

Noise in Collective Residential Buildings: A Qualitative Survey in the Champs de Manoeuvre Neighbourhood in Guelma

الضوضاء في المباني السكنية الجماعية: استطلاع نوعي في حي Champs de Manoeuvre في قلمة

Le bruit dans les bâtiments résidentiels collectifs : Une enquête qualitative dans la cité de Champs de Manoeuvre à Guelma

Ali, BOULEMAREDJ^{*1} ; Fatma Zohra, HARIDI² ; Amel, SAIFI³

Date of submission :13/02/2023

- Date of acceptance: 21/06/2023

- Date of edition: 15/12/2023

ملخص:

واحدة من أكثر القضايا انتشارًا التي يعاني منها الأفراد في مساكنهم هي الضوضاء. إنها قضية طبية واجتماعية وبيئية. الهدف من هذه الدراسة هو تقييم مصادر الضوضاء ودرجة الانزعاج التي يشعر بها سكان المباني السكنية في حي Champs de Manoeuvre في قلمة من أجل زيادة الوعي بمخاطر الضوضاء. تستند منهجية الدراسة إلى نهج نوعي باستخدام مسح اجتماعي لـ 60 شخصًا قريبًا من أصل 80. كشف تحليل إجابات المستجيبين عن التأثير الصحي السلبي للضوضاء، حيث يعاني 5/4 منهم من الإجهاد والغضب داخل مساكنهم، ويرجع ذلك أساسًا إلى ضوضاء الجيران والطريق، حيث من المحتمل أن يصل الأخير إلى مستويات الصوت فوق العتبات التي أوصت بها القوانين الصوتية الجزائرية. **الكلمات المفتاحية:** التلوث الضوضائي؛ التأثير الصحي؛ القوانين الصوتية الجزائرية؛ قلمة.

Abstract:

One of the most prevalent issues that individuals have in their households is noise. It is a medical-social and environmental issue. The goal of this study is to assess the sources of noise and the degree of discomfort felt by residents of residential buildings in the Champs de Manoeuvre neighbourhood of Guelma, in order to increase awareness of the dangers of noise. The study's methodology is based on a qualitative approach using a sociological survey of 60 nearby people out of 80. Analysis of the respondents' answers revealed the negative health impact of noise, with 4/5 of them experiencing stress and anger inside their households, primarily as a result of neighbor and road noise, where the latter probably reached sound levels above the thresholds recommended by Algerian acoustic regulation.

Keywords: noise pollution; health impact; Algerian acoustic regulation; Guelma.

Résumé :

Le bruit est l'un des problèmes les plus répandus dans les logements. Il s'agit d'une question médico-sociale et environnementale. L'objectif de cette étude est d'évaluer les sources de bruit et le degré de gêne ressentie par les habitants des immeubles résidentiels du quartier des Champs de Manoeuvre à Guelma, afin de les sensibiliser aux dangers du bruit. La méthodologie de l'étude est basée sur une approche qualitative à travers une enquête sociale auprès de 60 riverains sur 80. L'analyse des réponses des personnes interrogées a révélé l'impact négatif du bruit sur la santé, 4/5 d'entre eux ressentant du stress et de la colère à l'intérieur dans leurs logements, principalement à cause du bruit du voisinage et de la route, où ce dernier atteignant probablement des niveaux sonores supérieurs aux seuils recommandés par la réglementation acoustique algérienne.

Mots clés : pollution sonore; impact sanitaire ; réglementation acoustique algérienne; Guelma.

* Corresponding author.

¹ بولمارج علي، University of 8 mai 1945 Guelma, LGCH: Algeria, boulemaredj.ali@univ-guelma.dz

² حريدي فاطمة الزهراء، University of 8 mai 1945 Guelma: Algeria, haridi.fatmazohra@univ-guelma.dz

³ صيفي امال، University of 8 mai 1945 Guelma, LGCH: Algeria, saifi.amel@univ-guelma.dz

Introduction:

Noise pollution is acknowledged as an environmental issue and a social health concern in all nations, and residents perceive it as a threat to their mental health and well-being as well as a crucial component of housing quality. Buildings are constructed in accordance with regulations established by public authorities and experts in order to improve user comfort. These professionals are supposed to have a complete awareness of user wants and expectations (Gopikrishnan & Topkar, 2017).

1- Noise and health context

This menace has received attention increasingly as an essential subject in a number of research-action surveys and clinical diagnoses on metropolitan population. As a result, it is demonstrated that noise's negative impacts are multidimensional since the prevalence of hearing impairments is always rising (Nassur, 2018)

People who live in places where the Lday (Sound level during daytime) is more than 65 dB may experience a rise in blood pressure similar to that caused by traffic noise. According to research by (Bodin et al., 2009), excessive hormone releases like those caused by cortisol or catecholamines (dopamine, adrenaline) could have negative effects on the heart when a state of stress is brought on by noise exposure. It was also discovered that the amount of noise causes discomfort, aggravation, and intrusion in homes. In a study on cortisol as a stress marker, (Bluhm & Eriksson, 2011) noted that women who were exposed to airborne noise levels above 60 dB in the morning saw a considerable rise in cortisol levels in their bodies.

Surveys done in Europe, notably in Germany, found that more than 75% of the population was annoyed by noise annoyance generated mostly by traffic noise, according to the Williams working group (Williams et al., 1998). Furthermore, the impacts of irritation include private discontent, public complaints to authorities, and the previously described bad health implications. Because annoyance can be more than a little irritant, it refers to a major decrease in quality of life, which correlates to a decrease in health and well-being (Jariwala et al., 2017). Also, statements by (Cynthia Mclemore & Alan Coulson, 2018) have highlighted that sounds at 50 dB and particularly at night, cause cardiovascular problems.

2- Noise and regulatory context

As in other nations, noise pollution is becoming a bigger issue in Algeria, even though that the right to a healthy environment, which includes peace and quiet was stated in the Algerian state's constitution since 1964, yet it does not accurately represent daily living conditions. Due to a remarkable increase in population density, the volume of traffic fleet, and the absence of adequate urban planning, it is a major concern, particularly in medium-sized cities like Guelma. Also, construction activity on the public roadway, impolite horn or radio use by drivers, motorcycles and automobiles with modified exhaust systems, firecracker and pyrotechnic device explosions, loudspeaker entertainment are the common noise sources that seem to dominate the soundscape of the Algerian cities, even at night time (Rebah, 2022).

Noise pollution in Algeria has been addressed as a problem that needs to be looked at and controlled, in the national acoustic regulation since independence, with a primary objective of preserving public health and calmness in outdoor and indoor spaces (Boulemaredj & Haridi, 2022).

It was initiated afterwards by the decision of 25 February 1964 relative to excessive noise abatement, which stipulate from article 1 and 2 the prohibition of any kind of noise nuisance likely to disturb public tranquility and the well-being of the inhabitants, especially persistent noise emitted from vehicles with modified silencers and exhaust system. Even though, this decision was a clear image that the country is interested in reducing noise, but there was a lack of specifications and thresholds, due to multiple reasons such as scarcity of knowledge and expertise, lack of measurement equipment and universal documentation on noise laws and regulations.

In addition, to better control road noise and noise emitted from all types of vehicles at that time, another legal solution was later added by the decision of 4 April 1972 relative to the measurement of noise produced only by motor vehicles and to the conditions imposed on silencing systems, throughout fixing thresholds for maximum noise levels L_{max} for a running engine, according to vehicle categorization. Also, in a step to apply the protection of the environment law n° 83-03 enacted in February 1983, in order to have an optimized and adequate sound environment for the citizens, the Algerian legislator started expanding its understanding towards ambient noise abatement and control mechanism (Belayat, 2009), which led to publication of the first executive decree n°93-184 in July 1993, regulating noise emissions as defined in article 2 and 3, by introducing a different noise indicator (Leq_{max}) in function of time and type of area. It has fixed 70 dB as a maximum sound level during day time from 6am to 22pm and 45 dB during night time from 22pm to 6am, in the vicinity of residential areas, in public squares and roads, near hospital facilities, educational institutions and recreational spaces and gardens.

In other countries around the world, noise pollution is an issue that necessarily needs to be controlled. Since the 1960s, when the Swiss Parliament (Bundesrat) formed the first commission to assess environmental noise limitations, the problem of noise pollution has been acknowledged. This panel, in fact, created a structure that is presently used in Switzerland's anti-noise law (Schade, 2003).

Like in the United States, the Environmental Protection Agency (EPA) has imposed a 24-hour exposure limit of 55 dBA in residential zones since 1974 in order to protect the public from negative health and welfare repercussions. Furthermore, it also suggested a second exposure limit of 70 dBA for a 24-hour continuous average sound exposure level $LA_{eq,24h}$ as a limit to minimize hearing impairment (Hammer et al., 2014).

The European Directive on Environmental Noise (END) 2002/49/EC requires European member states to employ a methodological approach that relies on the noise mapping concept. This approach has been used to avoid or lessen the detrimental consequences of noise exposure, notably traffic noise below 55 dB. It establishes a five-year cycle for producing and reporting to the European Commission strategic noise maps and noise control plans (King & Murphy, 2016).

Noise pollution laws were introduced in India in the year of 2000 in order to address and avoid noise pollution in the industrial, commercial, and residential sectors, as well as to preserve noise pollution in quiet locations such as hospitals, educational institutions, and libraries. Ambient noise levels in residential neighborhoods ought to be 55 decibels throughout the day and 45 decibels during night time (Poddar, 2017).

3- Case Study

The first significant urban extension planned in the city of Guelma is the Champ de Manoeuvre neighborhood, a newly developed urban residential area. It includes both single-family houses and multi-story buildings. They were built between 1986-1990, constructed with a prefabricated construction system of ordinary reinforced concrete. They are oriented North West - South East, where they benefit from a good daily sunshine. The Champs de Manoeuvre housing estate is bounded on the north and north-east by the Guehdour Tahar residential area and the urban center of the city of Guelma, respectively. From the South, South West and South East, the neighborhood is lined up with the 19 Juin neighborhood and the university 8 May 1945, and the 60-cooperative city, respectively. On the East side, there are two high schools Mahmoud ben Mahmoud and Chaalal Mesoud (Figure -1).

The main reason that this area was chosen for the study is because the Champs de Manoeuvre neighborhood represents the biggest collective housing estate in Guelma city-center compared to other housing estates, with approximately 20000 inhabitants (Haridi, 2012). Also, a significant amount of everyday traffic flow passes through this neighborhood, and the multitude of potential noise sources in this urban area.

Figure -1: Localization of the studied area



Source: Google Earth, modified by the authors

The Champ de Manoeuvre housing estate is exposed to a remarkable level of noise. The perception of noise by the inhabitants of this housing estate recognizes it as an environmental problem and a public health concern common to all countries in the world. Moreover, if the risks to which the inhabitants are exposed represent a threat to their mental health and well-being, it is noted that the feeling of noise annoyance is a feeling of discomfort, which needs to be studied, evaluated and controlled by the regulatory framework in force.

Based on this observation, the research problematic revolves around the following question: To what extent has noise pollution impacted the health dimension of the inhabitants of the Champs de Manoeuvre neighborhood in Guelma?

The hypothesis set in order to answer this question is founded on a field qualitative survey, with the inhabitants of this residential neighbourhood.

The main objective of this study behind exploring the sound environment of the studied area is to assess the sources of noise and the level of discomfort felt by the inhabitants of residential buildings in the Champs de Manoeuvre housing estate in Guelma, in a step towards raise mindfulness against noise effects. The importance of the current study resides in the seriousness of fighting against noise issue itself. Moreover, the findings behind this contribution may help to increase public awareness against noise nuisance and in the development of practical remedies for dwellings impacted by this phenomenon, in order to provide a better outdoor soundscape and a good indoor living environment.

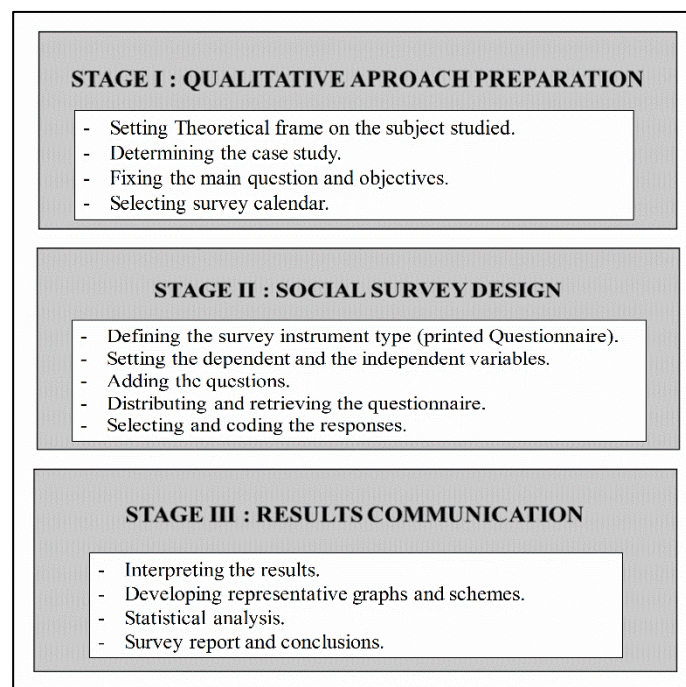
4- Methodology

One of the most crucial and fundamental research techniques in the social sciences and a key instrument in practical work is sample surveys. Sample surveys, which have just gained popularity in the last 75 years, are relatively recent tools for studying society, much like the social sciences itself (Marsden & Wright, 2010).

4-1. Approach

Data collecting for the inquiry in this study used a social sample survey based on a qualitative approach (Figure -2), to obtain people' opinions on noise pollution in their homes. This required the use of a questionnaire that represents the heart of this survey as a tool for gathering data.

Figure -2: Explanatory diagram of the Qualitative approach followed



Source: author 2022

4-2. Sociological sample survey procedure

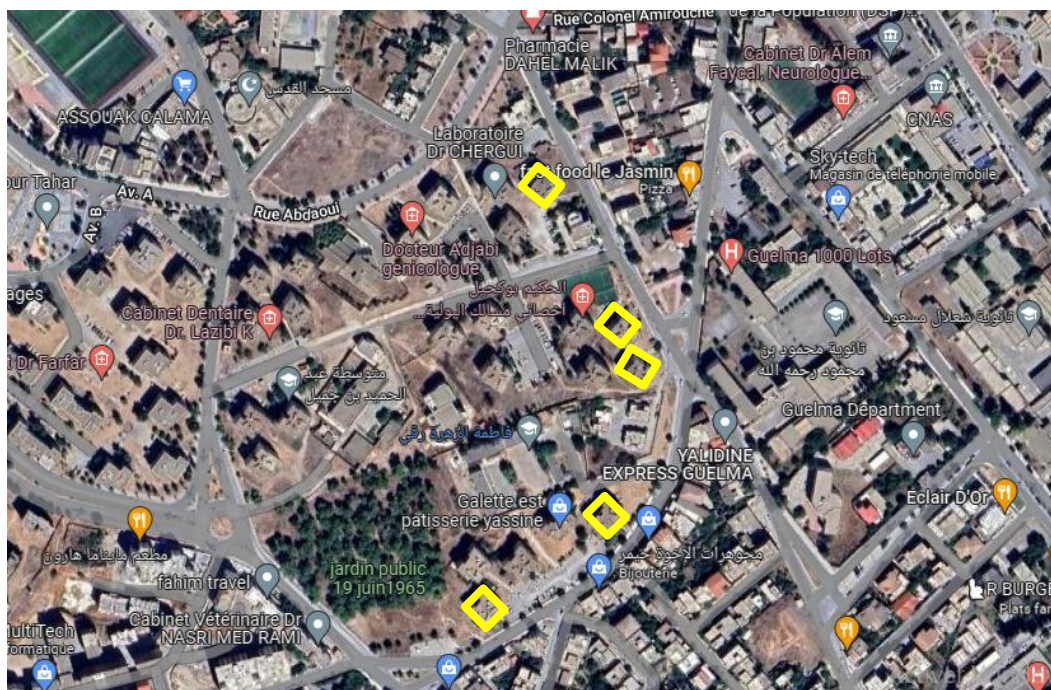
A social sample survey was carried out by handing out from door to door, printed questionnaires to a sample size of 80 dwellings residing in five buildings highlighted in yellow-colored squares in Figure -2, where only the lowest floors are thought to be the ones in the study region, that are most subjected to noise pollution. The reason why only these five buildings were surveyed because they were expected to be the most exposed to outdoor noise emitted mainly by transportation vehicles passing on the road in front of it. The printed questionnaire included fifteen closed questions requiring respondents to select an answer from a set of choices, and was ordered into four groups, constructed according to the quota method, with the following headings: Personal information - Dwelling characteristics - Noise perception - Awareness towards noise.

The main idea behind this questionnaire is to evaluate which and how noise nuisance (the independent variable) impacts people in their homes (the dependent variable) according to (Salès-Wuillemin, 2006). The authors worked with a total of 60 respondents (more than 2/3 of the overall sample size), and their responses were obtained, verified as genuine for analysis, and transformed into representative graphs using Origin software.

5- Results and discussion

The findings from this survey are displayed in the following sections after obtaining the responses from the questionnaire issued to the 60 inhabitants (Figure -3) who collaborated with the authors.

Figure -3: Localization of the surveyed buildings



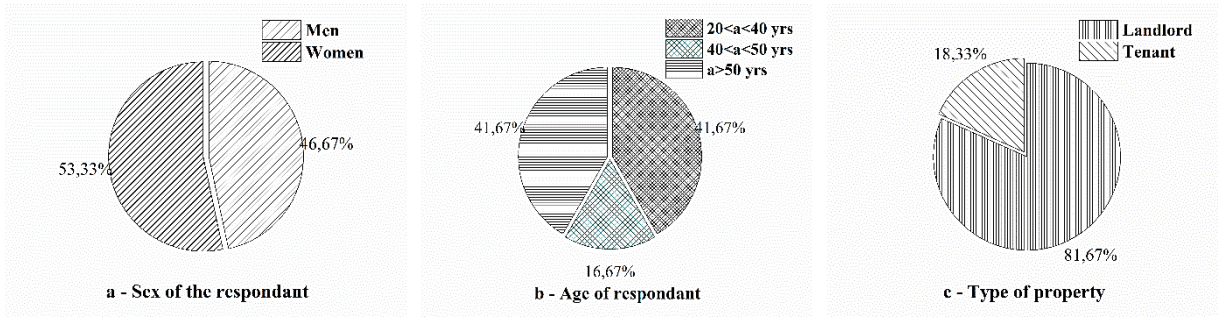
Source: Google Earth, modified by the authors

In the first group of the questionnaire, which asked for personal information about the respondent, Graph -4a reveals that nearly 53% of the respondents were women who lived in the surveyed homes and stated that since they spent the majority of the day there, they were undoubtedly subject to noise. In contrast, 47% of the respondents were men. Graph -4b demonstrates that there are three age groups, with 42% of respondents between the ages of 20 and 40 and over 50, and just 17%

Noise in Collective Residential Buildings: A Qualitative Survey in the Champs de Manoeuvre Neighbourhood in Guelma

between the ages of 40 and 50, which explains why the majority of residents representing 82% of respondents are homeowners (Graph -4c). These statistics' collection revealed that the respondents were adults with the capacity to provide thoughtful comments.

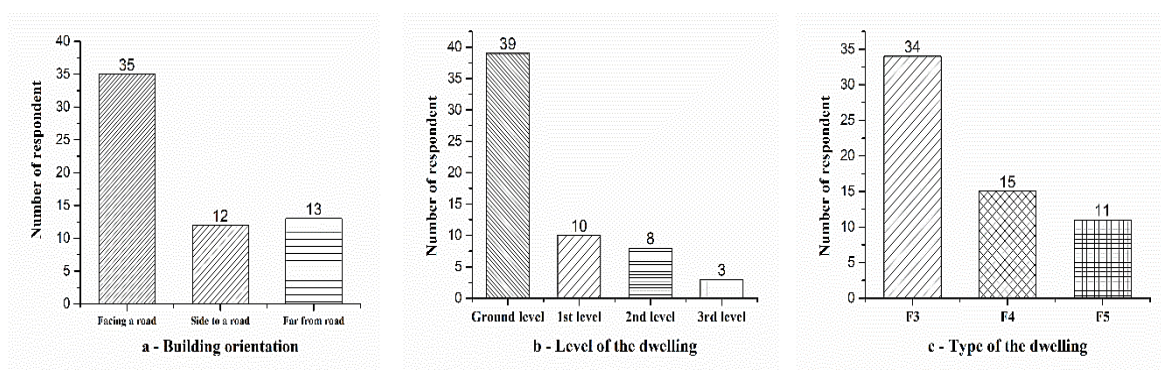
Graph -4: Personal information of the respondents



Source: authors 2022

The features of the examined houses were the subject of the next group of the questionnaire. Graph -5a reveals that 25 respondents (42%) said their home is either close to the main road or distant from it, while 35 respondents (58%) said they live in a residence that faces the main road. Additionally, it was discovered from Graph -5b that 39 respondents (65%) reside in apartments on the ground floor, 10 respondents (17%) in apartments on the first floor, only 8 respondents (13%) in apartments on the second floor, and 3 respondents (5%) in apartments on the third floor. According to the noise propagation theory, the sound pressure level decreases by 3 dB when the distance from a linear sound source such a road is doubled (Hamayon, 2008), also the further away you are, the less noise you get (Lee et al., 2008). This is why the authors only considered these three levels. Graph -5c shows that a total of 34 respondents (57%) said that they reside in an apartment of type F3 (two bedrooms and a living room), which accounts for the high proportion of residential tenancy in the data above. Only 15 of the respondents (or 25%) reside in an F4 apartment, whereas the remaining respondents (18%) do.

Graph -5: Surveyed dwelling's characteristics

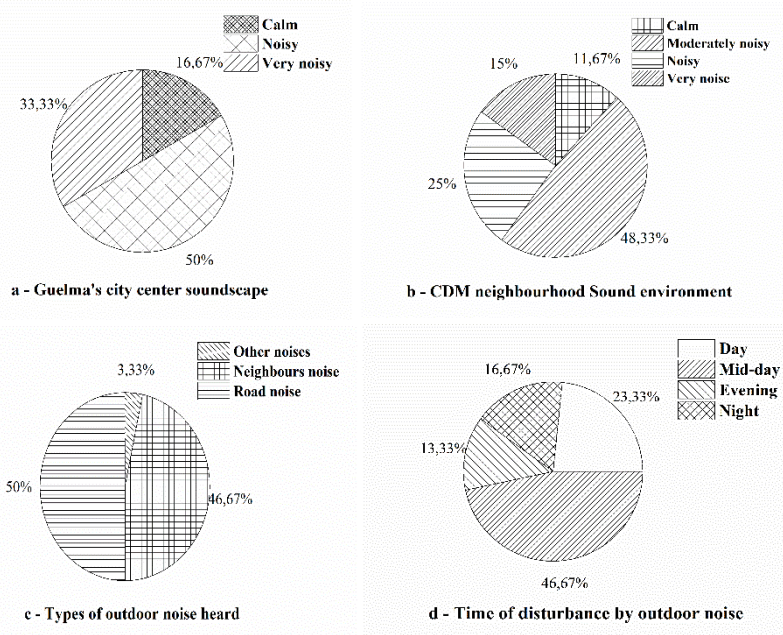


Source: authors 2022

The third group on the survey asked about the inhabitants' perceptions of both outdoor and interior noise. Only 17% of the inhabitants of the CDM neighborhood thought that Guelma's city center is tranquil and serene, whereas 50% and 33% of them believed that it has a noisy and very

noisy soundscape, respectively (Graph -6a). The CDM neighborhood, however, appears quiet and fairly noisy to 12% and 48% of the respondents, respectively, during specified times. 35% of them said the area was noisy or extremely noisy (Graph -6b). Additionally, 50% of the residents surveyed said they are most bothered by road traffic noise inside their homes (an average of 15 light vehicles, 2 motorbikes, and 1 minibus pass by in 1 minute), which indicates that more than half of the surveyed homes are probably subject to road traffic noise because of the buildings' proximity to the road. Only 3% of the remaining respondents criticized other sources of noise, such as animals and children, whereas 47% of them complained about noise from the neighbors (Graph -6c). 70% of respondents said they are bothered by outside noise, especially during the day (5 am to 13 pm), while 30% of the remaining respondents said they are bothered by it at night and in the evening, especially between 5pm and 3pm because of motor-cycles (Graph -6d).

Graph -6: Outdoor noise disturbance rates



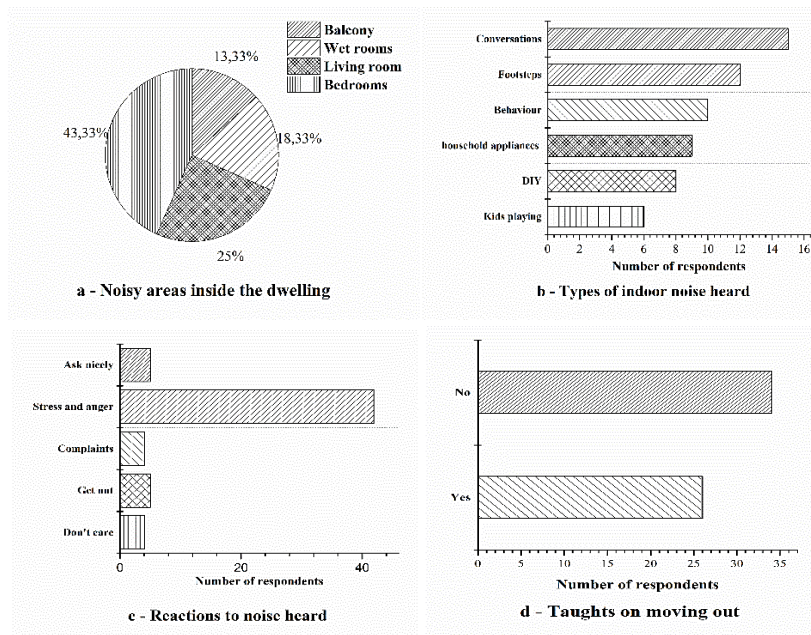
Source: authors 2022

Regarding indoor noise, according to 25% and 43% of respondents, respectively, their living rooms and bedrooms are exposed to outside noises (Graph -7a), mostly because of an unsuitable spatial arrangement of the interior spaces and inadequate sound-insulating qualities of the façade panels (walls and windows). Additionally, on their balconies and wet rooms, respectively, 13% and 18% of the respondents said that noise was a bother. Furthermore, 15 respondents reported hearing neighbors conversing, 12 ones reported hearing footsteps, and only 10 of them declared displeasure with the neighbors' behavior. However, other respondents reported being irritated by other types of pink noise, such as noise from household appliances, occasionally from DIY projects, and noise from children playing (Graph -7b). Since the residents were irritated and gave their neighbors' noise a high rating of sound discomfort (with a score of 4/5), it was discovered that 42 respondents (70%) had psychological effects from noise and were in a state of stress and rage, whereas an average of 4,5 respondents either grew accustomed to it, went outside, politely requested that it be turned down, or even complained about the noise heard (Figure -7c). For this reason, it was shown that due to the

Noise in Collective Residential Buildings: A Qualitative Survey in the Champs de Manoeuvre Neighbourhood in Guelma

intolerable loudness, 43% are considering leaving their homes, while 34 of them 57% decided to remain (Graph -7d).

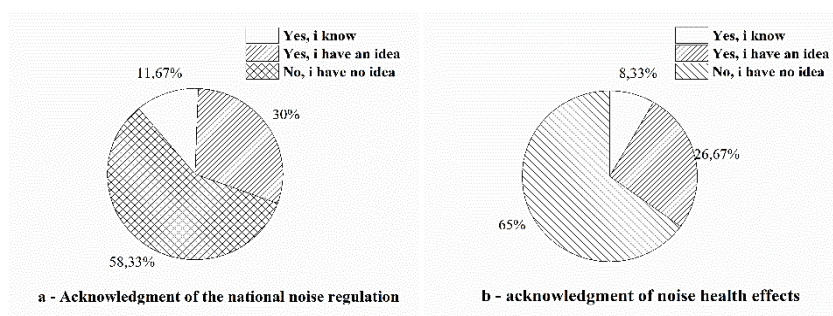
Graph -7: Indoor noise disturbance rates



Source: authors 2022

The respondents' level of awareness of noise effects was rated in the questionnaire's last part. The majority of respondents (58%) appeared to be unaware of the Algerian noise rule, while just 30% knew about it and only 12% of the remainder were aware of the regulations (Figure -8a). Furthermore, just 8% of respondents said they were aware of the hazards caused by noise, while 27% had a meager understanding of it. This means that 65% of respondents were unaware that noise had a harmful impact on human health (Figure -8b). As a result, there is a general lack of understanding among residents of the Champ de Manoeuvre neighborhood regarding the current national acoustic standards and the negative effects of noise on human health.

Graph -8: Awareness of the respondents



Source: authors 2022

Similar results were reported by other studies conducted in residential areas in various districts of Thailand and Korea, respectively, where noise levels exceeded the limits permitted by Thailand's noise regulation and residents' annoyance levels were identified with high scores, indicating their

dissatisfaction with noise in their living environment (Bunnakrid et al., 2017), (Thareejit et al., 2020) and in (Jeon et al., 2010). In these studies, noise is deemed to be an issue to be mitigated urgently due to its negative impact on human health if exposed to excessive levels.

Conclusion

In the present study, based on the results of the social survey, it was revealed that the health dimension of the inhabitants of the Champs de Manoeuvre neighborhood was impacted negatively by the receipt of excessive noise levels, that drive few of them move out or to search for efficient solutions for noise mitigation. Noise nuisance and the inhabitant's mental behaviour were found to be linked together, where approximately 70% of the respondents seem to suffer from annoyance, anger and stress due to high noise levels, whether if it is outdoor or indoor noise. Hence, they present a discomfort level of 4/5. The findings of the analysis also allowed researchers to determine that both of road traffic noise and neighbor noise, which probably have noise levels exceeding the thresholds admitted in the international and Algerian noise regulations, are problematic to these inhabitants.

What was also resulted through this social survey, that most of the respondents complain about noise in the living rooms, due to poor architectural spatial arrangement of the dwelling's spaces. It is at this stage, where the importance of the architect's role becomes noticeable, through a proper design, whereas such spaces should be on the one hand, designed in the back, away from the most exposed façade to noise, and on the other hand, built with efficient construction materials and systems, that help in mitigating airborne and impact borne noises. Also, as a recommendation, it is preferable in the first instance to reduce noise at its source and limit its propagation by implementing a set of direct and indirect actions, including raising society's awareness through educational programs and opinion polls, involving experts and specialists in the field of acoustical engineering.

Bibliography

- Belayat, N. B. (2009). Entertainment noise control in Algeria [Ph.D., London Metropolitan University]. <https://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.523012>
- Bluhm, G., & Eriksson, C. (2011). Cardiovascular effects of environmental noise: Research in Sweden. *Noise and Health*, 13(52), 212. <https://doi.org/10.4103/1463-1741.80152>
- Bodin, T., Albin, M., Ardö, J., Stroh, E., Ostergren, P.-O., & Björk, J. (2009). Road Traffic Noise and Hypertension: Results from a Cross-Sectional Public Health Survey in Southern Sweden. *Environmental Health: A Global Access Science Source*, 8(1), 38. <https://doi.org/10.1186/1476-069X-8-38>
- Boulemaredj, A., & Haridi, F. Z. (2022). La pollution sonore en Algérie: Le décalage entre le cadre juridique et la réalité. *Revue de Droit Public Algérien et Comparé*, 8(2), 8–17. <https://www.asjp.cerist.dz/en/article/208217>
- Bunnakrid, K., Sihabut, T., & Patthanaissaranukool, W. (2017). The relationship between road traffic noise and annoyance levels in Phuket Province, Thailand. *Asia-Pacific Journal of Science and Technology*, 22(4), Article 4. <https://doi.org/10.14456/apst.2017.39>
- Cynthia Mclemore & Alan Coulson. (2018). Noise Pollution Causes Heart Disease.
- Gopikrishnan, S., & Topkar, V. M. (2017). Attributes and descriptors for building performance evaluation. *HBRC Journal*, 13(3), 291–296. <https://doi.org/10.1016/j.hbrj.2015.08.004>
- Hamayon, L. (2008). Comprendre simplement l'acoustique des bâtiments. *Le Moniteur*.

- Hammer, M. S., Swinburn, T. K., & Neitzel, R. L. (2014). Environmental Noise Pollution in the United States: Developing an Effective Public Health Response. *Environmental Health Perspectives*, 122(2), 115–119. <https://doi.org/10.1289/ehp.1307272>
- Haridi, F.-Z. (2012). *Forme de ville rencontre des formes de vie et de l’imaginaire de l’habiter* [These de doctorat, Paris 10]. <https://www.theses.fr/2012PA100075>
- Jariwala, H., Syed, H., Pandya, M., & Gajera, Y. (2017, March 17). Noise Pollution & Human Health: A Review. *Noise and Air Pollution: Challenges and Opportunities*, India.
- Jeon, J. Y., Ryu, J. K., & Lee, P. J. (2010). A quantification model of overall dissatisfaction with indoor noise environment in residential buildings. *Applied Acoustics*, 71(10), 914–921. <https://doi.org/10.1016/j.apacoust.2010.06.001>
- King, E., & Murphy, E. (2016). Environmental noise – ‘Forgotten’ or ‘Ignored’ pollutant? *Applied Acoustics*, 112, 211–215. <https://doi.org/10.1016/j.apacoust.2016.05.023>
- Lee, S.-W., Chang, S. I., & Park, Y.-M. (2008). Utilizing noise mapping for environmental impact assessment in a downtown redevelopment area of Seoul, Korea. *Applied Acoustics*, 69(8), 704–714. <https://doi.org/10.1016/j.apacoust.2007.02.009>
- Marsden, P. V., & Wright, J. D. (2010). *Handbook of Survey Research*. Emerald Group Publishing.
- Nassur, A. M. (2018). Effets de l’exposition au bruit des avions sur la qualité du sommeil des riverains des aéroports français.
- Poddar, A. (2017). NOISE POLLUTION CONTROL AND IN RE NOISE POLLUTION CASE. *International Journal of Advanced Research*, 5, 1544–1550. <https://doi.org/10.21474/IJAR01/3979>
- Rebah, M. (2022, April 29). Algérie: Gaspillage alimentaire et nuisances sonores. *Journalistes Écrivains pour la Nature et l’Écologie*. <https://jne-asso.org/2022/04/29/algerie-gaspillage-alimentaire-et-nuisances-sonores/>
- Salès-Wuillemin, E. (2006). *Méthodologie de l’enquête*. 45. <https://shs.hal.science/halshs-00903244>
- Schade, W. (2003). Le bruit du transport: Un défi pour la mobilité durable. *Revue internationale des sciences sociales*, 176(2), 311–328. <https://www.cairn.info/revue-internationale-des-sciences-sociales-2003-2-page-311.htm>
- Thareejit, M., Sihabut, T., & Patthanaisaranukool, W. (2020). The association between road traffic noise and annoyance levels in residential and sensitive areas of Ayutthaya, Thailand. 25(3), 13. <https://doi.org/10.14456/apst.2020.28>
- Williams, R., Bachmann, T., Blokland, G. van, Fingerhut, H.-P., Hamet, J.-F., Sandberg, U., & Taylor, N. (1998). Bruit de contact pneu-chaussée: Etat de l’art. *Acoustique & techniques*, 15, 17–31.