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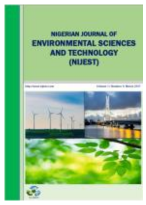

Indoor Sound Pressure Level and Associated Physical Health Symptoms in Occupants within a Students' Housing Neighbourhood in Southwest Nigeria

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ABSTRACT

This study examined indoor sound pressure level in selected rooms within a students' housing neighbourhood in Nigeria; assessed the self-reported physical health symptoms of the occupants; and analysed the relationships between the two. Sound pressure level was measured in each of the randomly selected 22 rooms at 15-minute intervals between 7hours and 19hours daily through a period of four weeks each during the peaks of both dry and wet seasons. The measurement was done with Data Loggers placed at work plane at the centre of the rooms. Purposive sampling was used to select all the occupants in the selected rooms as well as the two adjoining rooms to fill a questionnaire. This amounted to 696 respondents. The questionnaire, elicited information regarding what each respondent regarded as the most prominent source of noise, their gender, age and complexion, as well as their self-reported physical health status. This study found that a significant 79% of the respondents identified indoor noise sources as the prominent contributor to the acoustic condition in the rooms; that the mean measured sound pressure levels in each room layout ranged from 27.75 dB to 56.29 dB; and that the self-reported physical health symptoms with significantly high percentage of observation were cold, fatigue, and headache. Correlation analysis showed that there was an inverse relationship between the sound pressure level in the rooms and the frequency of observance of cold, fatigue, and headache among the occupants. However, the relationship is more significant during the wet season, and more pronounced in female occupants than in male.

Keywords: Health symptoms, sound pressure level, self-reported health, students' housing, indoor environmental quality.

1.0. Introduction

Acoustic conditions in occupied spaces is one of the main aspects of Indoor Environmental Quality which most scholars agreed have great impact not only on occupants' comfort and performance, but also on occupants' health. However, a review of studies in Indoor Environmental Quality revealed that the relationship between indoor acoustic conditions and occupants' health seems not to have received adequate consideration (Frontczak and Wargocki, 2011). This is especially so in residences as well as other indoor environments outside the office space as evident in Aylward *et al*, (2005). The study remarked that regarding the relationships between aspects of the indoor environment and occupants' health, there has been considerable research into occupational (office or work) environments, while other indoor environments with significant potential health impacts have not enjoyed similar level of examination.

The few Indoor Environmental Quality studies carried out outside the work environment concentrated more on other aspects of the indoor environment aside the acoustic aspect. Oguntoke *et al*, (2010) examined the relationship between Indoor Air Quality and occupants' health; Turunen *et al*, (2014) concentrated on the effect of thermal environment and Indoor Air Quality and occupants' health; and Apte *et al*, (2000) concentrated on an aspect of the Indoor Air Quality. This apparent lack on emphasis on the health impacts of indoor acoustic conditions especially in residences and other non-industrial environments may not be unconnected with the research findings regarding occupants' assessment of different aspects of indoor environment.

Several Indoor Environmental Quality studies have found that out of the several aspects of the indoor environment, the acoustic condition is hardly at the fore front when occupants are asked to assess the relative significance of the different aspect to their health and comfort. Lai and Yik, (2009) showed that the acoustic condition was only next to the thermal condition as the most important contributor to the acceptance of the indoor environment by occupants. Frontczak and Wargocki, (2011) concluded that thermal comfort was ranked by occupants to be of greater significance when compared with other aspects of the indoor environment. Also, De Giuli *et al*, (2012) found that pupils in Italian primary schools complained mostly about thermal conditions especially in warm season. Furthermore, Xue *et al*, (2016) and Kamaruzzaman *et al*, (2016) confirmed that the acoustic condition in residential buildings is far from being regarded as the most significant by occupants.

This may not be enough to deemphasize the impact of the indoor acoustic condition on the physical health of occupants in residential buildings. This is because some other studies have observed significant relationships between the acoustic conditions of occupied spaces and the health of their occupants. Among such studies are Evans and Johnson, (2000), Ana *et al*, (2009) and Lee *et al* (2016). It is however apparent that most of the studies that established relationships between the acoustic environment and occupants' health were carried out within office space and school environments. The impact of the indoor acoustic condition on occupants' health may be better appreciated in residences. This is because that is where occupants of indoor spaces spend about 16 out of the 24 hours of the day and hence are more exposed to the effects of the indoor conditions (Godish, 2016).

One of such residential spaces is the rooms in the students' hostels which are often designed as a sleeping cum study space. Among other scholars, Dahlan *et al*, (2009) showed that the indoor acoustic condition was second in importance to occupants of hostel room spaces, and that it was more important to them than the visual environment. However, the potential impact of this indoor acoustic condition on the physical health of the occupants is yet to be fully explored.

This study therefore examined the relationships between the acoustic condition in the rooms and the self-reported physical health of the occupants within a student's housing neighbourhood in Ile-Ife, Nigeria. This was done through an identification of the most prominent sources of indoor and outdoor noise in the spaces; an examination of measured indoor sound pressure level in the spaces; an assessment of the self-reported physical health symptoms of the occupants; and an analysis of the relationships between the self-reported physical health symptoms and the measured sound pressure level in the spaces.

The studied student housing neighbourhood is within the campus of Obafemi Awolowo University which is located within Ile-Ife. The city is located in South-western Nigeria between latitudes 7^0 28' N and 7^0 34'N and longitudes 4^0 27'E and $4^0$35' E, with an elevation of about 275m above sea level. There are nine main hostel buildings within the students housing neighbourhood. They have a combined capacity of 10,344 students. These are the Murtala Mohamed Post-graduate hall, Adekunle Fajuyi hall, Moremi hall, Ladoke Akintola Hall, Alumni hall, ETF hall, Angola hall, Awolowo hall, and Mozambique hall.

Each hostel building has study cum sleeping rooms as the main spaces with other ancillary spaces like bathrooms, laundry and kitchenettes at one end of each of the block of rooms. Observation revealed that the walls are of sandcrete blocks rendered on both sides with cement and sand plaster and painted with matte finish. The windows are made of glass louver. With the exception of Angola and Mozambique halls which have ceiling fans installed in all the rooms, the rooms within most of the hostel buildings were designed with no mechanical ventilation system that can generate noise indoor. Their doors are timber flush doors. The roofs are made of corrugated asbestos with asbestos ceiling to minimise the noise impact of rain water on the roofing sheets. Among different design and layout features characterizing the different hostel buildings which might influence the quality of the acoustic environment in the spaces are terraces and balconies, as well as vegetation and green spaces that serves as a buffer from street noise. (Zhao et al 2009; Dzhambov and Dimitrova, 2014).

2.0. Materials and Methods

The measurements of indoor sound pressure level in the selected rooms were done with DT-173 High Accuracy Digital Sound Noise Level Data Loggers with a measuring range of 30 dB to 130 dB and a data memory of 129,920 samples. It has a dynamic range of 50 dB, a frequency range of 31.5Hz to 8kHz, and an accuracy of +/-1.4 dB. The data loggers were connected to Personal Computers (PC) and placed at work plane (1.0m above the finished floor level) at the center of the selected rooms. The data was taken in each of the rooms at 15-minute intervals between 07hrs and 19hrs daily through a period of four consecutive weeks each during both the peak of dry season (January to February 2018) and the peak of wet season (June to July, 2018). This was done to be able to examine the trend across the two prominent seasons in the neighbourhood. The data was then downloaded into PC using the sound data logger application software for analysis. There were 22 rooms randomly selected for the measurements. They were selected such that at least two rooms represented each of the nine different room layout types identified within the students housing neighbourhood. All the selected rooms have the same wall, window and ceiling material finishes. Physical measurements were done to capture the different fenestration area relative to the different external wall area of the rooms.

In order to make sure that the subjects were responding to the measured sound pressure level, purposive sampling was used to select all the occupants in the selected rooms as well as the two adjoining rooms to fill a questionnaire. This amounted to 696 respondents. The questionnaire, which was filled immediately at the end of the measurement, elicited information regarding the activities carried out in the rooms, their average length of stay in the rooms per day, and the frequency at which occupants opened the fenestrations. The same questionnaire was used to capture other data about the occupants' gender, age and complexion, as well as the occupants' self-reported physical health status. The respondents were asked to indicate how frequently they observed some physical health symptoms that are related the indoor environmental condition during the period when the sound pressure level was measured. These symptoms are nausea, eye irritation, skin irritation, vomiting, dizziness, headache, fatigue, sore throat, runny nose, cold, cough, and respiratory problem (Reynolds *et al*, 2001; Wong and Jan, 2003; Ana *et al*, 2009). The frequency of observance of each symptom was ranked from 0 for "not at all", 1 for "occasionally", 2 for "more than half of the period", and 3 for "almost every day". The data collected were subjected to statistical analysis using the IBM SPSS Statistics 22. Correlation analysis was carried out to explore the relationships between the measured sound pressure levels in rooms with different window to external wall area ratio and the self-reported physical health status of the occupants.

3.0. Results and Discussion

3.1. Most prominent sources of indoor and outdoor noise

Out of the 696 administered questionnaires, 576 were returned. After the questionnaires were sorted however, 462 were usable for the analysis resulting in a 66.38% response rate. All the respondents were either undergraduate or postgraduate students in the University with 62.8% being males while 37.2% were females. Tables 1 and 2 showed that 76% of the respondents indicated "room-mates chatting" and "people walking along the corridor" as the most prominent sources of noise indoor and outdoor respectively. However, this study found that a significant 79% of the respondents identified indoor noise sources, rather than outdoor, as the prominent contributor to the acoustic condition in the rooms.

Table 1: Most Prominent Indoor Noise Sources in the Spaces as Rated by Occupants

	Frequency	Valid Percent	Cumulative Percent
None	16	3.5	3.5
Roommates chatting	346	76.0	79.6
Door slamming	25	5.5	85.1
Noise from electronic gadgets	57	12.5	97.6
Phone calls	11	2.4	100.0
Total	455	100.0	

Table 2: Most Prominent Outside Noise Source in the Spaces as Rated by Occupants

	Frequency	Valid Percent	Cumulative Percent
None	14	3.1	3.1
Religious activity	33	7.4	10.5
Sporting activity	34	7.6	18.1
Common room activities	99	22.1	40.3
People walking along the corridor	242	54.1	94.4
Traffic noise	8	1.8	96.2
Power generator	16	3.6	99.8
Noise from next room	1	0.2	100.0
Total	447	100.0	

Correlation analysis however showed that the measured indoor sound pressure levels are strongly related to the outdoor noise source. This is because this study found that 46.7% of the respondents always opened all the window area during the period of measurement, and that the direct relationship between measured indoor sound pressure level and the window to external wall area ratio was at significant level ($\rho<0.1$, $r=0.45$).

3.2. Examination of measured indoor sound pressure level

The mean measured sound pressure levels in each room layout ranged from 27.75 dB to 56.29 dB, with an overall mean value of 48.77dB. Figure 1 showed that the highest measured sound pressure level during the entire study period was far lower than 90dB which was the maximum allowable limit value in such spaces according to FEPA, (1991). Moreover, this study that throughout the study period there was no single reading that exceeded the allowable limit, and that the highest mean measured sound pressure level was lower than the allowable limit by 37.45%. This suggests that the spaces should provide comfortable acoustic conditions for the occupants.

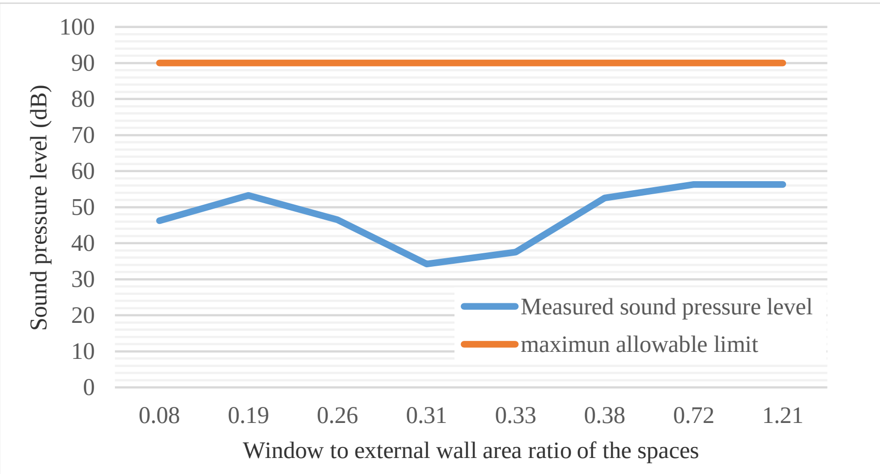

Figure 1: Mean Measured Sound Pressure Levels in the Different Room Layouts

3.3. Assessment of self-reported physical health symptoms of the occupants

During both the dry and wet seasons, this study found that the physical health symptoms with significantly high percentage of observation amongst the respondents were cold, fatigue, and headache. It was also observed that the frequency of observation of each of these three physical health symptoms was higher during the dry season as shown in Fig. 2.

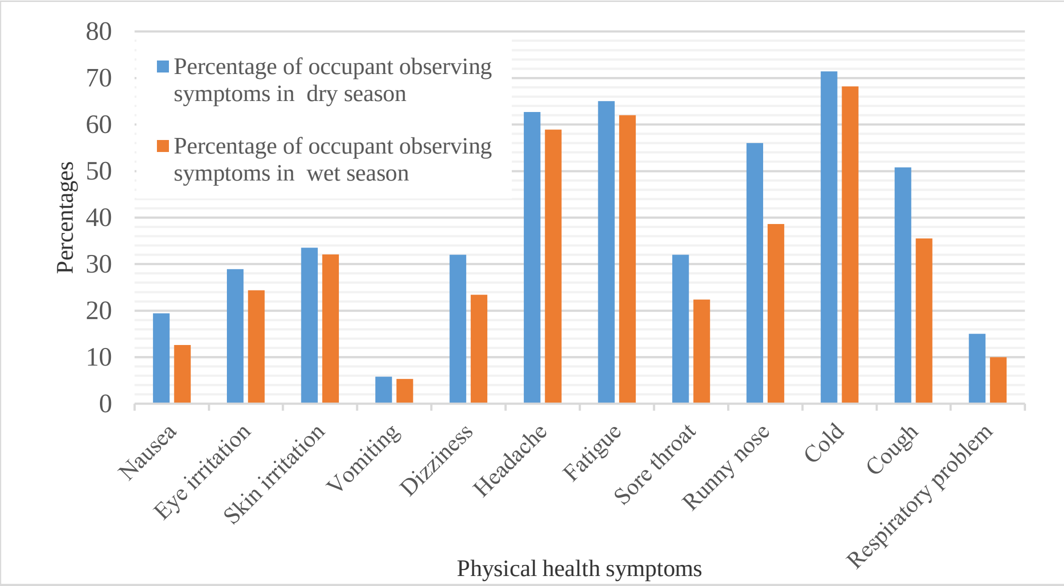

Figure 2: Frequency of Health Symptoms Observation among Occupants

3.4. Relationships between occupants' self-reported physical health symptoms and measured sound pressure level

During the dry season, correlation analysis revealed that the mean measured sound pressure level in the rooms had direct or positive relationships with the frequency at which occupants observed cold and fatigue but had an inverse relationship with frequency of observing headache. However, none of the relationships was found at a level that is statistically significant. Whereas during the wet season, the relationship between the mean measured sound pressure level and the frequency at which occupants observed the same three physical health symptoms became more significant.

This confirmed the position of World Health Organization (WHO) as presented by Schwela, (2001) which showed that headaches, fatigue and irritability are among health effects associated with the acoustic environment. Correlation analysis showed that the relationship between the observance of each of the three physical health symptoms and the mean measured sound pressure level was inverse. While the relationship was significant at $\rho<0.01$ for headache, and correlation coefficient of 0.24, it was significant at $\rho<0.05$ for both fatigue and cold with correlation coefficients of 0.16 and 0.20 respectively. This showed that during the wet season, the higher the sound pressure level, the less frequent occupants of the rooms observed headache, fatigue and cold. Analysis also revealed that this relationship was more pronounced for each of the health symptoms in female occupants than in male occupants. For example, while the correlation coefficient between mean measured sound pressure level and frequency of observation of headache was 0.15 among male respondents, it was 0.23 among the female respondent during the wet season.

This observed relationship was a bit different from the observations of Wong and Jan, (2003) as well as Turunen *et al*, (2014). Although both studies observed some relationships between sound pressure levels and some health symptoms in their subjects, the relationships were not inverse. While Turunen *et al*, (2014) established that fatigue and headache were among the most commonly reported symptoms among students in Finland when one of the most frequently reported indoor condition causing inconvenience was noise, Wong and Jan, (2003) found that the most common health symptoms reported by occupants were headache and cold among others, while the measured indoor noise level in many of the spaces studied was higher than the recommended value by 32%. However, Turunen *et al*, (2014) could not establish a significant relationship between the health symptoms and noise or sound pressure level as found in this study. While Wong and Jan, (2003) established some significant relationships between the health symptoms and some other indoor environmental condition, the study could not establish any link between the noise level in the spaces and the physical health symptoms reported by the occupants.

It is noteworthy that those studies were carried out not during the wet season. This may explain the agreement of their findings with that of this study during the dry season only. The main difference between the dry and wet seasons in southwest Nigeria is the increased solar radiation outdoor and subsequently indoor during the dry season (Ileoje, 2001). This suggests a possible interaction between the indoor sound pressure level and indoor temperature which might have de-emphasized the effect of indoor sound pressure level on the observed physical health symptoms as reported by the occupants during the dry season. This however need to be further explored.

Furthermore, in a study of associated health impact of noise in secondary schools at Ibadan, Nigeria, Ana *et al*, (2009) observed that at measured sound pressure level of between 68.3 and 84.7 dB, there was a direct relationship between the noise level and the level of tiredness or fatigue in the occupants. The relationship was different from the inverse relationship observed in this study, although the conclusion of Ana *et al*, (2009) was not expressed in quantitative terms. The difference may be due to the differences in the sources of noise in the study. Ana *et al*, (2009) identified vehicular traffic as the most significant source of noise in the schools studied.

Moreover, the inverse relationship between measured sound pressure level and the frequency of observance of some physical health symptoms during the wet season in this study was seemingly odd. This is so especially in view of the fact that most regulatory standards for indoor acoustic comfort stipulate the maximum allowable values, which suggests that the more the indoor sound pressure level approaches the maximum allowable limit, the more the occupants ought to report its negative impact on their well-being. However, this study found that the inverse relationships could be justified from the perspective of what the occupants regarded as the most prominent sound source indoor. Table 1 showed that during the study period, sound from electronic gadgets was regarded as the most prominent indoor sound source second to roommates chatting. Observation during the study revealed that both were not necessarily unwanted sound. This is especially so with sound from electronic gadgets which is entertaining, having a psychological soothing effect on the listeners. (Chang *et al*, 2008; Bonde, 2011; MacDonald *et al*, 2013). This therefore may rationalize why an increase in the sound pressure level in the space may lead to a decrease in the frequency with which occupants observed some physical health symptoms.

Since the mean measured sound pressure level in all the nine different room layouts was less than 90 dB, and there was even no single reading from the data logger that was up to this maximum allowable limit, it is therefore not apparent from this study if the inverse relationship observed above continues to hold at sound pressure levels beyond 56.29 dB. This may need to be further explored.

4.0. Conclusions

Cold, fatigue, and headache were confirmed as the most significant self-reported physical health symptoms with occupants' frequency of observance that is associated with the acoustic environment in the students' hostels. This study concluded that within the range of 27.75 dB and 56.29 dB measured sound pressure level during both dry and wet seasons, there is an inverse relationship between the sound pressure level in the rooms and the frequency of observance of cold, fatigue, and headache among the occupants. However, the relationship is more significant during the wet season, and more pronounced in female occupants than in male occupants.

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