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# Noise Pollution Effects on Mental Fatigue and Noise Annoyance among Bank Staffs

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## ABSTRACT

Noise discomfort is one of the important unpleasant physical parameters in open-plan offices**.** This study was aimed to investigate the status of noise pollution and its effects on subjective fatigue and noise annoyance among bank staffs. The equivalent sound pressure level ($Lp_{eq.T}$) of 100 bank employees was determined during the working time. Moreover, the sound pressure level (SPL) in client waiting areas and in the outer area of the studied banks was measured. For evaluating the mental fatigue, the standard Multidimensional Fatigue Inventory (MFI) questionnaire was used. Noise Annoyance Scale (NAS) questionnaire was also applied to study workplace noise annoyance and the subjective impressions of noise intensity. The mean $Lp_{eq.T}$ in the staff workstations, client waiting areas, and the outside area of the studied banks were determined 78.72, 61.14, and 81.32 dB (A), respectively. The mean values of the preferred noise criterion (PNC) and speech interference level (SIL) indices were 58.22 and 70.25, respectively. The results revealed that the feeling of mental fatigue and noise annoyance among bank employees were significantly affected by the $Lp_{eq.T}$, level (r=0.84 and 0.90, respectively). The findings indicated that the background noise in open-plan offices increased the PNC and SIL indices which can increase the mental discomfort of staff and decrease their job performance in cognitive tasks. Reflective and rigid surfaces increased the SPL scale in the interior area of banks, and therefore it is necessary to modify the internal surfaces in these open-plan offices.

**KEYWORDS:** *Noise; Mental Fatigue; Noise Annoyance; Acoustic Comfort; Open-Plan Offices*

## INTRODUCTION

Noise is identified as mechanical, irregular, unpleasant, unwanted, and unavoidable waves causing disruption of auditory system.

According to the nature of noise sources, there is not a regular and harmonic correlation between physical characteristics of noise such as sound pressure level (SPL), frequency, and wavelength. In public and industrial environments, noise is created or reflected by a variety of sources like human activity, machines, pagers, etc. Noise pollution is an important and inevitable health issue in public places and workplaces [1]. Over recent decades, noise comfort was considered as an important criterion for determining the quality of life and social well-being in developed countries [2-4].

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Noise adverse effects on human health were associated with various parameters such as noise type, frequency, intensity, pressure, exposure duration time, and personal sensitivity to noise. Acute or chronic exposures to high SPLs more than 85 dB, recommended by the ACGIH and national regulations, can directly affect the performance of the auditory system. Therefore, exposure to high levels of noise can cause a variety of disorders such as temporary changes in hearing threshold and permanent hearing loss (especially chronic exposure). Previous studies indicated that exposure to low-frequency noise (LFN: lower than 250 Hz) in public and occupational places can cause annoyance, discomfort, and dissatisfaction [5-8].

Acoustic comfort is one of the most important aspects of interior architecture. So, it is necessary to provide the satisfaction of residents in buildings (home or workplace) and minimize noise pollution. Acoustic comfort is defined as an environmental condition without any annoyance or disturbing sound. In such a condition, noise is controlled and did not cause any physical and psychological discomfort in the residents [9-10]. In order to minimize hormonal imbalance effects in workplaces with cognitive tasks such as adrenaline, noradrenaline, cortisol hormones, and subsequently causes behavioral disorders including mood changes and anxiety, it is essential to provide acoustic comfort for the employees [11-12].

The open-plan office is one of the most important places with LFN in public- occupational places. An open-plan office is a kind of work environment in which employees perform their tasks with collaboration, face to face interactions, and speech connection based on the mental and psychological functions, simultaneously [13]. Various compliances have been reported in these workplaces such as stress, anxiety, annoyance, and sleep disturbance among employees and clients. In such open-plan offices, the privacy requirements may not meet due to the lack of unsuitable acoustic conditions which is resulting in a decrease in job satisfaction, job performance, and organizational productivity. To predict the speech intelligibility in the open-plan office, the preferred noise criterion (PNC), speech interference level (SIL) curves or speech intelligibility index (SII), was commonly used. PNC is an audio comfort index that is usually used to investigate the acceptance of background noise from different sources in different frequency bands and SPLs. After analyzing the frequency of the background noise and comparing them with the standard curves, the PNC index was estimated [9]. The quality of speech communication between users in an open-plan office was evaluated by the SIL curve which demonstrates the level of speech masking by background sound based on the mean of the 500, 1000, 2000, and 4000 Hz octave bands [14].

Banks are generally considered as open-plan offices due to the nature of their work conditions. Therefore, it is important to provide good acoustic conditions for employees and clients [15-17]. Various tasks of bank staffs such as financial calculations require proper mental functions. The noise pollution can disrupt the quality of banking services and may lead to cognitive errors and mental fatigue among the employees [18-19]. Previous studies showed that in the open-plan offices, LFN mainly affects the cognitive performance and mental workload of the employees. It also reported that mental performance, job productivity, and job satisfaction among employees working in workplaces with noise pollution were lower than other employees [20-21].

Given that noise is one of the main causes of dissatisfaction and discomfort among bank staffs in open-plan offices, this study was aimed to determine the acoustic conditions in several Iranian banks. Moreover, the effects of noise exposure on mental fatigue and noise annoyance were investigated among bank staffs in 2019.

## MATERIALS AND METHODS

### *Participants and equivalent sound pressure level:*

This study was conducted in all branches of public banks in one of the southern provinces of Iran. For these reasons, a total of 100 employees from 12 branches were studied.

Based on the inclusion criteria, 100 staffs with at least one year of work experience, without any occupational hearing loss, addiction to drinking alcohol, and a history of mental diseases were included. Written informed consent was obtained from all subjects prior to participating in this study.

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SPL value was measured using a sound level meter (model TES 1358C, China. according to the protocol introduced by ISO 9612: 2009 standard [22], based on the job criteria strategy. In this regard, the SPL value was measured for various each workstation and tasks in the bank during the work shift (at 8:0, 10:0, 12:0, and 14:0).The equivalent sound pressure level ($Lp_{eq.T}$) was also calculated according to the equation recommended by ISO 9612: 2009 standard. An external calibrator (model Quest QC-20) was used to ensure the calibration of the SPL meter (slow speed mode, A-weighted at 250 Hz and 114 dB). Subsequently, the SPL was measured on the staff's workstations, client's waiting stations, and in front of the bank (in the street). For these reasons, all electronic equipment and air-conditioning systems were active during the measuring. Measurements were performed in a height of 1.5 m (standing position) and in a height of 1 m (sitting posture) for 10 min on each station. The SPL measurement and the frequency analysis of sound in the 1:1 octave band at 63, 125, 250, 500, 1000, 2000, 4000, and 8000 Hz were performed inside and at the entrance of the studied banks.

### *PNC and SIL*

To assess the effect of background noise on the quality of speech communication in the banks as an open-plan office, the preferred noise criterion (PNC) and speech interference level (SIL) curves were used. PNC is an audio comfort index that often determines the acceptance of background noise from different sources in different frequency bands and SPL [9]. Also, the SIL showed the interference of the overall noise in the environment and people's speech and conversations. To determine the SIL index, after analyzing the background noise frequency, the SIL index was estimated by calculating the mean SPL at 500, 1000, 2000, and 4000 Hz [23].

### *Mental Fatigue*

In the present study, a researcher-made demographic questionnaire was used to collect demographic data of bank staffs. Next, the Multidimensional Fatigue Inventory (MFI) questionnaire was designed to assess occupational mental fatigue in the studied participants. This 5-points Likert scale (0-4) standard questionnaire was first designed and introduced in 1996 by Smethers, which contained 20 items and 5 subscales including general fatigue, physical fatigue, decreased activity, decreased motivation, and mental fatigue [24]. The overall mental fatigue score was calculated by algebraic summing up scores of different subscales; a score in the range 20-40 indicates mild fatigue, 41-60 means moderate fatigue, 61-80 indicates distressing fatigue, and higher than 81 demonstrates debilitating fatigue. According to previous studies, the reliability coefficient of the questionnaire for determining the fatigue level was 0.878 [25].

### *Noise Annoyance Scale*

In this step, a self-report questionnaire was applied for assessing personal subjective noise intensity, and a self-report Noise Annoyance Scale (NAS) questionnaire was used to evaluate the noise annoyance feeling among the employees. The self-report subjective noise intensity questionnaire is a visual scale for scoring noise intensity on a 10 cm horizontal line, from 0 (no discomfort) to 10 (very annoying). The participants were requested to express their impression of the noise intensity in the work environment. According to previous studies, the reliability coefficient of this questionnaire for determining the noise intensity in the workplaces was determined to be 0.81 [26-27].

The self-report noise annoyance scale is a visual scale for assessing noise annoyance on 10 cm horizontal lines from 0 (no annoyance) to 10 (very annoying). The participants were asked to show their impression of noise annoyance in the work environment. Moreover, based on the previous studies, the reliability coefficient of this questionnaire for determining noise annoyance level in the workplaces was 0.88 [9].

### *Statistics Analysis*

Various descriptive and analytical statistics such as mean, standard deviation, relative frequency, one way ANOVA, Kolmogorov Smirnov (KS), Student's *t*-test, Kruskal-Wallis, chi-square test, and Pearson correlation coefficient test were used to analyze the collected data. All the analyses were performed using the SPSS software (version 22).

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# RESULTS

## *Demographics and $LP_{eq.T}$*

In the current study, a total of 100 employees (65 men and 35 women) were included. The mean and standard deviation of age (year) and work experience (year), of the subjects, were 36.23±7.33 and 13.45±7.63, respectively. The demographic characteristics of the studied bank staff have been presented in Table 1.

The descriptive statistics of the measurement of $Lp_{eq.T}$ and SPLs in various places, interior and exterior spaces of banks have been shown in Table 2.

The findings showed that the highest and lowest levels of $Lp_{eq.T}$ were observed at the workstations of bank's vice presidents and bank cashiers (with mean levels of 81.92 and 61.80 dB, respectively).

***Table 1.*** Demographic characteristics of studied bank staffs

| Variable | | Number | Percentage |
|---|---|---|---|
| Marital status | single | 34 | 34% |
| | married | 66 | 66% |
| Employment Status | Civil servant | 60 | 60% |
| | Contractual | 31 | 31% |
| | Short-term Contractual | 6 | 6% |
| | Wage work | 3 | 3% |

***Table 2.*** sound pressure level in different parts of the banks (dB (A)).

| Variable | Mean | Min | Max | SD |
|---|---|---|---|---|
| $Lp_{eq.T}$ at staff's workstation | 78.32 | 53.2 | 81.4 | 9.84 |
| SPL at wait- stations of client | 61.14 | 50.9 | 65.14 | 5.32 |
| SPL at the outer space of the bank | 81.32 | 62.70 | 85.30 | 6.04 |

$Lp_{eq.T}$ = Equivalent sound pressure level; SPL= Sound pressure level.

## *PNC and SIL*

The mean and standard deviation of the PNC index in the studied banks was 58.22±6.22 dB (A). It should be noted that the recommended value of the PNC for the office work environments was in the 30-40 dB range (A). The results of the frequency analysis of the background noise in the banks and comparing them with the standard PNC curves have been demonstrated in Figure 1.

In the present study, the SIL index was assessed to determine the quality of the speech communication between the staff and clients. Based on the results obtained, the mean, minimum (min),

maximum (max), and standard deviation (SD) values of the SIL index in the studied banks were 70.25, 58.76, 79.23, and 6.12 dB (A), respectively. It was also found that by increasing the SPL in the client's waiting area, the score of the SIL index increased at the staff's workstations ($p \leq 0.03$).

## Mental Fatigue

The obtained data of the MFI questionnaire showed that the mean, min, max, and SD values of the mental fatigue score among the studied employees were 64.48, 24.00, 91.00, and 12.19, respectively. The classified scores of the mental fatigues among studied bank employees have been illustrated in Figure 2.

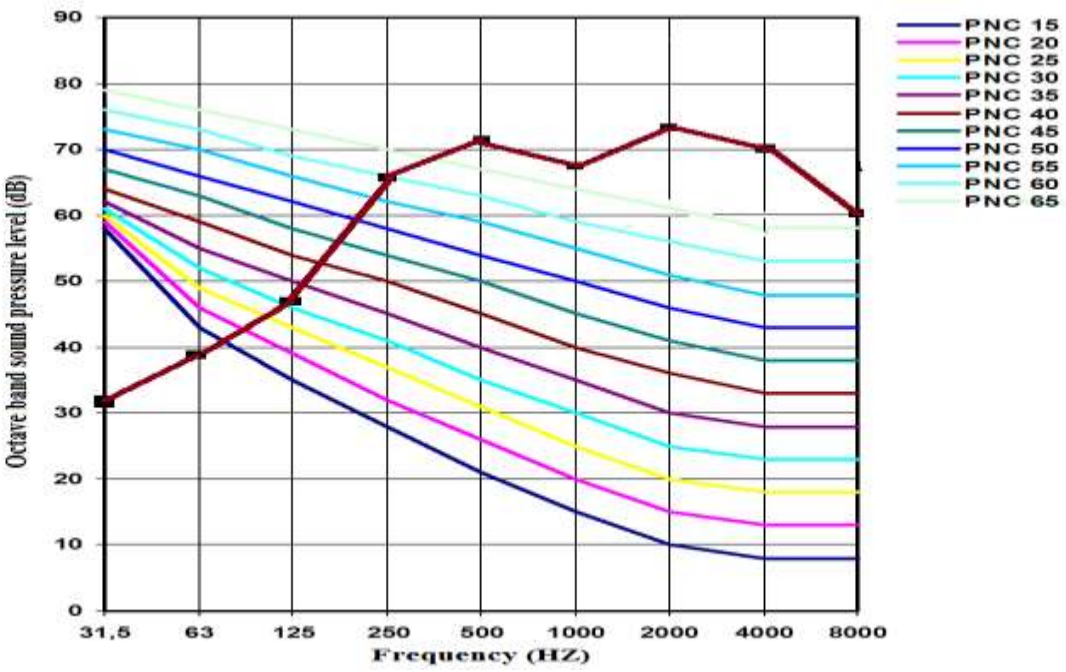


***Fig. 1.*** Results of the frequency analysis of background noise in the banks and comparing them with the PNC standard curve

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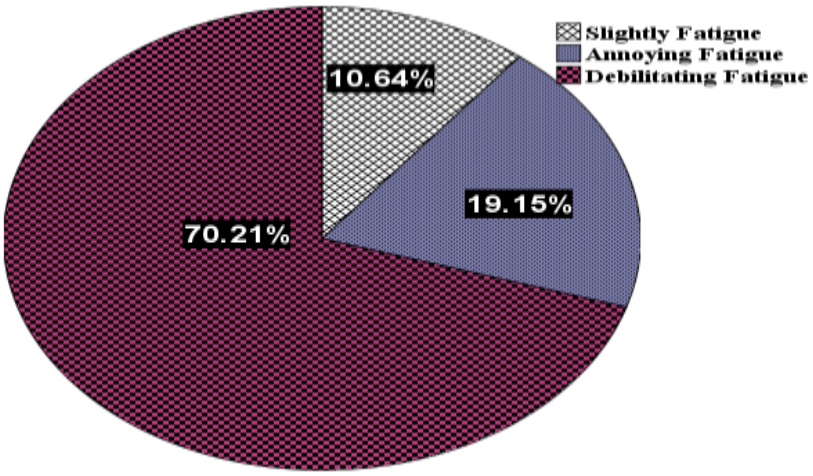


***Fig. 2.*** Scores of staff obtained by a multidimensional fatigue inventory

The results of this study indicated that with the increasing of equivalent SPL in staff workstations, their mental fatigue was increased ($r^2$= 0.90, p= 0.001). Furthermore, the highest and lowest levels of mental fatigue were obtained in bank vice presidents and bank cashiers (with a mean and deviation of 70.45±25.50 and 58.00±41.31, respectively). The mean and SD of the mental fatigue score of single and married subjects were 69.16±25.34 and 75.21±21.69, respectively. There was no significant correlation between the feeling of occupational mental fatigue and the marital status of employees (p = 0.05).

## Noise annoyance Scale

The summaries of descriptive findings of the subjective impression of noise intensity among bank staff have been presented in Table 3. It should be noted that a score higher than 5 indicated that the noise intensity was annoying for the participants. The results implied that the subjective noise responses of annoyance among employees increases by increasing the $Lp_{eq.T}$ at the staff's workstations ($r^2$= 0.84, p = 0.01).

Table 3 shows the descriptive results of the subjective noise responses among studied bank staff. The results demonstrated that the highest and lowest levels of noise annoyance at the workplace were observed in bank vice presidents and bank managers (42.5 and 20.76, respectively). The analytical results showed a significant correlation between the SIL indexes and reported score of the impression of noise intensity among employees. Accordingly, by increasing the SIL index in interior places of the bank, the reported score of a feeling of noise intensity was increased (r2= 0.89, p = 0.02). The scores of classified the subjective noise responses of annoyance among the studied bank employees have been illustrated in Figure 3.

***Table 3.*** descriptive results' score of subjective impression of noise intensity and noise annoyance bank staffs

| Variable | Max | 5th | Mean | 5th | D | Min |
|---|---|---|---|---|---|---|
| Noise intensity | .15 | .00 | .29 | .00 | .23 | .0 |
| Noise annoyance | 5.0 | 0.0 | 0.55 | 0.00 | 0.77 | .0 |

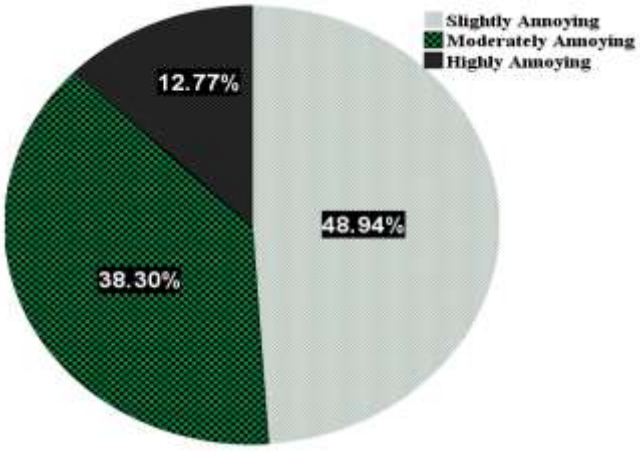


***Fig. 3.*** Noise annoyances in work environment reported by the studied staff

## DISCUSSION

In the present study, the acoustic conditions in several Iranian banks on open-plan workplaces were investigated. In addition, the effects of low-frequency noise exposure were investigated based on the mental fatigue and nose responses of annoyance among studied bank employees.

The Lpeq.T of the workstation in the studied banks (78.2 dB.A) was higher than the allowable exposure limit recommended by the National Institute for Occupational Safety and Health (NIOSH) for the administrative job required mental performances (30-40 dB.A) [28]. Previous studies reported that most banks in the developing countries were deprived of an appropriate acoustic condition [9-18]. Exposure to excessive noise level, as a source of environmental stress, can lead to lower focusing ability, cognitive performance, job satisfaction, and job productivity. Exposure to high levels of noise can also increase the physical and physiological disturbances, human error, and occupational incidents in workplaces [29-31]. LFN exposure can affect concentration, visual function, selective, and continuous attention.

The results of this study showed that the average SPL in the outsider areas of the studied banks' (81.3 dB. A) was higher than the permissible SPL recommended by the Environmental Protection Agency (EPA) for residential-commercial areas (55 dB. A) [32]. The results indicated that the noise caused by urban traffic was the main source of noise in the outside areas of the studied cases. The outdoor noise exacerbates noise pollution in the bank environment and subsequently disrupts speech communication between employees and the bank's client.

The main sources of noise in the studied banks were attributed to employees activities (e.g. working with computer keyboards, telephone conversations, talking with clients, talking with other colleagues, currency-counting machines, queue management system, alarms, and phone rings in banks), customer behaviors in the waiting station, air conditioning systems, and outdoor noise sources (such as car traffic). Indoor noise sources were attributed to the reflective surfaces covered by materials with low sound absorption coefficients. Sound reflection depends on sound power. The sound reflection increases the SPL and subsequently increases the harmful effects of exposure to LFN in banks as an open-plan office. Previous studies reported that an inappropriate design of surfaces in open-plan offices may exacerbate the production of sound and increases the retention time of sound in the interior places [9].

Some of the reflective materials used in the surfaces of the studied banks included glass barriers between the bank staff and clients (acoustic adsorption

coefficient ≤ 0.037), ceramic floor surfaces in the banks (acoustic adsorption coefficient ≤ 0.040), stone or wooden surfaces for building, the interior walls of banks (with acoustic adsorption coefficients of ≤ 0.037 and 0.182, respectively), and the metal chairs used in waiting-area (with an acoustic adsorption coefficient of ≤ 0.082). In this study, it was found that the SPL at the workstations was increased by increasing the bank staff activities, the number, and communications' time duration among studied employees or clients. Therefore, the mean of the SPL at the bank vice president's workstation (81.92 dB) was higher than other staff workstations (77.9± 9.8 dB.A). It can be concluded that daily exposure to the noise among bank employees was associated with their work activity, equipment used, and the number of clients.

The finding implied that the mean of the PNC index in the studied banks was higher than the permissible limit, which was consistent with the results of the previous studies [9-19]. The results of the frequency analysis showed that the highest SPL was observed at 500, 2000, and 4000 Hz frequencies, 71, 73, and 70 dB, respectively. Since these audio frequencies were close to speech frequencies, so these may interfere with communication among bank staff or clients [33]. Therefore, it can be concluded that the interior surfaces of the bank were influential in reverberant the disturbing noise at speech frequencies, which can lead to an increased feeling of noise annoyance by bank staff.

The acoustic comfort for staff in open-plan offices was mainly evaluated by the level of speech-privacy at their workstation. The SIL index represents the quality of verbal messages transferred between individuals in an environment. The results of this index revealed an improper condition of background noise in the studied banks (mean 70.25 dB). The noise generated by the work activities, equipment, clients, and traffic was reflected by the reflective interior surfaces of the bank, which had a significant effect on increasing the SIL index. The results showed that an increase in the SPL at waiting area of the clients can increase the SIL index at the staff workstations ($p \leq 0.03$). The rigid materials use in client wait- station (such as metal chairs), reflective materials in interior surfaces of the bank (such as wood, glass, stone, and ceramic), and improper architecture of interior surfaces in the banks increase the noise responses of the employees at the workstation. Some studies used the Speech Transmission Index (STI) to evaluate the clarity of speech in open-plan offices and reported that the job performance of employees in administrative jobs significantly reduced with an increase in the STI index [34-36].

The analysis results of this study approved that the highest level of mental fatigue score was reported by bank vice presidents (with a mean value of 79.45) which was consonant with the results of noise level exposure of the staff classified by their occupational position ($p< 0.03$). According to the results, an increase in Lpeq.T leads to increasing mental fatigue among the bank staff. The low-frequency noise affects the physio-psychological reactions of humans such as sleep quality, annoyance, mode changing, and memory responses, which can cause mental fatigue among bank employees.

According to the results, a high percentage of the subjects in the studied banks had an unfavorable status of mental comfort. Consequently, about 70% of them were in a distressing fatigue condition which can affect their job performance, productivity, and cause physical and mental health damage. It should be noted that the noise emission in the studied banks had a low-frequency band, as an open-plan offices. Previous studies reported that LFNs had a significant effect on alertness level, job satisfaction, sleep disturbance, irritability, focusing ability, and mental fatigue among employees [18-37-39]. The results of similar studies showed that 95% of bank staff feeling annoyance due to the background noise [33]. In another study, the mental effects of the LFNs exposure in the workplaces reported that the sensitivity of the workers to the noise rose with increasing the SPL at the workplace, and subsequently, the noise intensity scores of workers increased which was consistent with the findings of the present study [40].

Also, the results of both objective and measurable scales (SPL, PNC, and SIL indices) and subjective scale (MFI and NAS questionnaires) approved that there was an unacceptable acoustic condition at the workstation of the studied banks. The reflective surfaces and improper architecture of banks intensify noise generated by the work activities, equipment, and clients. Moreover, traffic can increase the noise responses among employees in the workplace, and subsequently, increase the mental fatigue and noise annoyance among bank staff. Therefore, this problem highlighted the need for

implementing noise control measures, such as technical and administrative controls for reducing staff exposure to noise and its subsequent impacts.

## CONCLUSION

In the present study, the effects of LFNs exposure were evaluated on mental fatigue and noise annoyance among the bank staff. The findings of this study indicated that the reflective surfaces in the banks increase the level of exposure to noise, which leads to exacerbating the mental fatigue and sense of noise annoyance among the bank staff. The sound frequencies in the studied banks were close to speech frequencies, so these can interfere with speech communication between bank employees and clients. Using inappropriate materials and improper architecture for building the interior surfaces in the banks can exacerbate the level of noise caused by the various noise sources in the bank's building. Engineering controls implementation on the noise sources and other control measures such as replacement of the internal surface materials with proper materials can improve the acoustic properties of banks. Such technical and administrative control measures can improve employee satisfaction and productivity which has a very important role in the relationship between employees and clients. Some limitation of this research included lack of investigation of room acoustic condition, relationship between the type of materials used in the internal surfaces and reverberant time, and their effects on the mental fatigue and noise annoyance among the bank staff.

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## CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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