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Field Measurements and Human Perception to Remediate Noise Pollution in the Urban Public Parks in Saudi Arabia

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Abstract: The deleterious effects of noise pollution on public health have been well documented, with traffic noise being identified as a significant contributor to stress and adverse impacts on the human body and mind. In this study, sound levels at 12 different points in Al-Oqailat Park in Buraydah, Saudi Arabia, were measured using a sound level meter (SLM), with the study's primary objective being to conduct this measurement. The experimental results were then compared with perception measurements collected from users who frequently visited Al-Oqailat park. Sound measurements were taken in four different zones (A, B, C, and D) during rush hours between 1:30 p.m. and 5:20 p.m. It was found that noise levels at point A1 peaked at 79 dBA at 4:40 p.m., while the lowest level recorded was 41.1 dBA at point D2 at 2:35 p.m. The range of noise levels varied between 79 and 41 dBA, with a rate of decline of 48.10%. Zones A and B seemed to have the highest noise levels during rush hours, since they were located closest to King Fahd Road and Al-Adl Street, while zone D exhibited the lowest noise levels due to its location as a parking lot for Buraydah Court. An intermediate noise level was found in zone C, in the middle of Al-Oqailat park. The people perception results, completed by 84 park visitors, showed that zone A was identified as having exceptionally high noise levels compared to the other zones, with zone D having the lowest levels. These results were consistent with the experimental findings and reflected that the points along King Fahd Road and Al-Adl Street had the highest noise levels. Overall, the research highlighted the dominance of car traffic and horns as the primary sources of noise pollution in and around Al-Oqailat Park, emphasizing the significance of meticulous site selection for parks in urban areas.

Keywords: noise level; urban parks; sound level meter; soundscape; environment; land use

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1. Introduction

Starting in the 1970s, researchers have undertaken extensive studies to develop effective strategies for reducing the effect of noise and implementing measures to mitigate its effects [1,2]. Air pollution is a complex environmental issue that encompasses both air pollution and noise pollution. It refers to the presence of harmful substances or pollutants in the air, resulting from various human activities such as industrial emissions, vehicular exhaust, and the burning of fossil fuels. These pollutants, such as particulate matter (PM) [3], ozone (O3) [4], and volatile organic compounds (VOCs) [5], have detrimental effects on human health, ecosystem balance, and overall air quality. In addition to air pollution, noise pollution (which is the main concern of this study) also contributes to the degradation of the environment, arising from sources such as transportation, construction, and industrial activities. The combined effects of air and noise pollution pose significant challenges to public health and necessitate comprehensive efforts to mitigate their impacts and safeguard the well-being of communities.

Concerning noise pollution, studies have shown that traffic noise seriously impacts the human body and mind [6,7]. The ultimate goal of these measures was to conduct a comprehensive study of the current noise condition, emphasizing its effects, in order to formulate future research directions. By characterizing the existing noise environment, this initiative aims to create healthier and more conducive surroundings that promote well-being for individuals and other living organisms. For example, highway noise can significantly affect individuals, ranging from stress and sleep disturbances to long-term physical health impacts. Moreover, the persistent stress reaction may negatively impact respiratory health, making individuals more susceptible to respiratory diseases [6]. M. Basner et al. [8] said that noise is standard daily and can have auditory and non-auditory health impacts.

Studies have shown that chronic annoyance can bridge noise exposure and illness development [9,10]. Furthermore, the perception of noise cannot be exclusively attributed to sound pressure levels, as other variables, including sound quality, ambient conditions, current activities, and listener participation, have also been shown to influence noise perception. Noise pollution affects children more than adults, although adults can feel more noise than children [11,12]. On the other hand, Tang et al. [13] highlighted the importance of noise mapping in an urban area in Taipei city using limited noise sensors and diverse data sources. The results shoswed a mean difference of −6.25 dBA to −4.46 dBA in the 2D noise model and a mean prediction error of 0.02 dBA to 1.93 dBA in the 3D noise model. The study revealed that over 30% of Taipei city's population is exposed to noise levels above 53 dBA Lden, and more than 25% experience noise levels exceeding 45 dBA Lnight. Through the analysis of three primary data sets, a study by Chitra et al. [14] investigated the acoustic ambience of an urban park. Soundwalk observations, ambient sound measurements, and visitor surveys were used. As a result, the sound levels of the park's fountain area have been reduced and dense vegetation has been shown to affect soundscapes. The soundscape can be manipulated by introducing desired sounds, such as birds chirping and water sounds.

Regarding noise pollution in the Kingdom of Saudi Arabia (KSA), there is currently a shortage of studies and research regarding sound noise in KSA, as well as a lack of measured noise levels of all types. Only a few studies have been conducted in the KSA on the noise level in urban areas and other areas of the KSA, including Jeddah [15] and the campus of Dammam University [16]. In the KSA, the Ministry of Environment, Water, and Agriculture announced the start of implementing the executive regulation for noise in July 2022 [17]. It aims to monitor and periodically evaluate noise levels throughout the Kingdom and monitor compliance with permissible noise limits in parks, residential areas, industrial areas, and others. The process of establishing regulations, requirements, and exerting control over noise levels aids in the planning, reduction, adoption, and monitoring of noise levels in an effective manner.. Comfort is obtained at specific levels of sound. Our situation in the parks should not exceed these levels to achieve human comfort. Due to the recent implementation of the executive regulations in the KSA, the study faced difficulty understanding the problem, identifying solutions, and finding a lack of information. Therefore, despite many studies that have looked at noise pollution in the built environment and its impact on people's lives and health, there is a lack of investigation on how to predict environmental noise in public spaces.

The executive regulation of noise sets the noise limits in residential and commercial areas, on the sides of roads, industrial areas, and construction sites, dividing areas into different categories depending on density in residential areas, theme parks, and environmentally sensitive areas. Category (A) deals with low-density residential areas (1000–3999 capita/km^2) in addition to areas of tourist attractions and theme parks, areas around hospitals, schools, and environmentally sensitive areas. In category (A), the allowable noise limits as A-weighted equivalent continuous sound level measured over a specified period (LAeq, T) are 50 dBA during day time and 40 dBA during evening time and increased on the roadside to 70 dBA during the day time and 65 dBA during evening time. However, each state and local government in the KSA has its noise ordinances [17].

Implementing environmental noise barriers is a highly effective and feasible approach to mitigating the impact of noise. Recent studies have demonstrated that installing noise barriers in areas sensitive to noise can significantly decrease its effects. Gabions, which are steel wire boxes filled with stones commonly utilized in civil engineering and road construction, have been found to reduce sound levels by approximately 5 dBA (dBA) [18]. According to Bougdah et al. [19], noise barriers with ribbed structures can provide an insertion loss of 10 to 15 dBA. Arenas [20] also discovered that noise barriers improve sleep conditions. Employing vegetation to minimize noise is effective and practical, particularly when the desired outcome is not extremely demanding [20]. A row of mature trees spanning over 7 m wide can offer an attenuation of 2 to 4 dBA [21]. For frequencies below 250 Hz and above 1000 Hz, a belt of tall and dense trees with a width ranging from 15 to 40 m can achieve a noise reduction of 6 to 8 dBA [22]. Additionally, alternative barriers such as waterfalls can be utilized to reduce the impact of traffic noise.

Due to a lack of research and studies on sound pollution in the KSA, this research was conducted to measure the noise levels in urban parks using field measurements and human perception methodologies. The study provides a comprehensive analysis of the soundscape in Al-Oqailat park, Buraydah, Saudi Arabia, aiming to reduce noise in an urban park and provide actual data and measurements to assist government agencies and those interested in this subject. The research selected a suitable public park in Buraydah based on specific criteria and collected noise data using sensitive sensors distributed across different study areas. Simultaneously, a perception survey was conducted among park visitors to understand their behaviour concerning noise pollution. The findings emphasize the impact of traffic and geographical position on noise pollution in urban areas, highlighting the need for effective noise control measures. Additionally, the study offers insights for enhancing the acoustic environment of the park and emphasizes the importance of considering sound pollution in future park designs for sustainable urban development.

2. Methodology and Data Collection

2.1. Study Area

Based on the 2022 urban observatory indicators of the Qassim region, KSA, the land use percentage for public parks and gardens in Qassim was between 4.17% and 0.6%. Most gardens are located within residential neighbourhoods, and most public parks are on the city’s public roads. For this reason, the park of Al-Oqailat in Buraydah, KSA (Figure 1) was chosen because (1) Buraydah city has a low land-use percentage for parks (0.95%), and (2) the park of Al-Oqailat in Buraydah is located at the heart of Buraydah and on one of the largest road, the King Fahad highway, and is exposed to high noise pollution from traffic and at the same time attracts many visitors. Al-Oqailat Park is one of the largest parks in Buraydah. It covers about 43,200 m^2 and is located next to the court building. It has three football fields and a walkway surrounded by palm trees for walking, but most of it is next to the main roads and is subject to considerable noise pollution. There are food stalls, a small theatre in the centre, an area for exercise, and a playground for children. Most parks consist of green areas that many visitors use, whether for sports, recreation, and/or children’s picnics, in addition to attracting many birds. Residential houses surround the park on the northeast side. This research studied the extent to which the park is affected by traffic noise and how the elements of the park reduce the annoying noise.

Figure 1 shows an aerial view of the park with the main King Fahad Road and secondary roads. The red line indicates the boundary of the park.

Figure 1. Satellite image of Al-Oqailat Park in Buraydah, KSA with surrounding roads and area (adapted from Google Maps©. Imagery date: 10 May 21 by Maxar Technologies).

2.2. Material and Methods

The acoustic environment was examined in two phases consisting of Phase (1), the sound measurements, and Phase (2), the survey of park visitors' perceptions (84 park visitors responded to this survey). The electronic survey using Excel forms was formulated so straightforwardly that it would be accessible to all groups of park visitors.

2.2.1. Phase 1: Sound Measurements

During Phase 1, the park's soundscape was measured on-site by measuring sound levels concerning landscape features. The site was divided into four zones and twelve points to conduct the background sound measurements according to the sound sources and landscape features identified by the site visit during the study. These twelve points were designated as four zones (A, B, C, and D), with three points in each zone, as shown in Figure 2. To evaluate the acoustic environment at different locations, background noise levels were recorded using a sound level meter. The measurements were taken three times per second, and the results were reported in decibels (dBA), which is the standard unit for measuring sound levels. . These devices were placed at a height of 1.5 m [14], above the ground. The instrument was oriented as humans perceive the acoustic environment far from any object by at least 1 m to obtain precise data. Measurements were taken during rush hours between 1:30 p.m. and 5:20 p.m., as identified by the Ministry of Transport, Saudi Arabia, because the traffic noise is the main factor affecting the acoustic environment in the case of the studied park.

Figure 2. Division of the park into 4 zones (A, B, C and D) and 12 points (each zone with three points) (image adapted from Google Maps©. Imagery date:10 May 23 by Maxar Technologies).

2.2.2. Phase 2: Survey of Park Visitors' Perceptions Using the ISO Soundwalk Method

The soundscape was evaluated by 84 Al-Oqailat Park visitors who were familiar with the soundscape through the ISO soundwalk method. The park visitors provided their perceptions of the soundscape through in-person interviews.

The ISO soundwalk method is a standard approach for measuring environmental noise that involves subjective assessments from human listeners. It was developed by the International Organization for Standardization and consists of taking a group of people on a walking tour of the area being studied. During the walk, the participants evaluate the sound environment using standardized rating scales and provide ratings for different soundscape aspects. Since the measurement of sounds depends on people's perceptions, the primary purpose of a soundwalk was to encourage participants to listen discerningly and make judgments about the sounds they hear. In this study, a group of individuals familiar with Al-Oqailat Park was selected to participate in the soundwalk survey. They were informed about the data collection procedure and the survey objectives, which included evaluating the noise levels at different points in the park as shown in Table 1. The information gathered from the soundwalk survey was analysed to better understand the acoustic characteristics of the park and the potential impact of noise on human health and well-being.

Table 1. Survey for measuring sound quality in Al-Oqailat Park addressed to visitors.

Category	Question	Answer	Landscape Element Nearby
Overall quality	How loud is it here?	(1) Very little (2) Little (3) Moderately (4) High (5) Very High	Trees, shrubs, ground/green cover, tower, structure, pavement, and fountain.
	How uncomfortable are you in this place in terms of the intensity of the sounds and the intensity of the annoyance?	(1) Very little (2) Little (3) Moderately (4) High (5) Very high	
	How appropriate is the sound to the surrounding?	(1) Very little (2) Little (3) Moderately (4) High	

	How often would you like to revisit this park? (because of the sound)	(5) Very High (1) Never (2) Rarely (3) Sometimes (4) Frequently (5) Very frequently
Sound source	Please list sound sources you noticed in descending order starting with the most noticeable sound source	Open answer limit ten items (list below) (1) Car sounds (2) Horns sound (3) People screaming sounds (4) Children screaming sounds (5) Children playing sound (6) Birds chirping sounds (7) Phone ringing sound (8) The sounds of people interacting with each other (1) Tree rattling sounds (2) Wind sound (3) Engines sound
Comment	List suggestions for improving the quality of the park's acoustic environment	Open answer

A soundwalk path with 12 points (break locations) (Figure 2) was chosen from the entire park to define the soundwalk path based on the area's landscape features and sound sources. Each participant was given the layout of the park prior to the study day and encouraged to visit the park before the actual survey began. The time of the soundwalk was determined based on the peak time of the park. After reaching each designated location, the individuals were directed to pay attention to the noise origins and answer the survey. Participants were also instructed to silently explore and observe the surrounding environment they perceived during the study. Likewise, the acoustic environment was assessed at various break locations (points) along a soundwalk path. For each zone, one break location was carefully selected based on specific features in the surrounding landscape, such as trees, walls, children's playgrounds, and the distance from the main road. At each break location, the sound level meter device was used to measure the sound levels for approximately five minutes. This approach allowed the researchers to examine the relationship between each break location and the factors surrounding it, as well as to capture the diverse range of sounds experienced throughout the soundwalk path.

2.3. The Sound Level Meter

The sound level meter device used to measure the sound was a calibrated PCE-322A (PCE Instruments U.K. Ltd., Southampton, United Kingdom), compatible with standard IEC61672-1 CLASS2 [23]. It is a handheld, portable noise meter with built-in data-logging or data-recording functionality. Its accuracy is up to 1.4 dBA and measures different levels of sound ranging between 30 dBA and 130 dBA. It includes data-logger software. The calibration of all devices has been certified and done by Anaum international electronics LLC, Abu Dhabi, UAE.

The equivalent sound level (L_{eq}) was applied due to the fluctuation of the measured sound samples and was calculated using the following formula [1]:

$$L_{eq} = 10 \log \sum_{i=t}^{i-n} (10^{L_i/10})(t_i) \quad (1)$$

where

n = total number of samples taken
L_i = the noise level dBA of the ith sample
t_i= fraction of total sample time

3. Results and Analysis

Measuring a soundscape is a complex task due to the fact that it is composed of multiple layers of sound, which cannot be effectively captured by a few simple numerical measurements. To comprehensively assess and evaluate a soundscape, it is necessary to combine both objective measurements of the acoustic environment and subjective evaluations based on human perception. The results of soundscape research can be divided into two main categories.

The first category of soundscape investigation is based on sound level meters, which measure sound intensity in dBA. Sound level meters provide objective measurements of the physical properties of sound, such as intensity, frequency, and duration. These measurements can be used to analyse the acoustic environment and identify potential sources of noise pollution.

The second category of soundscape investigation is based on survey analysis results. This involves gathering subjective evaluations of the acoustic environment from human participants, who provide feedback on their perceptions of sound quality, annoyance, and other factors contributing to their overall soundscape experience. By combining objective measurements and subjective evaluations, researchers can gain a more complete understanding of the complex and multi-layered phenomenon that is a soundscape.

3.1. Statistical Analysis of the Noise Data

The statistical information in Table 2 provides insights into the noise levels across various zones in the park with 14,084 records for each zone. When considering the central tendency, zone A1 exhibited the highest mean noise level (67.37), indicating a relatively higher average noise level compared to other zones. Conversely, zone D1 had the lowest mean noise level (46.59), suggesting a lower average noise level. In terms of variability, zone D1 displayed the highest standard deviation (4.48), indicating a greater variation in noise levels around the mean, while zone B1 demonstrated the lowest standard deviation (2.18), suggesting a relatively more consistent noise level. Examining the range of values, zone A1 had the highest maximum noise level (85), and zone B2 had the lowest maximum noise level (65.2).

Conversely, zone D1 had the lowest minimum noise level (40.5), and zone A1 had the highest minimum noise level (53). Overall, the statistical table highlighted variations in noise levels, including the central tendency, variability, and range of values across the different zones. This provided valuable insights into noise distribution and characteristics in each area.

Table 2. Statistical analysis of noise levels in different zones in the park.

Stat Measures	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3
mean	67.37	61.62	60.20	59.40	55.14	56.21	52.65	50.20	50.76	50.51	46.59	48.52
std	4.04	3.80	3.60	3.86	2.18	2.07	3.58	2.35	2.39	4.48	2.97	2.83
min	53	49	50	46.6	46.3	48.7	42.5	43.6	43.3	40.5	40.1	41.1
25%	65	59	58	57.4	53.8	55	50.2	48.6	49.1	47.3	44.6	47
50%	68	62	60	59.6	55.1	56.1	52.5	50	50.5	50	46.1	48.2
75%	70	64	62	61.9	56.6	57.4	54.9	51.7	52	53	48	49.9
max	85	94	82	93.9	65.2	76.9	72.3	82.7	70.9	71	70.8	73.1

3.2. Noise Level Measurements Results

The findings presented in Figure 3 depict the results of rush-hour noise levels between 1:30 p.m. and 5:20 p.m. It is important to note that a sound level meter was utilized to record measurements every second, but for clarity and focus, 10 min intervals were chosen to represent the main results. Upon first inspection, a clear tendency is evident, with point A1 recording the highest noise levels and D2 recording the lowest. Specifically, the noise level reached a peak of 79 dBA at 4:40 p.m. for point A1, located at the intersection of King Fahd Road and Al-Adl Street, while it was only 41.1 dBA at 2:35 p.m. for point D2, located on the southern side of Buraydah Street near the Court. This is understandable given the heavy traffic flow on the King Fahd Road. Overall, the noise levels, ranging from 79 to 41 dBA, exhibited a 48% decrease between these two points. The findings underscore the significant influence of traffic and geographical position on noise pollution levels during peak hours, particularly highlighting the relative distance of each zone to the highway.

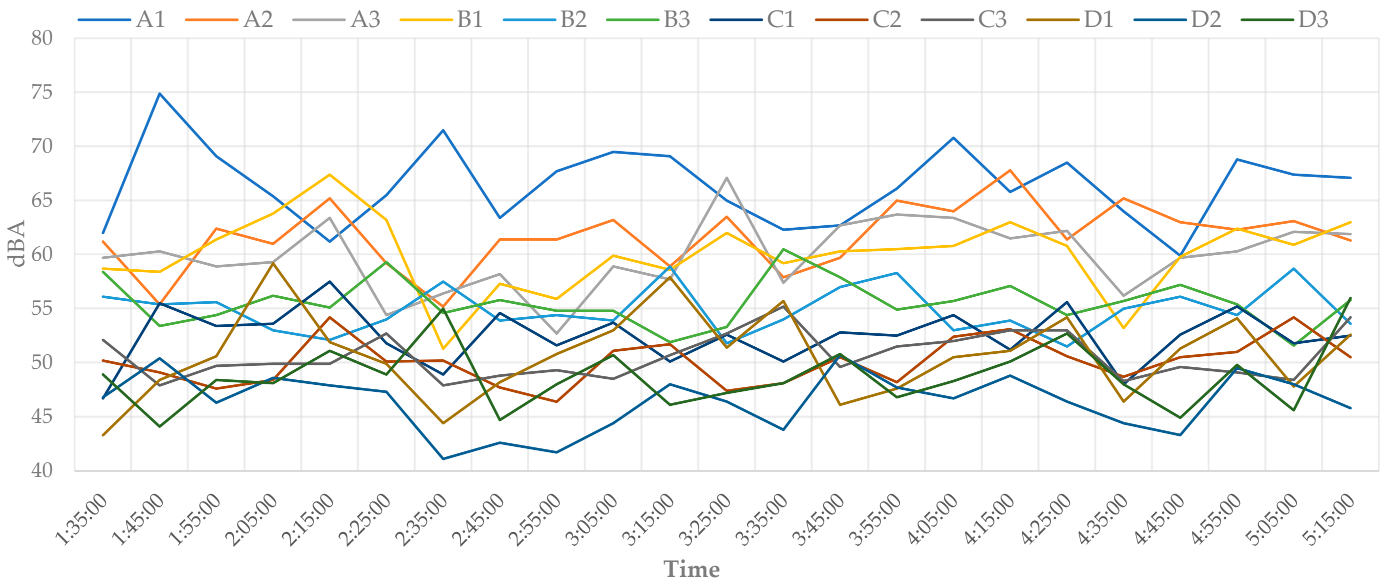
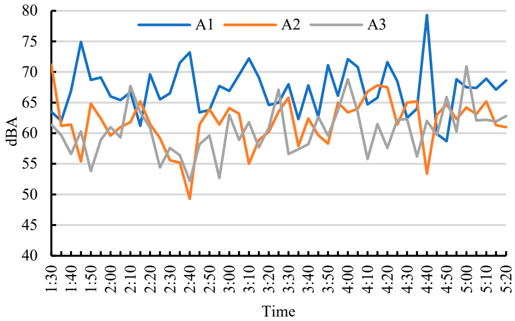


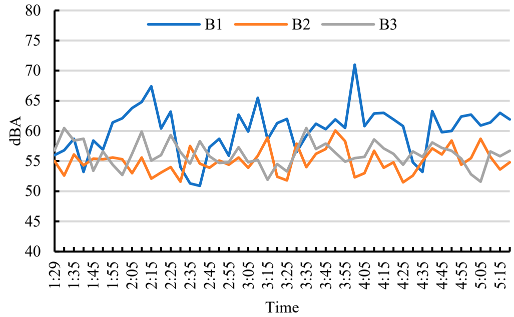
Figure 3. The sound level meter records at each point at 10 min intervals.

Figure 4 presents a comparative analysis of the sound levels recorded by the sound level meter device in all vertical and horizontal zones, consisting of three vertical and four horizontal zones. This comparison aimed to identify the primary recorded points and present the main trends of the device's results.

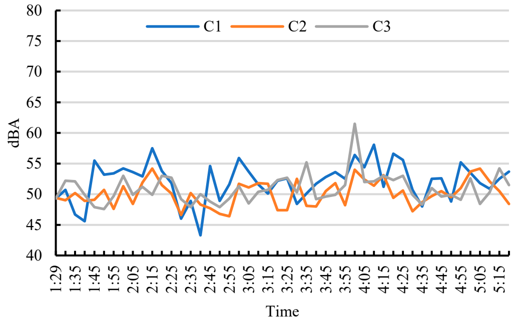
As seen in Figure 4, results show that the variability of sound between horizontal zones (e.g., A1, A2, A3) was less than the variability of sound between vertical zones (e.g., A2, B2, C2, D2). This observation suggests that the soundscape around the park was influenced by the adjacent highway road, King Fahad Road. The study implies that the sound levels are more consistent across different horizontal locations, which may be attributed to the buffering effect of the surrounding landscape on the noise level. On the other hand, the greater variability of sound between different vertical locations could be attributed to the varying heights of the sound sources, including vehicles and other urban elements, which affect the propagation of sound waves.



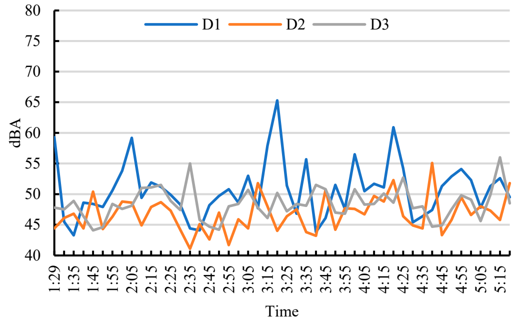
(**a**) zone A results



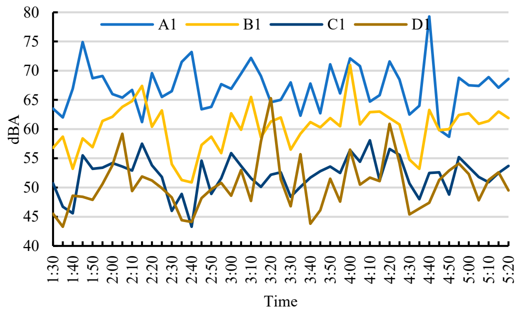
(**b**) zone B results



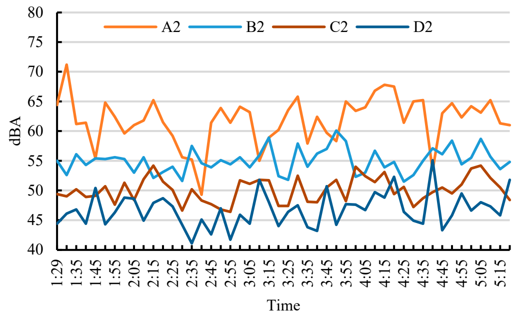
(**c**) zone C results



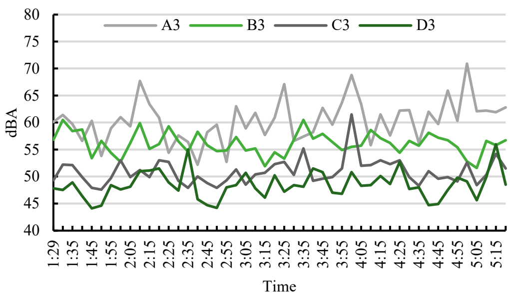
(**d**) zone D results



(**e**) first vertical zone results



(**f**) second vertical zone results



(**g**) third vertical zone results

Figure 4. Comparison between vertical zones and horizontal zones results: (**a**) zone A, (**b**) zone B, (**c**) zone C, (**d**) zone D, (**e**) 1st vertical zone, (**f**) 2nd vertical zone, and (**g**) 3rd vertical zone.

To elaborate that more effectively, Figure 5 provides a visual representation of the maximum, minimum, and equivalent continuous sound level (Leq) records for all points. The results show that zone A recorded the highest sound levels, ranging from 79 to 71 dBA, followed by zone B, with levels ranging from 71 to 60 dBA. In third place was zone D, with sound levels fluctuating between 65 and 55 dBA, while zone C recorded sound levels ranging from 62 to 54 dBA. In light of this finding, it can be observed that zones A and B are the closest to King Fahd Road and Al-Adl Street, the noisiest areas during peak hours. In contrast, zone D is located near the parking lot of Buraydah Court, and zone C is situated in the middle of Al-Oqailat park.

The highest sound levels during rush hours between zones were 79 dBA and 55 dBA, with a reduction of approximately 30%, while the highest levels during off-peak hours were 59 dBA and 41 dBA, also with a reduction of about 30%. Thus, it can be concluded that there was a similar reduction in sound levels during both peak and off-peak hours, despite the significant differences in the sound levels recorded at different zones.

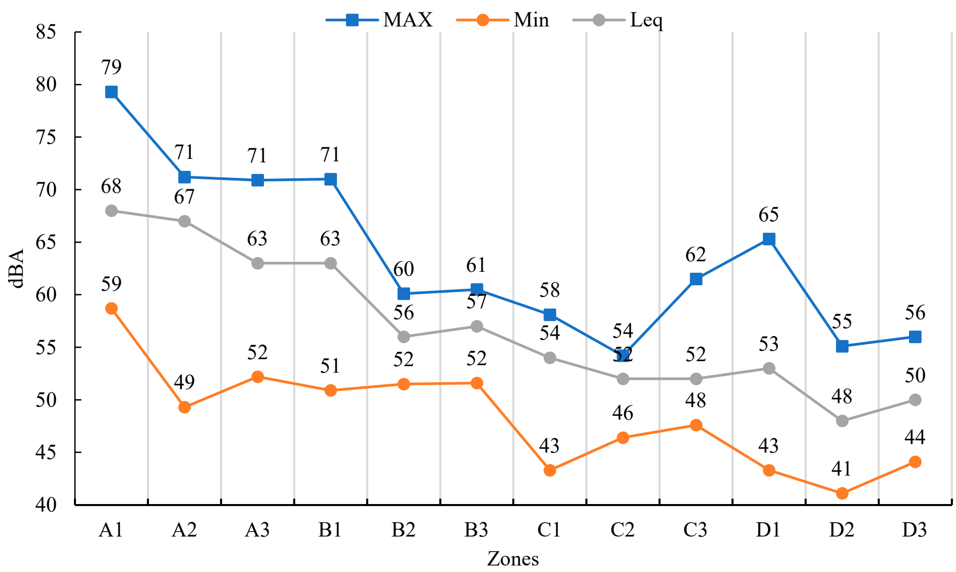


Figure 5. The maximum and minimum sound records of all points.

Similarly, Figure 6a,b show the comparison between the noise level results for the survey and field measurements. As seen in Figure 6a, the A1 point hits the peak with 67 dBA for the average of 4 hours' measurements, which agreed with the result of the survey by the peak sound level (seventh level). On the other hand, the average of 4 hours' measurements at the D2 point comes down to 47 dBA, with around a 30% reduction. Furthermore, the supplied chart delineates that zone D has noted the lowest points for both results (survey and measurement), with an apparent reduction compared to other zones. All figures fluctuate between the 20 dBA ranges for all 12 points. Ultimately, zone B and C have the median sound levels for both results. Figure 6b presents the relationship between the survey and field measurements. The scatter plot further reinforces this correlation by demonstrating how the data points align along a generally upward trend. The strength of this positive relationship was quantified by the coefficient of determination (R^2), which in this case was 0.9202. This value indicates a strong correlation between the survey data and the field measurements, suggesting that the survey results are reliable and representative of the actual measurements taken in the field.

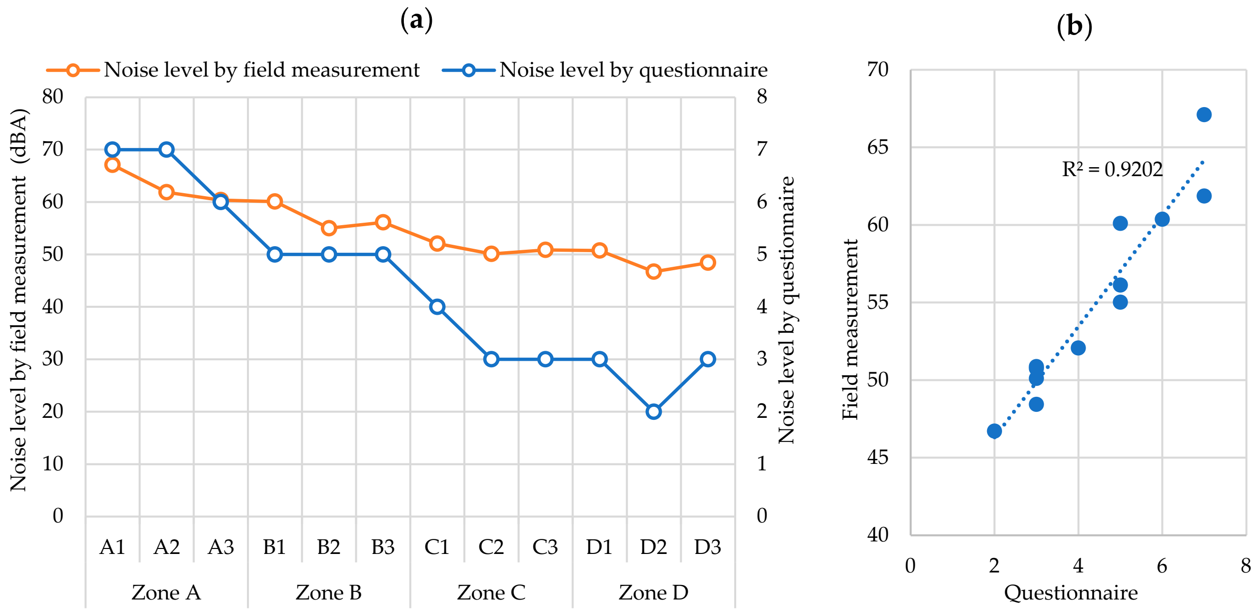


Figure 6. (**a**) Comparison and (**b**) correlation coefficient between survey data and field measurements of noise level.

Turning to average noise levels of the road noise comparison in Al-Oqailat Park (Figure 7), zone A (along with King Fahd Road) and the Court of Buraydah Road reached the highest and lowest average number, which were 63 dBA and 49 dBA, respectively. Zone D shared the lowest average number, where it was also recorded at 49 dBA. This may be interpreted as due to this zone being in the middle of the park with the lowest noise level from points on the intersecting streets. Furthermore, it was evident that Al-Adl Street reached the second apex with 58 dBA, with a slight, 7.93% decrease, but still in the next rank as the noise came from the street. Concerning zone B, the inside park (A3, B3, C3, and D3) and the central park (A2, B2, C2, and D2) documented the average values in noise levels. Zone B was mildly noisy compared to others since it is near King Fahd Road and Al-Adl Street.

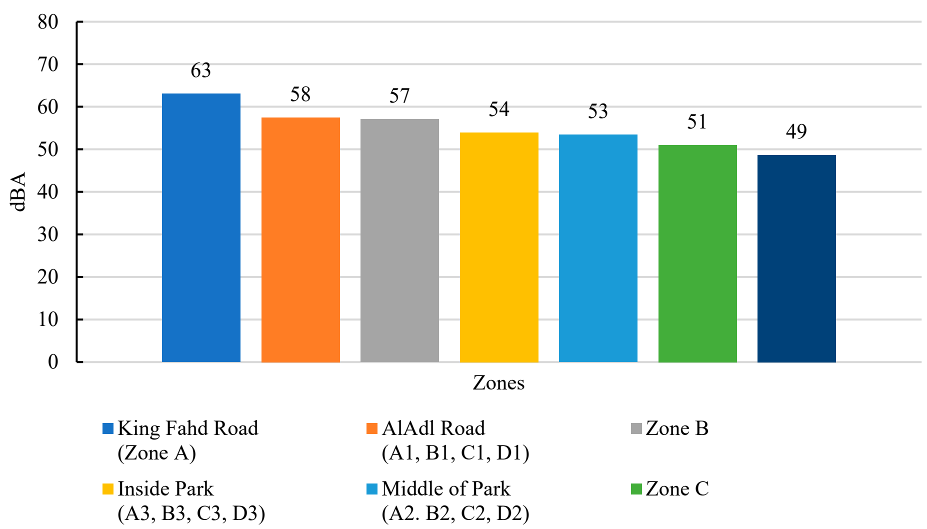


Figure 7. The average noise levels of the road noise comparison for the four zones.

3.3. ISO Soundwalk Survey Results

Saudi Arabian regulations prescribe permissible noise levels that vary based on the time of day and location. In recreational areas, such as parks and gardens, the permissible noise level should not exceed 50 dBA during the day and 40 dBA during the night. In roadside areas, the noise level should not exceed 70 dBA during the day and 65 dBA during the night. It is essential to note that exceeding these limits may adversely affect human health and well-being, including sleep disturbance, cardiovascular diseases, and annoyance. Thus, locating recreational areas at a safe distance from the roadside is advisable to ensure that noise levels do not exceed the permissible limits. This measure can help mitigate the negative consequences of noise pollution on people's health and well-being in urban areas.

The survey results in zone A (A1, A2, and A3) showed that the sound level was significantly higher compared to the other zones (Figure 8). In contrast, zone D (D1, D2, and D3) had the lowest levels, consistent with the experimental results, where points along King Fahd Road and Al-Adl Street recorded the highest sound level. The park visitors reported that zone C (C1, C2, and C3) was the most preferred place to stay, despite the prominent surrounding sounds of children screaming and car horns. These sounds were acceptable and could be tolerated. These results are consistent with the experimental results and underscore the importance of considering visitors' preferences when designing recreational areas. Nonetheless, it is necessary to mitigate the impact of noise pollution, especially in urban areas, to improve visitors' comfort and well-being.

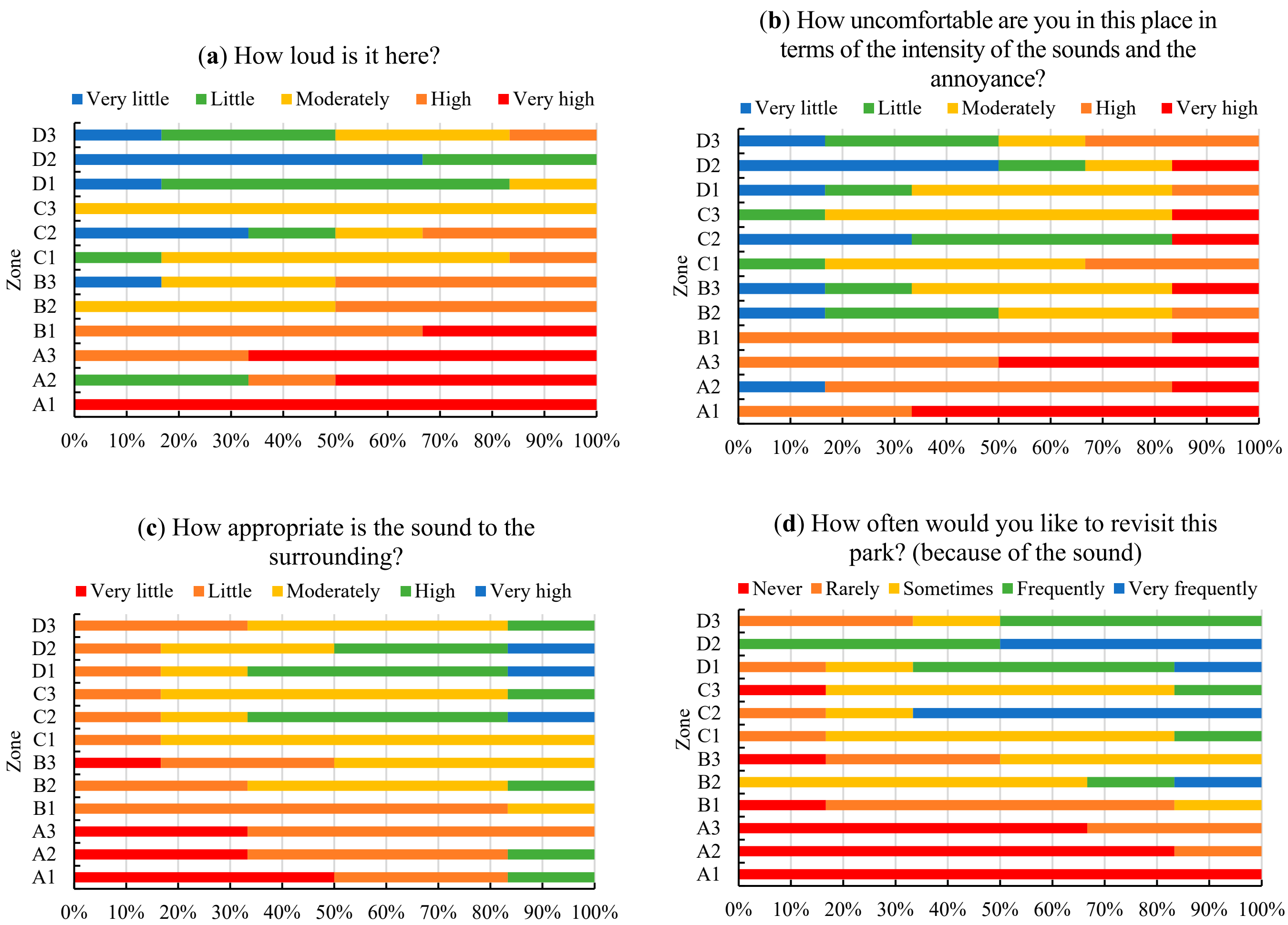


Figure 8. Survey results of park visitors using 100% stacked bar: (**a**) loud, (**b**) uncomfortable, (**c**) appropriate and (**d**) revisiting the park.

The heat map in Table 3 provides a comprehensive overview of the noise sources within the park zones, as observed from the survey results. Analysing the figure, it becomes evident that the park exhibits a diverse range of noise sources. Notably, the predominant noise source in zones A and B was cars, ranking highest in terms of noise contribution. Conversely, bird chirping sound stands out as the least significant contributor to the overall noise level across all zones.

Table 3. Sources and noise level of park zones based on the survey results with Red-Yellow-Green scale.

Activities	Zone A			Zone B			Zone C			Zone D		
	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3
Cars	7	6	6	7	4	4	6	4	2	6	3	4
Children playing sound	2	2	2	4	2	5	3	3	4	5	2	4
Birds chirping sounds	1	0	6	2	5	1	1	2	1	1	1	4
People socializing	6	5	5	3	4	3	3	5	2	4	2	2
Tree rattling sounds	2	2	4	2	5	1	1	2	0	0	1	4
Wind sound	3	3	6	5	6	2	2	2	0	0	3	5

Furthermore, when considering the noise levels across the various zones, zone A emerges as having recorded the highest overall noise level. This finding implies a greater presence of noise-generating activities or factors in zone A compared to the other zones. Conversely, zone D stands out as having the lowest recorded noise level among all the zones surveyed.

The results showcased in the heat map shed light on the significant influence of cars as a noise source in zones A and B. However, it is important to note that other factors may also contribute to the noise levels, which warrant further investigation and analysis. The variations in noise levels across different zones emphasize the importance of understanding and managing the acoustic environment within the park to ensure a more pleasant and serene atmosphere for park visitors.

4. Discussion

The present study aimed to systematically assess and evaluate the soundscape of Al-Oqailat Park by combining objective measurements and subjective evaluations. The results shed light on various aspects of the park's soundscape, including noise levels, variations across different zones, the influence of traffic and geographical position, and visitors' perceptions and preferences regarding noise sources. Measuring a soundscape is a complex task due to its multi-layered nature, comprising various sounds that cannot be effectively captured by simple numerical measurements alone. Therefore, a combination of objective measurements using sound level meters and subjective evaluations based on human perception was employed to provide a more comprehensive understanding of the soundscape.

The statistical analysis of noise data revealed significant variations in noise levels across different zones within the park. This is in line with many studies, including [24], which found variations of sound levels in three different zones due to traffic and various distances from the road. Another study by Ibili et al. [25] indicated that around 90% of the recorded traffic noise levels in the research location exceed 70 dBA. In the present study, zone A1 exhibited the highest mean noise level, indicating a relatively higher average noise level compared to other zones, while zone D1 had the lowest mean noise level. However, only a few times at zone A1 surpass the 70 dBA, which is the threshold limit set by World Health Organization's (WHO) Guideline for Community Noise [26].

These findings suggest that certain zones within the park are subjected to higher levels of noise pollution, possibly due to their proximity to main roads or other noise-generating activities. The analysis of variability and range of values further highlighted the differences in noise distribution and characteristics among the zones.

The noise level measurements during rush hours provided further insights into the impact of traffic and geographical position on noise levels. It was observed that zone A1, located at the intersection of King Fahd Road and Al-Adl Street, recorded the highest noise levels, while zone D2, situated on the southern side of Buraydah Street near the Court, recorded the lowest levels. This tendency can be attributed to the heavy traffic flow on King Fahd Road, which directly influences the noise levels in nearby zones. The results also indicate a significant decrease in noise levels between these two points, emphasizing the influence of traffic and relative distance from the highway on noise pollution during peak hours which was highlighted in previous review work carried out by Ihemeje and Onyelowe [27]. Additionally, the comparison between vertical and horizontal zones revealed that the soundscape near the park was more consistent across different horizontal locations, possibly due to the buffering effect of the surrounding landscape on noise propagation.

The ISO soundwalk survey provided valuable insights into visitors' perceptions and preferences regarding the park's soundscape. Zone A, located near the busiest roads, recorded significantly higher sound levels compared to other zones, aligning with the objective measurements. Conversely, zone D, representing the parking lot of Buraydah Court, exhibited the lowest sound levels. Surprisingly, despite the presence of prominent sounds such as children screaming and car horns, zone C was reported as the most preferred place to stay by park visitors. These findings underscore the importance of considering visitors' preferences in designing recreational areas. Furthermore, the predominance of car noise in zones A and B, in close proximity to major roads, suggests the significant role of vehicular traffic in the overall noise levels within the park. It is worth noting that natural sounds, such as birds chirping, had relatively less influence on the park's soundscape and can be used as preferred sounds, as highlighted by Chitra et al. [14].

The results of this study provide valuable insights into the soundscape of Al-Oqailat Park and its implications for urban planning and design. Understanding the variations in noise levels across different zones, the influence of traffic and geographical position, and visitors' perceptions and preferences can inform decision-making processes aimed at creating a more pleasant and serene environment for park visitors. Mitigating the impact of noise pollution, particularly in urban areas, is crucial to safeguarding human health and well-being.

While this study contributes to understanding the soundscape in Al-Oqailat Park, there are some limitations to acknowledge. The study focused on a specific park and its immediate surroundings, and the findings may not be directly generalizable to other locations. Additionally, the study primarily examined noise levels and did not explore other aspects of the soundscape, such as the quality and character of sounds. Future research could delve deeper into these aspects and consider additional factors influencing the soundscape, such as time of day, weather conditions, and seasonal variations.

5. Conclusions

This study presented a comprehensive analysis of the soundscape in Al-Oqailat Park, Buraydah, Saudi Arabia, focusing on rush hours between 1:30 p.m. and 5:20 p.m. Both objective measurements and subjective evaluations were used to evaluate the soundscape. Sound level meters were used to measure the physical properties of sound, while survey analysis was used to collect subjective evaluations from human participants.

The results showed that noise levels varied significantly across different points in the park, with the highest levels recorded near busy roads and intersections. The study found that traffic and geographical position significantly contributed to noise pollution in urban regions. The analysis also revealed that the variability of sound between different vertical zones was higher than that between horizontal zones, suggesting that the heights of sound sources, including vehicles and other urban elements, significantly affect the propagation of sound waves.

In conclusion, the study emphasized the importance of effective measures to control noise pollution in urban regions, especially during busy times. The results of this study provide valuable insights into the soundscape of Al-Oqailat Park and can be used to inform future efforts to enhance the acoustic environment of the park and other urban regions. Further investigation could explore additional factors that contribute to the levels of noise pollution, including the physical characteristics of the park, the time of day, and the weather conditions. The findings of this study can serve as a basis for future research, aiding researchers in identifying solutions that raise awareness in society regarding the acoustic aspect of pollution. Moreover, these findings can assist in the institutional realm by offering concepts and solutions that government institutions and companies can incorporate into future park designs, considering noise pollution as a significant factor that impacts the environment and human comfort. Such insights would be valuable in the development of effective measures for noise control, thus improving the quality of public spaces and the well-being of urban residents. The lack of information and studies on noise pollution in Qassim, particularly in the Kingdom of Saudi Arabia, highlights the significance of this research in enhancing our understanding of the environment and guiding land use governance towards sustainable urban development.

The future work can be summarized as the following:

1. Understand how park elements, such as vegetation, water bodies, and architectural structures, influence the overall soundscape.
2. Analyse the effect of different times of day and weather conditions on noise pollution levels.
3. Investigate the psychological, physiological, and social consequences of noise pollution on park visitors and nearby residents.
4. Analyse government policies, regulations, and best practices in noise control.

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References

1. Yu, C.; Kang, J. Acoustics and sustainability in the built environment: An overview and case studies. In Proceedings of the 2005 Congress and Exposition on Noise Control Engineering, Rio de Janeiro, Brazil, 7–10 August 2005.
2. Ekici, I.; Bougdah, H. A Review of Research on Environmental Noise Barriers. *Build. Acoust.* **2003**, *10*, 289–323. https://doi.org/10.1260/135101003772776712.
3. Dai, H.; Huang, G.; Wang, J.; Zeng, H.; Zhou, F. Spatio-Temporal Characteristics of $PM_{2.5}$ Concentrations in China Based on Multiple Sources of Data and LUR-GBM during 2016–2021. *Int. J. Environ. Res. Public Health* **2022**, *19*, 6292. https://doi.org/10.3390/ijerph19106292.

4. Dai, H.; Huang, G.; Wang, J.; Zeng, H. VAR-tree model based spatio-temporal characterization and prediction of O_3 concentration in China. *Ecotoxicol. Environ. Saf.* **2023**, *257*, 114960. https://doi.org/10.1016/j.ecoenv.2023.114960.
5. Dai, H.; Huang, G.; Wang, J.; Zeng, H. Analysis of Spatio-Temporal Characteristics and Trend Forecast of Building Industry VOCs Emissions in China. *Buildings* **2022**, *12*, 1661. https://doi.org/10.3390/buildings12101661.
6. Okokon, E.O.; Yli-Tuomi, T.; Turunen, A.W.; Tiittanen, P.; Juutilainen, J.; Lanki, T. Traffic noise, noise annoyance and psychotropic medication use. *Environ. Int.* **2018**, *119*, 287–294. https://doi.org/10.1016/j.envint.2018.06.034.
7. Stansfeld, S.A.; Sharp, D.S.; Gallacher, J.; Babisch, W. Road traffic noise, noise sensitivity and psychological disorder. *Psychol. Med.* **1993**, *23*, 977–985. https://doi.org/10.1017/s0033291700026441.
8. Basner, M.; Babisch, W.; Davis, A.; Brink, M.; Clark, C.; Janssen, S.; Stansfeld, S. Auditory and non-auditory effects of noise on health. *Lancet* **2014**, *383*, 1325–1332. https://doi.org/10.1016/s0140-6736(13)61613-x.
9. Hammersen, F.; Niemann, H.; Hoebel, J. Environmental Noise Annoyance and Mental Health in Adults: Findings from the Cross-Sectional German Health Update (GEDA) Study 2012. *Int. J. Environ. Res. Public Health* **2016**, *13*, 954. https://doi.org/10.3390/ijerph13100954.
10. Maschke, C.; Niemann, H. Health effects of annoyance induced by neighbour noise. *Noise Control Eng. J.* **2007**, *55*, 348. https://doi.org/10.3397/1.2741308.
11. Stansfeld, S.; Clark, C. Health Effects of Noise Exposure in Children. *Curr. Environ. Health Rep.* **2015**, *2*, 171–178. https://doi.org/10.1007/s40572-015-0044-1.
12. Foraster, M.; Esnaola, M.; López-Vicente, M.; Rivas, I.; Álvarez-Pedrerol, M.; Persavento, C.; Sebastian-Galles, N.; Pujol, J.; Dadvand, P.; Sunyer, J. Exposure to road traffic noise and cognitive development in schoolchildren in Barcelona, Spain: A population-based cohort study. *PLOS Med.* **2022**, *19*, e1004001. https://doi.org/10.1371/journal.pmed.1004001.
13. Tang, J.-H.; Lin, B.-C.; Hwang, J.-S.; Chen, L.-J.; Wu, B.-S.; Jian, H.-L.; Lee, Y.-T.; Chan, T.-C. Dynamic modeling for noise mapping in urban areas. *Environ. Impact Assess. Rev.* **2022**, *97*, 106864. https://doi.org/10.1016/j.eiar.2022.106864.
14. Chitra, B.; Jain, M.; Chundelli, F.A. Understanding the soundscape environment of an urban park through landscape elements. *Environ. Technol. Innov.* **2020**, *19*, 100998. https://doi.org/10.1016/j.eti.2020.100998.
15. Zytoon, M.A. Opportunities for Environmental Noise Mapping in Saudi Arabia: A Case of Traffic Noise Annoyance in an Urban Area in Jeddah City. *Int. J. Environ. Res. Public Health* **2016**, *13*, 496. https://doi.org/10.3390/ijerph13050496.
16. El-Sharkawy, M.F.; Alsubaie, A. Study of environmental noise pollution in the university of dammam campus. *Saudi J. Med. Med. Sci.* **2014**, *2*, 178. https://doi.org/10.4103/1658-631x.142532.
17. MEWA, Executive Regulations for Noise for the Environment System. 2022. Available online: https://www.my.gov.sa (accessed on 24 May 2023).
18. Koussa, F.; Defrance, J.; Jean, P.; Blanc-Benon, P. Acoustic performance of gabions noise barriers: Numerical and experimental approaches. *Appl. Acoust.* **2013**, *74*, 189–197. https://doi.org/10.1016/j.apacoust.2012.07.009.
19. Bougdah, H.; Ekici, I.; Kang, J. A laboratory investigation of noise reduction by riblike structures on the ground. *J. Acoust. Soc. Am.* **2006**, *120*, 3714–3722. https://doi.org/10.1121/1.2372594.
20. Arenas, J.P. Potential problems with environmental sound barriers when used in mitigating surface transportation noise. *Sci. Total. Environ.* **2008**, *405*, 173–179. https://doi.org/10.1016/j.scitotenv.2008.06.049.
21. Egan, D. *Architectural Acoustic*; July; McGraw-Hill: New York, NY, USA, 2016.
22. Kotzen, B.; English, C., *Environmental Noise Barriers: A Guide to Their Acoustic and Visual Design*; CRC Press: Boca Raton, FL, USA, 2014. https://doi.org/10.1201/9781482272024
23. PCE Instruments Pce-322a Instruction|ManualsLib. Available online: https://www.manualslib.com/manual/1368042/Pce-Instruments-Pce-322a.html (accessed on 24 May 2023).
24. Klompmaker, J.O.; Hoek, G.; Bloemsma, L.D.; Marra, M.; Wijga, A.H.; Brink, C.V.D.; Brunekreef, B.; Lebret, E.; Gehring, U.; Janssen, N.A. Surrounding green, air pollution, traffic noise exposure and non-accidental and cause-specific mortality. *Environ. Int.* **2020**, *134*, 105341. https://doi.org/10.1016/j.envint.2019.105341.
25. Ibili, F.; Owolabi, A.O.; Ackaah, W.; Massaquoi, A.B. Statistical modelling for urban roads traffic noise levels. *Sci. Afr.* **2022**, *15*, e01131. https://doi.org/10.1016/j.sciaf.2022.e01131.
26. Clark, C.; Paunovic, K. WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Quality of Life, Wellbeing and Mental Health. *Int. J. Environ. Res. Public Health* **2018**, *15*, 2400. https://doi.org/10.3390/ijerph15112400.
27. Ihemeje, J.; Onyelowe, K.C. State-of-the-art review on the assessment and modelling of traffic noise intensity on roadside dwellers: The Port Harcourt, Nigeria case. *Clean. Eng. Technol.* **2021**, *5*, 100328. https://doi.org/10.1016/j.clet.2021.100328.