Analysis of factors that influence noise levels inside urban buses

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This study presents evaluation of noise levels in urban buses. Noise exposure was evaluated in 80 buses of four models. Differences were found in noise among various bus models and among buses with different engine configurations. No strong correlations were found in year of fabrication and LA\textsubscript{eq}. ANOVA and Tukey’s test characterized conventional buses as noisiest buses and speedy buses as lowest noise inducing buses.

Keywords: Bus drivers, Occupational noise pollution, Statistical analysis, Urban buses

Introduction

Drivers are subjected to high sound pressure levels due to 8-h workday, old vehicles (in most cases with mechanical defects and with engine located at front of the bus), poorly paved streets and roads, and also intense movement of passengers\textsuperscript{1-14}. This daily and prolonged exposure may lead to non-auditory pathological symptoms\textsuperscript{15-17} (racing pulse, elevated blood pressure, dilated pupils, and increased production of thyroid hormones, and stomach and abdominal cramps). These physiological phenomena are manifested as behavioral alterations\textsuperscript{18,19} (nervousness, mental fatigue, frustration, poor work performance, increased work absenteeism, and social conflicts) among workers exposed to noise.

This study presents evaluation of occupational noise exposure of urban bus drivers, seeking to quantify sound pressure level found inside buses, identifying characteristics of buses that influence noise emission, and compare findings with Brazilian regulatory standards.

Experimental Section

Materials and Methods

Buses (80) with diverse characteristics of four different models (conventional, speedy, micro, articulated) owned by an urban public transport company in Curitiba, Brazil were selected to evaluate equivalent sound pressure level (LA\textsubscript{eq}). For best possible comparison of models, 20 vehicles of each model were chosen randomly. LA\textsubscript{eq} was measured inside buses, as well as maximum (LAF\textsubscript{Max}) and minimum (LAF\textsubscript{Min}) sound levels. Measurements were taken in running buses for 5 min with a class 1, Brüel & Kjaer 2238 sound level meter, which was placed 10 cm away from driver’s right-hand auditory zone, as per ISO 1999:1990\textsuperscript{20}. Sound level in these buses is related to the noise of engine running at high rotation, type of traveling location and level of noise generated by vehicle traffic. The 5 min measurement encompasses bus route from the moment it exited garage up to first stop to pick up passengers. Thus on this stretch, bus circulates without passengers. Hence, measured sound levels correspond to noise generated by vehicle (accelerating, changing gears and braking) and by traffic outside the bus, without passengers. Other works are reported\textsuperscript{11,12,25} on buses with passengers.

Statistical Analysis

Measurements were analyzed by subjecting data to Kolmogorov-Smirnov normality test. Results with normality were then treated by parametric statistics. Pearson’s correlation coefficient was used to check for a +ve or -ve correlation between equivalent sound pressure level and the year of bus model. One-way analysis of variance (one-way ANOVA) and Tukey’s multiple comparison test were applied to compare mean LA\textsubscript{eq} values of different bus models.

Results and Discussion

Results of measurements of four types of buses showed a normal distribution according to
Kolmogorov-Smirnov test. Conventional bus models (ordinary vehicles that stop to pick up passengers at fiberglass bus stops along their route) have one passenger entry door and two exit doors. Two people work on these buses, driver and fare collector. These buses travel along preestablished routes together with normal street traffic, and cover both paved and dirt roads. All buses of this model (manufacture, 1989 - 2006) have a front-engine design.

Speedy buses (vehicles whose doors are located on the left side of bus contrary to other models) carry no fare collector, since these employees work inside cylindrical bus stops destined for passenger embarkation and debarkation. Their routes are on ordinary streets but distance between bus stops is usually greater than in case of conventional or articulated buses. All buses of this model (manufacture, 1992-2001) have a rear-engine design.

Micro-buses are models with similar characteristics to those of conventional ones, but they are smaller and carry no fare collector. All buses (manufacture, 1991-2006) have a front-engine design. Articulated buses (manufacture, 1994-2003) are composed of two cars joined together by a flexible articulation, which allows them to carry a larger number of passengers. In most of such buses, engine is located in the middle of front car. However, measurements were also taken in three recent models with a rear-engine design manufactured in 2007.

Measurements taken inside buses on mean values and standard deviations of $L_{A_{eq}}$ were found as follows: conventional buses, 80.2 ± 2.3; speedy buses, 75.1 ± 2.0; micro-bus, 78.3 ± 2.4; and articulated buses, 77.0 ± 2.6 dB(A). Findings are similar to those of earlier studies carried out in Curitiba, Brazil with conventional and speedy buses during their entire route and noise levels normalized to 8 h, $L_{A_{eq}}$. Zannin$^{12}$ found that $L_{A_{eq}}$ were emitted by conventional buses [79.9 ± 2.8 dB(A)] and by speedy buses [73.0 ± 2.6 dB(A)], and in the study of Zannin et al$^{11}$, $L_{A_{eq}}$ results were in conventional bases [79.9 ± 3.1 dB(A)] and in speedy buses [72.7 ± 2.4 dB(A)]. Thus present study showed results similar to those of earlier findings, differing by less than 2.5 dB(A), demonstrating that measurements taken in less time can be effective in evaluating noise level emitted by conventional and speedy buses. Results of present study were considered normal when compared with Brazilian legislation (Regulation Act NR-15: Insalubrious Operations)$^{21}$ and with occupational hygiene standard (NHO-01) of Fundacentro$^{22}$ (Table 1). Values recorded were at a threshold below 85 dB(A) of exposure in a daily 8-h workday. However, NR-17$^{23}$ standard (Regulation Act 17: Ergonomics) establishes that a level of exposure exceeding 65 dB(A) during 8 h of work is considered uncomfortable. Therefore, current values recorded should not be considered optimal for health, and should be reduced in order to improve the work environment of bus drivers subjected to such noise levels. Earlier studies$^{11,24}$ on sound pressure levels in bi-articulated, speedy and conventional bus models were close to those measured in present study.
ANOVA results demonstrated a significant difference among bus models, but Tukey’s multiple comparison test revealed differences among bus models. This allows for characterization of buses with highest and lowest noise immissions in terms of statistical differences. Measurements indicated that conventional, micro- and articulated buses (most of which have a front-engine design) produce higher noise levels, probably because engine is located near driver and also near the point of measurement (Table 2).

Analysis of various bus models revealed significant differences among four engine configurations of buses, p<0.05. Thus, engine configuration in different locations in bus influences LA$_{eq}$, demonstrating that drivers who work with rear-engine vehicles are exposed to lower noise levels than those who work in buses with front-engine design.

Under Pearson’s correlations of comparison between year of manufacture and noise level measurements (Table 3), negative correlations found between year of manufacture of vehicle and LA$_{eq}$ demonstrated association between older buses and higher noise immissions, even though strong correlations were not found. This association is even more evident in articulated models, which showed a stronger correlation (close to -1.0). This sample comprised buses ranging from articulated vehicles with front engines manufactured in 1994 to vehicles with rear engines manufactured in 2007; latter models presented lowest equivalent sound pressure levels. These findings indicate that fleet of new buses is meeting demand for lower noise emissions from vehicle to drivers.

Weak correlation found in present study demonstrated that there is no linear association among older vehicles and consequently higher LA$_{eq}$ levels, thus presenting contrasts between newer vehicles and higher noise levels and old vehicles with lower noise levels. However, based on mean results, conventional buses showed highest noise immission levels.

Conclusions

Four bus models meet requirements of NR-15 and NHO-01 regulatory standards in terms of immission of occupational noise inside buses for an 8-h exposure time. However, some of buses showed noise levels very close to the limit established by aforementioned standards and above 65 dB(A), which may render driving environment uncomfortable, according to Brazilian NR 17 standard for ergonomics, and may also give rise to noise-induced health problems. Conventional bus models showed highest noise levels, followed by micro-buses, articulated models, and lastly speedy buses. A statistical difference was found between models with different engine configurations; vehicles with front engines showed higher equivalent sound pressure levels than rear engine models. No strong correlations were identified between year of manufacture and LA$_{eq}$. However, a comparison of older models against newer ones indicated that work environment in older buses was more unfavorable for driver’s performance.

References