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# Levels of environmental noise and perceived health implications in bus termini in Nairobi city county, Kenya

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**Abstract**
**Background:** Environmental noise remain a leading public health concern globally due to its prevalence especially with industrialization. Environmental noise is an increasing risk factor for hearing impairment and other health-related risks particularly in low and middle income countries. Regardless, lack of legislative intervention, noise surveillance, and paucity of research means environmental noise remains neglected in many developing countries.
**Purpose:** This study aimed to establish the levels of environmental noise and perceive health implications in bus termini in Nairobi City County, Kenya.
**Methods:** A cross-sectional study comprising 422 respondents randomly selected across gazetted bus termini within Nairobi central business district was done. Noise levels were measured using Calibrated sound level meter (Model # 8926). A self-administered semi-structured questionnaire was used to assess safety practices and perceived health risks of environmental noise. Association between noise levels and reported health implications was explored using Chi-square test of independence.
**Results:** High noise levels were recorded across all the bus termini with the maximum (118.44dB) recorded at Moi Lane. The mean sound pressure levels varied across time with the highest (98.65dB) recorded in the evenings. On exploring the health effects of excessive noise, an equal number of male and female (M30, F30) respondents visited the doctor due to the hearing problem as well as headache and speech interference perceived to have been caused by excessive noise exposure. It was further observed that a significant association existed between number of days spent at the bus termini per week and visiting a doctor for a noise induced hearing problem ($\chi 2 = 6.113$, df=1; $p<0.04$). There was a significant association ($\chi 2=27.663$; df=8; $p>0.001$) between a respondent visiting a doctor for a noise induced hearing problem and bus termini in which they operated.
**Conclusion:** Noise levels in the studied termini exceeded regulatory limits. Environmental noise was associated with auditory and non-auditory effects among respondents. Noise surveillance, public education and deconcentration of bus termini is recommended.

**Keywords:** noise intensity, perceived health effects, bus termini, Nairobi city county

## Introduction

Noise is defined as unsolicited sound or any unwarranted sound disruption within a useful frequency band (Olayinka, 2013). Environmental noise refers to noise emanating from all other sources except the industrial workplace (Belojevic *et al*. (2016). According to Hammersen, Niemann, & Hoebel, (2016) [5], the main sources of environmental noise include road, rail and air traffic, industries, construction, public works and social activities. Noise pollution remains a pervasive global health hazard. Cohen *et al*. (2014) reports that noise exposure is on the increase, especially in the general living environment, both in industrialized nations and in developing world regions and emphasizes that the noise exposure in the twenty-first century is a major public health problem. According to Münzel, Gori, Babisch, and Basner (2014) [13, 14], exposure to high levels of noise can result in significant adverse health impact while Hammersen *et al*. (2016) [5] argue that the annual per capita exposure to noise pollution is high enough to cause harm to human health. The leading health outcome of noise exposure is loss of hearing acuity caused by repeated exposure to high noise levels, such exposure occurs primarily in the workplace. Exposure to extremely high levels of noise is a major avoidable cause of permanent hearing impairment worldwide. In developing countries, environmental noise (especially traffic noise) is an increasing risk factor for hearing impairment and other health-related risks (Rom & Markowitz, 2007) [18]. WHO (2008a) [22] states that 16% of the disabling hearing loss among adults emanates from environmental noise, with a range of 7% to 21% from region to region? Hammer *et al*. (2014) reports that noise-induced hearing loss (NIHL) affects 10 to 15 million people in the USA. In the UK, research shows that the young adults have severe hearing difficulties that point to noise at work (Prendergast *et al*., 2017) [17]. Furthermore, Basner *et al*. (2014) indicated that cases of tinnitus emerge as a result of exposure to concert noise around Nottingham and England. Moreover, Basner *et al*. (2014) [13, 14] argue that noise can cause annoyance, interference with speech and community responses, hearing loss and other adverse effects; he explains that the most significant risk factor is Noise is induced hearing loss, heart diseases and accidents (Basner *et al*., 2014) [13, 14]. Noise at every level can affect our physical health, psychosocial health, and cognitive functions. Potential health effects range from annoyance, sleep disruption, decreased school performance, to ischemic heart

disease, high blood pressure, and speech disruption (Hambrick *et al*., 2008). Despite its widespread occurrence and effects on health and well-being, noise pollution remains largely under-prioritized in developing countries with Kenya lacking effective policy and practical interventions to control noise pollution (Enda, 2014). In addition, there has been inadequate public health studies directed towards assessing the prevalence, risk factors and health costs of environmental noise in Kenya (Musiba, 2015) [15]. In Nairobi, Wawa and Mulaku (2015) [21], measured noise levels from predetermined source of noise with the aim of documenting spatial distribution of noise levels in the Nairobi Central Business District. While their study observed high levels of noise between 61-78db, they did not assess the impact of high noise levels on health and well-being in the population. From their findings it was evident that noise levels in Nairobi are high and there was need for further assessment on health effects of noise in the general population. This study was therefore conducted to establish the levels of environmental noise and perceived health implications in bus termini in Nairobi City County, Kenya. Specifically, the study sought to determine the noise intensity at the termini in Nairobi City, establish the perceived health effects of noise exposure and explore factors associated with perceived health effects of noise at the bus termini in Nairobi City.

## Materials and Methods

The study used a cross-sectional study design. The target population comprised of men and women who operated daily in the gazetted bus termini within Nairobi central business district namely; Old Nation Bus Station, Ngara Bus Station, Railways Bus Station, Tyskys Bus Station, St Peters Clavers Bus Station, Latema Bus Station, Central Bus Station, Ronald Ngala Bus Station, Moi Lane( Mondlane) Bus Station. The accessible population was defined as community members comprising of business vendors, conductors, drivers, and supervisors within the respective bus termini. Fishers *et al* (1983) formula was used to determine the sample size and a random sample of 422 community members working within nine bus termini for more than 8 hours a day were approached and recruited in the study. Noise levels were measured using Calibrated sound level meter (Model # 8926). A self-administered semi-structured questionnaire was used to collect data to identify perceived health risks of noise among community members across the bus termini. Chi-square test of independence was used to test the association between noise levels and reported health implications. A *p*-value less than 0.05 was considered statistically significant. Analysis was done using Statistical Package for Social Sciences (SPSS)-software Version 20. The response rate was 94.7% (n= 397).

## Results

### Levels of environmental noise across bus termini

**Table 1:** Distribution of noise levels in decibels for the nine bus termini at different times of the day

| Location | 6-8am | 12-2pm | 6-8 pm |
|---|---|---|---|
| Old Nation Bus Station | 93.65 | 91.39 | 104.97 |
| Ngara Bus Station | 93.63 | 85.45 | 92.31 |
| Railways Bus Station | 92.60 | 91.08 | 91.68 |
| Tuskys Bus Station | 91.00 | 94.28 | 115.04 |
| St Peters Clavers | 90.80 | 90.88 | 90.53 |
| Latema Bus Station | 89.54 | 92.08 | 85.56 |
| Central Bus Station | 88.35 | 93.99 | 90.13 |
| Ronald Ngala | 88.14 | 91.50 | 99.18 |
| Moi Lane (Mondlane) | 84.18 | 90.62 | 118.44 |
| Average | 90.21 | 91.25 | 98.65 |

Table 1 displays the distribution of average noise levels in decibels for the 9 bus termini across three time intervals. In the morning the maximum mean noise level was 93.65 dB recorded at Old Nation Bus Station with a minimum of 84.18 dB recorded at Moi Lane Bus station. At midday the maximum mean noise level was 94.28 dB recorded at Tuskys Bus Station with a minimum of 85.45dB recorded at Ngara Bus Station. In the evening, the maximum mean noise level was 118.44 dB recorded at Moi Lane Bus Station with a minimum of 85.56 dB recorded at Latema noise level. The table shows the results of one-way ANOVA conducted to test if the mean noise level varies across the three time points (6-8 am, 12-2 pm, and 6-8 pm) at the bus termini

**Table 2:** One-Way ANOVA: Mean Noise Levels at 3 Time points

| Source of Variation | SS | df | MS | F | P-value | F critical |
|---|---|---|---|---|---|---|
| Between Groups | 296.74 | 2 | 148.37 | 2.67 | p>0.09 | 3.4668 |
| Within Groups | 1167.21 | 21 | 55.58 | | | |
| Total | 1463.95 | 23 | | | | |

The results as indicated in this table shows that the mean noise levels are not different across the three-time points [F=2.67; df= (2, 21); p>0.009)]. Figure 2 shows the Arc GIS map concentration of noise levels across the main bus termini in the Central business District of the city of Nairobi.

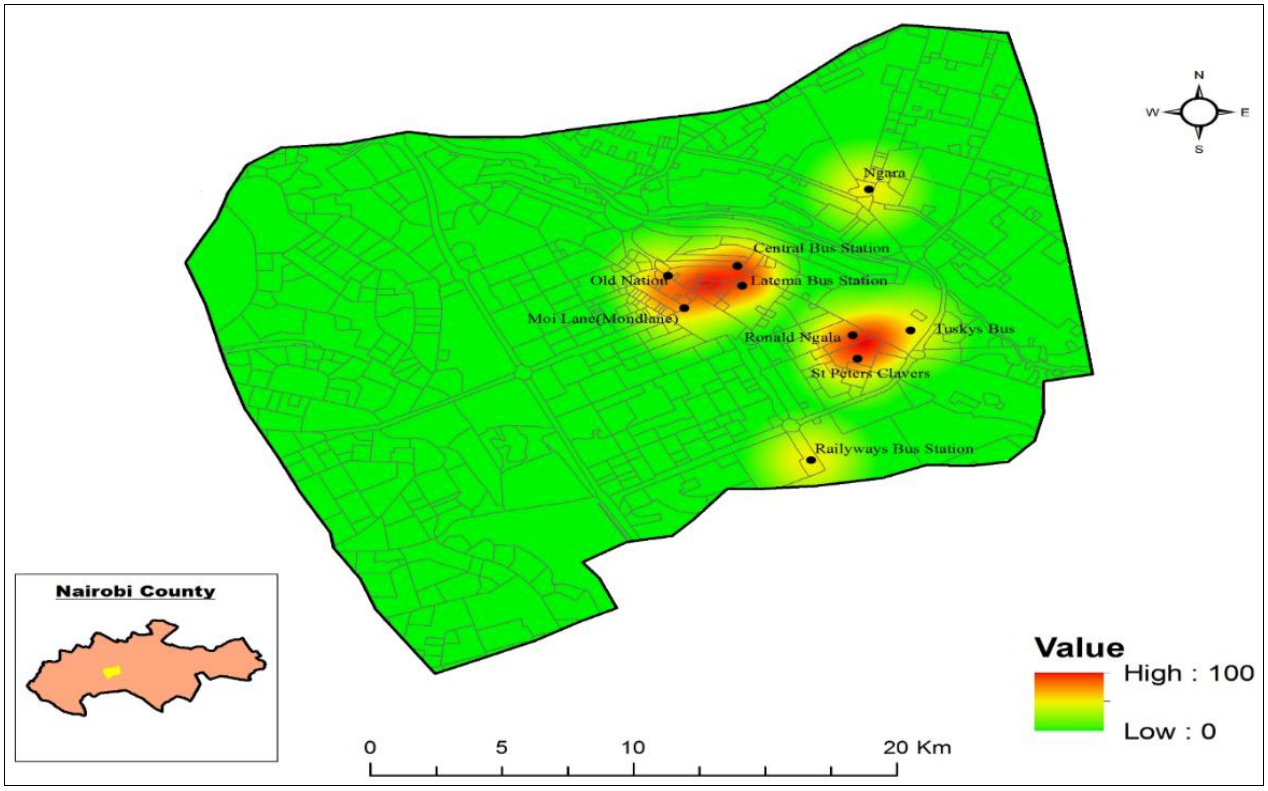


**Fig 1:** Heat Map showing: Concentration of noise pollution at bus termini in Nairobi

Bus termini that reported very high concentration of noise levels include: Tuskys, St Peters Clavers, Central Bus station, Latema and Ronald Ngala. Those that reported moderately low concentration of noise levels are Ngara and Railways bus station.

**Major Sources of Excessive Noise levels**

Figure 2 shows the perceived leading sources of excessive noise at bus termini

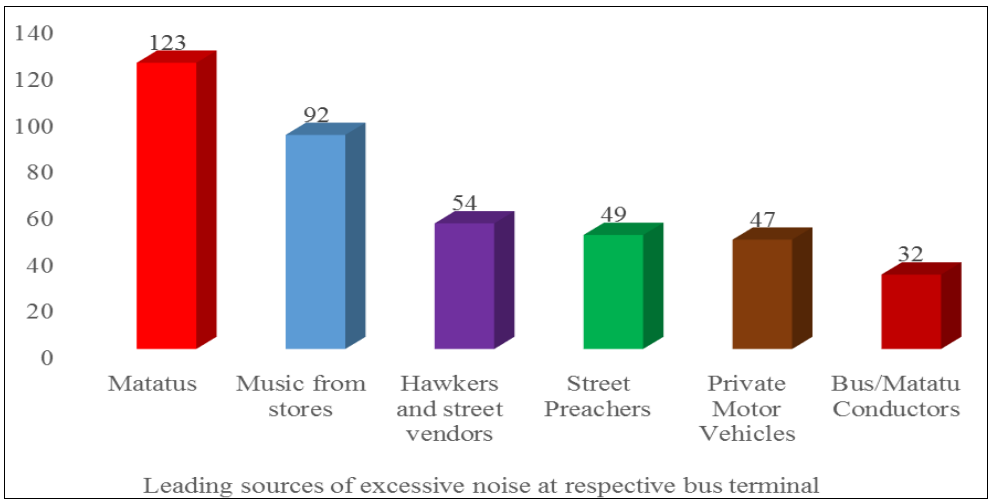


**Fig 2:** Sources of excessive noise at respective bus termini

In this study respondents were asked to identify what they considered as major contributors of noise in their respective bus termini. Across all the termini respondents identified the leading sources of noise were; matatu (n=123), music form stores (n=92), hawkers and street vendors (n=54). On the other hand, respondents also associated street preachers (n=49), private motor vehicles (=47) and bus/matatu conductors (n=32) as sources of excessive bus termini.

**Perceived Health Effects of Excessive Noise Levels**

This table shows acute health effects due to excess noise exposure as perceived by the respondents

**Table 3:** Acute Health Effects of excessive noise exposure as reported by respondents

| Common Health effects | N | % |
|---|---|---|
| Sleep Disturbance | 152 | 24.17 |
| Hearing impairment | 145 | 23.05 |
| Exhaustion | 82 | 13.04 |
| High Blood Pressure | 80 | 12.72 |
| Annoyance | 64 | 10.18 |
| Increases risk of Road accidents | 46 | 7.31 |
| Cause Disturbance to Immune system | 40 | 6.36 |
| It is harmful to babies | 20 | 3.18 |

Table 3 above the five leading acute health effects of excessive noise were perceived to be sleep disturbance at 24.17% (n=152), hearing impairment at 23.05% (n=145), exhaustion at 13.04% (n=82), high blood pressure at 12.72% (n=80) and annoyance at 10.18% (n=64). Other acute effects of excessive noise exposure were; increased risk of road traffic accidents, disturbances to the immune system and noise as being harmful to babies.

**Association between Demographic characteristics and perceived chronic effects of noise**

This table shows the association between demographic characteristics and opinion on perceived chronic effects of excessive noise

**Table 4:** Demographic characteristics and perceived chronic effects of noise

| | Hypertension | Cardiac Illness | Stroke | Noise Induced hearing loss |
|---|---|---|---|---|
| Gender | $\chi^2$=0.148; df=1; p>0.700 | $\chi^2$=0.001; df=1; p>0.982 | $\chi^2$=1.019; df=1; p>0.313 | $\chi^2$=6.844; df=1; p<0.009* |
| Level of education | $\chi^2$=2.386; df=2; p>0.496 | $\chi^2$=4.821; df=2; p>0.185 | $\chi^2$ =4.069; df=2; p>0.254 | $\chi^2$ =6.977; df=2; p>0.026 |
| Occupation | $\chi^2$=2.404; df=2; p>0.662 | $\chi^2$ = 5.960; df=2; p>0.202 | $\chi^2$=3.525; df=2; p>0.474 | $\chi^2$=8.878; df=2 p>0.028 |

There was a significant association between gender ($\chi^2$=6.844; df=1; p<0.009), level of education ($\chi^2$ =6.977; df=2; p>0.026) and occupation ($\chi^2$=8.878; df=2 p>0.028) with perceived of noise induced hearing loss as chronic health effect of excessive noise. In this study it was observed as indicated in table 4.1, that 35%(n=133) of the respondents have spent more than 5 years working at the bus termini as compared to 65% (n=257) who had spent between less than 5 years working at the bus termini. A Chi-Square test of independence was performed in order to assess the association between lengths of years spent working at the termini versus reporting of chronic effects of noise exposure as shown in table 6 below.

**Association between Length of years at the Terminus and perceived chronic effects of noise**

**Table 5:** Length of years at the Terminus versus perceived chronic Effects of Noise Exposure

| | | Length of working (in years) at Terminus | | |
|---|---|---|---|---|
| **Perceived Long Term Health Effects** | **Opinion** | **<5Yrs** | **>5Yrs** | **Chi-Square test** |
| Hypertension | Agree | 53 | 60 | ($\chi^2$=8.131; df=1; p<0.043) * |
| | Disagree | 16 | 36 | |
| Heart diseases | Agree | 51 | 66 | ($\chi^2$=9.13; df= 1; p<0.028) * |
| | Disagree | 15 | 42 | |
| Stroke | Agree | 40 | 83 | ($\chi^2$=7.508; df=1; *p*<0.05) * |
| | Disagree | 9 | 49 | |
| Noise Induced hearing loss | Agree | 18 | 105 | ($\chi^2$=34.50; df=1; p<0.02) * |
| | Disagree | 10 | 54 | |

It was observed as indicated in table 5 above that working for longer period (more than 5 years) was statistically significantly associated with reporting of chronic health effects of prolonged exposure to noise. This includes, hypertension ($\chi^2$ = 8.131; df=1; p<0.043), Heart diseases ($\chi^2$ = 9.13; df=1; p<0.028), stroke at ($\chi^2$ = 7.508, df=1; *p*<0.05), and noise induced hearing loss ($\chi^2$=34.50; df=1;p<0.02). As shown in table 7 below, a chi-square test was performed to assess the significance of hours spent at the terminus on reporting of perceived health effects of noise exposure.

**Association between Number of hours at terminus per day and perceived chronic effects of noise**

**Table 6:** A Chi- square test: Number of hours at terminus per day versus perceived health effects

| | | Number of Hours at the Terminus | | |
|---|---|---|---|---|
| **Perceived Health Effects** | **Opinion** | **< 4Hrs** | **>4Hrs** | **Chi-Square test** |
| Hypertension | Agree | 8 | 18 | ($\chi^2$=0.671; df=1; p>0.715) |
| | Disagree | 64 | 174 | |
| Heart diseases | Agree | 7 | 20 | ($\chi^2$=0.710; df= 1; p>0.701) |
| | Disagree | 58 | 193 | |
| Stroke | Agree | 6 | 26 | ($\chi^2$=0.301; df=1; p>0.860) |
| | Disagree | 41 | 228 | |
| Noise Induced Hearing Loss | Agree | 17 | 270 | ($\chi^2$=6.113; df=1; p<0.04) * |
| | Disagree | 23 | 35 | |

Table 6 shows the relationship between numbers of hours spent in a day at bus terminus and reporting of perceived health effects of noise pollution. Spending more than 4 hours at the bus termini was statistically significantly associated with reporting of hearing impairment ($\chi^2$ = 6.113, df=1; p<0.04) as a health effect of noise pollution. On the other hand spending more than four hours at any of the bus termini were not significantly associated with reporting of hypertension ($\chi^2$ =0.671, df=2; p>0715), Heart diseases ($\chi$2 = 0.701, df=2;p>0.701) and stroke at ($\chi^2$ = 0.301, df=2;p>0.860) as perceived health effects of noise pollution respectively.

**Health Effects of Noise across Bus Termini**

Figure 3 shows reporting of perceived health effects of excessive noise across bus termini

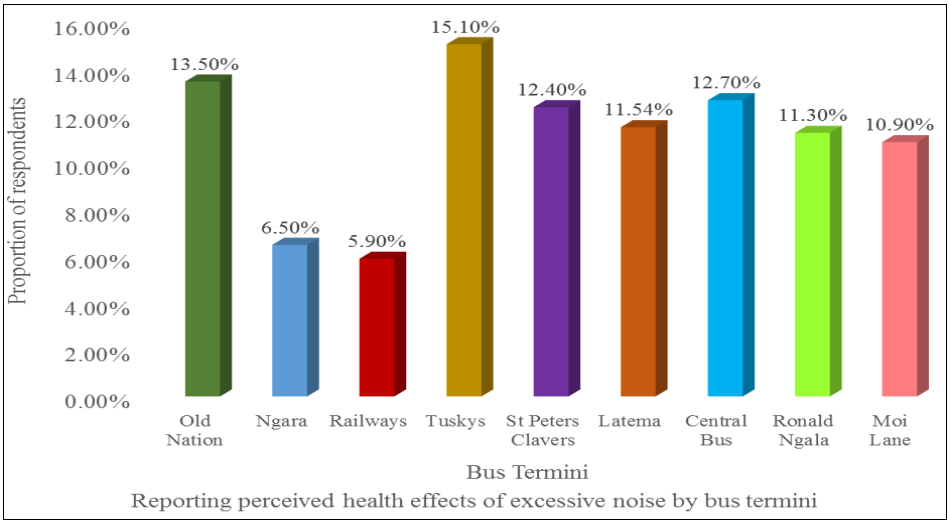


**Fig 3:** Proportion of respondents reporting perceived health effects of noise by bus termini

A high proportion of perceived health effects of excessive noise were reported from bus termini with high concentration of noise levels such as Tuskys, Old Nation, Central Bus station and St Peters Clavers Bus termini. On the other hand, a lower proportion of perceived health effects of excessive noise were reported from bus termini with moderately low concentration of noise levels such as Ngara and Railways Bus termini respectively.

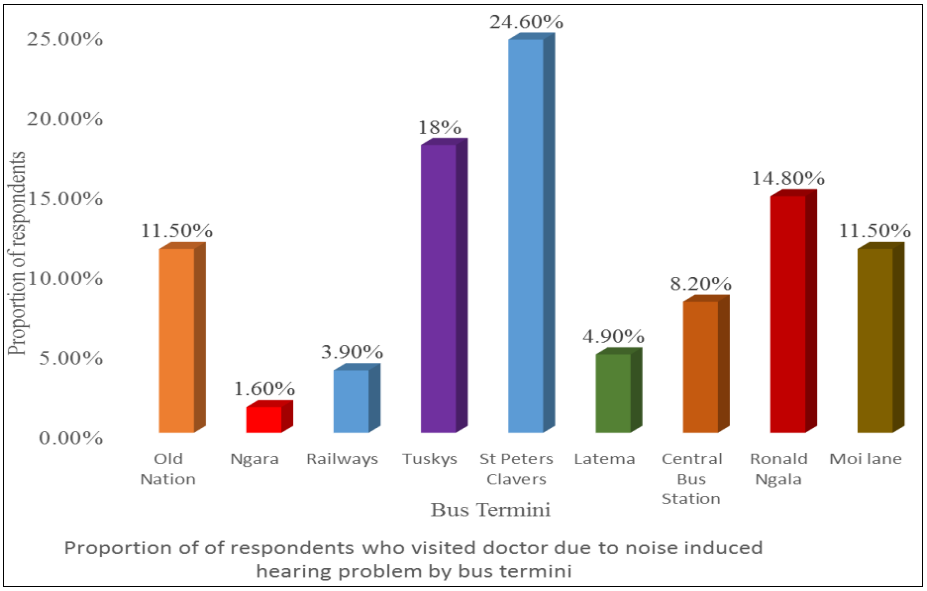


**Fig 4:** Proportion of respondents who visited doctor due to noise induced hearing problem by bus termini

Figure 4 shows the proportion of respondents who visited the doctor due to noise induced hearing problem across the nine bus termini A higher proportion of respondents who visited the doctor due to noise induced hearing problems were from bus termini that recorded high concentration of noise levels such as Tuskys (18%), St Peter's Clavers (24.6%) and Ronald Ngala (14.8%) respectively. On the other hand, a low proportion of respondents who visited the doctor were from bus termini that recorded moderately low concentration of noise levels such as Ngara (1.60%) and Railways (3.9%) respectively.

**Table 7:** Visiting a doctor for noise induced hearing problem versus Bus Termini

| | **Visited Doctor for noise induced Hearing Problem** | | |
|---|---|---|---|
| **Termini** | **Yes** | **No** | **Chi-Square Test** |
| Old Nation | 7 | 40 | ($\chi^2$=27.663; df=8; p<0.001) |
| Ngara | 1 | 47 | |
| Railways | 3 | 34 | |
| Tuskys | 11 | 45 | |
| St Peters Clavers | 15 | 32 | |
| Latema | 3 | 40 | |
| Central Bus Station | 5 | 40 | |
| Ronald Ngala | 9 | 19 | |
| Moi lane | 7 | 27 | |

Table 7 shows the association between bus termini and visiting a doctor for noise induced hearing problem. This table shows there is a significant association ($\chi^2$=27.663; df=8; $p$<0.001) between a respondent visiting a doctor for a noise induced hearing problem and the bus termini in which they are located. Hence a high frequency of respondent who visited the doctor for noise induced hearing problem were from bus termini that recorded high noise levels such as Tuskys, St Peter's Clavers and Ronald Ngala.

## Discussion

### Perceived Health Effects on Resultant Noise Levels on Bus Termini

This study demonstrated that respondents were aware of harmful effects of excessive noise and considered excessive noise to be a health hazard. It was observed that Matatu operators (conductors and drivers), as well as other respondents who spent more than 3 days in a week working at the respective bus termini, indicated that noise is a health risk and that prolonged exposure would lead to hearing impairment. This study established that a significant proportion of respondents 68% (n=254) indicated that noise levels in bus terminus are annoying. Lerner *et al*. (2010) concurs that annoyance (a feeling of displeasure) increases when noise is accompanied by vibration or by low-frequency components. On exploring the health effects of excessive noise, it was observed from this study that an equal number of male and female (M30, F30) respondents visited the doctor due to the hearing problem perceived to have been caused by excessive noise exposure. Hearing impairment, tinnitus, accidents, annoyance, headache and speech interference were reported as adverse effects of excessive noise in the city bus terminus. This demonstrates that the public have awareness on potential effects that arise from noise pollutions in the bus terminus. However, what is lacking is the inability of authorities to control the high noise levels to protect the public from developing the adverse effects they have identified. Additionally, physical effects of hearing impairment at bus terminus were associated with spending more than four working hours at any of the bus termini. These points to the fact that since most respondents spend much of their time at the bus terminus, there is an increased risk of developing hearing impairment. It was further observed that a significant association exist between number of days spend working at the bus termini in a week and visiting a doctor for a noise induced hearing problem ($\chi$2 = 6.113, df=1; p<0.04). In which those who had spent more than 3 days working at the bus termini reported visiting the doctor more often for noise induced hearing problem. Furthermore, this study established that prolonged exposure to noise pollution was significantly associated with the ability of respondents to identify long-term effects of noise pollutions such as the occurrence of hypertension and associated cardiac conditions. These findings are consistent with those of Carlson *et al*. (2013) who reported that occupational exposure to noise among students working as part-time employees in entertainment venues had contributed to hearing impairment as well as frequent visits to ear specialists for management of the hearing problem. This study demonstrates that noise pollution in bus terminus is a health hazard that needs to be controlled since according to World Health Organization (2010), noise is currently one of the most common complaints amongst urban dwellers and workers in a huge metropolis.

### Noise Level in Bus Termini

High noise levels were observed across the city bus terminus with the maximum mean level of 98.65dB being reported in the evenings. While the maximum noise level was above the permissible limits, the lowest noise levels of 90.21dB recorded in the city bus terminus were equally above the permissible noise limits. It was observed in this study that there was no significant difference in mean noise levels across the three-time points that are morning, daytime and evening. However, there was a clear difference regarding the concentration of noise levels due to the location of the bus terminus in the city. There was a high concentration of noise levels at Old Nation, Moi Lane, Central Bus station, Latema, Ronald Ngala, St. Peters Clavers compared to Ngara, Railways, and Tuskys bus station respectively. High concentration of noise levels in five bus termini can be attributed to their close location of within a 1 km radius of each other. On the other hand, there was a low concentration of noise levels at Ngara and Railways since they are located far away from other bus terminus. As such, close location of several bus termini within a small radius contributes to the significant generation of noise in the city. In concurrence with the findings from this study Ozer *et al.* (2009) in their evaluation of noise pollution caused by vehicles in the city of Tokat Turkey suggested that routes of public transportation vehicles should be reorganised so as not to accumulate at one point in the city. In assessing the health effects of noise concentration across bus termini it was observed that a high proportion of perceived health effects of excessive noise were reported from bus termini with a high concentration of noise levels such as Tuskys, Old Nation, Central Bus station and St Peters Clavers. On the other hand, lower proportion of perceived health effects of excessive noise were reported from bus termini with moderately low concentration of noise levels such as Ngara and Railways respectively. Furthermore, it was observed that a higher proportion of respondents who visited the doctor due to noise induced hearing problems were from bus termini that recorded high concentration of noise levels as compared to respondents from Termini with a moderately low concentration of noise levels. This finding showed that there is a significant association ($\chi$2=27.663; df=8; p>0.001) between a respondent visiting a doctor for a noise induced hearing problem and bus termini in which they are located. In this regard, this study demonstrates that noise exposure is a public health problem that needs to be addressed. Basner *et al.* (2014) [13, 14] concurs there is need to regulate and reduce noise levels at the source and also enforce exposure limits to reduce the negative health consequences of prolonged exposure to excessive noise. In this study, public vehicles fitted with booming music systems were identified as responsible for increased noise pollution in the city. In association to the public vehicles, their operators commonly known as conductors were identified as major contributors to the sustained occurrence of noise in the city. Similarly, Tandel *et al.* (2011) [20] observed that poor transportation systems in urban areas contribute to increased noise hence there is a need to develop an efficient Mass Transit System.

## Conclusion

This study measured the noise levels across nine bus termini

in the city of Nairobi. From this study, various perceived health effects of noise pollution were identified, and this study confirms the existence of noise-induced hearing problems in the general public. This study has also demonstrated the existence of non-auditory health defects such as hypertension, annoyance, headache and accidents that was perceived to might have occurred due to high levels of noise pollution in the City. The findings of this study confirmed that noise levels in the city of Nairobi are beyond the permissible levels as per local standards as well as World Health Organization recommendations on noise levels. From this study, it is concluded that location of bus termini close to each other significantly contributes to noise generation as such spreading the bus terminus far apart would help in reducing the noise levels. Consistent with existing social situation, this study confirms that public vehicles, bus conductors and music from boom cars are the leading sources of noise at bus terminus in the city of Nairobi. The study recommends that regulatory bodies such as NEMA, County Public health officials, to conduct regular measuring of noise levels in the city with a focus on maintaining recommended noise levels at all times. Secondly, there is a need for city management to spread out bus termini far apart from one another so as to reduce high concentration of noise levels at single hot spots in the city

Again, there is need for awareness and sensitization campaigns on occupational health and safety/ on safety practices on noise pollution among the community dwellers of the Central Business District of Nairobi City.

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