Environmental Noise Exposure On Occupants In Naturally Ventilated Open-Plan Offices: Case Of Selected Offices In Kumasi, Ghana

Koranteng, C., Amos-Abanyie, S., Kwofie, T. E.

Abstract: The design of buildings in public educational institutions in Ghana predominantly adopts open-plan offices that are naturally ventilated with the aid of operable windows for reasons such as achieving adaptable spaces, improved social climate and effective ventilation. However, adoption of open-plan naturally ventilated offices in these educational institutions expose occupants to noise that emanates indoors and from outdoor sources which can interfere with and impede work performance. The study aimed at assessing noise exposure levels and occupants' satisfaction with noise level in selected naturally ventilated open-plan offices in Ghana. The study employed an empirical assessment of the noise levels in and around three of the office buildings using a PCE222 Digital Sound Level Meter and a survey involving interviews to assess workers' satisfaction of noise levels of the open-plan offices at the Kwame Nkrumah University of Science and Technology in Kumasi. The results show that mean outdoor noise levels for offices ranged from 11 per cent below to 5 per cent above the WHO permissible limits, while mean indoor noise levels exceeded the limit by between 20-40 per cent during the course of the day. In spite of the high levels of noise, occupants generally considered the overall noise level in their offices as acceptable. Likewise, the results indicate that there are no significant differences in occupants' exposure to noise from their various sitting positions in an office space and floor levels in an office building. The paper recommends strategies to manage and improve ambient noise quality within naturally ventilated open-plan office spaces in Ghana. The study will be of relevance as a useful guide to organizations and policy makers concerned with built environmental issues.

Index Terms: Noise, Acoustics, Perception of noise, Open-plan offices, Natural ventilation, Ghana

1 INTRODUCTION

THE exposure of communities to environmental noise has become a worldwide concern with most cities being subjected to noise levels that are a disturbance to human activities [1], [2]. A large proportion of buildings in public educational institutions in Ghana are designed to be predominantly ventilated by natural means with the aid of operable windows. Operable windows are strongly preferred because occupants can be comfortable over a wide range of temperatures with improved ability to manage their comfort, and it is seen as a cost effective alternative without the need for energy input [3]. Unfortunately, the use of natural ventilation in offices in these educational institutions can expose occupants in a space to direct noise from outdoor sources which interferes with and impedes work performance. Adoption of open-plan offices has become a very common variety in the design of buildings over the past years in Ghana. An open-plan office layout is much more adaptable, enables the accommodation of greater number of employees in a given space and facilitates communication, thus improves satisfaction, morale and productivity [4]. The absence of interior walls enhances the effectiveness of lightening systems and reduces energy use.

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In spite of the improved social climate with open-plan offices, occupants also suffer from elevated noise generated by common and shared work equipment such as telephone, copiers, computers, printers, and conversations that emanate from the spatial workplace configuration [5], [6]. In developed countries, buildings in noisy environments have sound insulation techniques incorporated in the design to minimize noise from the surroundings [7]. The above context raises issues such as what are the sources of noise in an open-plan office; what are the satisfaction levels of occupants of noise in open-plan offices; what are the noise levels in open-plan offices; and what are the variations in the level of exposure of occupants? In response to the above issues, the study aimed at assessing noise exposure levels and occupants' satisfaction with noise level in naturally ventilated open-plan offices in Ghana. The study focused on selected naturally ventilated open-plan offices at Kwame Nkrumah University of Science and Technology (KNUST, Kumasi, Ashanti Region), the second largest city in Ghana.

2 EFFECTS OF NOISE IN OFFICE ENVIRONMENTS

The word noise has been concisely defined as unwanted sound [1], and may emanate from a variety of sources such as vehicular traffic, construction processes or from neighbourhoods [8]. Martin [9] et al. opines that noise from vehicles contribute highly to community noise. Community noise may not be high enough to cause a hearing defect within buildings, but may have an unfavourable effect on general health [10]. However, when the level increases to an irritable level in the community, it can be considered as "noise pollution" [11]. The effects of noise on humans are difficult to quantify because tolerance levels amongst different people and types of noise vary greatly [12]. In the office environment, human response to noise displays a systematic qualitative pattern, but quantitative responses for individuals vary with age, health, fatigue and temperament, amongst other factors. Continuous exposure to noise may not only affect occasional

memory, but also material observation memory is decreased [13]. Excessive noise exposure could carry several ill effects in addition to annoyance, speech interference and lack of concentration [14]. In addition, speech interference results in a large number of disabilities, handicaps and behavioural changes, problem with concentration, fatigue, uncertainty and lack of confidence, irritation, misunderstandings, decreased work capacity and problem in human relation [15]. Kaarlela-Tuomaala [16] et al. in a survey of office environments identified that people arriving or departing, keyboard sounds and ventilation equipment as major noise sources, with conversation and computer/printer beeping reported to be the most annoying by 90 per cent of the survey respondents. Field studies have shown that noise from ringing phones especially at vacant work stations and other people's conversation are rated as the most common causes of complaint in open-plan offices [17] et al., [18]. Studies by [6] and [8] have shown that certain levels of noise can incapacitate a person's ability to concentrate on a particular task. Most people find that in noisy conditions, more effort is required to maintain concentration and that the onset of fatigue is quicker [9] et al. Balazova [19] et al., in a laboratory study observed that the speed of text typing and false detection of mistakes in a proof reading task were affected by acoustic exposure indicating that tasks requiring processing of words may be affected by noise. Performance studies indicate that tasks requiring more concentration such as proof-reading, complex analysis, reading comprehension and memory are the most sensitive to noise, especially noise sources related to co-workers speech [20]. Research indicates that prolonged exposure to noise reduces office workers motivation to persist at a difficult task [21]. The recommended levels by WHO for maximum indoor noise levels in administrative office environment to maintain good speech intelligibility, which is the ability to understand others, is 45dB and 65dB outside of office environments [22]. Office conversation is interfered at 50dB [5]. Moreover, sound intensities greater than 65dB are believed to be distractive when office workers do not have control over the noise source and it is unpredictable. Among outdoor noise sources, it is well established that long exposure to traffic noise is a particular source of annoyance in an office building [23]. Gulian and Thomas [24] study showed that at noise levels below 85dB (the level of a commercial truck) slowed work performance, but did not affect accuracy. Noise at this volume would, however, hinder telephone and other conversations [25].

3 MATERIALS AND METHODS

The approach for the study involved two stages. The first stage was a survey involving interviews to assess the satisfaction of noise level of a sample size of seventy (70) workers. These workers were of twelve (12) selected naturally ventilated open-plan offices of eight (8) selected buildings at the KNUST. The second stage involved an empirical assessment of indoor and outdoor noise levels in three of the selected office buildings.

3.1 Studied Offices and Respondents

The selected buildings for the empirical assessment are the Main Registry Office which is located on the first floor of the Main Administration Block (see Figure 1), the Development Office and the Main Internal Audit Office in the Administration Block II (see Figure 2) which is at the civic zone of the KNUST Campus (commercial area) with relatively busy access roads (Figure 3). The Main Registry office is a large open space with no internal partitions with workers stationed side by side at adjoining stations. The Development Office (drawing section) has a large open space layout and with no form of partitioning (Figure 4). The Internal Audit office has workstations set up in plywood cubicles. All the offices have sandcrete blocks that are rendered, and finished with emulsion paint. Operable windows with louver blades are used that facilitate the use of natural ventilation. The spaces have either a floor carpet or porcelain tile floor. Ceiling materials are either of fair-faced concrete or plywood. Regarding the activities most carried out by the occupants during their working hours (8-17hrs), 37 per cent are involved in working on documents (reading and writing by hand), 36 per cent work on the computer, 6 per cent are engaged in working (drawing and designing) on sheets and computer, 16 per cent were involved in attending to official phone calls, and 3 per cent were involved in filing of documents.

3.2 Noise Level Monitoring

Monitoring of indoor and outdoor noise levels were done with a calibrated PCE222 Digital Sound Level Meter, having an accuracy of +/-1.5dB and a measuring range between 30 to 130dB [26], [27]. Noise levels were monitored over a three week period (from 16th March to 3rd April 2016), in the morning (8:00 to 12:00hrs) and afternoon (13:00 to 17:00hrs). Continuous data was collected at an interval of 2 minutes for all the time periods in the selected offices. Internal and external monitoring was done simultaneously during the study period. All sound monitoring were made at the centre of the office spaces (Figure 5) with the Sound Level Meter at a height of 1.5 m above floor and ground levels (approximate height of seated occupants).

3.3 Survey

The data for the study was solicited through structured questionnaires administered on occupants of the open-plan office spaces. The questionnaire was designed with focus on three areas of data, namely, background information of respondents, noise sources and occupants' satisfaction of noise level in their offices, and their sitting position. In assessing the occupants' satisfaction of the overall noise level experienced in their space, the questions were asked on a conventional five- point likert scale rating of 5 = very good level (being the highest), 4 = good, 3 = acceptable, 2 = very bad and 1 = unacceptable noise level (being the lowest). Out of the total of 70 questionnaires given out, 54 copies representing 77% were received and found suitable for the analysis.

Figure 1: *Main Administration Block*

Figure 3: *View of KNUST Commercial Area*

Figure 2: *Administration Block II*

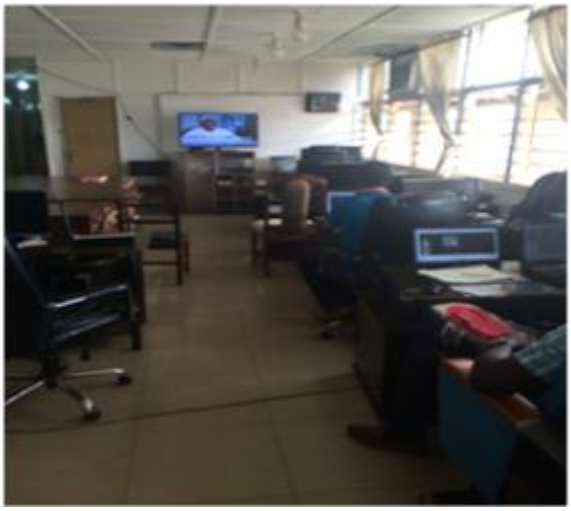

Figure 4: *Drawing Office of the Development Office*

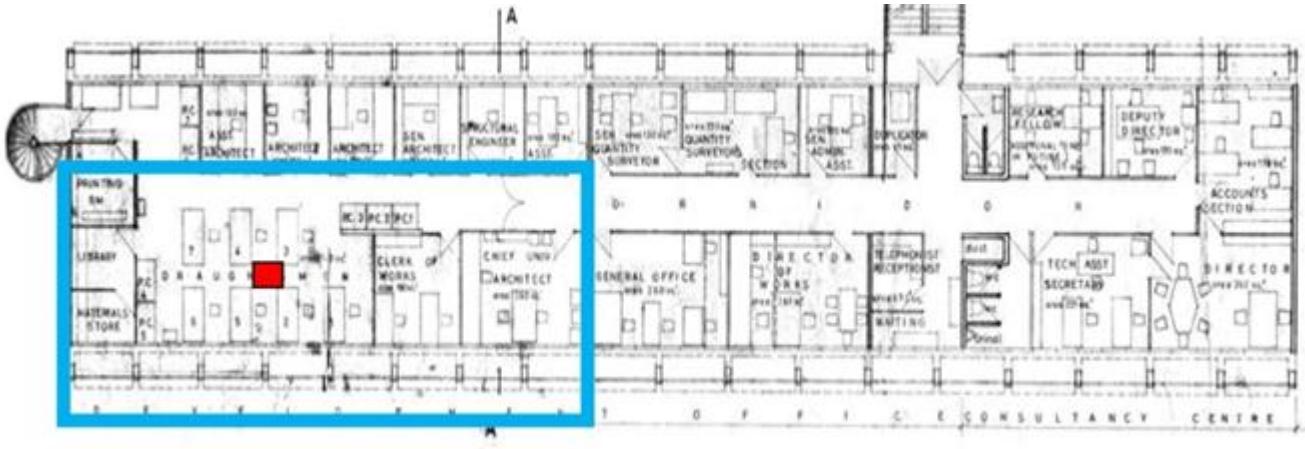

Figure 5: *Floor plan of the Drawing Office of the Development Office showing the location (in red) of sound level metre [28]*

3.4 Analysis

Raw monitored noise levels were pooled together and classified as morning and afternoon timeframes. Mean sound level for each timeframe was calculated using the expression in Equation 1 [29]. Mean sound levels were compared with recommended level by the World Health Organisation (WHO) sound levels [22]. The magnitudes of mean sound levels above or below the permissible sound level were computed in percentages.

$$Leq = 20 \log (1/N) \Sigma 10 Lj/20 \quad (1)$$

Where N is the number of observations and Lj is the jth noise level. The survey data was analyzed using t-test and analysis of variance (ANOVA). A one sample t-test was undertaken to determine whether the population considered the overall satisfaction of the noise level as acceptable or otherwise. The null hypothesis is that the overall satisfaction of the noise level was unacceptable (H0: U = U0) and alternative hypothesis was that it was acceptable (Ha: U > U0), where U0 is the population mean (U0 was fixed at 3.5, drawing from [30]. The significance level was set at 95% in accordance with conventional risk levels [30]. The analysis of variance (ANOVA) was also undertaken to determine whether there was a significant difference in the noise level experienced by the population from the various sitting positions and floor levels of the buildings or otherwise. Tables 1 and 2 provide a summary of the results for sitting positions and floor levels respectively. For each sitting position and floor level, the null hypothesis was that it was insignificant (H0: U = U0) and alternative hypothesis was that it was significant (Ha: U > U0).

Table 1: *Patterns Of Sound Levels In Decibel For Office Spaces At Different Time Periods*

	Office Space	Week	Time (Hours)								
			Morning (8:00 - 12:00)				Afternoon (1:00 - 5:00)				Mean
			9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	
Outdoor	Dev. Office	1	69.28	71.29	71.27	70.79	69.67	69.95	71.96	68.16	
		2	64.26	68.41	62.12	60.63	64.97	68.92	73.31	68.23	66.94
		3	67.15	67.82	61.02	59.69	63.03	67.62	61.23	65.81	
	Audit office	1	65.05	66.37	63.10	61.98	60.39	61.18	68.30	63.58	
		2	65.06	64.76	58.85	60.62	62.96	62.35	68.95	64.54	63.54
		3	67.7	58.9	56.2	62	69.8	62.7	61.6	68	
	Main Registry	1	55.11	56.57	56.16	58.45	58.32	57.16	57.63	59.32	
		2	59.13	57.64	58.35	57.26	57.85	57.30	57.71	55.44	57.54
		3	58.07	58.89	57.85	57.6	57.00	58.28	56.12	57.71	
Indoor	Dev. Office	1	65.48	65.37	66.74	66.18	64.48	65.50	64.17	66.15	
		2	65.69	64.43	61.15	62.59	62.30	63.46	62.10	65.87	62.79
		3	58.67	58.67	57.88	59.52	58.80	60.73	60.87	60.22	
	Audit office	1	52.47	51.42	51.37	55.55	55.09	58.23	58.05	58.47	
		2	52.58	51.73	55.46	56.59	60.48	60.38	59.35	59.69	56.79
		3	54.5	48.8	55.1	64.2	60	59.8	62.5	61.2	
	Main Registry	1	53.45	53.85	55.29	54.81	57.81	54.92	55.40	56.34	
		2	55.93	55.74	55.34	57.29	55.811	54.51	53.58	54.63	55.56
		3	56.71	57.40	56.53	54.83	53.79	54.87	56.94	57.69	

4 RESULTS AND DISCUSSIONS

The mean values of monitored indoor and outdoor noise levels in each of the three office spaces selected for detailed study, results of the one sample t-test of the overall satisfaction of occupants of the noise level in the offices, and the analysis of variance of how significant the difference in noise level to occupants at their sitting positions and level of floor in the office buildings are presented and discussed.

4.1 Noise Level in Open-Plan offices

The offices are the Development Office (DO), the Internal Audit Office (AO) and the general office of the Main Registry (RO). The mean values of the outdoor and indoor data of the selected open-plan offices over the study period are presented in Table 1. Outdoor noise levels were monitored parallel to the time periods for which indoor noise levels were monitored for the various office spaces. For this reason, even though, the DO and the AO are on different floors in the same building, they have different levels of outdoor noise. The monitored mean outdoor noise levels for all the time periods (morning and afternoon) fell between 57-68dB for the DO and the AO, with a maximum of 81.6dB and a minimum of 50.5dB both occurring on an afternoon. The morning period recorded a maximum of 77.1dB and a minimum of 51.4dB. The RO had a mean outdoor noise level of approximately 57.6dB. With the buildings being institutional structures, the permissible ambient sound limits of 65dB by [21] suggests, as presented in Table 2, that the monitored mean outdoor noise level are high for some time periods for the DO and the AO. However, the mean outdoor noise level of the RO had mean noise level that fell below the permissible limit. The relatively higher outdoor level of the DO and the AO could be explained by the indirect effect of outdoor traffic noise pollution, since the DO is located at the commercial zone of the University Campus (Commercial Area) with a relatively higher vehicular traffic activity. During the time frame of monitoring for the DO, the mean outdoor noise levels exceeded the permissible limit by 1.6 per cent and 4.2 per cent for the morning and afternoon periods respectively (Table 2). With respect to the AO, the outdoor mean level exceeded by 3.6 per cent for the morning and fell below by 11.5 per cent for the afternoon. Even though this part is the commercial

zone of the KNUST Campus, the limited activities as compared to the CBD make noise levels relatively lower. In a similar study, outdoor noise levels of some sections of the CBD had noise levels exceeding the permissible limits by 14.0 per cent, 15.1 per cent and 18.0 per cent for mornings, afternoons and evening time periods respectively [27]. On the other hand, the RO had outdoor mean noise levels falling below the permissible limit by an average of 11.5 per cent for all the time periods.

Table 2: *mean sound levels in decibel for office spaces at different time periods. The values indicated in the parenthesis are the per cent change of sound level than the permissible level.*

	Office Space	Allowable Noise Levels (dB)	Time (Hours)					
			Morning (8:00 - 12:00)			Afternoon (1:00 - 5:00)		
			Min	Max	Mean	Min	Max	Mean
Outdoor	Dev. Office	65	51.4	77.1	66.1 (1.6%)	51.2	81.6	67.7 (4.2%)
	Audit office		54.3	75.0	62.6 (3.6%)	50.5	78.1	57.49 (-11.5%)
	Main Registry		51.6	69.2	57.6 (-11.4%)	50.5	78.1	57.5 (-11.5%)
Indoor	Dev. Office	45	51.8	74.1	62.7 (39.3%)	52.9	76.4	62.9 (39.7%)
	Audit office		47.3	67.8	54.15 (20.3%)	46.8	67.3	59.4 (32.0%)
	Main Registry		44.0	64.7	55.6 (23.5%)	46.7	65.5	55.52 (23.4%)

TABLE 3: *One Sample t-Test of Overall Noise Satisfaction Level*

	Test Value = 3.0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Satisfaction of Noise Level in Space	-1.484	49	.144	-.200	-.47	.07

Monitored indoor mean noise levels for all the offices were lower than that of outdoor but not significant. Moreover, all the offices had mean noise levels exceeding the permissible limit for office environments. The DO recorded a maximum of 76.4 dB on a morning, with a mean of 62.7dB and 62.9dB for morning and afternoon respectively. The mean noise levels for the DO, in percentage terms, exceed the permissible limits by 39.3 per cent and 39.7 per cent for morning and afternoon time period. The observed high sound levels in the office space is attributed to relatively high human activity within the vicinity and noise from several vehicles ranging from private cars, public cars through to delivery vans and occasionally, trucks. During the survey, it was observed that the office environment was not too busy during the mornings but became busy from midday. The AO recorded a maximum of 67.8dB on a morning and a minimum of 46.8dB on an afternoon. The mean noise levels of the AO were 54.dB and 59.4dB for morning and afternoon time period respectively. With these mean noise levels for morning and afternoon of the AO, the permissible limits were exceeded by 20.3 per cent and 32.0 per cent respectively. The RO had mean noise level of 55.6 per cent and 55.52 per cent for morning and afternoon, thus exceeding the permissible limit by 23.5 per cent and 23.4 per cent respectively. The recommended levels by WHO for maximum indoor noise levels in administrative office environment to maintain good speech intelligibility, which is the ability to understand others is 45 dB [22]. A conducive and a controlled noise environment are crucial for worker productivity as well as for well-being. The monitored indoor noise level of the open-plan office environments exceeds the permissible limit recommended by the [22] in all time periods of the study and as such not found to be ideal for an administrative work environment. Moreover, the American Refrigeration and Air conditioning recommends that open-plan offices must have a noise criterion between 49 and 58 decibels so as not to interfere with verbal communications and complex mental tasks [5], whereas for all the offices studies mean indoor noise levels ranged from 54.15 - 62.9dB. A study by [5] concludes that sound above 50dB can interfere with conversation among occupants, thus suggesting that conversation among occupants of the selected open-plan offices could very much interfere with verbal instructional processes in their daily work activities. Even though the permissible limit for indoor office environment is 45dB, [31] observed evidence of annoyance in population exposed for more than one year to sound levels of 37 dB and severe annoyance at 42 dB. The level of noise pertaining in the offices can affect noise sensitive tasks such as those requiring comprehension and memory, and especially prolonged exposure to such noise can reduce office workers motivation to persist in a difficult task [21].

4.2 Noise satisfaction level in open-plan offices

The results of the respondents' sitting positions in the office spaces revealed that 32 (64%) sat very near windows, 14 (28%) also sat in the Middle of workspaces whereas 8% (4) were sitting far from windows. Additionally, 13 (24%) of the total 54 respondents occupied office spaces on ground floors, 25 (46%) were on first floors and 16 (30%) occupied second floor office spaces. The distribution of the respondents in the office spaces and floors tend to suggest that there is a fair representation of the respondents on the various aspects of the analysis and thus the findings drawn from their responses are more likely to be a sound and credible representation of the noise profile of office spaces. The results of the one

sample t-test of the overall noise satisfaction level experienced in the office buildings are presented in Table 3. From the results, the mean score of the overall noise satisfaction level experienced was 3.30 with the standard mean error of 0.135. Thus, based on the five-point Likert rating scale, the noise level experienced is deemed acceptable if it had a mean score of 3.0 or more. Hence, the 3.30 mean score registered suggests that the noise level experienced by respondents were generally acceptable. The t-test also registered a t-value of -1.484 with 49 degree of freedom and sig. value of .144 (p>0.05). The sig. value suggests that the difference between the means is not significant. This indicates that even though generally the noise satisfaction level experienced was acceptable, and thus there is no significant difference in noise level experienced between the various sitting positions and floor levels in the office spaces. Table 4 shows the results of the one-way ANOVA of responses with respect to noise level from the sitting positions in the office space relating to hypothesis 2. According to [32], the interpretation of an ANOVA results must first ensure that the homogeneity assumptions is not violated. This is done by observing the Levene's test of homogeneity of variances is not significant (p>0.05) and thus be confident that the population variances for each group are approximately equal. From Table 4, none of the noise from the various sources from the sitting positions of the respondents in the office spaces had values less than 0.05, hence it can be stressed that the assumption of homogeneity variances is not violated and thus the results are more likely to be valid and credible. Additionally, among all noise sources, none of them was significant from the various sitting positions in the office space as all the sig values related to the F-statistics were greater than 0.05. Hence, the null hypothesis is, therefore, accepted. Consequently, it can be asserted that there is no significant difference in the experience of noise level from the various sources with respect to the sitting positions in the office space.

TABLE 4: *One Sample t-Test of Overall Noise Satisfaction Level*

	Sum of Squares	df	Levene's Statistic (Sig)	Mean Square	F	Sig.
People talking on phone:						
Between Groups	.180	2	.743	.090	.134	.875
Within Groups	31.500	47		.670		
Total	31.680	49	Sig. = 481			
Telephone ringing:						
Between Groups	.644	2	1.098	.322	.252	.778
Within Groups	60.076	47	Sig.= .342	1.278		
Total	60.720	49				
Music from radio/sound system:						
Between Groups	3.576	2	.359	1.788	1.240	.299
Within Groups	67.804	47	Sig.= .700	1.443		
Total	71.380	49				
Conversation in neighbouring offices:						
Between Groups	2.454	2	1.841	1.227	.766	.471
Within Groups	75.326	47	Sig.= .681	1.603		
Total	77.780	49				
AC systems:						
Between Groups	.304	2	.489	.152	.146	.865
Within Groups	49.076	47	Sig.= .618	1.044		
Total	49.380	49				
Footsteps:						
Between Groups	.354	2	1.525	.177	.176	.839
Within Groups	47.326	47		1.007		
Total	47.680	49	Sig.= .228			
Office lighting systems:						
Between Groups	.744	2	.950	.372	.236	.791
Within Groups	74.076	47		1.576		
Total	74.820	49	Sig.= .394			
Office Equipment (printer, PC etc):						
Between Groups	1.537	2	.189	.768	.590	.558
Within Groups	61.183	47		1.302		
Total	62.720	49	Sig.= .828			
Echoing of voices or other sounds:						
Between Groups	2.161	2	.482	1.081	.928	.402
Within Groups	54.719	47		1.164		

Total	56.880	49	Sig.= .621			
Outdoor (traffic) noise:						
Between Groups	1.441	2	1.058	.720	.421	.659
Within Groups	80.339	47	Sig.= .355	1.709		
Total	81.780	49				

TABLE 5: *ONE SAMPLE T-TEST OF OVERALL NOISE SATISFACTION LEVEL*

	Sum of Squares	df	Levene's Statistic (Sig)	Mean Square	F	Sig.
People talking on phone:						
Between Groups	.727	2	.094	.363	.552	.580
Within Groups	30.953	47		.659		
Total	31.680	49	Sig. = 910			
Telephone ringing:						
Between Groups	6.588	2	1.246	3.294	2.860	.067
Within Groups	54.132	47	Sig.= .282	1.152		
Total	60.720	49				
Music from radio/sound system:						
Between Groups	3.664	2	1.854	1.832	1.272	.290
Within Groups	67.716	47	Sig.= .168	1.441		
Total	71.380	49				
Conversation in neighbouring offices:						
Between Groups	2.981	2	.081	1.491	.937	.399
Within Groups	74.799	47	Sig.= .922	1.591		
Total	77.780	49				
AC systems:						
Between Groups	1.114	2	.540	.557	.543	.585
Within Groups	48.266	47	Sig.= .587	1.027		
Total	49.380	49				
Footsteps:						
Between Groups	.727	2	2.451	.363	.364	.697
Within Groups	46.953	47		.999		
Total	47.680	49	Sig.= .097			
Office lighting systems:						
Between Groups	3.943	2	2.798	1.971	1.307	.280
Within Groups	70.878	47		1.508		
Total	74.820	49	Sig.= .071			
Office Equipment (printer, PC etc):						
Between Groups	.054	2	1.854	.027	.020	.980
Within Groups	62.666	47		1.333		
Total	62.720	49	Sig.= .168			
Echoing of voices or other sounds:						
Between Groups	2.202	2	1.251	1.101	.947	.395
Within Groups	54.678	47		1.163		
Total	56.880	49	Sig.= .296			
Outdoor (traffic) noise:						
Between Groups	3.014	2	1.631	1.507	.899	.414
Within Groups	78.766	47	Sig.= .207	1.676		
Total	81.780	49				

From Table 5, the Levene's test of homogeneity revealed that none of the associated sig values was less than 0.05. This suggests that the assumption of homogeneity variances is not violated and thus the population variances of each group are approximately equal. Likewise, all the significant values associated with the F-statistic in Table 3.0 are all greater than 0.05. This is an indication that there is no significant difference in the experience of noise level from the various sources with respect to the floors in the office buildings. Hence, the null hypothesis is, therefore, accepted. The generic assessment of the overall assessment reveals an acceptable level of overall noise experienced by occupants. Likewise, there is an indication that sitting position does not have any significant variations in noise experienced from the various noise sources in the office spaces. This however does not concur with the general perception that noise level reduces with respect to the distance from the noise source [33]. With respect to the floor levels in the office building, the study revealed that there is no significant variation in the noise levels from sources. The findings are in line with a previous study, [27] Botchway et al. (2014) and suggest that occupants' satisfaction level in relation to noise level do not conform to data on the levels of the monitored noise. This could be attributed to occupants being unaware of the permissible levels for the work environment and their associated likely harmful effects on exposure to noise, especially over a long period of time.

5 CONCLUSION AND RECOMMENDATIONS

The exposure of the occupants of open-plan naturally ventilated office buildings to environmental noise is gradually becoming a public health concern. The study aimed at assessing noise exposure levels and perception of occupants in naturally ventilated open-plan offices in Ghana. To achieve the aim, the The findings of the study show that the office environments are not conducive for administrative work process with varied noise levels in offices depending on where they are located. Mean outdoor noise levels for the offices ranged from 11 per cent below to 5 per cent above the WHO permissible limits, while mean indoor noise levels exceeded the limit by between 20-40 per cent during the course of the day. In spite of the high levels of noise, occupants generally considered the overall noise levels in their offices as acceptable. Likewise, the results indicate that there are neither significant differences in occupants' exposure to noise from their various sitting positions nor floor levels in an office building. The study suggests that even in an educational institution with restricted activities, noise level can attain levels beyond the permissible noise limits. The above implies that noise has become an environmental problem in Ghana as a whole and needs to be addressed urgently. The following recommendations are outlined for future studies based on the findings to manage and improve ambient working environment within naturally ventilated open-plan office spaces in Ghana:

- Noise level monitoring in this study was done in occupied offices with occupants' activity. Studies should be done in unoccupied offices with no activity to determine whether indoor noise levels are due to external sources or to noise generated within the offices.
- The association between the sizes of space, number of occupants, types of openings with indoor noise levels in office spaces should be investigated.
- Noise maps should be prepared for educational institutions to inform location and design of prospective buildings to the existing stock.
- Indoor noise level should be assessed with respect to floor, wall and ceiling finishes of office spaces.

It is expected that the findings of this study will be a useful guide to organizations and policy makers concerned with built environmental issues.

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