INVESTIGATION OF NOISE EXPOSURES, PERCEPTION, AND HEALTH EFFECTS IN DIFFERENT MICROENVIRONMENTS IN A UNIVERSITY COMMUNITY

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ABSTRACT: This study aims to assess noise levels in selected outdoor and indoor microenvironments in a University community in Oman. The perception of noise levels within the Sultan Qaboos University campus was investigated through a survey study. Also, the effect of exposed noise levels on annoyance and sleep disturbance were predicted including their potential risk on cardiovascular health. Among all the measured parameters, it was found that outdoor (41.6%-50%) and indoor (38.5%-46.2%) microenvironments have exceeded the critical levels of 55 dB during morning and afternoon periods. The respondents (698 people) identified traffic and indoor building-related activities as the main sources of noise levels but the majority (44%) of them rated their impact as low. However, more than 30% of the respondents considered traffic as the main contributor to University noise levels. The percentage of highly annoyed persons was predicted to be high in outdoor areas especially in the residential (25%) and near the hospital (13%) areas. However, indoor environments including construction materials and structures labs (14%) showed similar annoyance rates. Also, the percentage of high sleep disturbed persons was found higher in residential areas (7.4%) areas compared to hospital areas (5.3%) locations. The study concluded that there might be an association between the exposed noise levels and the risk of developing cardiovascular diseases. This is the first study that has provided a high spatial variability noise exposure levels across a University environment in Oman, this will contribute to designing future sustainable mitigation strategies to improve the health and well-being of the exposed population. The study has provided a baseline knowledge needed for future epidemiological studies.

Keywords: Noise levels; annoyance; sleep disturbance; health effects; University campus; Oman.

دراسة تأثير الضوضاء على الادراك، والآثار الصحية الناتجة عنه ببيئات داخلية وخارجية في حرم جامعي

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الملخص: تهدف هذه الدراسة إلى دراسة تأثير مستويات الضوضاء في بيئات داخلية وخارجية في حرم جامعة السلطان قابوس. ولتحقيق أهدافها، تم استخدام نظام الاستبيان لاستقصاء رأي المجتمع الجامعي، كما تم التنبؤ بتأثير مستويات الضوضاء على الانزعاج واضطراب النوم ومخاطرهما المحتملة على صحة القلب والأوعية الدموية. و أظهرت النتائج أن من بين جميع العوامل التي تم قياسها، حوالي (41.6٪ و50٪) من مستويات الضوضاء في البيئات الخارجية و(38.5٪ و46.2٪) في البيئات الداخلية قد تجاوزت الحدود المسموحة للضوضاء عالميا (55 ديسيبل) في أوقات الصباح وبعد الظهر. حدد المشاركون (698 شخصًا) الأنشطة المتعلقة بحركة المرور والمباني الداخلية كمصادر رئيسية لمستويات الضوضاء ولكن تم تصنيف تأثيرها منخفض من قبل الغالبية (44٪). ومع ذلك، فإن أكثر من (30٪) من المشاركين يرون أن حركة المرور هي السبب الرئيسي لرفع مستويات الضوضاء في الجامعة. وبينت الدراسة كذلك أن نسبة الأشخاص الذين يعانون من انزعاج شديد كانت مرتفعة بشكل عام في البيئات الخارجية، وخاصة في المناطق السكنية (نسبة الانزعاج الشديد= 25٪) وبالقرب مستشفى الجامعة (نسبة الانزعاج الشديد = 13٪). اما فيما يتعلق بالبيئات الداخلية، فقد أظهرت معامل مواد البناء والانشاءات نسب مماثلة من النتائج (نسبة الانزعاج الشديد = 14٪). كما وجد أن اضطراب النوم - لدى بعض المشاركين في الدراسة - مرتفعة في المناطق السكنية (7.4٪) بالمقارنة مع المستشفى الجامعي (5.3٪). وقد خلصت الدراسة الى أنه قد يكون هناك ارتباطا بين مستويات الضوضاء وحدوث أمراض القلب والأوعية الدموية في المناطق السكنية (النسب الفردية = 1.11) والمستشفى الجامعي (النسب الفردية = 1.02).

الكلمات المفتاحية: مستويات الضجيج؛ إزعاج؛ اضطراب النوم؛ آثار صحية؛ حرم الجامعه؛ سلطنة عمان.

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NOMENCLATURE

CVD	Cardiovascular disease
dB	Decibel
dBA	Decibel average
IMEs	Indoor microenvironments
IPD	In-patients department
OMEs	Outdoor microenvironments
OR	Odds ratios
SLM	Sound level meter
SQU	Sultan Qaboos University
SQUH	Sultan Qaboos University Hospital
WHO	World Health Organization
%HA	Percentage of highly annoyed
%HSD	Percentage of high sleep disturbed

1. INTRODUCTION

According to the World Health Organization (WHO), community noise exposure is one of the serious environmental health problems facing the general population especially among the vulnerable group (WHO 1999). This is attributed to the diverse sources of these noise levels including traffic, railways, industries, and the nearby neighbourhoods, thereby making it difficult to control (Al-Mansour 2006; Liu *et al.* 2017; Sieber *et al.* 2018). Also, indoor activities in construction, religious and recreational areas were recognized as another source of noise pollution (Ali 2013; Pierrette *et al.* 2012; Ramazani *et al.* 2018). The health impacts of noise may be exacerbated especially in microenvironments such as schools and hospitals where the population (i.e. students, staff, patients) spend a substantial amount of time (i.e. average of 7 - 12 hours) (Rogers *et al.* 2004). In the case of health facilities, in-patients could spend > 90% of their time (> 100 hours) in indoor environments especially in hospital wards (Amoatey *et al.* 2018; Henshall *et al.* 2018; UPSO 2017). Thus, considering the longer durations and high frequency of noise exposures from multiple sources, it is therefore expected that its adverse health impact and annoyance levels may worsen (Al Harthy 2006; Kamal *et al.* 2020). In a systematic review study involving more than 5 million subjects, an association was observed between residential noise exposures (median noise levels of 56.7 dBA) and an increase in the risk of hypertension among the adult population (Dzhambov and Dimitrova 2018). Similar studies have also reported an increase in diabetes mellitus (Zare Sakhvidi *et al.* 2018), blood pressure in children (Dzhambov and Dimitrova 2017), and arterial stiffness (Foraster *et al.* 2017) due to community noise exposures.

The health effect of noise levels from multiple sources including traffic, aircraft, railways, neighbourhood, sports facilities, construction activities, and hospitality industries was investigated (Dreger *et al.* 2015) among a total of 1,185 school children in Germany by estimating their relative risks (RR). The study found a risk of incidence of mental health problems (e.g. inability to conduct themselves (RR=1.62), hyperactivity (RR=1.69), and emotional symptoms (RR=1.69) among the students. In Spain, Díaz *et al.* (2020) observed that an increase in 1 dBA of traffic noise with median Leq_{day} levels of 61.9 dBA was associated with emergency hospital admissions from anxiety and depression. A cohort study involving a total of 52,758 residents was conducted across two major cities (Aarhus and Copenhagen) in Denmark to determine how road traffic noise exposures affect cardiovascular health among the population (Thacher *et al.* 2020). It was estimated that, per increase in noise levels at the interquartile range of 10 dBA, there was an increase in the risk of incidence of stroke with a hazard ratio of 1.11, and 1.06 for ischemic heart diseases, and 1.13 for cardiovascular diseases among the exposed population (Thacher *et al.* 2020). There is also evidence from recent studies that multi-pollutants exposures including noise and air pollutants could result in several health impacts including the effect on mental health performance levels (Klompmaker *et al.* 2019), childhood obesity (Bloemsma *et al.* 2019), and stillbirth (Smith *et al.* 2020). Over the recent years, noise pollution was recognized as one of the serious public health concerns in schools including health care environments as they could have profound effects on the quality of learning and exacerbate the health conditions of patients, especially those with underlying chronic health conditions (Al-Dorzi *et al.* 2020; Al-Khanjari *et al.* 2014).

A noise exposure study involving monitoring of more than 34 different locations across a University campus in Nigeria showed daily noise levels ranging from 42 to 97 dB. It was concluded that these high noise levels were attributed mostly to high road traffic, the existence of several car parks, and commercial activities occurring in closer proximity to the University campus (Okolie *et al.* 2020). This is deemed as a major occupational risk factor to cause noise to induce hearing loss problems to University staff, and students who spend most of their time in such environments. It was found in Kuwait that a maximum 8-hour noise exposure level of more than 100 dBA in a school environment was greater than the recommended National Institute of Occupational Safety and Health standard of 90 dBA (Yassin *et al.* 2016). The study found that 38%, 63%, and 30% of the teachers have complained about poor sleep quality, vocal problems due to excessive shouting during teaching as a result of high background outdoor noise levels, and headache problems, respectively. In Qatar, Shaaban and Abouzaid (2021) reported a positive association between traffic volume and noise levels of 61-72 dBA near school environments during the daytime which was higher than Qatar and WHO (1999) permissible limit of 55 dBA. According to Caviola *et al.* (2021), noise can have a long-term effect on mathematics performance levels of school-age children as result of listening difficulties caused by frequent exposure to environmental noise. However, as the child grows, these cognitive effects can reduce significantly.

Therefore, it has been recommended that application of effective mitigation measures including the use of acoustic barriers, and growing of vegetation near buildings can improve the learning performances of school children (Margaritis *et al.* 2018; Ow and Ghosh 2017; Umbas *et al.* 2021).

Most arid Middle East countries including, Oman have a high outdoor temperature (> 30ºC) and humidity (> 90%) levels especially during the summer seasons. Therefore, to reduce exposure to such harsh environmental conditions, many road networks have been constructed to ease the transportation of people to their residences, schools, hospitals, and shopping malls. However, the presence of these road networks could also serve as potential sources of community noise levels. Also, due to the limited public transportation systems in these countries, there has been an increase in the number of private vehicle users, and this could potentially increase community noise levels (Abdul-Wahab and Fadlallah 2014). To date, there are limited studies assessing noise levels and the potential adverse health effects in most schools, academic institutions, and hospital facilities in Oman. Therefore, the objective of this study is to conduct a comprehensive assessment of indoor and out exposure levels noise levels in different microenvironments of a University community in Oman. The annoyance and health impact assessment of the noise levels was evaluated using both social survey and dose-response model. It is expected that this study will provide valuable datasets for future community noise mitigation policies and also as a model for similar studies across the globe.

2. RESEARCH METHODOLOGY

Study Area

The study was carried out within Sultan Qaboos University (SQU) and SQU Hospital (SQUH) communities in Muscat (23° 36' 51.5808 "N, 58° 32' 43.0224" E), the capital city of Oman (Amoatey *et al.* 2020).SQU is the oldest and the largest University in the country. The rapid growth of the University community was partly due to an increase in the number of residential buildings as most female students are offered on-campus accommodation throughout their entire study duration. Also, since SQU does not currently have any other campuses, there has been an increase in the density of students, staff population, and residential buildings over the years. Currently, SQU has a total of nine (9) colleges, 1 teaching hospital (SQUH) and thirteen (13) research centres, which are involved in providing teaching, research, and consultancy services at both local and international levels. Figure 1 illustrates the map of Muscat and an aerial view of SQU. SQU community has one of the effective on-campus transportation systems with several buses transporting students within and outside the University campus. In addition, due to limited public transportation systems in Oman, most of the staff and students use private vehicles thereby increasing road traffic volumes in the university and consequently causing environmental problems (noise and air pollution). It is estimated that the average number of vehicles entering the SQU community is about >16,000 per day (Abdul-Wahab and Fadlallah 2014). This high influx of vehicles during the day is deemed as a major source of environmental noise exposure.

Study Population

The overall estimated number of exposed population in the SQU community is 58,997 people consisting of students, administrative staff, academic staff, hospital staff. Out of this, the majority are within SQUH (31,987 people) with hospital in-patient population contributing to the highest number of people within the SQU community (UPSO 2017). The large population size of these vulnerable groups shows that potential noise levels near and within the SQUH area are an important public health concern. The high number of undergraduates (66.3%) in the SQU campus also indicates how excessive noise levels may cause difficulties in learning and cognitive performance levels among them (Woolner and Hall 2010). Table 1 shows a detailed breakdown of the proportion of different population categories found within the SQU community.

Noise Assessment Areas

To accurately assess noise levels in areas where the majority of people spend most of their time and also take into consideration the closer proximity to roads/streets to these areas, noise levels were measured across residential facilities, student apartments, lecture theatres, libraries, and in-patients department (IPD) within the SQU community. In addition, to better understand the noise exposure levels, the 25 measurements were taken from both indoor and outdoor locations across twenty-five (25) microenvironments within the SQU community within two months (Febuary and April 2018) duration. The detailed description of all the measured noise points and their corresponding locations are shown in Table 2 and Figure 1, respectively. The noise level in each of the locations was measured three times daily: morning (7:30-8:00 am), noon(1:00-2:00 pm), and evening (6:00-8:00 pm) time.

Noise measurements

At each of the 25 microenvironments (Figure 1), noise levels were measured with a sound level meter (SLM) (EXTECH®, Model HD 600) installed on a triploid stand at a height of 1.6 meters (EXTECH 2015). SLM was equipped with a high precision microphone (electret condenser) with a precision of ± 1.4 dB and could measure sound pressure levels within a specified minimum (30 dB) and maximum (130 dB) range at the highest frequency of 8 kHz (Chew and Wu 2016).

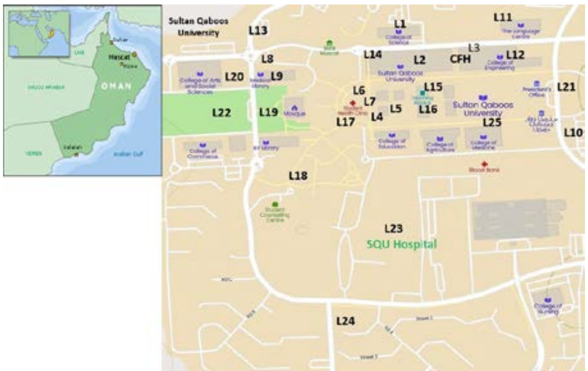

Figure 1. Location of Muscat and the measured microenvironments in the SQU community.

Table 1. A detailed description of sub-population data of SQU community, Source: UPSO (2017).

(A) SQU	(N)	(%)
Undergraduates	15,878	66.3
Postgraduates	1,652	6.9
SQU Teaching staff	3,364	14.0
SQUH Staff	3,058	12.8
Total	23952	100.0
(B) SQUH	(N)	(%)
Medical Doctors	454	14.8
Nursing Staff	1,371	44.8
Technical Staff	579	18.9
Administrative Staff	654	21.4
Total	3058	100.00
(C) Number of In-Patients	31,987	

Table 2. Detailed all measured noise locations within SQU community.

	Indoor microenvironments
L1	College of Science: Corridors
L2	College of Science: Computer labs
L3	College of Science: Chemical labs
L4	Classrooms corridors block (A)
L5	Classrooms at Block (A)
L6	Conference Hall
L7	Exhibition Hall
L8	Classrooms at Block (E)
L9	Block (E) Corridors
L10	Inside the main Library
L11	Civil Engineering Construction lab
L12	Civil Engineering Computer lab
L13	Student Service area
	Outdoor microenvironments
L14	Road opposite to the College of Science
L15	Road opposite to the Block (A)
L16	Road opposite to the Building (C)
L17	Out of Conference Hall
L18	Botanical garden
L19	The road between the Mosque and the College of Economy and Political Science
L20	Around Block (E)
L21	Around the Cultural Center
L22	Al Andalus Garden
L23	Around the SQU Hospital
L24	SQU Residential Area
L25	Main Entrance

The SLM used in this study was certified by International Electrotechnical Commission (IEC) as Class II and American National Standards Institute (ANI) as a Type II noise measurement instrument (Zaw et al. 2020). In-house calibration was done on SLM before and after monitoring each selected location and the instrument was operated continuously for 1 min as start-up time. The device was controlled to measure a resolution of 10 seconds continuously for 3 minutes where the readings of the noise were automatically recorded and saved in the device memory. In each location (L1-L25), measurements were taken 2 times. At the end of each measurement, the average weighted noise value (LAeq) was considered as a representative noise level.

The Social Survey

SQU community noise perception levels were assessed across all the university populations including students, academic staff, and administrative personnel. Based on the total number of the SQU population n= 58,997 and considering a sample error of 5% at a 95% confidence interval, a sample size of 852 people was estimated (Paiva *et al.* 2019). The questionnaires were designed using google Forms in both Arabic and English. The questionnaires were distributed to the respondents through the SQU email system to the target respondents. A 4-point Likert scale was used to assess the respondent's perception about the degree of sources of noise levels for both the selected indoor and outdoor microenvironments (Table 2). When the question of "How would you rate each of the following; Trucks, Buses, Traffic Horns, Speed Vehicles, Aircraft as sources of outdoor noise in SQU, responses were evaluated by using simple metrics such as "very high", "high", "low " and " very low". A similar question was also asked about the perception about the degree of potential sources of indoor noise levels in the University community. Respondents were asked " What is the degree of noise levels from Air Conditioning, Laboratory Instruments, Vacuum Cleaners, and Maintenance Activities in indoor environments in SQU". These questions were also evaluated by using the same 4-scale points responses such as "very high", "high", "low " and " very low".

Health Impact Assessment

In this study, the percentage of highly annoyed (%HA) and high sleep disturbed (%HSD) persons were quantified using exposure-response models recommended by WHO (2011). These models were developed based on the results of a meta-analysis from several epidemiological studies conducted across the globe. The %HA model Eqn. (1) was based on L_{den} and noise exposure levels ≥ 45 dB and ≤ 75 dB, noise levels that do not fall within these ranges were excluded due to the risk associated with limited very high, and low noise data. Also, %HSD dose-response model was developed as a function of L_{night} noise exposure levels Eqn. (2) and was based on noise data within the range of 45-65 dBA only due to high levels uncertainties associated with noise levels that do not fall within these defined ranges (WHO 2011).

In addition, the association between exposure to noise levels and incidence of cardiovascular disease (CVD) was determined using the odds ratio (OR) estimates as indicated by Eqn.3. This model was developed from studies where day (L_{day}) noise levels were limited to 55-80 dBA (WHO 2011). The above health impact assessments were focused on the population living near SQU residential and SQUH areas due to the longer durations people spend in these areas at night times (Table 2).

$$\%HA = 9.868*10^{-4} (L_{den}-42)^3 - 1.436*10^{-2} (L_{den}-42)^2 + 0.5118 (L_{den}-42) \quad (1)$$

$$\%HSD = 20.8 - 1.05 (L_{night}) + 0.01486 (L_{night})^2 \quad (2)$$

$$CVD_{OR} = 1.63 - 0.000613* (L_{day})^2 + 0.00000736*(L_{day})^3 \quad (3)$$

where, $L_{den} = L_{day} + 2.3$ dB, and $L_{night} = L_{evening} - 4.4$ dB according to conversion formulae developed by Brink *et al.* (2017).

3. RESULTS

Measured Noise Levels in Indoor microenvironments

The study assessed environmental noise exposure levels within the SQU community by focusing on indoor microenvironments (IMEs) considering the longer durations spent by the students and staff. As detailed in Table 2, IMEs (L1-L13) include laboratories, classrooms, libraries, and enclosed corridors. Table 3 indicates all the measured noise levels observed across the selected IMEs in SQU for the morning, day, and evening times. Out of the thirteen (13) selected IMEs (L1-L13), both morning and daytime noise levels in most laboratories (L3 = 57 and 56.7dB, L11= 62.9 and 61.2 dB) exceeded the WHO critical limits of 55 dBA (Table 3). Similarly, noise produced in building corridors (L4 = 58.8 and 57.1dB) and student services buildings (L13 = 57.3 and 58.1dB) were also observed to be high. Overall, all the measured IME noise levels at evening times satisfied the WHO's threshold of 55 dB compared to morning/day times (Table 3**)**. The lower noise levels at the latter are due to the closure of university activities such as lectures, laboratories, and student services. Overall, the average noise levels of all IMEs for the morning (53.8 dB), noon (54.9 dB), and evening (42.6 dB) durations were very low compared to WHO's acceptable threshold limits (55 dB).

Measured Noise Levels in Outdoor Micro-environments

The study also estimated the outdoor noise exposure levels with the University community. Twelve selected (L14-L25) outdoor microenvironments (OMEs) consisting of near roads, around staff residential apartments, SQU hospital areas, gardens, and forecourt of buildings were considered. This is due to the presence of several road networks around these locations which are deemed as one of the main sources of community noise levels. During the morning and daytime, the noise levels near the majority of the roads (L14= 59.6 and 61.2 dB, L16= 61.8 and 56 dB) within the University were high, this was similar to the evening noise levels observed near the various roads (i.e L14 and L16) as indicated in Table 4. However, near the hospital (L23= 67.9 and 60.4 dB), residential apartments (L24= 62.3 and 67.8 dB) and the University entrance (L25 = 64.5 and 62.8 dB) areas showed the highest noise levels during the morning and day times (Table 4). All these locations have exceeded the WHO's limits of 55 dB indicating that noise levels from road sources and around most residential locations including hospital areas pose serious environmental health concerns to the University community. The study also found that the majority of the noise levels during the evening times were very low, and were found below the thresholds limits (Table 4). While noise level was high in the aforementioned areas, most of the remaining OMEs including L17, L18, L19, L21, and L22 had very low noise levels and were found acceptable per WHO limits with average noise pressure levels across all the OMSEs slightly beyond the WHO limits of 55 dB.

Perception of Noise Exposures

A total of 698 individuals participated in the online noise survey, representing a response rate of 82% when compared to the estimated sample size of 852 people. Table 5 indicates a brief socio-demographic profile and respondent perception about sources of noise within SQU. In this study, the age range of the respondents who took part in the survey was within 18-65 years. The study found that majority of respondents were males (58.4%), students (73.5%) with about 25.9% representing employees/staff (Table 5). Regarding perception about outdoor noise levels within the SQU community, an average of 29.8% are of the view that noise levels from traffic-related activities are high while 35.8% considered it to be low. Out of these, the sources of noise levels due to both car speeding (33.8%) and intercampus bus activities (30.6%) including traffic horning (26.8%) were reported to be high and very high, respectively (Table 5). Contrastingly, the majority of the interviewees agreed that the contribution of noise from aircraft (35.3%) and buses (43.1%) within the SQU community was low as provided in Table 5. Regarding noise levels from indoor environments, 27% and 23.7% of the respondents reported that indoor noise levels from maintenance and vacuum cleaners' activities, respectively are high. However, noise generated as a result of the operation of laboratory equipment (49.9%) was found to be low and that of air conditions (30.6%) was very low.

High Annoyed Persons

Results of %HA persons due to noise exposures within the two main microenvironments (IMEs and OMEs) using WHO's exposure-response relationships are shown in Figures 2 and 3. Overall, the highest %HA persons were found in OMEs compared to IMEs which may be attributed to high noise levels produced by road traffic. In IMEs, the highest %HA persons were mostly in exhibition areas (L9 =15%), construction materials and structures laboratories (L11=14%), and student service centres (L13 =11%). Interestingly, in microenvironments that require sedentary activities and which subsequently tend to produce low noise levels, especially in computer laboratory (L12), and library (L10), the lowest %HA persons were 4% and 5%, respectively. For OMEs, residential areas (L24 =25%) and near the University entrance (L25=16%) which serve as main hotspots of vehicular noise revealed the highest %HA persons. This was followed by the hospital (L23 =13%) and near other individual road networks (L14 = 14%, L15=12%) linking to the various SQU facilities. The study found that most OMEs especially L21 (3.3%), L18 (3.8%), L19 (3.8%) showed the lowest %HA persons compared to several IMEs as illustrated in Figures 2 and 3.

Sleep Disturbance and Cardiovascular Disease

As indicated in Table 6, the %HDS persons were estimated using WHO's exposure-response model in some specific OMEs such as near the hospital (L23) and residential areas (L24) of the University. The assessment of %HDS persons was limited to only L23 and L24 since they serve as homes for the university staff/students and hospitalization of patients (i.e IPD capacity is about 31,436 patients) (Table 1). The developed model revealed that %HDS persons were 7.4% and 5.32%, for L24 and L23, respectively. The %HDS person estimates were consistent with the measured noise levels observed in L24 (58.4 dB) and L23 (54.1) during the evening times. The association between noise exposures and the incidence of cardiovascular diseases was also determined based on WHO's exposure-response model (Table 6). The odds ratio (OR) estimates from the model showed that the current noise levels at L24 may be associated with the incidence of cardiovascular diseases with an OR of 1.11. However, in the case of L23 (OR = 1.02), the exposure may not show an association with the incidence of cardiovascular diseases (Table 6).

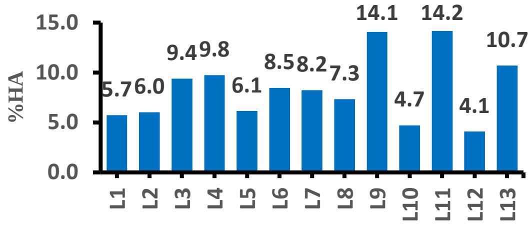

Figure 2. Percentage of highly annoyed (%HA) persons in the indoor microenvironments.

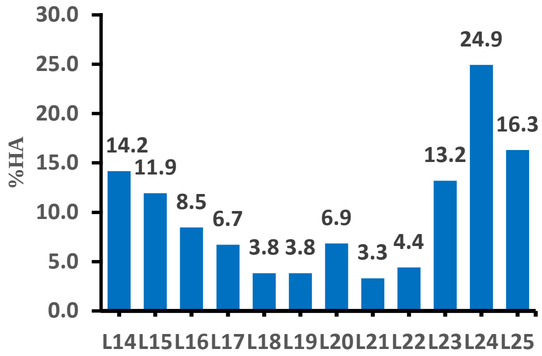

Figure 3. Percentage of highly annoyed (%HA) persons in the outdoor microenvironments.

Table 3. Measured noise levels at different indoor microenvironments (IMEs)

Code	[a] LAeq (dB)		
	Morning	Noon	Evening
L1	50.3	51.6	42.5
L2	51.2	52.1	39.2
L3	*57.0*	*56.7*	46.8
L4	*58.8*	*57.1*	38.8
L5	54.2	52.3	43.3
L6	*48.1*	*55.6*	41.9
L7	*56.0*	55.0	38.6
L8	52.7	54.1	46.9
L9	52.9	*61.1*	46.8
L10	48.3	49.8	37.8
L11	*62.9*	*61.2*	38.6
L12	49.8	48.6	46
L13	*57.3*	*58.1*	46.9
Average	53.8	54.9	42.6

[a] The italicized noise levels exceeded the WHO limits of 55 dB

Table 4. Measured noise levels at different outdoor microenvironments (OMEs).

Code	[a] LAeq (dB)		
	Morning	Noon	Evening
L14	*59.6*	*61.2*	*56.3*
L15	52.6	*59.3*	*56.3*
L16	*61.8*	*56.0*	49.0
L17	47.0	53.2	42.1
L18	48.3	48.0	44.0
L19	50.0	48.0	45.0
L20	51.6	53.4	46.2
L21	48.5	46.9	47.6
L22	55.0	49.2	43.9
L23	*67.9*	*60.4*	54.1
L24	*62.3*	*67.8*	*58.4*
L25	*64.5*	*62.8*	50.9
Average	56.0	56.0	49.5

[a] The italicized noise levels exceeded the WHO limits of 55 dB

[b]Italics indicates values above the WHO limits

Table 5. Respondents profiles, outdoor and indoor noise perceptions.

Indicators	Number (*n*)	Percentage (%)		
Gender				
Male	408	58.4		
Female	290	41.6		
Total	698	100		
Exposed groups				
Students	513	73.5		
Employees	181	25.9		
Other residents	4	0.6		
Total	698	100		
Perception of noise				
A. Outdoor		**Responses**		
Traffic	Very high (%)	High (%)	Low (%)	Very low (%)
Trucks	19.3	31.9	36	12.8
Buses	15.1	30.6	43.1	11.2
Traffic Horns	26.8	29.4	30.5	13.4
Speed of Vehicles	21	33.8	34.1	11.2
Aircraft	21	23.3	35.3	20.3
Average	20.64	29.8	35.8	13.78
B. Indoor		**Responses**		
None-traffic	Very high (%)	High (%)	Low (%)	Very low (%)
Air Conditioning	10.8	21	37.6	30.6
Lab instruments	6.4	19.5	49.9	24.3
Vacuum cleaners	11.4	23.7	39.5	25.4
Maintenance activities	22.6	27	36.8	13.6
Average	12.22	22.3	41.46	24.06

Table 6. Estimates of the percentage of highly disturbed sleep and the incidence of cardiovascular diseases from noise exposures.

Microenvironment	%HSD	Odds Ratio (OR) CVD
Around the SQU Hospital (L23)	5.32	1.02
SQU Residential Area (L24)	7.43	1.11

4. DISCUSSION OF RESULTS

The measured noise levels across the different microenvironments in the SQU community showed relatively high levels ranging from 56 - 68 dB for both morning and noon times. Thus on average, closer to 50% of the individual University environments exceeded the critical levels of 55 dB. The exceedance of these current noise levels has the potential of creating acoustic discomfort to the University community. A similar study carried out on a University campus in Brazil also reported that more than 80% of the measured noise points exceeding the recommended limits (Zannin *et al.* 2013). Another noise exposure level exceeding 76 dB was observed following one-week continuous monitoring of noise in the University of Jos, Nigeria. The exceedance of about excees 21dB of noise level compared to WHO's limit of 55 dB shows that noise is an important public health problem that requires urgent mitigation measures (Akintunde *et al.* 2020). Similar results were also found in a University campus in Turkey where the average levels (62.7 dBA) slightly exceeded the critical limits (Ozer *et al.* 2014). The evidence from these studies calls for urgent needs for effective urban planning and sustainable land use management policies in schools, hospitals, and residential areas to manage the burden of community noise exposures.

To reduce the impact of environmental noise levels on the general public, it is imperative to employ an acoustic mapping tool (Zytoon 2016). This approach could show the dispersion of noise levels across several locations including sensitive areas such as schools and hospitals. Thus, a noise map is deemed as an effective tool for noise pollution management as it could forecast and give alerts about current and future acoustic conditions of a particular location thereby safeguarding the health of the exposed population. Although community noise is difficult to control due to its diverse sources (including road traffic, railway, aircraft, industries, etc), it is, therefore, important to adhere to the specific noise control guidelines that are established by WHO to help reduce health impacts relating to speech interference, sleeping difficulties, and disruption of tranquil environments (WHO 1999). In the case of this study, among the evaluated points, about 38.5% and 46.2% of indoor locations and 41.6% and 50% for outdoor areas for morning and afternoon times, respectively exceeded the critical levels of 55 dB. It is therefore important for continuous evaluation of environment-specific (e.g. laboratories, corridors, residential apartments) noise exposure levels in University communities to aid in the reduction of source-specific noise pollution levels.

The survey study among the SQU community revealed that noise pollution from traffic (30%) and indoor activities (22%) was viewed as high, while about 44% of the respondents considered them as low. The 80% response rate mostly among students is an indication that community noise issues were well received. This is an important indicator for the successful implementation of future noise mitigation programs. Thus, environmental regulations that could reduce vehicle population levels within the SQU community may substantially reduce noise levels. The application of indoor building noise abatement technologies could also reduce noise levels in most buildings (Garg *et al.* 2013).

Annoyance and sleeping difficulties due to community noise exposures have been recognized as serious environmental health concerns. This is because, in an academic environment, excessive annoyance from noise exposures could interfere with comprehension in learning and cognitive performance levels of students (Klatte *et al.* 2015). In University communities where there are kindergartens, despite children having well-developed psychophysiological reaction levels compared to adults, annoyance could disrupt their communication, reading, singing and can also affect their sleep (Tesoriere *et al.* 2018). A study evaluated students' activity levels and academic achievements among 336 residence and 450 non-residence students who have been exposed to > 60.3 dBA (Leq_{24h}) of noise (Onchang and Hawker 2018). The study concluded that students' overall grade point average scores were adversely affected by noise exposures due to frequent sleeping disturbances, reading difficulties, and poor cognitive performance levels compared to off-campus students.

This study found that the %HA persons in the SQU community were generally high in OMEs especially at the University residence (%HA = 25%) and hospital areas (%HA = 13%). In the same locations, sleep disturbances were highly affected by the former compared to the latter. However, IMEs in construction materials and structures laboratories (%HA = 14%) showed a similar % of high annoyance persons. Community noise annoyance is attributed to discomfort, irritation, anxiety, and stress (Di and Xu 2017; Khaiwal *et al.* 2016; Pohl *et al.* 2018; WHO 1999), and these effects are also influenced by the economic and sociodemographic factors of the exposed population. A study conducted by (Ahmed and Ali 2017) assessed annoyance levels and hearing impairment problems in College campuses where maximum noise levels were in the range of 67-79 dBA. The findings showed that the majority (80%) of students have faced some levels of annoyance problems. Out of this, more than half reported some degree of hearing difficulties. Based on these aforementioned health impacts, several studies have recommended acoustic control techniques and sustainable measures to control community noise exposure levels (Ahmadi and Dianat 2019; Mukate 2013; Tristán-Hernández *et al.* 2016).

Furthermore, there is a growing body of evidence revealing the incidence of cardiovascular diseases (Khosravipour and Khanlari 2020), respiratory diseases (Recio *et al.* 2016), and an increase in adiposity (An *et al.* 2018) from long-term exposure to the noise level. The health risk estimates from this study show that the current noise exposures levels are likely to cause the incidence of cardiovascular diseases in SQU residential areas, however, no association or health risk was established within the hospital areas, despite being recognized as the most sensitive areas in the University community as far as noise pollution is a concern. These findings imply that most staff who have lived in SQU for several years may be vulnerable to noise pollution-related health problems. While this study has assessed the noise exposure levels in both indoor and outdoor environments including, annoyance levels, sleep disturbances, and incidence of cardiovascular diseases, there are several limitations associated with this study. Thus, the noise exposure assessment was short-term, and could not account for noise levels during vacations and school sessions to understand the temporal noise levels within the University. In addition, the dose-response model used in this study was developed from meta-analysis, the population of those studies may have different socio-economic and demographic profiles compared to the exposed population under this study. These factors are therefore considered as important indicators for a particular noise exposure health outcome, sensitivity, irritation, annoyance, and sleep disturbance levels. It is expected that future studies would utilize clinical/health data including potential cofounders (e.g. meteorological factors, green space, economic, and socio-demographic data) to better understand the burden of environmental noise exposures among populations within University campuses and other communities where noise levels are considered as an important environmental health issue.

5. CONCLUSION

Community noise exposures are recognized as a serious public health concern considering the annoyance, irritation, sleeping difficulties including cardiovascular and cardiometabolic diseases it poses to the general population. In this study, noise exposure assessment via field measurement was conducted across various indoor and outdoor environments in the SQU community. Perceptions of sources of noise levels, annoyance, sleep difficulties, and their effect on cardiovascular health were also assessed using both field survey and dose-response models. On average, about half of the measured points in both indoor and outdoor environments have exceeded the critical threshold levels. A significant number of the respondents identified traffic and indoor building-related activities as main sources of noise levels but their impact was rated as low by the majority. However, more than a quarter of the respondents view traffic as the main contributor to University noise levels. The study found that highly annoyed persons were high in most indoor and outdoor microenvironments especially in residential areas and in construction materials and structures laboratories of the University. It was also revealed that persons who were affected by sleep disturbances were higher in residential areas compared to that of the hospital vicinity. This study also found an association between noise levels and incidence of cardiovascular diseases in residential areas of the University, however, no association was established within the hospital areas. This is the first study that has provided a high spatial variability noise exposure levels across a University environment in Oman, this will contribute to designing future mitigation strategies to improve the health and well-being of the exposed population.

It is expected that future studies will employ a comprehensive epidemiological approach including the use of clinical/health data and their potential cofounders to better understand the health effects due to noise exposures. This will provide more reliable datasets to design mitigation techniques and intervention policies for reducing the burden of health impacts from community noise exposures.

CONFLICT OF INTEREST

The authors wish to declare no competing conflict of interest.

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