BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Volumul 64 (68), Numărul 2, 2018
Secţia
CONSTRUCŢII. ARHITECTURĂ

ASSESSMENT OF THE ENVIRONMENTAL NOISE LEVEL FOR HOSPITAL BUILDINGS

BY

VLAD LUPĂŞTEANU*, COSTEL CHINGĂLATĂ and RADU LUPĂŞTEANU

”Gheorghe Asachi” Technical University of Iaşi,
Faculty of Civil Engineering and Building Services

Received: May 10, 2018
Accepted for publication: June 29, 2018

Abstract. Nowadays, the urban areas are characterized by a large number of activities that can produce high levels of noise. Moreover, if the noise level exceeds certain limits it can have negative impacts upon humans, by either affecting their comfort level or, for high intensities or long exposures, even their health. This paper presents some specific aspects regarding the noise level in urban areas and it is divided in two parts. Thus, the first part presents certain theoretical aspects of noise as a physical parameter and also, specifies the possible negative effects upon the human body, as consequence of exposure to noise which is either high in intensity or long in duration.

The second part of the paper presents a case study which consists in measurements of the environmental noise level due to external sources, transmitted inside the hospital buildings. The in-situ recorded values have been statistically processed and graphically represented. Further-more, the experimental values have been compared to the allowable ones, presented by the technical regulations. Based on the results of the case-study it was concluded that the noise level inside the analysed hospital buildings is generally higher than the allowable limit and certain improvements have to be made in order to increase the acoustic comfort degree of the direct or indirect users.

Keywords: environmental noise; acoustic comfort; acoustic measurements; hospital buildings; case study.

*Corresponding author: *e-mail:* vlad.lupasteanu@tuiasi.ro

1. Introduction

One of the typical issues facing modern society is the increase in the level of external noise, which also implies an increase in the noise level perceived inside buildings. Some of the most important sources of urban noise consist in: real estate or industrial development, increasing number of motor vehicles, urban infrastructure development etc. Since most of the noise which is produced in the urban areas is transmitted inside the surrounding buildings, the acoustic comfort degree of the direct or indirect users can be strongly affected.

From a physical point of view, sound is defined as a variation in pressure (from air, water) that can be perceived by the human ear. Also, noise is defined as a disordered overlap of sounds characterized by different intensities and frequencies. Generally, the human ear perceives sounds with frequencies in the range of 16 ÷ 20,000 Hz, but it has been concluded that the upper limit of the interval decreases with age (Enescu *et al.*, 1998). The intensities of the noise which can be perceived by the human hearing system is within the range of 0 ÷ ÷ 130 dB. The noise considered at the upper limit of this range is characteristic for aviation or industry fields (jet engine - 130 dB, pneumatic hammers - 120 dB) and can cause irreversible damage to the hearing system. Values ranging from 80 ÷ 110 dB can cause temporary hearing damage, and those in the 20 ÷ ÷ 70 dB range are considered to be acceptable (Ştefănescu & Velicu, 2009).

When encountering an obstacle, the acoustic wave undergoes certain changes in its characteristics and in the direction of propagation. Thus, the total sound energy is composed by the reflected sound energy (E_r), the energy absorbed by the building element (E_a) and the energy transmitted through the building element (E_t) respectively, as shown in:

$$E = E_r + E_a + E_t. \tag{1}$$

This paper presents some aspects regarding the noise level specific to civil buildings located in urban areas and certain particularities related to the methods of measuring the noise level inside buildings. Also, in the second part of the paper, a case study is presented, consisting in experimental measurements of the environmental noise level inside three hospital buildings, located in Iasi city.

2. Negative Effects of Noise Upon the Human Body

The acoustic noise level is expressed in decibels, while the sounds are usually measured based on the A, B or C weightings, depending on their frequency. In the Romanian technical norms, simplified noise curves are used, denoted C_z. The allowable values of the noise level inside buildings due to external sources are expressed in decibels A-weighted, being the nominal value, and with respect to the corresponding noise curve, C_z (Ghiocel *et al.*, 1985; C 125-1/2013).

In order to determine the negative effects that noise can have upon humans, complex experimental programs have been conducted so far. Thus, it has been concluded that long-term exposure to high or excessive noise levels may cause increased blood pressure, hearing, cardiac and/or respiratory damages, may induce irritation/impatience and may decrease performance in all domains of activity (Ampt *et al.*, 2008). Other studies have attempted to determine the impact of noise exposure upon the immune system and new-born diseases, but their confidence is still limited (Passchier-Vermeer & Passchier, 2000), since it can be possible that the reaction of a new-born to different sounds may represent a way of accommodation to the noisy environment (Morris *et al.*, 2000).

In 1999, the World Health Organization (WHO) publishes the "Guidelines for community noise", which also presents some requirements specific to the hospital buildings. Thus, the WHO experts concluded that the high level of noise in most of the functional units of the hospital buildings, has a negative impact upon patients, generally causing irritation, sleep disturbance and communication interference (Wiese, 2010).

3. Noise Protection – an Essential Quality Requirement

The protection against noise is one of the 7 essential quality requirements, denoted with „E" in Law no. *10*/1995 with its subsequent amendments, which must be fulfilled by all constructions that are made in Romania. Furthermore, this quality requirement is also presented in Code NC 001/1999, where specific performance requirements are established with respect to the configuration of the construction elements in order to satisfy the necessary conditions.

Thus, constructions must be designed, executed and operated based on these minimum performance requirements in terms of acoustic protection. However, when analysing the life cycle of a building, the design stage is probably the most important one because it represents the phase when all noise sources, both external and internal, must be evaluated for each functional unit of the building. Next, depending on their particular requirements, the allowable noise limits are selected or calculated based on the provisions of the corresponding technical norms. The final step consists in establishing the appropriate configuration of the construction elements in order to satisfy all necessary performance requirements in terms of acoustic protection and comfort. The process of designing the configuration of the construction elements for any functional unit can be divided in 4 phases, as presented in Fig. 1.

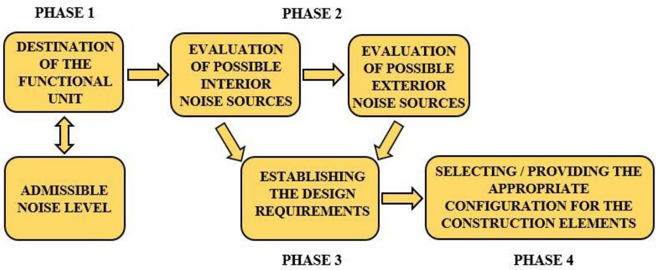

Fig. 1 – Acoustic design phases for a functional unit.

4. Case Study – *In-Situ* Measurements of Noise Level Inside the Hospital Buildings

4.1 Measurements Methodology

For this case study, three hospital buildings located in Iaşi have been analysed and are generally denoted in this paper by H1, H2 and H3. For these buildings, several types of functional units have been selected, three of them being common to all investigated hospitals (2-beds hospital wards, 3 or more beds hospital wards and examination / treatment offices) and the other two (conference hall and dining hall) belonging to H1 or H2 buildings, respectively.

The assessment of the noise level inside the hospital buildings was carried out according to SR 6161-1/2008 - *"Building acoustics. Part 1: Noise level measurement in buildings. Measuring methods"* and SR ISO 1996-2/2008 – *"Acoustics – Description, measurement and assessment of environmental noise. Part 2: Determination of environmental noise levels"* standards.

The device which was used during the acoustic measurements consists in a sound level meter and a calibrator, both having the performance class 2, fulfilling the requirements of SR EN 61672-1/2014. All measurements were made with respect to the reference frequency of the sound level meter (1,000 Hz, A-weighted). In order to obtain recorded values with a high degree of accuracy, the sound level meter was calibrated in each day of the investigations, at the beginning, during and at the end of the recording process.

Since the interior volume of the functional units in which the acoustic measurements have been performed ranged between 20 to 200 m^3, only five distinct locations were applied in each unit for recording the noise level (Fig. 2). In each location, the sound level meter recorded the noise level for 35 minutes and the final values were obtained by averaging the peak values recorded every 5 minutes. The aim of the sound measurements consisted in determining the noise level produced by the external sources of noise. For this reason, during the sound recording stage, all functional units were not occupied by the patients or medical staff and all doors/windows were kept closed. The sound level meter was positioned at a height of 1.30 m from the floor level and at a distance of 1 meter from the marginal walls, in order to avoid possible sound interferences.

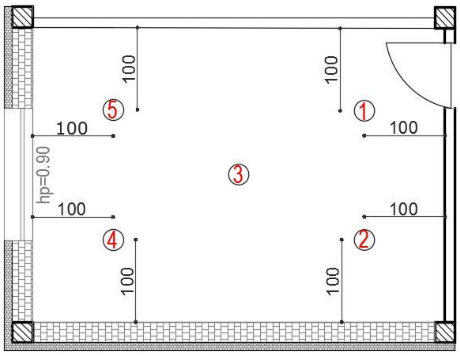

Fig. 2 – Example of functional unit and recording locations.

4.2. Buildings Description

For this case study three hospital building were selected, all being located in Iaşi. The geometrical and constructive properties of investigated buildings are presented in Table 1.

Table 1
Geometrical and Constructive Characteristic for the Investigated Hospitals

Characteristic	H1	H2	H3
No. of floors	B+G+7F	B+G+10F	G+4F
Structural system	two-way R.C. frames and slabs		
Maximum dimensions in plan [m]	29.00 × 19.00	27.00 × 25.80	24.00 × 19.00
Exterior walls	20 cm thick ACC masonry	24 cm thick hollow brick masonry	
Interior walls	12.5 cm thick, 2 gypsum panels fixed on light metallic frame and 10 cm of mineral wool		
Types of doors	Exterior – aluminium Interior – MDF	Aluminium	
Types of windows	Aluminium frame and double-glazed windows		
Interior finishing layers (walls, ceilings)	Smooth finishing, 1 cm lime-based plaster and antibacterial paint		
Floors	PVC antibacterial		
Exterior finishing layers for walls	2 cm of cement-based plaster and paint		

All three buildings are located near local roads and the minimum distances between the axis of the roads and the buildings are 9.5 m for H1, 5.5 m for H2 and 19.3 m for H3. Also, each building has parking areas, on one side for H1 and H2 and on two sides for H3. During the stage of recording the interior noise level produced by outside sources, near H2 building (approximately 100 m distance, at the right facade) dismantling works were carried out for a R.C. building, using heavy specific equipment (hydraulic jackhammers, excavators, trucks etc.). For H1 and H3 buildings, during the sound level recording stage, no special activities were carried out in its proximity that could generate important sources of noise. Table 2 presents the allowable values for the environmental noise level due to external noise sources for different functional units inside hospitals.

Table 2

Allowed values of environmental indoor noise level for functional units in hospitals

No.	Functional unit	Admitted noise level, [dB (A)]		
		Romanian norm C 125-3/2013	WHO*	HTM 08-01**
1	2 beds hospital ward	30	30	40
2	3 or more beds hospital wards	35	30	45
3	Intensive care unit	35	As low as possible	35
4	Examination/treatment office	35	30	40
5	Conference halls	35	35	35 (area > 35 m^2) 40 (area ≤ 35 m^2)
6	Dining hall	45	–	50

*WHO – World Health Organization; **HTM – Health Technical Memorandum

4.3. Noise Level Assessment

The case study aims to assess the environmental noise levels within certain functional units inside hospital buildings and to compare the in-situ recorded values with those provided by technical regulations in the field of acoustics. The investigations were carried out according to the methodology described in subchapter 4.1. Subchapters 4.3.1, 4.3.2, 4.3.3. and 4.3.4 present the results of the experimental program and compare the recorded values with the allowable ones, with respect to each functional unit that was analysed.

4.3.1. *Noise Level Assessment – 2 Beds Hospital Wards*

For each hospital, the recordings were made in three distinct wards positioned at different levels and at different locations with respect to the sides of the buildings. The in-situ noise levels are presented in Fig. 3 together with the allowable limit and their statistical interpretation is presented in Table 3.

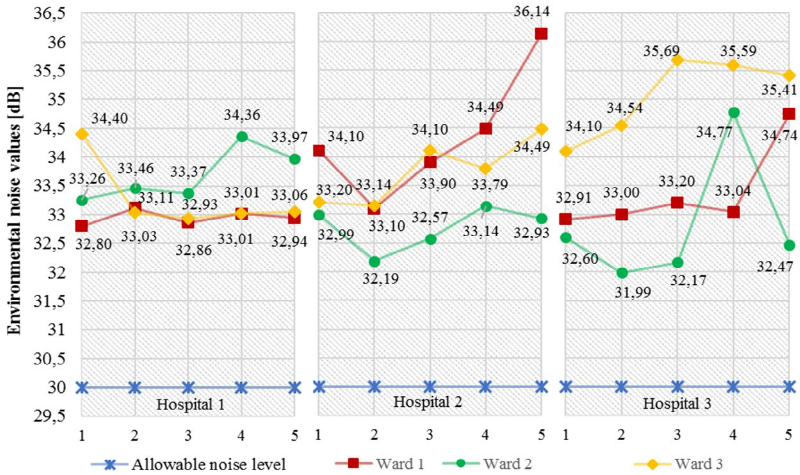

Fig. 3 – Recorded noise levels – hospital wards with 2 beds.

Table 3
Statistical interpretation – hospital wards with 2 beds

No	Hospital	Functional unit	Recorded noise values			Statistical parameters	
			Min [dB]	Max [dB]	Average [dB]	RMSE [dB(A)]	MAPE [%]
1	H1	Ward 1 – 4th floor, right facade	32.1	34.2	32.94	2.95	9.82
		Ward 2 – 4th floor, main facade	32.3	36.2	33.68	3.71	12.28
		Ward 3 – 4th floor, left facade	32.6	38.4	33.28	3.33	10.95
2	H2	Ward 1 – 8th floor, main facade	32.5	37.5	34.34	4.46	14.49
		Ward 2 – 2nd floor, main facade	31.7	35.8	32.76	2.78	9.21
		Ward 3 – 4th floor, main facade	32.7	36.7	33.74	3.78	12.48
3	H3	Ward 1 – 4th floor, right facade	32.2	38.3	33.38	3.45	11.27
		Ward 2 – 4th floor, main facade	31.7	36.0	32.80	2.98	9.33
		Ward 3 – 4th floor, left facade	33.8	38.4	36.07	5.10	16.89

4.3.2. *Noise Level Assessment – 3 or More Beds Hospital Wards*

Only H1 and H2 hospital have wards with three or more beds. For the latter, the recordings were made in two distinct wards positioned at different levels and at different locations with respect to the sides of the buildings. The in-situ noise levels are presented in Fig. 4 together with the allowable limit. The statistical interpretation of these values is presented in Table 4.

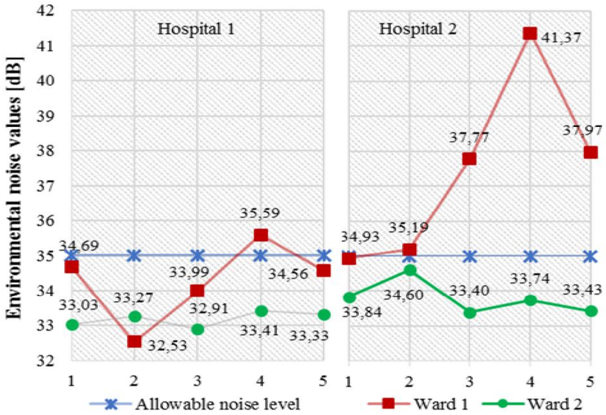

Fig. 4 – Recorded noise levels – hospital wards with 3 or more beds

Table 4

Statistical interpretation – hospital wards with 3 or more beds

No	Hospital	Functional unit	Recorded noise values			Statistical parameters	
			Min [dB]	Max [dB]	Average [dB]	RMSE [dB(A)]	MAPE [%]
1	H1	Ward 1 (3 beds) – 4th floor, main facade	32.0	46.6	34.27	1.24	2.76
		Ward 2 (5 beds) – 2nd floor, left facade	32.6	36.2	33.19	1.82	5.17
2	H2	Ward 1 (5 beds) – 8th floor, right facade	33.4	42.4	37.45	3.38	7.07
		Ward 2 (5 beds) – 8th floor, rear facade	32.8	34.6	33.80	1.27	3.42

4.3.3. *Noise level assessment – examination/treatment offices*

The recordings were made for each hospital in two distinct offices, positioned at different levels and at different locations with respect to the sides of the buildings. The in-situ noise levels are shown in Fig. 5 together with the allowable limit and their statistical interpretation is presented in Table 5.

Table 5

Statistical Interpretation – Examination/Treatment Offices

No	Hospital	Functional unit	Recorded noise level			Statistical parameters	
			Min [dB]	Max [dB]	Average [dB]	RMSE [dB(A)]	MAPE [%]
1	H1	Office 1 – 4th floor, main facade	34.7	40.1	36.94	2.07	5.54
		Office 2 – 4th floor, rear facade	35.1	39.3	37.15	2.20	6.14
2	H2	Office 1 – ground floor, main facade	34.4	40.5	36.14	1.18	3.25
		Office 2 – 2nd floor, main facade	32.3	36.2	33.54	1.48	4.18
3	H3	Office 1 – 2nd floor, right facade	37.7	43.6	39.20	4.26	12.01
		Office 2 – 2nd floor, rear facade	32.8	36.6	33.46	1.60	4.39

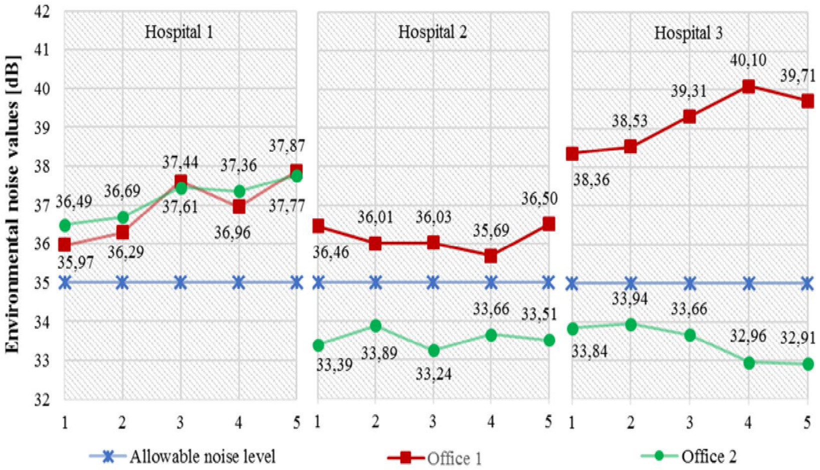

Fig. 5 – Recorded noise levels – examination/treatment offices.

4.3.4. *Noise Level Assessment – Distinct Functional Units*

Other function units which were analysed consisted in a conference hall, specific to H1 building, and a dining hall, specific to H2 building. The in-situ recorded noise levels for these functional units are presented in Fig. 6 together with the corresponding allowable values, while their statistical interpretation is presented in Table 6.

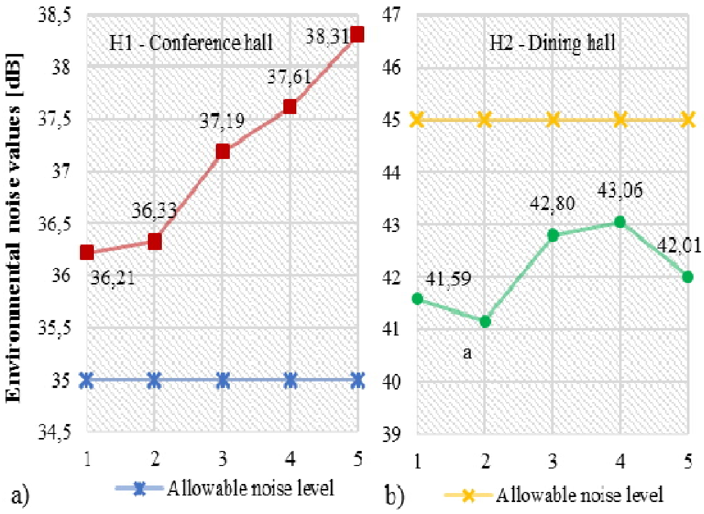

Fig. 6 – Recorded noise levels: a) conference hall (H1); b) dining hall (H2).

Table 6
Statistical Interpretation – Distinct Functional Units

No	Hospital	Functional unit	Recorded noise values			Statistical parameters	
			Min [dB]	Max [dB]	Average [dB]	RMSE [dB(A)]	MAPE [%]
1	H1	Conference hall – 7th floor, right facade	35.5	39.4	37.13	2.27	6.09
2	H2	Dining hall – underground level, rear facade	38.6	46.6	42.12	2.96	6.39

5. Conclusions

By analysing the recorded values of the noise levels for the 2 bed hospital wards (Table 3 and Fig. 3), it can be concluded that for all three buildings the in-situ values are higher than the allowable ones. Based on the statistical interpretation, the lowest average values for the noise level were recorded for H1 (average value of 33.3 dB) and for H2 (average value of 33.61 dB). The highest noise value was recorded for H3 building, with an average level of 34.08 dB.

For hospital wards with 3 or more beds, by analysing Fig. 4 and Table 4, it can be concluded that the recorded values are generally lower when compared to the allowable ones. Exception makes the hospital ward 1 of H2, for which the average recorded value is 37.45 dB. These high values were recorded when construction works were carried out on the site near the building, by using heavy specific equipment.

For the examination/treatment offices, the noise limit is exceeded for H1 and H3 buildings, with average recorded noise values of 37.05 dB and 36.33 dB respectively. For H2, the average value for the two investigated offices is 34.84 dB, having the largest value for the examination office 1, positioned towards the main facade (average value of 36.14 dB).

For the conference hall within H1, the inside recorded values are higher than the allowable ones (average value of 37.13 dB). The cause of these increased values may be the envelope closing solution, which consists in glass panels on three sides of the functional unit, having lower acoustic damping capacity when compared to the conventional brick or ACC masonry. For the dining room in H2 building, the recorded values are lower than the acceptable ones, with average value of 42.12 dB, due to its position at the underground level of the hospital.

By analysing the results of the experimental program, it can be concluded that the recorded values inside the hospital buildings are generally higher compared to the allowable ones, especially for hospital wards with 2 beds and for the examination/treatment offices. Also, high values were recorded for the functional units positioned near the facades adjacent to the streets, due to traffic noise. The difference between the acoustic levels for these units and the ones having same function but being positioned near the opposite façade, is between 1 and 3 dB. Some of the factors that have a negative impact upon the acoustic comfort inside the analysed functional units consist in: the acoustic properties of the materials that are used for the envelope/partitioning walls, the special exterior activities that are generating noises having levels above the allowable ones, the traffic intensity, the properties and the physical condition of the road wear material.

For keeping the noise levels within the allowable limits, some improvements are recommended in order to increase the amount of absorbed sound energy. Some of the suitable interventions refer to: replacing the sealing gaskets of the exterior doors and windows, replacing the interior finishing layers with ones that have rough surface and low density (porous plaster), boarding the walls (at the interior side) with high acoustic absorption elements (mineral wool, felt or porous ceramic tiles) or providing new exterior windows and doors that have superior sound insulation properties.

REFERENCES

Ampt A., Harris P. and Maxwell M., *The Health Impact of the Design of Hospital Facilities on Patient Recovery and Wellbeing, and Staff Wellbeing: a Review of Literature*, Centre for primary health Care and Equity, University of New South Wales, Sydney, 2008.

Enescu N., Magheţi I., Sârbu M.A., *Acustică Tehnică*, Edit. ICPE, Bucureşti, 1998.

Ghiocel D., Dabija F., Ispas M., Demir V., Asanache H., Darie M., Nicolau V., Popescu L., Vierescu R., *Construcţii civile*, Edit. Didactică şi Pedagogică, Bucureşti, 1985.

Morris B., Philbin K., Bose C., *Psychological Effects of Sound to the Newborn*, Journal of Perinatology, *20*, 54-59 (2000).

Passchier-Vermeer W., Passchier W.F., *Noise Exposure and Public Health*, Environmental Health Perspectives, vol. 108, Supplement 1, March 2000.

Ştefănescu D., Velicu C., *Fizica construcţiilor*, Edit. Societăţii Academice „Matei Teiu Botez", Iaşi, 2009.

Wiese C., *Investigation of Patient Perception of Hospital Noise and Sound Level Measurements: Before, During and After Renovations of a Hospital Wing*, A thesis University of Nebraska-Lincoln, August 2010.

* * * *Acustică – Descrierea, măsurarea şi evaluarea zgomotului din mediul ambiant. Partea 2: Determinarea nivelurilor de zgomot din mediul ambiant*, SR ISO 1996-2:2008, 2008.

* * * *Acustica în construcţii. Partea 1: Măsurarea nivelului de zgomot în construcţii civile. Metode de măsurare*, SR 6161-1:2008, 2008.

* * * *Department of Health. Health Technical Memorandum 08-01: Acoustics,* 2013.
* * * *Electroacustică. Sonometre. Partea 1: Specificații*, SR EN 61672-1:2014, 2014.
* * * *Legea privind calitatea în construcții*, Legea 10:1995, republicată 2018.
* * * N*ormativ cadru privind detalierea conținutului cerințelor stabilite prin Legea 10/1995*, Indicativ NC 001:1999.
* * * *Normativ privind acustica în construcții şi zone urbane. Partea I – Prevederi generale privind protecția împotriva zgomotului*, Indicativ C 125-1/2013.
* * * *Normativ privind acustica în construcții şi zone urbane. Partea III – Măsuri de protecție împotriva zgomotului la clădiri de locuit, social-culturale şi tehnico-administrative,* Indicativ C 125-3/2013.
* * * *World Health Organization. Guidelines for community noise*, Technical Report WHO, 1999.

EVALUAREA NIVELULUI DE ZGOMOT DIN MEDIUL AMBIANT LA CLĂDIRI PENTRU ACTIVITĂȚI SANITARE

(Rezumat)

În prezent, zonele urbane sunt caracterizate de un număr ridicat de activități care pot produce nivele ridicate de zgomot. În plus, dacă nivelul zgomotului depăşeşte anumite limite, acesta poate avea efecte negative asupra oamenilor, afectând fie nivelul de confort sau, pentru intensități mari sau expunere îndelungată, sănătatea acestora. Această lucrare prezintă câteva aspecte specifice cu privire la nivelul de zgomot în zonele urbane şi este împărțită în două părți. Astfel, prima parte prezintă anumite aspecte teoretice ale zgomotului ca parametru fizic şi, de asemenea, precizează posibilele efecte negative asupra corpului uman, ca urmare a expunerii la zgomot de intensitate ridicată sau pentru o durată îndelungată.

A doua parte a lucrării prezintă un studiu de caz care constă în măsurarea nivelului de zgomot din mediul ambiant datorat unor surse de zgomot exterioare, transmis la interiorul spitalelor. Valorile înregistrate in-situ au fost prelucrate statistic şi reprezentate grafic. Mai mult, valorile experimentale au fost comparate cu cele admise, prezentate de reglementările tehnice. Pe baza rezultatelor studiului de caz s-a concluzionat că nivelul zgomotului din spitalele analizate este, în general, mai mare decât limita admisibilă şi sunt necesare anumite lucrări de intervenție pentru a creşte gradul de confort acustic al utilizatorilor direcți sau indirecți.