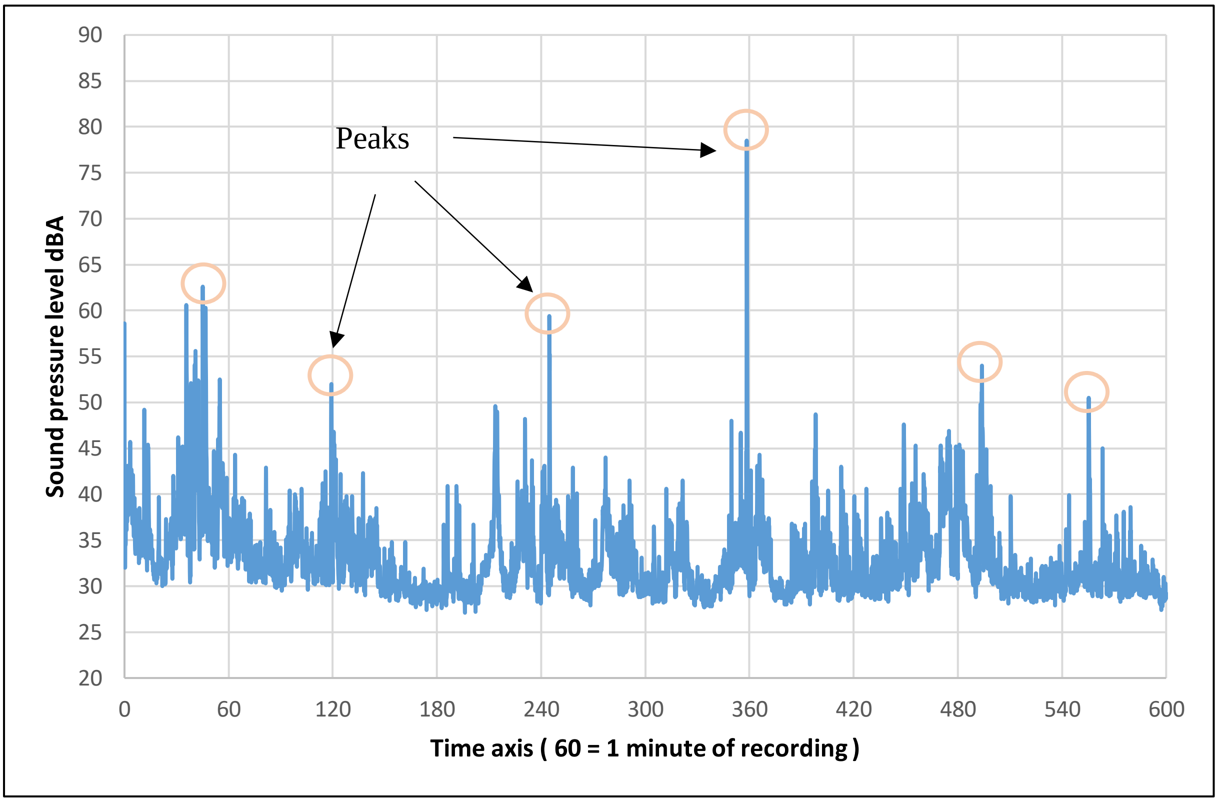

Figure 7 : Time history of sound pressure levels on Tuesday night (Source: author; 2023)

The results of measurements conducted on a weekend day (Saturday) and two weekdays (Monday and Tuesday) (Figure 8) show that the sound pressure levels (SPLs) measured in the occupied room are higher than the SPLs measured in the identically unoccupied room. In the occupied room, the SPLs measured at noon are the highest, and the SPLs measured at night are the lowest due to the remarkable contrast in noise-generating activities between the lateral and central periods. For the unoccupied room, the SPLs show less significant variation depending on weekend days and weekdays. In the results of the measurements on Saturday and Monday, the SPLs at night in the unoccupied room are higher than in the occupied room. This can be justified by the exposure of the facade of the unoccupied room to road noise, which reduces the variation between SPLmax and SPLmin, unless there are notable sound events outside. The facade of the occupied room is exposed only to sound events produced in the parking, of administration and emergency departments, which occur less frequently. The results of the measurements conducted on Friday, where both rooms are unoccupied, show less significant differences due to the reduction in activities generating noise. Road noise is also less significant on Friday, which is both a weekend day and a religious day, unlike Saturday, which is a weekend day but not religious day. During Friday, only a minimum of activities remains in operation.

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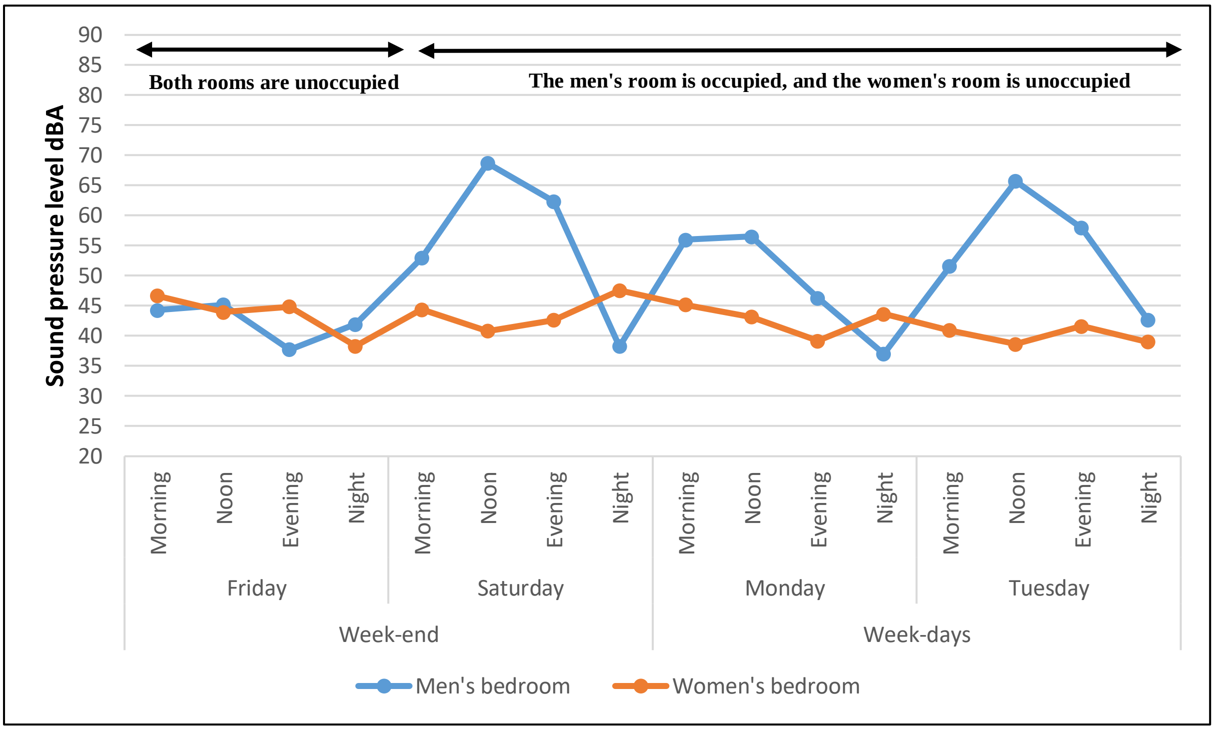

Figure 8 : Evolution of LAeq in different days and moments (Source: author; 2023)

The results in L_{Aeq}/daytime inside the occupied male room, presented in Figure 9, indicate that the measured levels exceed 94% of the studied acoustic standards with indoor limits for hospitals. This is with the exception of the Consensus Committee for Neonatal Intensive Care Unit Design standard, which has a relatively less severe threshold of 65 dBA. For the L_{Aeq}/night levels in the same occupied room, the measured levels exceed the limits of 80% of the standards analysed and are permissible for the remaining 20% of the indoor hospital standards in our study. These include the Consensus Committee for Neonatal Intensive Care Unit Design, Portuguese Decree-Law No. 9/2007 of January 17, and the Resolution of the Colombian Ministry of Health 8321 of August 4, 1983. These three standards have less severe nighttime limit values for noise in hospitals. However, other acoustic standards for hospitals, such as the WHO standard limits of 35 dBA during the day and 30 dBA during the night, are considered highly stringent and challenging to achieve, if not impossible, as indicated by several studies (Van Rompaey, 2012; Arora, 2017; Althahab, 2022).

The results of the L_{Aeq}/daytime measurements in the corridor (see Figure 10) are similar to those of the occupied men's room, exceeding 94% of the limit values of the studied standards, with the exception of the Consensus Committee for Neonatal Intensive Care Unit Design standard, which recommends a level of 65 dBA inside hospitals. These results exceed the limit values of 47% and 20% of the studied standards, with a difference of approximately 12 dBA and 2 dBA, respectively.

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For the results of nighttime measurements in the corridor, the levels comply with approximately 20% of the studied standards and exceed 80% of the standards studied that have indoor limit values, with a difference of about 8 dBA

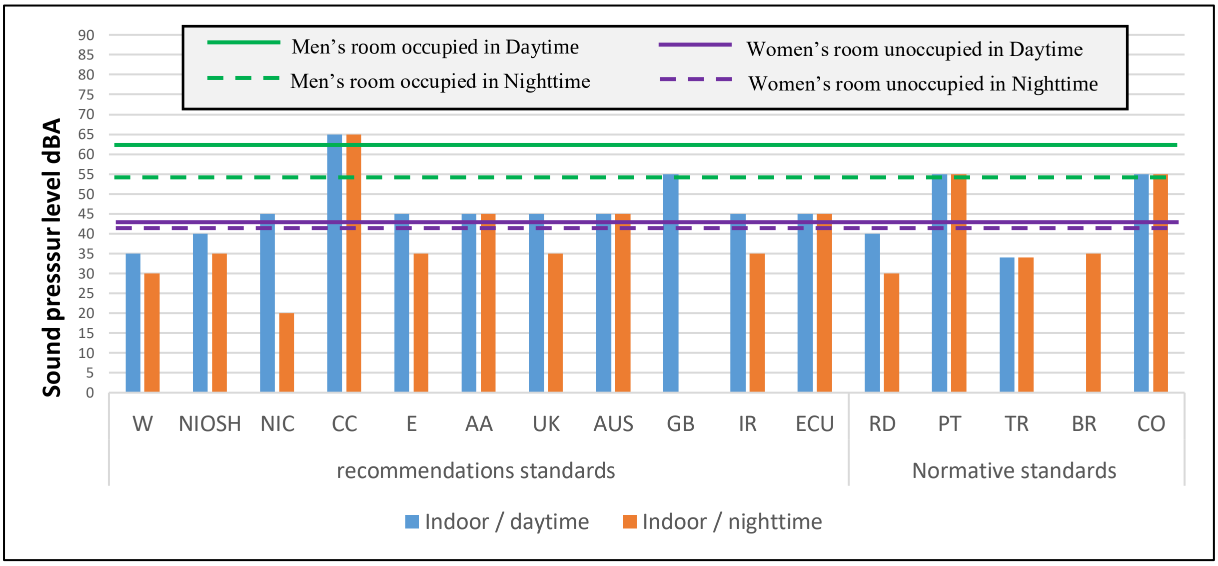

Figure 10 : comparison between SPLs measured in bedrooms and limit values according to analysed standards (source: author; 2023)

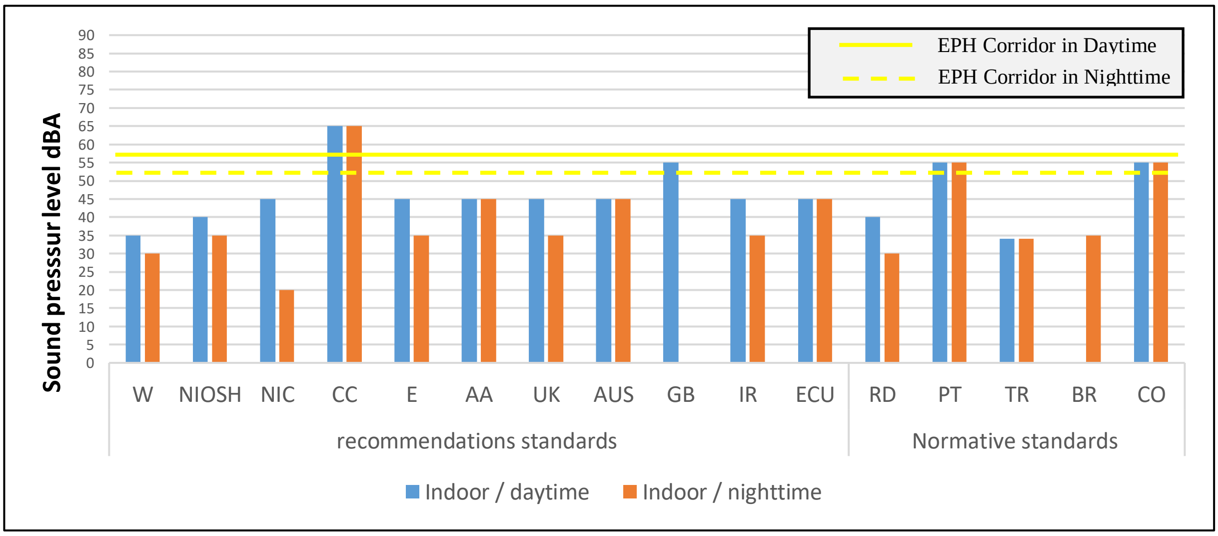

Figure 9 : comparison between SPLs measured in corridor and limit values according to analysed standards (Source: author; 2023)

For the results of exterior measurements (see figure 11), and in relation to the analysed standards which have limit values for exterior noise, the levels of the daytime period are respected according to one standards, however they exceed four standards by a difference of about 2 dBA. For the night period, the measured levels are respected by three standards, and exceed two standards by a difference of about 8 dBA and two other standards by a difference of 13 dBA. For the Algerian standard, levels measured exceed the standard by a difference of about 13 dB during both daytime and nighttime periods; however, the Algerian regulation specifies 45 dB during the daytime and 40 dB during the nighttime.

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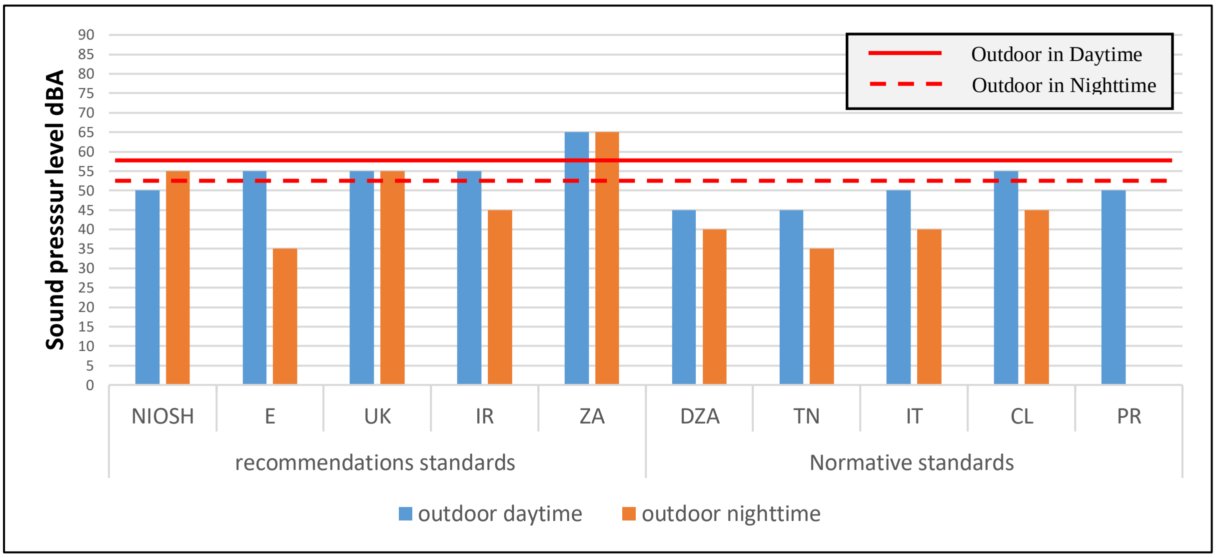

Figure 11 : comparison between SPLs measured in outdoor and limit values given by analysed standards (Source: author; 2023)

5- Conclusion

Noise has become a significant issue on both national and international scales, owing to its detrimental effects on humans and the environment. This is particularly critical in spaces requiring heightened attention, such as hospitals. Hospitals accommodate individuals more vulnerable to noise, including patients, as well as workers who require a quiet environment due to the sensitivity of their tasks. Additionally, visitors may experience stress and demoralization due to the circumstances of their loved ones.

This study carried out in the Urology Department of Abderezzak Bouharra Hospital in Skikda, Algeria, and based on the analysis of several national and international standards regarding recommended noise levels in hospitals, reveals that Algeria only has regulations concerning noise levels permissible in the immediate vicinity of hospitals. However, these regulations do not specify permissible noise levels inside hospitals and in different spaces of them.

The comparison between the results of in-situ acoustic measurement and the analysed recommended sound pressure levels shows that daytime noise levels exceed almost all the values. During the nighttime period, measured noise levels exceed 80% of the recommended values, for both occupied patient rooms and corridors.

Regarding external noise, results indicate that sound pressure levels during the day exceed nine out of ten studied standards with recommendations for permissible noise levels outside hospitals, and for the nighttime, noise levels exceed seven out of nine studied standards. The Algerian regulation specifies 45 dB during the daytime and 40 dB during the nighttime. Despite this, the measured noise

https://doi.org/10.37896/pd92.6/92611

levels exceed the limits of Algerian regulations with a constant difference of 13 dB during both the day and night periods.

On the other hand, the analysis of the time history of sound pressure levels measured at intervals of 0.1 seconds in an unoccupied room throughout the day and on weekdays and weekends reveals that measured noise levels exceed the permissible levels of certain standards, such as those set by the World Health Organization (WHO). Indeed, the WHO requirements appear stringent and challenging to achieve also in unoccupied bedrooms because of noise coming from outside and from corridors.

Based on nighttime noise level recordings, the least intense, a significant number of peaks occur within a ten-minute interval. These peaks can cause awakenings, impairing the quality of sleep and even the patient's recovery process. However, in Algeria and also in all the analysed countries, the standards used for hospital noise evaluation do not emphasize these sound events, unlike the WHO recommendations, which highlight the importance of considering the number of disturbing events.

Furthermore, comparing noise levels recorded in occupied and unoccupied rooms throughout the day shows that noise is more pronounced during the central periods of the day, around noon and in the evening, compared to the peripheral periods in the morning and at night. Nevertheless, these results also indicate that the primary source of noise is from internal activities (in the bedrooms and in the corridors).

Noise is a complex phenomenon, and its understanding requires the integration of various methods. This study provides an overview of average A-weighted sound pressure levels while a frequency analysis of noise spectra could offer more information on the noise sources and also on annoyance. The future development of this study will therefore include a spectrum analysis of noise sources and also the evaluation of acoustic isolation through different transmission paths. Simulation will also support these findings to examine the effectiveness of possible interventions.

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