Acoustic analysis and control measures for noise in university: a case study of Adrar University, Algeria

Análise acústica e medidas de controle de ruído em universidades: um estudo de caso da Universidade de Adrar, Argélia

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ABSTRACT
The purpose of this research is to investigate the complex dynamics of noise pollution at the University of Adrar-Algeria, with a particular emphasis on the impact that the dry desert climate has on the acoustic environment of the campus. With the goal of cultivating an environment that is characterised by tranquilly, comfort, and optimal conditions for attention, learning, and practical engagement, the research attempts to achieve the goal of enhancing the existing discourse on noise management inside academic institutions. The inquiry makes use of a methodical approach in order to investigate the many climatological characteristics that are unique to the desert climate and that lead to increased noise levels within the university grounds. In addition, the research investigates the ways in which noise emissions from various sources alter inside the confines of Adrar University, taking into account the ways in which the harsh desert climate influences the parameters that control these emissions. The investigation of human behaviour patterns is relevant to this investigation. In particular, the investigation will focus on instances of protracted assemblage in air-conditioned places, which correlates with increased noise levels. In light of the fact that noise control is an essential component of the academic environment, the research being conducted at the University of Adrar includes the collection of questionnaires, the administration of on-site sound measurements, and the creation of an all-encompassing noise map. The findings shed light on the climatic factors that are primarily responsible for the excessive amount of noise that exceeds the standards that are suggested by the World Health Organisation (WHO).

Keywords: noise, university, desert climate, Adrar, noise mapping.

RESUMO
O objetivo desta pesquisa é investigar a complexa dinâmica da poluição sonora na Universidade de Adrar, na Argélia, com ênfase especial no impacto que o clima seco do deserto tem sobre o ambiente acústico do campus. Com o objetivo de cultivar um ambiente caracterizado por tranquilidade, conforto e condições ideais para atenção, aprendizado e envolvimento prático, a pesquisa tenta atingir a meta de aprimorar o discurso existente sobre o gerenciamento de ruídos dentro de instituições acadêmicas. A pesquisa faz uso de uma abordagem metódica para investigar as diversas características climatológicas que são exclusivas do clima desértico e que levam ao aumento dos níveis de ruído dentro das instalações da universidade. Além disso, a pesquisa investiga as maneiras pelas quais as emissões de ruído de várias fontes se alteram dentro dos limites da Universidade de Adrar, levando em conta as maneiras pelas quais o clima rigoroso do deserto influencia os parâmetros que controlam essas emissões. A investigação dos padrões de comportamento humano é relevante para essa pesquisa. Em particular, a investigação se concentrará em instâncias de reunião prolongada em locais com ar-condicionado, o que se correlaciona com o aumento dos níveis de ruído. Considerando que o controle de ruído é um componente essencial do ambiente acadêmico, a pesquisa que está sendo realizada na Universidade de Adrar inclui a coleta de questionários, a administração de medições de som no local e a criação de um mapa de ruído abrangente. Os resultados lançam luz sobre os fatores climáticos que são os principais responsáveis pela quantidade excessiva de ruído que excede os padrões sugeridos pela Organização Mundial da Saúde (OMS).

Palavras-chave: ruído, universidade, clima desértico, Adrar, mapeamento de ruído.
1 INTRODUCTION

Deserts, constituting 40% of the world's continents and accommodating 20% of the global population, have garnered heightened attention due to their vast energy potential (solar, wind) and rich mineral and groundwater resources. Despite their apparent inhospitality, deserts, exemplified by the Sahara, play a pivotal role in the strategic establishment of infrastructure, including universities, in North Africa. The arid desert climate, characterized by deficient and erratic rainfall, elevated temperatures, and persistent winds, poses unique challenges for sustaining life in such environments. Notably, the proliferation of oil sites in North African deserts, coupled with historical, cultural, scientific, and ethnic dimensions, has spurred the growth of universities in these regions. However, this development has introduced a contemporary concern noise pollution. The escalating global apprehension regarding noise pollution, recognized as a hazardous form of environmental pollution, has prompted regulatory interventions by authoritative bodies such as the World Health Organization (WHO). The WHO has set standards and limits for noise levels on university campuses to foster serene learning environments (Berglund et al., 1995). Noise pollution within university premises is a multifaceted challenge, with varied sources contributing to its manifestation. These sources encompass ambient noise from activities, human voices, electronic devices, and construction activities. The impact of noise on the effectiveness of learning, teaching activities, and overall student performance is well documented (Bronzaft, 1981; Cohen et al., 1973; Connolly et al., 2015; Thompson et al., 2022). As a microcosm of diverse activities, the university campus exhibits numerous factors influencing noise generation and propagation. These include climatic conditions and the number of students, both of which play pivotal roles in noise pollution dynamics. In desert-region universities, the prevalent use of air conditioning, coupled with extreme temperatures, dictates student movements and affects the utilization of communal spaces, contributing to the overall acoustic landscape (Tadjeddine, 2023; Bendjillali, 2023). Amidst the imperative of cultivating a calm and conducive learning environment, noise management within universities becomes paramount. This involves a spectrum of measures, encompassing sound insulation, spatial planning, organizational strategies, and educational initiatives to maintain acceptable noise levels.
The situation at Adrar University in southwest Algeria reflects an alarming rise in noise pollution concerns, prompting an investigative approach. This study undertakes a series of noise level measurements within Adrar University, scrutinizing existing noise sources and particularly monitoring key desert climate parameters responsible for heightened noise levels within the university. New developments in research methods, like using simulation software to map noise and look into different ways to reduce noise in buildings and cities, show that proactive noise control strategies are becoming more important (Tadjeddine, 2023; Aletta et al., 2015; Baclet et al., 2022; Matteis et al., 2024; Tang et al., 2022; Xu and Liu, 2022). This research contributes to the broader objective of evaluating the impact of desert climates on noise pollution on university campuses. Focusing on the case of Adrar University, situated in a desert environment, this study addresses a notable gap in the existing literature by juxtaposing noise levels in tranquil desert settings with those on the bustling university campus. Additionally, it seeks to identify and analyse factors contributing to heightened noise levels within the university context, thereby enhancing our understanding of noise pollution dynamics in desert-based educational institutions.

The main objective of this work is to investigate the dynamics of noise pollution within the University of Adrar in Algeria, with a specific focus on understanding the influence of the arid desert climate on the campus acoustic environment. The research aims to enhance the existing discourse on noise management within academic institutions, with the goal of cultivating an atmosphere characterized by serenity, comfort, and optimal conditions for concentration, learning, and practical engagement. The study examines the various climatological parameters inherent to the desert climate that contribute to increased noise levels, as well as the impact of human behavior patterns on noise emissions within the university premises. The findings from this research are intended to inform the development of proactive noise control strategies for desert-based educational institutions.

2 MATERIALS AND METHODS

We chose three desert cities in southern Western Algeria to study the characteristics of the peaceful desert environment and the many factors that affect
the spread of noise on university campuses. We also wanted to find out how differences in traffic, population density, and economic activities affect noise propagation in cities and, in turn, how these factors affect noise spread on university campuses.

This selection aims to comprehensively understand the acoustic environments in both the natural desert landscape and urban centres, particularly those associated with university campuses. We chose cities with different features, like Adrar, Timimoun, and Tamanittit, so we can see how different factors affect noise dynamics in different desert settings. This multifaceted approach lets us look at the acoustic landscape as a whole, considering both environmental and urban factors. This makes it easier to understand how noise moves through university buildings in desert areas.

2.1 STUDY AREAS AND CHARACTERISTICS OF CLIMATE:

2.1.1 Sites of noise measurement

2.1.1.1 The southwest region of Algeria: Adrar-Tamentit- Timimoune

The choice of Adrar, Tamentit, and Timimoune in the southwest region of Algeria, along with the inclusion of the University of Adrar, emanates from a strategic intent to present a comprehensive portrayal of the urban milieu in the region. This selection facilitates a holistic evaluation of noise pollution levels within an educational institution. The accessibility of these locations, coupled with the availability of pertinent data and cooperation from local authorities, has streamlined the collection of requisite information crucial for appraising noise pollution within the study area. Moreover, the region's selection provides a distinctive opportunity to juxtapose noise pollution levels across divergent urban settings, enabling an assessment of the influence of various environmental factors on sound propagation and attenuation.

Several factors underscore the rationale behind choosing the regions of Adar-Tamentit and Timimoune:

**Environmental and Desert Climate Relevance:** The inclusion of these regions aligns with the environmental and desert climate focus of our study.

**Geographical Proximity and Urban Diversity:** The geographical proximity of Adar-Tamentit and Timimoune, coupled with their representation of
distinct urban settings within the desert climate region, enhances the comprehensiveness of our assessment.

**Diverse Population Densities and Infrastructure Characteristics:** The chosen regions exhibit varying population densities, infrastructure characteristics, and potential sources of noise pollution, offering a nuanced understanding of the acoustic landscape.

**Relevance to Research Objective:** The selection is motivated by the relevance of these cities to the research objective, emphasizing the assessment of noise pollution in urban environments marked by significant anthropogenic activities and urban development.

**Central Location:** The central location within each city renders the selected regions representative of the overall noise exposure encountered by students and faculty members.

2.1.1.2 The campus of Ahmed Draia University of Adrar

The University of Adrar, situated in the city center of the Adrar province, serves as a focal point for our study. Its selection as a study site is grounded in several considerations:

**Substantial Student Population:** With a notable student population of 16,500, the university provides a diverse spectrum of activities and potential sources of noise, including classrooms, laboratories, and recreational areas.

**Representative Noise Exposure:** The central location within the city ensures that the university campus is emblematic of the broader noise exposure experienced by students and faculty.

**Diverse Activity Spaces:** The campus encompasses various spaces contributing to the diversity of potential noise sources, fostering a comprehensive evaluation of noise pollution within an academic setting.

The geographical position of the University of Adrar is illustrated in the accompanying figure below, emphasizing its centrality within the city.
2.1.2 Characteristics of Climate

2.1.2.1 Geographic Context: The City of Adrar

The province of Adrar, positioned in the extreme southwest of Algeria, spans a distance of 1500 km. Bounded by longitudes 1 degree East and 3 degrees West of Greenwich and situated between altitudes 20 degrees and 30 degrees North, the province encompasses an expansive area of 427,968 km², accommodating a population exceeding 400,000 individuals. The climate within the province manifests in two discernible climatic zones: a semi-desert region extending from Timimoune towards Bechar and a desert zone commencing from Timimoune towards Timiaouine.

The city of Adrar experiences notable temperature fluctuations, delineated across seasons. During the summer months of June, July, and August, temperatures soar to a maximum of 50°C. Conversely, winter months, particularly December and January, witness temperatures occasionally dipping to 0°C, while the transitional months of February, March, April, and May register temperatures ranging between 30°C and 40°C. The prevalence of winds, notably the sirocco, attains high speeds of up to 100 km/h throughout the year. Notably, the spring season, encompassing March and April, witnesses an elevated frequency of sandstorms. The annual average wind speed in the region is recorded at 5.9 m/s.
The geographical orientation of the province of Adrar is visually depicted in Figure 2, underscoring its strategic location in the southwestern extremity of Algeria.

Figure 2. The geographical position of the province of Adrar

2.1.2.2 Geographic Context: The City of Timimoune

Situated in the southwest region of Algeria within the Gourara area, Timimoune encompasses an expanse of 9936 km². The city is home to a population of approximately 33,060, yielding a population density of 3 individuals per square kilometer. Timimoune experiences a desert climate marked by elevated temperatures ranging from +38°C during the months of April to October, with an average temperature of +22°C in the remaining months of the year. This climatic pattern contributes to a notable expansion of the thermal range.

The region of Timimoun is further characterized by a desert climate, marked by deficient and irregular rainfall typically below 200 mm per year. The annual average temperature of Timimoune, derived from monthly averages, hovers around 25.98°C, underscoring the climatic nuances prevalent in this locale.

Winds emerge as a defining element in the Timimoune region, exhibiting persistence throughout the year. Notably, the spring season, encompassing March and April, witnesses the occurrence of vigorous sandstorms. Recorded wind speeds in the Timimoun region display an average ranging between 19.88 km/h and 25.10 km/h.

Figure 3 visually represents the geographical location of the city of Timimoune on the map, offering insight into its strategic positioning within the southwestern expanse of Algeria.
2.1.2.3 Geographic Context: The City of Tamentit

Positioned southwest of its wilaya of Adrar and at a distance of 1512 km from the capital of Algeria, Tamentit occupies a land area of 6937 km². The city is home to a population exceeding 9481 inhabitants, contributing to a distinctive community within this southwestern enclave.

Tamentit experiences a temperate Mediterranean climate characterized by hot and dry summers. The temperature in Tamentit consistently exceeds 32°C from April through October. The region witnesses minimal rainfall, contributing to the arid nature of this locale. The climatic conditions prevalent in Tamentit reflect a notable absence of rain, creating an environment characterized by dryness. During the months of February and March, Tamentit encounters southerly winds, specifically Sir Yaku’s winds, which carry sandstorms across the city at speeds reaching up to 100 km/h. This meteorological phenomenon during the early spring months underscores the dynamic climatic conditions experienced in Tamentit. Figure 4 visually delineates the geographical position of the city of Tamentit, providing a spatial context to its location in the southwestern region of Algeria.
2.2 Survey Application

The survey was meticulously designed to address key aspects related to noise pollution within Adrar University, focusing on the identification of primary noise sources, the precise location of noise occurrences, and the determination of optimal measurement periods. The survey encompasses seven distinct objectives:

1. Concerns about Noise Pollution:
   - Question: Do you harbor any concerns regarding noise pollution within the university?

2. Impact on Academic Performance:
   - Question: In your opinion, does noise pollution inside Adrar University have a detrimental effect on students' academic performance?

3. Individual Sensitivity to Noise:
   - Question: Are you personally sensitive to noise?

4. Perception of Acoustic Comfort:
   - Question: To what extent do you agree or disagree that acoustic comfort exists in university classes and blocs, and how does it influence the quality of university activities?
5. Annoyance During Activities:
   • *Question:* To what extent did you experience annoyance during practical sessions, courses, and recreational areas, and how do you perceive the impact of this annoyance on your overall experience?

6. Identification of Noise Annoyance Locations:
   • *Question:* Where, specifically, does the noise annoyance exist within the university?

7. Period and Duration of Noise Exposure:
   • *Question:* What was the period of your exposure to loud noise, and for how many hours were you exposed to loud noise?

These carefully formulated questions aim to elicit comprehensive insights into the perceptions, experiences, and subjective evaluations of noise-related factors among the university community. The survey serves as a valuable tool to gauge the multifaceted dimensions of noise pollution within the academic setting, facilitating a nuanced understanding of its impact on various aspects of university life.

2.3 MATERIALS USED AND PROCEDURE OF MEASUREMENT:

In adherence to Algerian regulations and industry best practices, a meticulous approach was undertaken to ensure accuracy and reliability in the measurement of sound pressure levels both inside and outside the university buildings. The following materials and procedures were employed:

2.3.1 Materials used

The primary instrument utilized for sound pressure level measurements was the portable digital sound pressure level equivalent model DEC-5030 1/1 and 1/3 Octave Band Time Analyzer. This device was selected based on its compliance with Algerian regulations, recommendations for calibration, and suitability for capturing sound pressure levels in various frequency bands. The technical specifications and calibration details were verified through the device's technical report, ensuring its correct configuration for measurements of sound pressure level equivalents in "A" and "Fast" modes, with a 95% probability of accuracy.
2.3.2 Measurement procedure

1. Instrument Calibration and Selection of Measurement Time:
   - the instrument was calibrated in accordance with Algerian regulations, adhering to recommended procedures;
   - measurements were scheduled at times devoid of unfavorable natural interferences, such as wind and rain, in alignment with Algerian regulations.

2. Sound Pressure Level Measurements:
   - sound pressure levels were measured both inside and outside the university buildings;
   - the sound pressure level equivalent was positioned 1.2 meters from the ground for consistency in measurements;
   - for outdoor measurements, the equipment was placed at least two meters away from surfaces capable of reflecting sound waves, ensuring accurate readings.

3. Instrument Configuration:
   - the sound pressure level equivalent was configured to measure sound pressure levels equivalent in "A" weighting and "Fast" response mode, as specified in the technical report.

4. Exclusion of Unusual Sounds:
   - the measurement process adhered to Algerian standards, automatically excluding any unusual sounds (e.g., vehicle horns) occurring at the moment of measurement to maintain data integrity.

This methodological approach was meticulously designed to align with regulatory guidelines, ensuring the precision and reliability of sound pressure level measurements both inside and outside the university buildings. The chosen instrumentation and adherence to standard procedures enhance the credibility of the acquired data, facilitating a robust analysis of noise pollution within the study area.

2.3.3 Time and period of measurement

At each measuring site, sound pressure levels were recorded using frequency A-weighting and "fast" time weighting. The main noise index employed in this study to evaluate and analyse noise is the continuous equivalent sound pressure level (LAeq). LAeq measures the energy level produced by a particular
sound source during a defined period, considering the frequency weight A that reflects the human ear’s sensitivity to audible noise. The computation of LAeq follows the subsequent formula:

\[
LAeq,Te = 10\log \left[ \frac{1}{Te} \int_{0}^{Te} \left( \frac{P_{A}(t)}{P_{0}} \right)^{2} \cdot dt \right]
\]  

(1)

Where:

- LAeq is the equivalent continuous A-weighted sound pressure level re 20 µPa, determined over a measured time interval Te.
- \(P_{A}(t)\) is the instantaneous A-weighted sound pressure.
- \(P(t)\) is the instantaneous sound pressure of the sound signal.
- \(P_{0}\) is the reference sound pressure of 20 µPa.

To measure the noise level in our selected desert cities, we chose LAeq,10min in the period from 7 to 10 a.m. This period is characterised by high traffic on the roads and the movement of people to carry out their daily activities. On the other hand, we chose the period 10 to 12 a.m. to conduct the noise measurements inside the university since the survey participants declared that it is the period when they are most exposed to noise.

The Algerian regulations indicate that a decision should be made to characterise the local noise. Still, they do not stipulate a minimum time to collect the sound measurements. A previous test was conducted to optimise time and equipment (one-minute measurements were taken at random intervals of three, fifteen, and sixty minutes). This test determined the minimum amount of time required for accurate measurements. In those situations, the pressure sound recording was made as soon as the obtrusive sound.

2.4 NOISE MAPPING AND METHODOLOGY ADOPTED

In accordance with recent guidelines from the European Environment Agency (EEA) emphasizing the management of areas with favorable environmental noise quality, the study incorporated noise mapping as a pivotal analytical approach. The methodology employed for noise mapping involved the utilization of ArcGIS 10.8 software, coupled with the Inverse Distance Weighted (IDW) interpolation technique within the Spatial Analyst Module. This robust
approach facilitated the analysis of data and the subsequent generation of noise level maps across diverse measurement points within the study area.

2.4.1 Methodological steps

1. Guidelines from European Environment Agency (EEA):
   - the study adhered to the recommendations outlined by the EEA for managing areas with suitable environmental noise quality.

2. Utilization of ArcGIS 10.8 Software:
   - ArcGIS 10.8, a widely recognized Geographic Information System (GIS) software, was employed for its versatile spatial analysis capabilities.

3. Inverse Distance Weighted (IDW) Interpolation Technique:
   - the IDW interpolation method was chosen for its effectiveness in estimating values at unsampled locations based on the proximity and weightage of neighboring data points;
   - this technique is acknowledged in scientific research for its robustness in spatially interpolating data, particularly in scenarios involving noise level assessments.

4. Spatial Analyst Module Integration:
   - the IDW interpolation technique was integrated within the Spatial Analyst Module of ArcGIS 10.8, enhancing the software's capability to perform spatial analyses and generate noise level maps.

5. Assessment and Visualization of Noise Levels:
   - the IDW interpolation facilitated the accurate assessment and visualization of noise levels across the entire study area;
   - the spatial distribution of noise pollution was effectively captured, providing valuable insights into the variability and concentration of noise levels.

By adopting this comprehensive methodology, the study achieved a nuanced understanding of the spatial distribution of noise pollution within the university environment. The integration of noise mapping, ArcGIS 10.8 software, and the IDW interpolation technique served as a robust framework for spatial analysis, enabling informed decision-making and mitigation strategies related to noise pollution.
3 RESULTS AND DISCUSSION

3.1 RESULTS OF NOISE POLLUTION MEASUREMENTS IN THE CITIES OF ADRAR, TAMENTIT AND TIMIMOUNE

In our research work, to study the influence of the Desert climate on noise pollution in the academic environment a case of the University of Adrar, we initially chose to have the noise levels in three different cities located in the southwest of Algeria: Adrar, Tamentit and Timimoune. We chose to start with Adrar (Table 1), Tamentit (Table 2) and Timimoune (Table 3). The results found are listed in the following data:

Table 1. The noise level recorded in the city of Adrar.

<table>
<thead>
<tr>
<th>Points</th>
<th>Site</th>
<th>GPS coordinates</th>
<th>Average noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>N° 1</td>
<td>City Centre</td>
<td>N°17'19&quot;W°31'52&quot;27</td>
<td>64,5</td>
</tr>
<tr>
<td>N° 2</td>
<td>Hatba neighborhood</td>
<td>N°17'24&quot;W°32'52&quot;27</td>
<td>68,0</td>
</tr>
<tr>
<td>N° 3</td>
<td>District 400 housing</td>
<td>N°17'10&quot;W°01'53&quot;27</td>
<td>70,5</td>
</tr>
<tr>
<td>N° 4</td>
<td>Tililane</td>
<td>N°15'48&quot;W°19'52&quot;27</td>
<td>68,0</td>
</tr>
<tr>
<td>N° 5</td>
<td>Souq-bouda</td>
<td>N°17'15&quot;W°19'52&quot;27</td>
<td>71,0</td>
</tr>
<tr>
<td>N° 6</td>
<td>Ibn Sina Hospital</td>
<td>N°16'29&quot;W°59'51&quot;27</td>
<td>64,5</td>
</tr>
</tbody>
</table>

Source: Authors

Table 2. The noise level recorded in the city of Tamentit

<table>
<thead>
<tr>
<th>Points</th>
<th>Site</th>
<th>GPS coordinates</th>
<th>Average noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>N° 1</td>
<td>Moulay Larbi</td>
<td>*27°46’08,49N 0°16’07,63W</td>
<td>71,0</td>
</tr>
<tr>
<td>N° 2</td>
<td>Aghmar aqpour</td>
<td>*27°45’38,90”N 0°16’17,59”W</td>
<td>55,0</td>
</tr>
<tr>
<td>N° 3</td>
<td>Bossiah</td>
<td>27°45’53,54N 0°15’39,70W</td>
<td>47,0</td>
</tr>
<tr>
<td>N° 4</td>
<td>Sidi Youssef</td>
<td>27°45’46,23N 0°15’24,89W</td>
<td>67,5</td>
</tr>
</tbody>
</table>

Source: Authors
Table 3. The noise level recorded in the city of Timimoune

<table>
<thead>
<tr>
<th>Points</th>
<th>Site</th>
<th>GPS coordinates</th>
<th>Average noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>N° 1</td>
<td>Souq sabt</td>
<td>29°16'08.39 N 0°14'09.33 E</td>
<td>79.0</td>
</tr>
<tr>
<td>N° 2</td>
<td>Sassi Ben Issa (Street)</td>
<td>29°15'42.09 N 0°14'04.74 E</td>
<td>84.0</td>
</tr>
<tr>
<td>N° 3</td>
<td>Abd-el-Kader ibn Mohiédine district</td>
<td>29°15'38.48 N 0°14'01.79 E</td>
<td>79.0</td>
</tr>
<tr>
<td>N° 4</td>
<td>Mosque (Khalil)</td>
<td>29°15'49.72 N 0°14'03.60 E</td>
<td>64.7</td>
</tr>
<tr>
<td>N° 5</td>
<td>District of 1 November</td>
<td>29°15'37.77N 0°13'41.42 E</td>
<td>67.0</td>
</tr>
<tr>
<td>N° 6</td>
<td>Covered market</td>
<td>29°15'45.32N 0°13'46.14E</td>
<td>70.0</td>
</tr>
</tbody>
</table>

Source: Authors

When assessing noise pollution in the cities of Adrar, Timimoune and Tamenitit, it is essential to take into account several specific factors that can influence noise levels, such as The density of population, intense human activities, road traffic, Transport infrastructure, Residential neighbourhoods; Public spaces: Parks, squares, stadiums, restaurants, cafes and entertainment venues; Topographic characteristics; metrological conditions: such as wind, rain, temperature, etc. can affect sound propagation. At the same time, particular weather conditions can act as a natural barrier or amplify noise levels.

To consolidate the results, we have represented our results found in the following Figure (6-7). We have shown in red the noise level recommended by Algerian regulations, which is 70 dB.

Figure 6. Sound pressure level measured from 7 a.m. to 10 a.m. in Adrar City (left). Sound pressure level measured from 7 a.m. to 10 a.m. in Tamentit City (right).

Source: Authors
The results show that the noise level is acceptable in certain ADRAR districts; we cite the Hatba neighbourhood, district 400 housing and Tililane (66 dB(A)). On the other hand, we recorded a low noise level. High at the level of Souq-bouda (79.4 dB(A)). This is mainly due to the following reasons:

a) Road traffic involves an association of noise;

b) The ambient noise inevitably leads to an increase in the noise level, mainly since the vegetable market is located in a narrow and closed place, which leads to an increase in sound echoes and a high noise level.

3.2 RESULTS OF THE SOCIAL SURVEY

Before carrying out the necessary measurements of noise levels within the University of Adrar and studying the impact of the desert climate on the propagation of noise inside the university campus, we first carried out a questionnaire to know the different sources of noise in the university and to determine the period of most significant exposure to noise during the university day, knowing the extent of its impact on the learning rate of students.

Three groups of people responded: students made up 60% of the sample, professors 25%, and administrators 15%. Since 74% declare that they are concerned by noise pollution at the university, this result is alarming (Figure 8.left).
In order to know the impact of noise pollution on students, we counted the number of people who answered this concern in the questionnaire; the result in Fig (8.right) was more than 83% of those who think that the noise recorded inside Adrar University has a negative effect and impact on student's academic performance, even if the values are not strong enough.

However, The calm of the Desert environment and its tranquillity made people sensitive to low noise levels. For this reason, 51% of respondents were sensitive to the lowest noise level fig (9.left). On the other hand, concerning the quality of acoustic comfort within classrooms and campuses, Figure (9.right) reveals that 55% of the subjects answered that there is no acoustic comfort, which affects the quality of university activity; this latter should be more acceptable. These results encouraged us to look for where the noise annoyance exists;
Figure (10. Left) illustrates that 45% were annoyed during the practical sessions, 30% during the courses, and 25% at rest places.

According to the results shown in Figure (10.right), it was evident that more people, 64%, were exposed to loud noise from 10 to 12 a.m. when the climate parameter in this period was appropriate and favourable for university activity. In addition, to noise sources that have been identified by objective acoustic techniques. The figure below which concerns the impact of noise on people, according to the sources of noise, the responses are 28% for voice and communication, 26% for construction and renovation work, and 22% for the noise generated with the air conditioning system fig(11). In the last stage of the social survey, the groups concerned have proposed building soundproof halls for better acoustic comfort at the university. As a result, we concluded that there was a significant correlation between meteorological parameters and the time when people were more exposed to noise.

The meteorological parameters play a paramount role; whenever the weather is pleasant, the movement of students and university workers peaks, which leads to an increase in the noise level inside the university.
3.3 RESULTS OF NOISE POLLUTION MEASUREMENTS INSIDE THE CAMPUS OF THE UNIVERSITY OF ADRAR

As part of our study on the impact of desert climate on noise propagation within the university campus, we aimed to compare noise levels between the quiet desert environment and the university campus and analyse the contributing factors. Therefore, we have allocated this section of our study to the impact of the desert climate on noise pollution in the university environment. In our study concerning noise pollution at the University of 'Adrar, most noise measurements were made inside the rooms due to the climatic conditions of a desert environment, characterised by the often-windy sands, which prevent precise acoustic measurements from being taken outside. The figure below illustrates the principal measures sites inside the University of Adrar.

Figure 11. Impact of Noise Sources on Individuals.

Source: Authors

Figure 12. The principal sites of measurement inside the University of Adrar.

Source: Authors
3.3.1 The amphitheatres and classrooms

The amphitheatres of the University of Adrar have a capacity that varies from 110 to 250 students. The results found for noise levels inside these rooms are presented in the tables below:

Table 4. Noise measurement results inside the amphitheatres 1, 2 and 3

<table>
<thead>
<tr>
<th>Points</th>
<th>Noise level in dB (A)</th>
<th>Points</th>
<th>Noise level in dB (A)</th>
<th>Points</th>
<th>Noise level in dB (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N° 1</td>
<td>48.25</td>
<td>N° 1</td>
<td>50.95</td>
<td>N° 1</td>
<td>56.5</td>
</tr>
<tr>
<td>N° 2</td>
<td>54.65</td>
<td>N° 2</td>
<td>49.15</td>
<td>N° 2</td>
<td>41.95</td>
</tr>
<tr>
<td>N° 3</td>
<td>54.05</td>
<td>N° 3</td>
<td>51.55</td>
<td>N° 3</td>
<td>48.05</td>
</tr>
<tr>
<td>N° 4</td>
<td>55.55</td>
<td>N° 4</td>
<td>34.75</td>
<td>N° 4</td>
<td>58.85</td>
</tr>
<tr>
<td>N° 5</td>
<td>56.7</td>
<td>N° 5</td>
<td>53.8</td>
<td>N° 5</td>
<td>39.3</td>
</tr>
<tr>
<td>N° 6</td>
<td>57.9</td>
<td>N° 6</td>
<td>55.25</td>
<td>N° 6</td>
<td>49.8</td>
</tr>
</tbody>
</table>

Source: Authors

Table 5. Noise measurement results inside the amphitheatres C, D and K

<table>
<thead>
<tr>
<th>Points</th>
<th>Noise level in dB (A)</th>
<th>Points</th>
<th>Noise level in dB (A)</th>
<th>Points</th>
<th>Noise level in dB (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N° 1</td>
<td>48.7</td>
<td>N° 1</td>
<td>55</td>
<td>N° 1</td>
<td>65.65</td>
</tr>
<tr>
<td>N° 2</td>
<td>55.15</td>
<td>N° 2</td>
<td>55.65</td>
<td>N° 2</td>
<td>67.95</td>
</tr>
<tr>
<td>N° 3</td>
<td>52.75</td>
<td>N° 3</td>
<td>55.9</td>
<td>N° 3</td>
<td>70.1</td>
</tr>
<tr>
<td>N° 4</td>
<td>56.45</td>
<td>N° 4</td>
<td>54.7</td>
<td>N° 4</td>
<td>68.2</td>
</tr>
<tr>
<td>N° 5</td>
<td>51.45</td>
<td>N° 5</td>
<td>54.19</td>
<td>N° 5</td>
<td>64.6</td>
</tr>
<tr>
<td>N° 6</td>
<td>63.35</td>
<td>N° 6</td>
<td>54.55</td>
<td>N° 6</td>
<td>58.95</td>
</tr>
</tbody>
</table>

Source: Authors

Table 6. Noise measurement results inside the amphitheatres E and G.

<table>
<thead>
<tr>
<th>Points</th>
<th>Noise level in dB (A)</th>
<th>Points</th>
<th>Noise level in dB (A)</th>
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<tr>
<td>N° 1</td>
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<td>N° 1</td>
<td>50</td>
</tr>
<tr>
<td>N° 2</td>
<td>51.2</td>
<td>N° 2</td>
<td>58.2</td>
</tr>
<tr>
<td>N° 3</td>
<td>51.45</td>
<td>N° 3</td>
<td>61.95</td>
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<td>69.35</td>
</tr>
<tr>
<td>N° 5</td>
<td>49.55</td>
<td>N° 5</td>
<td>61.25</td>
</tr>
<tr>
<td>N° 6</td>
<td>67.95</td>
<td>N° 6</td>
<td>63</td>
</tr>
</tbody>
</table>

Source: Authors

The amphitheatre noise measurement results (Table 5) show that the average noise level varies between 34.75dB (A) - and 57.9dB (A), which proves that these places are not suitable quiet places for learning and teaching.

The noise measurement results in amphitheatres (C, D, E, G and K): show that there is a significant increase compared to those recorded in amphitheatres 1, 2 and 3, knowing that the recorded noise value varies from 48.7dB(A) - 70.1dB(A). This latter is due to several factors, such as the room reverberation time, the internal sound absorption and the capacity of the amphitheatre for students; when
the higher the capacity, the noise level is higher, as well as the location of the amphitheatre, which is beside the road, is also characterised by the movement of pedestrians and cars. However, it should also be noted that a vital remark was taken into account during the noise measurements, which is due to the high temperature and certain climatic factors that characterise the desert region, such as the winds, which make the students prolong their stay time inside the rooms and classes due to the availability of air conditioners and cooling systems. This latter is responsible for generating a slightly high background noise inside classes.

Figure 13. Sound pressure level measured from 10 a.m. to 12 a.m. inside Amphitheatre 1 (left). Sound pressure level measured from 10 a.m. to 12 a.m. inside Amphitheatre 2 (right).

Source: Authors

Figure 14. Sound pressure level measured from 10 a.m. to 12 a.m. inside Amphitheatre 3 (left). Sound pressure level measured from 10 a.m. to 12 a.m. inside Amphitheatre D (right).

Source: Authors
3.3.2 The libraries of the university

Table 7. Noise measurement results in scientific and technical libraries

<table>
<thead>
<tr>
<th>ST Library</th>
<th>Library of economic, commercial and management sciences</th>
<th>Central Library</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points</td>
<td>Noise level in dB (A)</td>
<td>Points</td>
</tr>
<tr>
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<td>54.75</td>
<td>N° 1</td>
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<td>N° 3</td>
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<tr>
<td>N° 4</td>
<td>53.45</td>
<td>N° 4</td>
</tr>
<tr>
<td>N° 5</td>
<td>70.9</td>
<td>N° 5</td>
</tr>
<tr>
<td>N° 6</td>
<td>70.05</td>
<td>N° 6</td>
</tr>
</tbody>
</table>

Source: Authors
3.4 THE BLOCKS OF PRACTICAL WORK AND UNIVERSITY LABORATORY

Table 8. Noise measurement results in the blocks of practical work and university laboratory.

<table>
<thead>
<tr>
<th>Technology Hall</th>
<th>Computing centre</th>
<th>Educational laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points</td>
<td>Noise level in dB (A)</td>
<td>Points</td>
</tr>
<tr>
<td>N° 1</td>
<td>60.55</td>
<td>N° 1</td>
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<tr>
<td>N° 2</td>
<td>61.05</td>
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<tr>
<td>N° 3</td>
<td>63.7</td>
<td>N° 3</td>
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<td>72.25</td>
<td>N° 5</td>
</tr>
<tr>
<td>N° 6</td>
<td>75.20</td>
<td>N° 6</td>
</tr>
</tbody>
</table>

Source: Authors

3.5 THE ADMINISTRATIVE BLOCKS, MEDIA-AUDIOVISUAL LIBRARY AND MEDICAL-SOCIAL CENTRE

Table 9. Noise measurement results in the administrative blocks, Media-audiovisual library and Medical-social centre.

<table>
<thead>
<tr>
<th>Faculty Administration</th>
<th>Media and Audiovisual Library</th>
<th>Medical-social center</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points</td>
<td>Noise level in dB (A)</td>
<td>Points</td>
</tr>
<tr>
<td>N° 1</td>
<td>54.05</td>
<td>N° 1</td>
</tr>
<tr>
<td>N° 2</td>
<td>55.5</td>
<td>N° 2</td>
</tr>
<tr>
<td>N° 3</td>
<td>62.4</td>
<td>N° 3</td>
</tr>
<tr>
<td>N° 4</td>
<td>47.51</td>
<td>N° 4</td>
</tr>
<tr>
<td>N° 5</td>
<td>50.85</td>
<td>N° 5</td>
</tr>
<tr>
<td>N° 6</td>
<td>53.3</td>
<td>N° 6</td>
</tr>
</tbody>
</table>

Source: Authors

Figure 17. Sound pressure level measured from 10 a.m. to 12 a.m. inside faculty administration (left). Sound pressure level measured from 10 a.m. to 12 a.m. inside the media and audiovisual library (right).

Source: Authors
Figure 18. Sound pressure level measured from 10 a.m. to 12 a.m. inside the medical-social centre (left). Sound pressure level measured from 10 a.m. to 12 a.m. inside the ST Library (right).

Source: Authors

Figure 19. Sound pressure level measured from 10 a.m. to 12 a.m. inside the Library of Economics (left). Sound pressure level measured from 10 a.m. to 12 a.m. inside Central Library (right).

Source: Authors

Figure 20. Sound pressure level measured from 10 a.m. to 12 a.m. inside the Technology Hall (left). Sound pressure level measured from 10 a.m. to 12 a.m. inside the Computing centre (right).

Source: Authors
By analysing the noise results inside the university campus, we can conclude that the most important noise sources are the movement of vehicles, student activities, and construction work.

The influence of vehicle traffic on noise pollution inside the University of Adrar appears well in Table 7, where we recorded 75.2 dB (A) because of the secondary entrance road next door to the Library of Economics, Commerce and Management.

Table 8 also illustrates the student activities' effect on noise pollution varies from 60 dB(A) to 77 dB(A), where they do their practical work at the level of Technological Hall, Computing Center and Pedagogical Laboratory; these three blocks are not equipped with anti-noise measures and are not covered by walls and screens against noise pollution. The construction and renovation work inside the university thus have a significant effect on noise pollution. This is well shown in Table 9, which presents slightly high values; we cite the case of Faculty Administration; these works are generally accomplished during the vacation period during the summer season. However, the hot desert climate does not encourage the authorities to schedule work outside teaching time for practical and health reasons of the workers.

3.6 NOISE MAPPING OF THE UNIVERSITY OF ADRAR

The noise mapping of the University of Adrar employed a simulation methodology integrating real-time noise data and an advanced multidimensional model of the university campus. The noise data utilized in the simulation were
derived from outdoor measurements conducted across various classes and districts, providing a comprehensive representation of the ambient acoustic environment. These data points were meticulously integrated into Geographic Information System (GIS) software, specifically leveraging the capabilities of ArcGIS version 10.8. The variables extracted from the measurements were employed to construct a prediction surface utilizing the Kriging interpolation method.

The discerned elevated noise levels were notably attributed to the operational activities of the air conditioning systems and ongoing maintenance endeavors throughout the academic season. Notably, these activities, crucial for maintaining optimal conditions amid high temperatures and sandy winds, are constrained from execution during vacation periods.

Additionally, our observations revealed that a significant portion of inter-building transportation within the university occurs via automobiles, emerging as a predominant source of noise pollution this source as known to be the most important source of noise in urban settings. On-site data collection encompassed floor areas and building facades, and a systematic distribution of one hundred point receptors at a consistent height of 1.6 meters was executed within the study area. Figure 22 visually encapsulates the noise map portraying the existing acoustic conditions before any intended intervention. The depiction showcases a prevalent exposure of the majority of the study area to sound levels surpassing 65 dB(A), with specific locations falling within the ranges of 51 to 69 dB and 70 to 85 dB (A).

The outcomes derived from the noise mapping substantiate the imperative for planned interventions aimed at mitigating the impact of noise pollution sources and instituting solutions to cultivate a more conducive sonic environment for the university campus. Prospective interventions include meticulous landscaping and campus planning to curtail noise propagation, alongside the integration of soundproofing materials in the construction of buildings, classrooms, and dormitories. The strategic plantation of trees, hedges, and bushes is advocated to serve as natural noise-reducing barriers.
Equally vital is the orchestration of activity schedules, aligning noisy endeavors such as building maintenance, construction work, and sporting events with minimal disruptions to students and staff. Moreover, a judicious avoidance of noisy activities during class hours and examination periods is recommended for the preservation of an academically conducive soundscape.

4 CONCLUSION

In this study, the analysis of the different climatological parameters (temperature, humidity, precipitation, wind speed) gives a precise idea of the desert climate, which is characterised by a high annual temperature and by an alternation of sandy winds of varying speed depending on the time of Year, with low or even non-existent humidity in certain areas. These parameters have a significant effect on pollution sound inside the campus of the university; we have concluded that:

- the overall noise level inside the rooms and building at Adrar University is unacceptable;
- the most crucial noise sources inside the university are the movement of vehicles, student activities, and construction activities;
- the temperature and certain climatic factors that characterise the desert region, such as the winds, cause students to extend their time inside the
rooms due to the availability of air conditioners and cooling systems. These cause high background noise inside the classrooms;

- the increased noise levels have been considered a contributing factor to university students' decreased academic performance. Therefore, it is imperative to prioritise establishing a favourable acoustic environment within university buildings and their environs to reduce noise levels;

- the noise measurement results in the urban desert environment of Adrar, Tamantit and Timimoune show that the desert environment is calmer, favourable for living well, resting and having a better quality of life;

- exposure to loud noise was 10 a.m. to 12 a.m., coinciding with the best climate parameters;

- the hot desert climate does not encourage the authorities to schedule work outside teaching time for practical and health reasons of the workers.

The social survey results show that more than 83% of respondents think that the noise recorded inside Adrar University negatively affects and impacts students' academic performance. The Desert environment's calm and tranquillity made people sensitive to low noise levels. For this reason, 51% of respondents were sensitive to the lowest noise level. 55% of the subjects answered that there is no acoustic comfort inside the University of Adrar. However, 45% of the respondents were annoyed during the practical sessions, 30% during the courses, and 25% at rest places.

On the other hand, regarding the impact of noise sources on individuals, the responses are 28% for voice and communication, 26% for construction and renovation work, and 22% for noise generated with air conditioning systems. As a result, we concluded that there was a significant correlation between meteorological parameters and the time when people were more exposed to noise. The meteorological parameters play a paramount role; whenever the weather is pleasant, the movement of students and university workers peaks, which leads to an increase in the noise level inside the university. Finally, we have done noise mapping of the University of Adrar to determine the noisiest areas that are less noisy and for the planning of the campus university to reduce the spread of noise. Testing architectural and urban noise reduction alternatives and promoting adequate acoustic conditions depend on joint action between campus planning and room design.
The findings of this research hold significance for both society and academia:

- provide a nuanced understanding of the distinct challenges posed by desert climates in exacerbating noise pollution on university campuses;
- can inform the development of targeted noise mitigation strategies for universities in arid regions, enabling more serene and conducive learning spaces;
- results generated can extend benefits to surrounding communities, informing noise management approaches in desert-based institutions and municipalities;
- highlights the importance of considering unique climatic and behavioural factors when addressing noise dynamics in desert-based academic settings;
- empower universities, policymakers and urban planners to devise more effective noise mitigation strategies, fostering enriching educational experiences and enhancing quality of life.

However, the study is limited in geographic scope, focusing solely on the University of Adrar. Further research is needed to explore noise pollution patterns in other desert-based universities to validate generalizability.

Future work should integrate advanced noise modelling, incorporate longitudinal data, investigate secondary health/well-being effects, and explore economic/environmental impacts of mitigation strategies. Addressing these limitations can strengthen the evidence base and provide more robust recommendations for enhancing acoustic environments in arid academic settings.
REFERENCES


