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Industrial Noise Pollution and its Health Effects on Workers in Nairobi City

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Abstract **- Industrial noise pressure levels within the work places, its perceived effects on the workers and its progression outside the industrial boundaries was monitored within non-formal metal and formal industries that deal with metal works, grain milling, plastic production and wood works. The assessment was carried out in accordance with the provisions of ISO 1996-2002, using a digital integrating sound level meter, SLM (SVANTEK 971). A hand-held GPS receiver was used to determine the coordinates of noise sources. Noise levels in the non-formal metal industries, formal metal industruies and grain mills were above 90 dB(A), exceeding international guidelines (WHO, NIOSH,OSHA) and the local work place noise standards. Noise levels progression into the streets adjacent to the industries were also above acceptable limits and contributed significantly to background street noise. Questionnaires were used to evaluate the perception of industrial worker on noise levels. Noise effects on the workers were manifested through complaints of loss of hearing (7%), headaches (36%), ringing sound in the ears (19%), irritability (15%), and sleeplessness (9%). Up to 86.5% of the workers were affected at least in one of these ways. The study determined that most workers considered noise as part of their work environment and 65% of the them did not use any protective gears against injury, and 60% were not aware of the existence of safety committees in their work places. The noise prevention and control programmes as required by Kenya's Environmental Management and Cordination Act (EMCA) of 2009, Legal Notice No. 25; and the Factories and Other Places of Work (Noise Prevention and Control) Act of 2005, were not enforced. This study concludes that it is not only the working areas in industries that are excessively polluted with noise, but also street noise on a normal working day exceeds the acceptable limits. It is recommended that deliberate efforts should be put in place to reduce workplace noise levels, create awareness of its harmful effects and provide workers with appropriate protective gear.**

1.0 INTRODUCTION

High levels of occupational noise remain a problem in all regions of the world and there is evidence of its increasing prevalence in the work place (Mithanga, 2013). In the United States of America (USA), for example, more than 30 million workers are exposed to hazardous noise exceeding 85dB(A). In Germany, 4-5 million people (12-15% of the workforce) are exposed to noise levels defined as hazardous by WHO, (2001). Data for developing countries is scarce, but available evidence suggests that average noise levels are well above the recommended standards in many developing nations (Boateng & Amedofu, 2004; WHO, 2001; Mithanga, 2013). Studies done in various cities in Egypt indicate that 70% of workers were exposed to hazardous noise levels (Ali,2010). In Kenya, a study by Mithanga, (2013) showed that 75.8% of the employees work in the production areas where the noise levels were above the standards.

The common effects of noise can be seen in the forms of annoyance, speech interference, sleep disturbance, stress, anger, hearing losses, concentration disorders as well as difficulties in resting and perception (Cheung,2004; Öhrström, 1989). High noise level is considered to be the commonest reason of annoyance and permanent hearing loss (Koffeman & Kerkers, 2000). Barreto (1997) showed that the risks attributed to noise and hearing loss together accounted for nearly half the injuries. Noise therefore interferes with working efficiency, by hindering communication between employees; it may also be a cause of accidents, by masking warning signals. In a study done in the manufacturing sector in Thika District in Kenya, the majority of the participants agreed to have problems working and concentrating when heavy and noisy machines were running (Mithanga, 2013). In the same study, Mithanga (2013), the majority of the employees indicated that high occupational noise levels in the manufacturing industries affect the work performance and communication among them.

The U.S. Occupational Noise Exposure Regulation limits the noise levels subjected to industrial workers at 90 dB(A) for an eight hour working period (USEPA, 1973). In Turkey, the maximum allowable noise is 75 dB(A) for a 7.5 hour working period (Republic of Turkey Ministry of Environment, 1986) while in Kenya, the maximum permissible work-place noise level is 90dB(A) for an eight hours duration. The existing regulation in Kenya requires that a noise control and hearing protection programme should be in place in all workplaces (Legal Notice No. 25, the Factories and other places of work (Noise Prevention and Control, 2005). This study was done in Nairobi City to assess industrial noise levels and evaluate the extent to which industry complies with existing industrial noise pollution control measures. Nairobi city is not only the commercial, industrial and administrative capital city of Kenya, it is also a leading business hub for East and Central Africa with the current population standing at about four (4) million people (KNBS, 2009). Also, 56% of all formal medium and large enterprises are located in Nairobi (KNBS, 2009; Kenya, 2006).

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2.0 MATERIALS AND METHODS

Noise Measurement Equipment and Selection of Study Sites

Detailed measurements were carried out to determine the occupational noise levels and its extent into the environment, using a digital integrating sound level meter SLM (SVANTEK 971) which record the changes in noise level on the basis of sound pressure. The study covered metal, grain mills; and non-formal metal industries. For each source, three (3) samples were taken for sound pressure measurements making a total of fifteen (9) samples. Additional sites were included for social study to raise the requisite sample of workers. The industries were selected through literature review and discusions held with officers at DOSHS, that identified them as the leading sources of industrial noise pollution. The selected industries also constituted a wider geographical distribution of industries and formed a major manufacturing segment in the industrial area of Nairobi.

Work-place Noise Measurement

To determine occupational noise levels, measurements were taken in the production section of the industries at the operator' station. The microphone was held at a height of (1.5) meters and at least 1m from reflecting surfaces for a duration of 10 minutes for each of the three samples at (9-10hrs), (12-13hrs) and (15-16hrs). The sound meter recorded the A-weighted sound pressure levels for specific time intervals which were downloaded onto the supervisor software on the PC and the readings taken. The principal noise index was the L_{Aeq} (the A-weighted equivalent continuous level averaged over a specified time period) which was a representative noise exposure level of the industry as indicated and used in the Kenyan law. Three sampling times selected in this study were based on the previous study (Tsai et al., 2009; Momammed et al., 2012).

The environmental noise measurement parameters used in this study were: $L_{Aeq8\text{-}17;}$ the average noise level during the measurement period (8-17hrs), which includes all noise events; L_{A90}: the noise level exceeded for 90% of the time, general representative of the steady background noise at a location, and; $L_{APeak;}$ peak sound level which is the maximum instantaneous sound level in dB(A). Using the specific interval measurements for 8 hours from 8 to 17 hours, $L_{Aeq8\text{-}17}$ was calculated for each noise source using equation (1) in which $L_{Aeq8\text{-}17}$ is the continuous equivalent A-weighted noise pressure level from 8 to 17 hours; n is the number of 10 minutes measurements between 8.00 and 17.00 hours; $LA_{eq(i/10)}$ is the A-weighted continuous noise pressure measurement in the one 10 minutes instant; i is the frequency of the measurement where i varies from 1 to n.

$$L_{Aeq8-17} = 10\log\frac{1}{n}\left(\sum_{i=1}^{n} 10^{L_{Aeq\frac{i}{10}}}\right) \quad (1)$$

Measurements were taken according to the provisions of the International Standard for Assessment of Environment Noise ISO-1996.

Street Level Noise Measurement

To determine the extent of the noise into the environment, the equipment set up and parameters were as in the previous section. The measurements were taken for 10 minutes duration at 10m interval from the industrial boundary in the available direction up or down the street windward with readings observed at street boundaries and the 30m, NEMA designated distance for determining the noise emission levels from source boundary (Noise and Excessive Vibration Pollution (Control) Regulations, 2009). At each grid, at least a set of three readings were recorded at an interval of 3 hours from 8.00 to 17.00 hour. Measurements were taken when the weather was sunny, wind was less than 3 m/s, and temperature was about 25^{o}C.

3.0 RESULTS AND DISCUSSION

Extent of Noise Pollution From Non-formal Metal Industries

Results of the extent of noise pollution in Kamukunji non formal metal industry site are summarised in Table 1 and Figure 1. Across three different sections, the $L_{Aeq8\text{-}17}$ values were 93.8, 90.5 and 92.2 dB(A), exceeding the maximum permissible level of 75 dB(A) (WHO,1999) by 25.1, 20.7 and 22.9% respectively. Stastically these variations were not significant (F=5.01 and p-value=0.14). On daily basis, the average levels were 91.6±1.5 dB(A) in the morning, 90.6±3 dB(A) at mid-day 93.0±0.67 dB(A) in the evening. The morning and evening sessions were the loudest though statistical these variations were also not significant (F=0.17 and p-value=0.82).

The average continuous equivalent noise level ($L_{Aeq8\text{-}17}$) for non-formal metal industry was 92.2±1.6 dB(A). This was significantly high (t-value=202.1 and p-value=0.00) and exceeded the exposure limit of 90dB(A) by the Kenyan law (Legal notice no. 25). The recorded peak noise level was 114.2±0.5 dB(A). Kimani (2011) also reports the noise level in Kamukunji Jua Kali ranged from 72.0 to 113.8 dB(A). These high levels imply workers in all sites in Kamukunji Non-formal metal industry are exposed to dangerous noise levels which is likely to have serious health effect. The workers at point A and C were exposed to more extreme levels. The processes here involved bludgeoning pans and other metal utilities from thick rail bars and other heavy metals.

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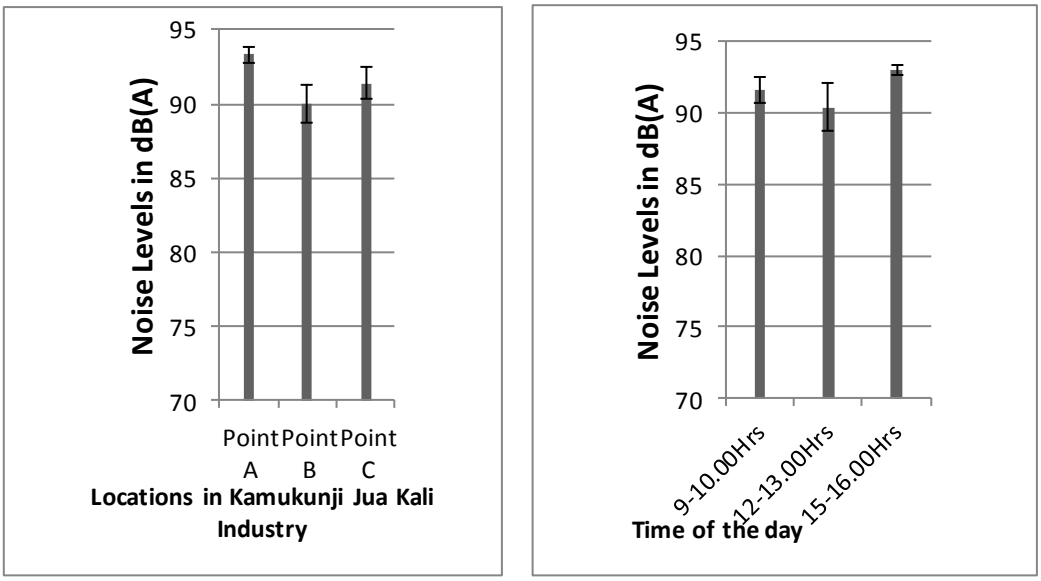

Figure 1: Noise Level variations in non-formal metal industries during the day

Observations also revealed these artisans worked for much longer periods upto 10 hours than stipulated by the law. Occupational Safety and Health Association (OSHA) stipulates that for L_{Aeq} of 92dB(A), exposure limits should be less than 6 hours (OSHA,1983). Literature also describes exposure to these kind of noise as very high risk (Table 6) and is likely to result into hearing loss, speech interference and annoyance (Kujawa & Liberman, 2009). On 25th October, 2014, the chairman of Kamunji Jua Kali while speaking during the launch of a two day free medical camp complained of "The level of noise these artisans are exposed each day is far beyond the recommended levels". He goes on to say, "Some artisans have been working in such conditions for so long that some of them have lost sense of hearing totally" (http://kassfm.co.ke/hme/index.php/component/k2/item).

As per Figure 2, the mean noise level transmitted from Kamkunji non-formal metal industries towards Landhis Road of 73.0 dB(A) was 4.3% higher than the recommended street noice level. The transmission level was also higher than the recommended value of 60 dB(A) from a business premise into the environment by 21.7% (the Environment Management and Cordination (Noise and Excessive Vibration Pollution control, 2009). This is likely to have contributed the measured high background noise of 73 dB(A) beyond the street noise limit of 70 dB(A).

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Table 1 : Noise Level variations in Non-formal Metal Industries during the day

Time	Peak	Max	LEQ	LAeq8-17
9.00am	115.0	102.0	93.0	93.8
12.00am	116.0	105.0	94.6	
15.00pm	114.8	104.3	93.7	
9.00am	112.4	99.2	89.5	90.5
12.00am	113.1	101.0	87.7	
15.00pm	112.4	105.3	92.8	
9.00am	114.6	103.0	92.3	92.2
12.00am	113.3	100.2	88.9	
15.00pm	116.5	104.8	93.9	

The levels indicated in the table are in dB(A)

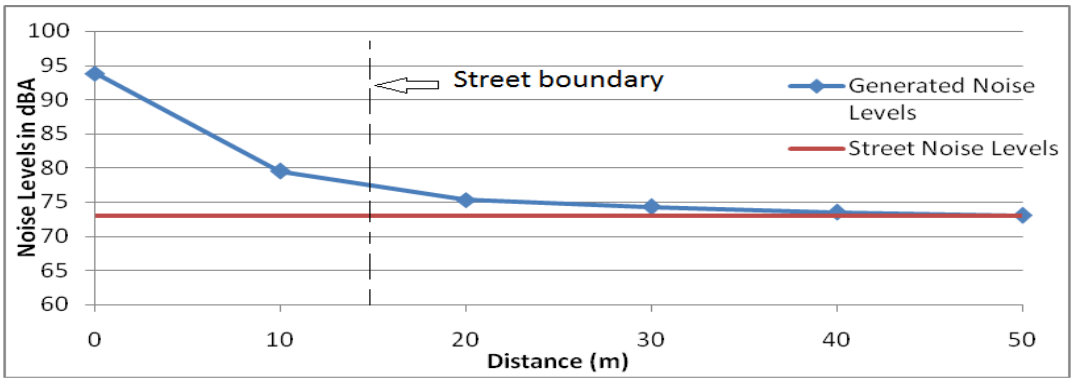

Figure 2: Noise level variation from Kamukunji non-formal metal sheds towards Landhis road.

Extent of Noise Pollution in Grain Milling Industries

Grain millers were among the industries that generate high noise levels in contravention of the law (Legal Notice No. 25), and the WHO (1999) guidelines. Across the mills A, B and C, the, $L_{Aeq8\text{-}17,}$ in the pneumatic grinder section were 93.0, 95.6 and 94.6 dB(A) and found to be 24.0, 27.5 and 26.1%, respecitvely, above the limits (Figure 3 and Table 2). These variations were not signficant across the mills (F=3.07 and p-value=0.12) and at all times of the day (F=0.12 and p-value=0.89). This implies that in the grain industry the level of technology, the processes and noise controls mechanism were the same. The average measured L_{Aeq} for the grain mill industry of 94.4±1.3 dB(A) was significantly higher than the recommended limits (t-value=197.4 and p-value=0.00) and exceded the exposure limit of 90 dB(A) by the Kenyan law(Legal notice no. 25). The peak noise level recorded was 109.9±1.5 dB(A).

OSHA (1983) limits exposure durations of 94 dB(A) to 4.6 hours while NIOSH (1998) limits exposure duration of 94 dB(A) to 1 hour. According to OSHA, the length of time a worker is able to work is reduced by half for every 3 dB(A) increase in noise levels above 90 dB(A). In the current study, the workers exposed to this kind of noise should have been allowed maximum exposure of less than 4 hours in a 24 hour cycle. However as observed, the exposure durations of 94.5 dB(A) was for the 8 hour work shift and this was highly detrimental to the well being of the workers. This noise level is also classified as very high risk to the public health and welfare (Table 6).

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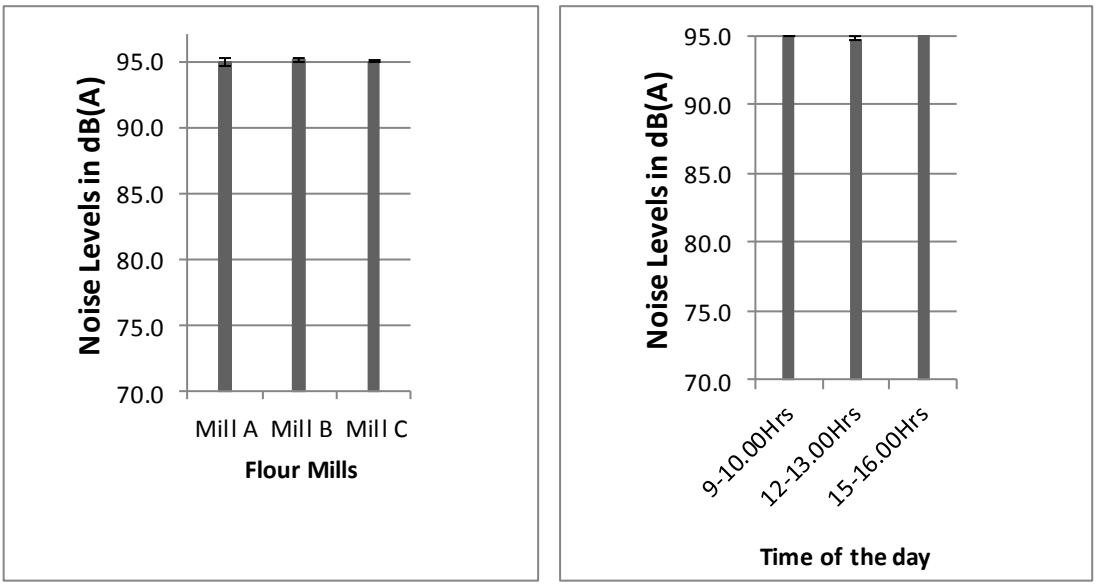

Figure 3: Noise level variations in flour mills in Nairobi.

The results of the current study were slightly higher than 87 dB(A) that Ali (2010) recorded for the same type of industry. The difference could have been Ali (2010) is likely to have recorded his measurements in the packaging section, which had similar readings to the 87.4 dB(A) as recorded in the same section in the current study. The findings in this study however concur with those of a study done on feed mills in Ibadan, Nigeria in which, Yahaya et al. (2012) measured noise levels from 82.5-113.9 dB(A).

Table 2: Noise level variations in grain milling industries during the day

Miller	Time	Peak	Max	LEQ	$L_{Aeq8\text{-}17}$
A	9.00am	110.5	98.3	95.0	93.0
	12.00am	105.6	97.8	94.5	
	15.00pm	110.5	98.5	95.4	
B	9.00am	110.1	97.5	95.2	95.6
	12.00am	107.0	96.5	94.7	
	15.00pm	110.6	98.4	95.4	
C	9.00am	112.0	95.5	94.9	94.6
	12.00am	112.3	96.5	95.2	
	15.00pm	110.5	94.5	95.1	

The levels indicated in the table are in dB(A)

As shown in Figure 4, the mean noise level of 75.4 dB(A) transmitted by Mill B into the environment was 7.7% higher than the recommended street noice level of 70 dBA for industrial and commercial area at day time (WHO, 1999). The transmission level is also higher than the recommended value of 60 dB(A) from a business premise into the environment by 25.7% and just like in non-formal metal, the grain millers were contributing to higher street background noise levels in industrial area of Nairobi.

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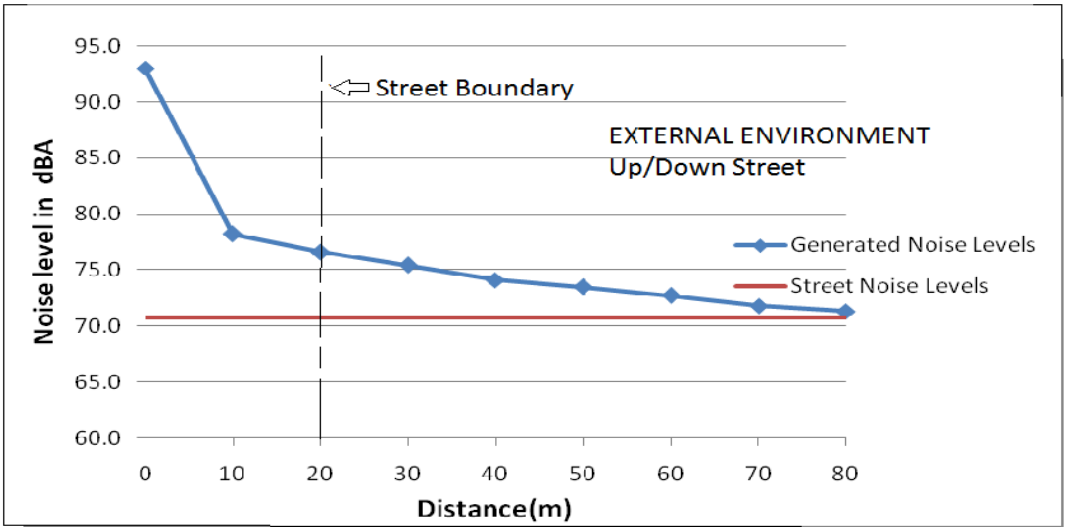

Figure 4: Progression of noise from Mill B into the street.

Extent of Noise Pollution in Metal Industries

The metal industries expected to be the noisiest were less noisier than grain millers. The measured noise levels averaged 90.4±1.3, 90.0±1.4 and 90.3±1.2 dB(A) in the morning, mid-day and evening. The continuous equivalent noise levels ($L_{Aeq8\text{-}17}$) across industries A, B and C were 93.3, 89.3 and 88.1dB(A), respectively. These were higher than the WHO (1999) guidelines by 24.4, 19.1 and 17.4%, respectively (Figure 5 and Table 3). The one tailed t-test also shows the average $L_{Aeq8\text{-}17}$ for the metal industries as 90.2±2.7, which was significantly higher than the recommended levels (t-value=19.31 and p-value=0.000) and exceded the exposure limit of 90 dB(A) by the Kenyan law (Legal notice no. 25). However, there were no significant differences in the noise levels at different times of the day (F=0.02 and p-value=0.983) but there were significant differences across factories (F=247.11 and p-value=0.000). This implies that though the activities were continuous throughout the day, the processes were different from one plant to another. The peak noise levels recorded was 123.8±2.5 dB(A).

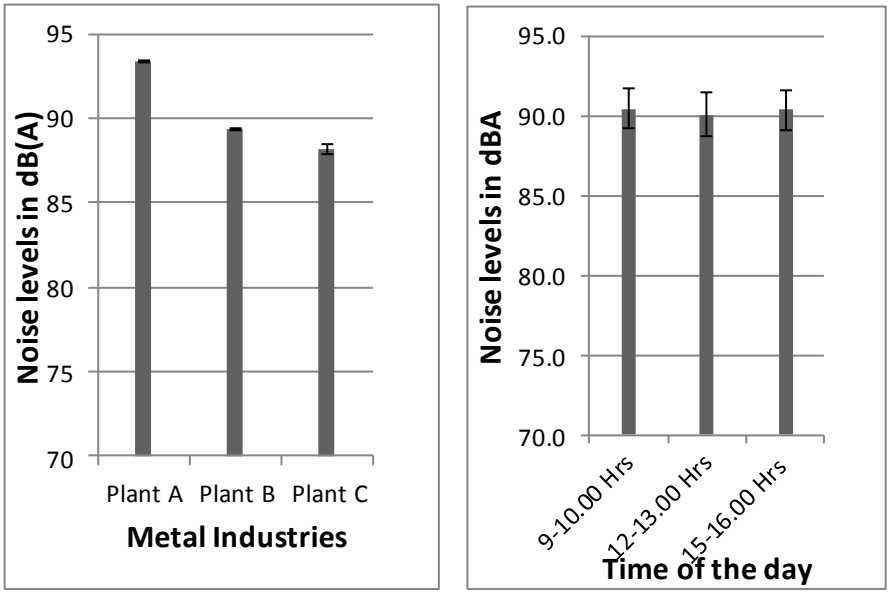

Figure 5: Variation in noise levels in metal industries.

These results are in agreement with those of Ali (2010) who recorded an average noise level of 92.6dB(A) for workshops of metal works in Egypt. The metal industries are also classified as very high risk (Table 6) and like in the case of millers and non-formal metal industries, hundreds of workers who are continuously exposed to these noise levels are at a high risk of induced noise hearing loss among other psychological effects. Studies have shown that for the 90th percentile exposed population, the risk of presumed noise induced hearing loss (NIHL) increases exponentially for noise levels beyond 85 dBA and over a prolonged period (Gierke & Johnson, 1978). Besides, they also experience many other side effects of noise pollution including speech interfere, annoyance, sleep disturbance and concentration disorders as well as difficulties in resting and perception (Cheung, 2004; Öhrström, 1989).

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Table 3: Noise level variations in metal industries during the day

Factory	Time	Peak	Max	LEQ	LAeq8-17
A	9.00am	125.5	105.4	93.5	93.3
	12.00am	125.3	105.6	93.2	
	15.00pm	125.4	105.3	93.3	
B	9.00am	121.3	100.3	89.5	89.3
	12.00am	120.8	101.4	89.3	
	15.00pm	120.7	99.8	89.2	
C	9.00am	125.0	113.0	88.3	88.1
	12.00am	125.2	113.3	87.6	
	15.00pm	125.1	112.7	88.5	

The levels indicated in the table are in dB(A)

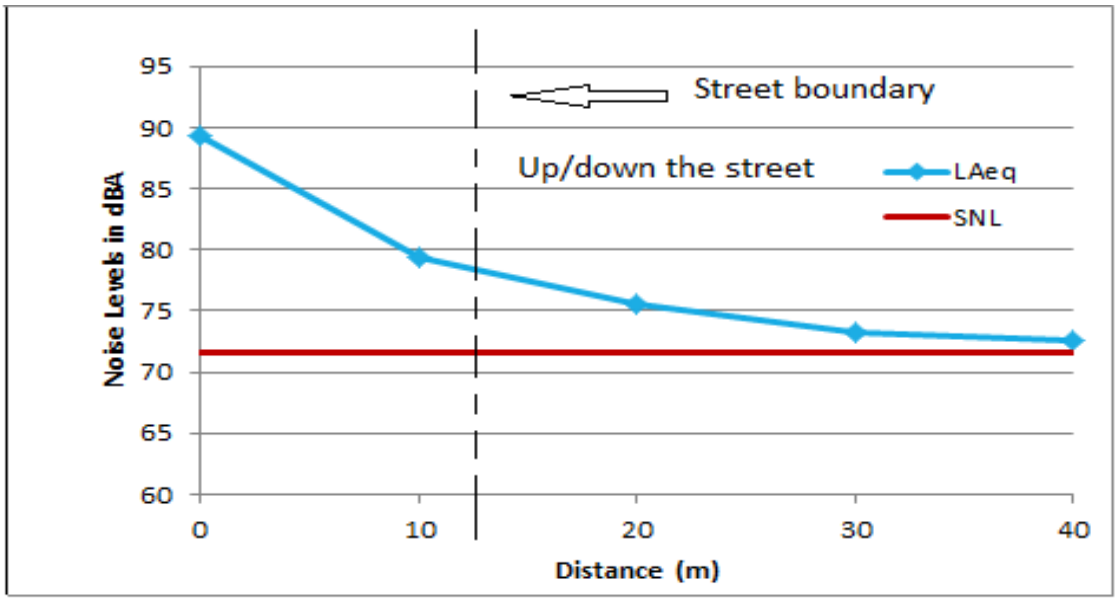

Figure 6: Progression of noise level from metal industry A into the street.

Figure 6 shows that the mean noise level of 73.2 dB(A) transmitted by metal industry A into the environment was 4.6% higher than the recommended street noice level. This was also higher than the recommended maximum noise transmisson level of 60 dB(A) from a business premise into the environment, by 33.1%.

Health Effects of Industrial Noise Pollution

Since sound does not become 'noise' until it reaches and is appreciated by a person, it was important to consider the subjective effect of noise. The study sought to establish the effect of industrial noise on public health. The measured data indicated that all the industries exceeded the maximum permissible occupational noise levels (Table 6) thus putting public health at very high risk. While the observed noise levels require that a working shift should not exceed 8 hours in a 24 hour day for a five-day working week (Legal Notice No. 25), over 50% worked for over 8 hours. This is contrary to Section 4(1) which states that 'No worker shall be exposed to a noise level in excess of (a) the continuous equivalent of 90 dB(A) in 8 hours within any 24 hours duration and (b) 140 dB(A) peak sound level at any given time.

Some 48% of the respondents had the opinion that industrial noise ranged between severe and very severe (Table 4). However, almost 20% of the respondents felt that the noise was mild and therefore had no problem with it. This suggests that industrial workers have accepted hazardous noise as part of their work environment.

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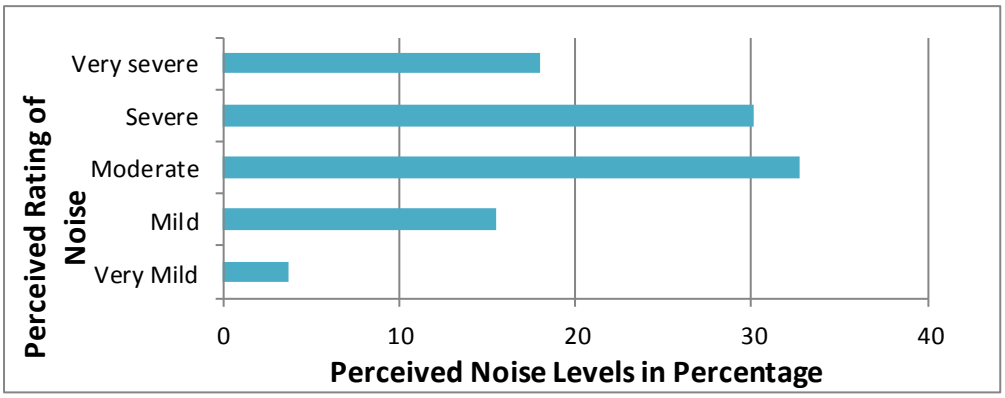
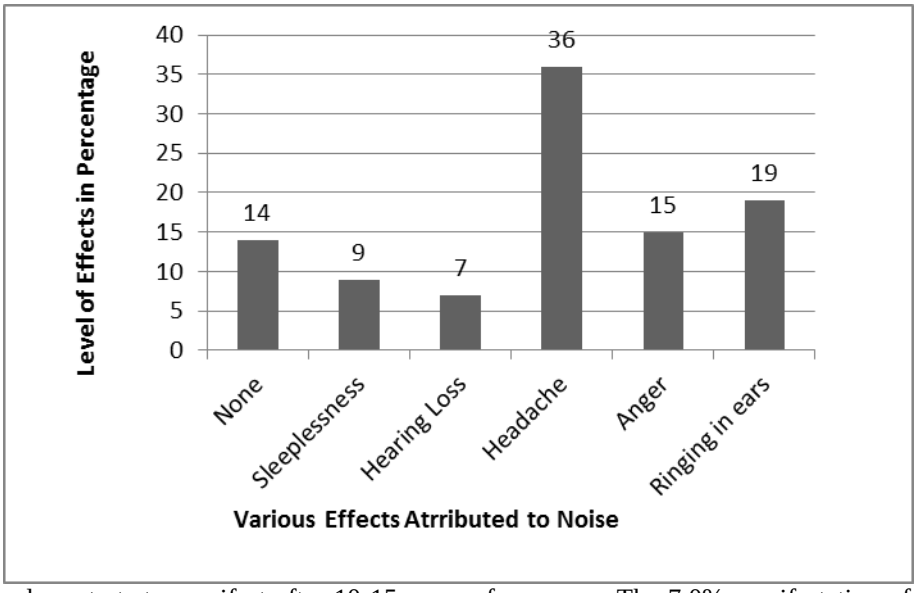
Table 4: Rating of noise generated by an organization



The health effects were manifested in the form of headaches, interference with communication, interference with concentration, annoyance/irritation and sleeplessness. Table 5 shows that 86.5% were affected by noise. Some 36% experienced headache, while 9, 7, 15, and 19% experienced sleeplessness, hearing loss, anger and ringing in the ears, respectively.

Table 5: Perceived impacts of industrial noise on the health of workers



Noise induced hearing loss starts to manifest after 10-15 years of exposure. The 7.0% manifestation of hearing loss is a big percentage considering that only 33.0% of the respondents had worked for more than 10 years.

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Table 6: Effects of noise pollution on public health and welfare

Effect of noise	Protective noise limit (LAeq, 24h, dBA)	Duration of exposure (Years)	Measured noise level in various industries (LAeq, 8h, dBA)/Inference (level of risk)				
			Grain mills	Metal	Plastic	Wood	Non-formal Metal
Noise Induced Hearing Loss (NIHL)	70	20-40	94.4/Very High risk	90.2/Very High risk	83.2/High risk	82.1/High risk	92.2/Very High risk
Physiological Effects (Hypertension, Cardiovascular Disease, etc.)	65-70	30	94.4/Very High risk	90.2/Very High risk	83.2/High risk	82.1/High risk	92.2/Very High risk
Psychological/Mental Illness/Stress	70	ST-LT	94.4/Very High risk	90.2/High risk	83.2/High risk	82.1/High risk	92.2/Very High risk
Speech Interference (Indoors)	35	ST	94.4/Very High risk	90.2/Very High risk	83.2/High risk	82.1/High risk	92.2/Very High risk
Speech Interference (Outdoors)	55	ST	94.4/Very High risk	90.2/Very V High risk	83.2/High risk	82.1/High risk	92.2/Very High risk
Sleep Disturbance	30	ST	94.4/Very High risk	90.2/Very High risk	83.2/ High risk	82.1/ High risk	92.2/Very High risk
Activity Interference	45-55	ST	94.4/Very High risk	90.2/Very High risk	83.2/High risk	82.1/High risk	92.2/Very High risk
Annoyance/Social/Behavioural Effect	80	ST	94.4/Very High risk	90.2/Very High risk	83.2/High risk	82.1/High risk	.2/ Very High risk

Industrial Noise Pollution Control

Noise-induced hearing loss is the most common occupational health problem in industrialized countries. One of the ways of offsetting this negative health impact is to wear hearing protection devices (HPDs) (CSA Z94.2). This study sought to find out whether the respondents used HPDs and determined that 65.0% of the workers did not use any protective equipment for the ears. This is an understatement for the observations made during the study did not spot any worker wearing HPDs even in areas with the highest noise levels. Most of them when asked casually said, "we only had problems at the beginning, but since we need the job we consider the noise as part of our work".

According to Table 7, the reasons for not wearing protective hearing equipment were further explored and a majority (45.0%) indicated that they did not wear HPDs because they were not available. Workers further indicated that the available equipment was of low quality and uncomfortable to wear.

Table 7: Reasons for not wearing a hearing protection device

Reason	Frequency	Percentage (%)
Not available	78	44.8
Equipment is uncomfortable	61	35.1
Equipment is Expensive	7	4.0
Not aware I need thee equipment	17	9.8
No reason	11	6.3
Total	174	100.0

Among the 35.1% of the respondents who used HPDs, 59.0% indicated they used the equipment for less than 8 hours with only 12.7% of the work force using the equipment effectively. This is a very insignificant ratio considering that 86.0% of the workers experienced negative health effects of noise (Table 5).

Majority (60.0%) of the workers indicated that they were not aware of existence of safety committee in their company. A similar number had not participated in safety committee elections as per regulations which require that elections should be done once every three years (Legal Notice No. 25); and how often the organization monitors the use of HPDs is important in their effectiveness. The results indicated that 21.0% of the workers came from organisations that never monitor the use of HPDs.

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5.0 CONCLUSION

Results showed that in all of the industrial sites visited, the noise level was above WHO standards of 75dB(A), which is recommended for where occasional communication is required like in workshops and plant area. In 77.8% of work places, the workforce were exposed to continuous equivalent noise levels for longer durations and which was higher than the 90 dB(A) limit set by the Kenyan law and international guidelines, and was classified as very high risk for public health and welfare.

This study found that millers, non-formal metal sheds and metal industries were the leading noise polluters within the workplaces at 94.4, 92.2 and 90.2 dB(A), respectively. In addition, the noise emission into the environment from these industies was beyond the recommended transmission level of 60 dB(A) and contributed significantly to the high background noise level of 73.8 dB(A) above the recommended level of 70dB(A).

The study found that 86.5% of workers are affected by the noise, with 36% suffering from headaches, 19% ringing in the ears, 15% anger, 9% sleeplesness and 7% hearing loss. Scarce job opportunities and family obligations are seen as limitations to the workers options for choice of suitable work environment. The study found that 65% of the workers did not use ear protectors and 45% these indicated they felt the noise levels was worse with the protectors on. Most wokers regarded noise as part of their work environvironment. The study also found that there was no effective noise control and hearing conservation programme in place, and the Kenyan law on OSHA with regard to noise - the Factories and other places of work (Noise prevention & control) rules 2005, was violated in most places.

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