Study Relationship Between Noise Metrics Parameters Exposure Among Electrical Production Workers

Hany A. SHAWKY
National Institute of Standard (NIS), Acoustic department, Mass and force Metrology Division, Egypt. E-mail: hany.amir15@gmail.com

Abstract: - This paper represents the exposure–response relationships for noise-induced hearing loss are relatively well established, metrics of noise exposure are best represent risk of hearing damage. In particular, while equivalent sound pressure level L_{eq}, based on a 3dB exchange rate (ER) is used by most agencies, USOSHA's standard is based on the L_{avg}, which uses a 5 dB ER. In addition, peak levels of exposure, which are commonly found in some industries, including electrical site are believed to increase risk above that predicted by the L_{eq}. This paper presents an analysis of noise matrix exposures parameters among electrical workers, comparing several noise metrics, over time intervals measurements such as 60, 180, 300, 480 minutes. Metrics examined were the L_{avg}, L_{eq}, L_{min} and L_{max}, expressing average levels of exposure across an exposure interval. Two novel metrics were derived from these monitored metrics, L_{eq}/L_{avg} and L_{max}/L_{eq}, as measures of exposure variability and 'peakiness', respectively. A time intervals of noise matrix exposure to workers in three sites (Metal, Epoxy and Cutting workshop) with different activities were examined. Correlations between average metrics (L_{eq}, L_{avg} and L_{max}) are generally around very high and well, while the variability of ratio metrics are between middle and poorly correlated with either average levels, or with each other, indicating that they characterize different aspects of exposure at 480 minute interval. The specific activities of each sites estimates of exposure using the various metrics will be applied to the cohort's work history to explore the importance of this matrix in estimating risk of noise- exposure that induced damage.

Keywords: - noise exposure assessment; occupational noise exposure; exposure metrics; electrical workers

1. INTRODUCTION

Occupational noise exposure and associated hearing loss have been well researched and are well understood [1] and is 100% preventable; however, it is reported in approximately 10 million workers annually in the US [2]. Noise induced hearing loss (NIHL) generally occurs over a long period of exposure, developing unnoticeably and gradually as time passes. Noise exposures contributing to NIHL can be continuous or intermittent in nature and cause hearing loss as a result of damage to the hair-like cells of the cochlea. Damage to these cells is irreparable and results in permanent hearing loss [3].

The National Institute for Occupational Safety and Health (NIOSH) estimates that somewhere between 22 million and 30 million workers are overexposed to noise in the US each year [4] (May, 2000). NIHL is prevalent across industries [5] and is not unique to workers in the US, as hearing loss accounts for approximately one third of the occupational illnesses reported in Europe [6]. In a study by Masterson [7] 23% of workers who were exposed to noise presented difficulty in hearing compared with only 7% of those not exposed. Fifteen percent of participants who had been exposed to noise suffered from tinnitus and 9% experienced both hearing loss and tinnitus. Only 5% of participants from the non-exposed group reported tinnitus and 2% reported effects of both tinnitus and hearing loss. In addition to long term consequences, noise and hearing impairment.

Cause employees to miss contextual cues or warning sounds leaving them unaware of safety hazards in their work area. In case, noise and hearing impairment results in increased incidence of injury or other accidents [8].

Selection of an appropriate metric for noise exposure in relation to noise-induced hearing loss is particularly relevant. The standard metric for monitoring noise is the L_{eq}, a measure based on the equal energy hypothesis (EEH), which states that equal amounts of sound energy produce equal amounts of damage regardless of their distribution over time. The EEH implies a 3 dB exchange rate—the increase in dB allowed with a halving of exposure duration in order to keep the total energy equal. Thus the EEH contains the same assumptions as cumulative exposure about linearity of time and duration, and some authors argue that it is the most appropriate metric for integrating noise exposure of any type or duration [9, 10]. Most national and international occupational and environmental health agencies use the L_{eq} [12]. However, the US Occupational Safety and Health Administration (OSHA) standard specifies a 5 dB exchange rate and is termed the L_{avg} [11]. The L_{avg} is based on the premise that damage occurred in the ear during periods of high noise is partially repaired during intermittent low noise periods. This assumption results in lower estimates of damage from high noise periods than would be predicted using the EEH. Whether the L_{eq} or the L_{avg} is the correct metric for predicting noise induced hearing loss continues to be a subject of debate [12]. Furthermore, there is substantial evidence that high peak noise levels produce more damage than would be expected based on the EEH [13, 14]. In animal studies, peaks over _120–135 dBA induce mechanical damage to the hearing mechanism, while lower-level chronic noises produce toxic effects through metabolic alterations [15]. Typical continuous type industrial noise levels are well under 120 dBA, but many processes including those in the construction industry do produce peaks in this range.

Although it may be important to include peak levels in an exposure metric, methods for summarizing peaks in a highly variable exposure environment over extended periods of time are not well developed. And also Noah Seixas [16] studied the noise metrics for noise exposure to construction workers, but in this work that give new elements and idea in this research.

In the context of a longitudinal study of noise-induced hearing damage among construction workers, we have developed a series of exposure metrics that attempt to capture the important characteristics of noise exposure—exposure level, intermittency and ‘peakiness’—using available dosimeter measurements. This paper describes the development of these metrics and their relationship to each other.

2. MATERIAL & METHOD

2.1. Experimental setup and exposure facility

The present research studies noise of three different occupational areas in electro-production instruments factories participated in this cross-sectional study, where 99 workers were exposed to this noise at different time intervals 60, 180, 300 and 480 min for 6 days every day at each site. The study was divided into 3 parts with different sites and different activities or task as follows:

1- Metal site
2- Epoxy site
3- Cutting workshop site

Measurements of matrix parameters were carried out in each site, which included noise measurements such as L_{eq}, L_{avg}, and Lmax. L_{min} and calculated ratios of L_{eq}/L_{avg} and L_{max}/L_{eq}

Description of each site

Electro-production instrument is used in metal site such as hydraulic and centric machines for cutting and bent ting the metals to form the bodies of electrical tools, i.e. refrigerators, air conditioners, etc.

1- Metal site

Metal site with dimensions (50 x 31) m includes 8 types of machines with different electric powers and forces. Noise emission from the machines, and noise matrix parameters in this site were measured.

2- Epoxy site

Epoxy site of dimensions (51 x30) m includes 2 types of activities areas such as: chemical treatment area and assembling area include hanging, container storage, furnace area, some workers in this site exposed to chemical vapor and chemical powder.

3- Cutting workshop site

Cutting workshop site of dimensions (54x33) m includes 5 types of machines such as: cutting machine, forging machines age 1 and 2, lathe machine, machine of lifting weights and machine Gelg, which workers have done.

2.2 Noise Measurement

Noise measurement was made using Type 1 Model 2260 Precision Integrating Sound Level Meter (Bruel and Kjaer, in Denmark), of accuracy 0.5 dB and resolution 0.1 dB to assess the noise level and frequency characteristic. The instrument was calibrated by using primary calibration system of Sound Level Meter type 9600. Before measurement the Sound Level Meter was adjusted at 1000 Hz and 94 dB by using Reference Acoustical Calibrator B&K type 4231.

Noise parameters were measured at each factory or at different positions with different activities at distance of 1.5 m from the sources of noise, placing the sound level meter and microphone at height of approximately 1.5 m for standing person, 0.91 m for seated person, closer to head position of workers during work according to [17].

2.3 Metrics definition

Several exposure metrics were logged each minute during every monitored work shift: equivalent sound pressure level during certain period of time L_{eq}, using a 3 dB exchange rate, slow response time (1 s) and no threshold; average sound pressure level during certain period of time L_{avg}, using a 5 dB exchange rate, slow response time and a 80 dB threshold; and maximum and minimum sound pressure level L_{max}, L_{min} with a fast (0.125 s) response time. All levels described in this paper were measured using A-weighting. The L_{eq} and L_{avg} represent average levels integrated over a 1 min period and L_{max} represents the highest maximum level measured during that same period and minimum sound pressure level L_{min}.The three metrics defined above (L_{eq}, L_{avg} and L_{max}) were summarized for a 60, 180, 300 min and 480 min (8 h) full shift, during the duration in which specific tasks were measured, by using the following:

$$L_{ij} = q \log [\frac{1}{\sum_k w_{ijk}} \sum_{k=1}^{nij} w_{ijk} 10^{\frac{L_{ijk}}{q}}] \quad (1)$$

where L_{ij} is the level for individual i over shift (or task) j summarized over the k = 1 to n_{ij} time intervals.

The n time intervals were nominally 60, 180, 300 min and 480 min (8 h) but where more than one task was reported within a minute, the time-periods were fractions of the minute represented by w. The L_{eq} and L_{max} were calculated using q = 10, while L_{avg} was calculated using q = 16.6 [18]. Note that L_{max} across a sampling period represents the average of the L_{max}levels measured within that period, and as with L_{eq} and L_{avg} levels, averaging was conducted on the exponential scale to appropriately weight the higher-level maxima. These three metrics represent different, widely accepted measures of average levels across the work period Two novel metrics were also developed to represent the variability of exposure. It is well known that L_{avg} and $L_{eq}$are equivalent in steady state noise, and that their difference becomes larger with increasingly variable noise levels within an Exposure interval. Thus, the ratio of $L_{eq}$to L_{avg} represents the degree of variability, or intermittency independent of the average exposure level during the time interval. L_{eq}/L_{avg} was thus calculated:

$$\frac{L_{eq}}{L_{avg}} = \frac{1}{\sum_k w_{ijk}} \sum_{k=1}^{nij} w_{ijk} \frac{10^{L_{eq,ijk/10}}}{10^{L_{eq,ijk/10}}} \quad (2)$$

Similarly, the degree of 'peakiness' of an exposure can be represented by the ratio of the L_{max} to the L_{eq}. The ratio of L_{max}/L_{eq} can be thought of as similar to an average crest factor (ratio of peak to average level) over the exposure interval and was calculated with equation (2), exchanging L_{max} for L_{eq} and L_{eq} for L_{avg}. In summary, five metrics were compared. L_{eq}, L_{avg} and L_{max} indicate average levels of exposure over 60, 180, 300 min into full-shift 480 min sampling periods. Two ratio metrics were also developed: L_{eq}/L_{avg} expresses the average variability in levels and increases in increasingly intermittent exposures and L_{max}/L_{eq} expresses the degree of 'peakiness' across the exposure period.

Each of these metrics was described by trade and compared using scatter plots and Pearson's correlation coefficients on each time scale and for full shifts.

2.4 Estimation of metrics for cohort exposure assignment

In order to estimate exposure levels for the cohort activities-based approach was adopted to exploit the substantial in exposure between activities as in metal, Epoxy and cutting workshop site and variable time study subjects reported doing specific task. These analyses used a task of activity event was defined as the period of time during single work shift that individual subject (belonging to particular task) Although many tasks were reported by several site, they were kept independent to allow for different activities exposure levels.

The estimation strategies were developed and compared as follow: measurement of sound exposure levels and some parameters of noise exposure for each activity at each site with different task at different time. Exposure estimates were first made by calculating mean exposures by each activity in the model development data subset. The means were estimated using equation (1). To compare these different estimation approaches, model development and validation data subsets were created by each task event, and then measured the mean of different parameters levels in dB were used to calculate task exposure level at different time interval. By using statistical analysis to know the correlation between each parameter of noise matrix at each activity on each site.

3. RESULTS

Noise exposure on workers in three trades with different activities at different shift time 60, 180, 300 and 480 min. were measurements on different sites. Three different trades were measured as activities such as: chemical treatment activities, storage site and cutting area with different tools to cut metal sheet workers on different shift time

In metal site (Tables 1, 2, 3, 4, 5, 6, and 7) can be represented for noise exposure of different noise matrix parameters on machines during different minutes, 60.180.300 and 480 min (8 h), the data were measured in metal trade site for 7 types of machines

Table 1. Noise matrix parameters at different time shift in metal site 1[mean (SD)].

n (min)	L_{eq} (SD)	L_{avg} (SD)	L_{max} (SD)	L_{min} (SD)	L_{eq}/L_{avg} (SD)	L_{max}/L_{eq} (SD)
60	88.36 (0.53)	56.07 (0.7)	98.34 (1.35)	81.98 (1.59)	1.58 (1.24)	1.11 (2.12)
180	83.59 (0.68)	63.14 (3.35)	93.57 (1.32)	77.21 (1.46)	1.32 (1.54)	1.12 (2.41)
300	81.38 (0.72)	59.46 (3.59)	91.35 (1.34)	74.99 (1.46)	1.37 (2.31)	1.12 (1.39)
480	79.33 (0.72)	56.07 (4.05)	89.31 (1.22)	72.95 (1.33)	1.41 (1.11)	1.13 (2.12)

From Table 1, we represented that noise parameters measurements on different times at 60, 180, 300, and 480 min (8 h) exposure levels that would be calculated using appropriate averaging equations. Over metal site 1, the L_{avg} were 32.29, 20.45, 21.92, 23.26 dBA difference from L_{eq} at different time measurements from 60 min to 480 min <L_{eq}, while L_{max} was around 9.98 dBA higher than L_{eq} at different time measurements and 42.27, 30.43, 31.89, 33.24 dBA difference from L_{avg} at each time intervals respectively, the exposure variability ratio metrics L_{eq}/L_{avg} was much higher at 60 min interval, as might be expected given the nature of their work. L_{max}/L_{eq} was around 1.12 for most time intervals. Among the highest ratio metrics, 1.58 for L_{eq}/L_{avg} and 1.13 L_{max}/L_{eq} at 480min, respectively.

Table 2. Noise matrix parameters at different time shift in metal site 2[mean (SD)].

n (min)	Leq (SD)	Lavg (SD)	Lmax (SD)	Lmin (SD)	Leq/Lavg (SD)	Lmax/Leq (SD)
60	92.42 (0.94)	75.09 (2.69)	106.38 (5.68)	98.63 (8.12)	1.23 (3.38)	1.15 (3.04)
180	87.65 (0.89)	67.17 (3.14)	101.61 (6.23)	93.86 (8.12)	1.30 (5.53)	1.16 (3.59)
300	85.43 (0.83)	63.49 (3.86)	99.4 (5.23)	91.64 (8.54)	1.35 (5.31)	1.16 (3.11)
480	83.39 (3.09)	60.10 (4.09)	97.35 (5.7)	89.6 (9.97)	1.39 (4.24)	1.17 (4.44)

Table 3. Noise matrix parameters at different time shift in metal site 3[mean (SD)].

n (min)	L_{eq} (SD)	L_{avg} (SD)	L_{max} (SD)	L_{min} (SD)	L_{eq}/L_{avg} (SD)	L_{max}/L_{eq} (SD)
60	87.32 (1.58)	70.02 (1.04)	95.90 (1.99)	71.60 (0.88)	1.25 (2.68)	1.10 (0.1)
180	82.54 (1.47)	62.10 (2.21)	91.13 (1.99)	75.86 (0.77)	1.33 (4.65)	1.10 (1.0)
300	80.33 (1.39)	58.41 (5.09)	88.91 (1.88)	73.64 (0.92)	1.38 (3.17)	1.11 (1.56)
480	78.28 (2.21)	55.02 (2.04)	86.87 (1.79)	71.6 (0.87)	1.42 (3.74)	1.11 (2.83)

Table 4. Noise matrix parameters at different time shift in metal site 4[mean (SD)].

n (min)	Leq (SD)	Lavg (SD)	Lmax (SD)	Lmin (SD)	Leq/Lavg (SD)	Lmax/Leq (SD)
60	91.79 (0.92)	74.47 (2.33)	95.90 (1.99)	80.63 (0.77)	1.23 (2.94)	1.04 (1.91)
180	87.02 (0.86)	66.55 (3.67)	91.13 (1.77)	75.86 (0.99)	1.31 (3.08)	1.05 (2.42)
300	84.80 (0.81)	62.87 (2.83)	88.91 (1.88)	73.64 (0.88)	1.35 (1.91)	1.05 (2.12)
480	82.76 (1.21)	59.48 (2.87)	86.87 (1.79)	71.60 (0.81)	1.39 (2.42)	1.05 (2.69)

Table 5. Noise matrix parameters at different time shift in metal site 5 [mean (SD)].

n (min)	Leq (SD)	Lavg (SD)	Lmax (SD)	Lmin (SD)	Leq/Lavg (SD)	Lmax/Leq (SD)
60	88.60 (0.84)	71.29 (2.7)	99.17 (2.12)	80.48 (0.56)	1.24 (0.91)	1.12 (1.58)
180	83.83 (0.78)	63.37 (1.79)	94.40 (3.12)	75.71 (0.65)	1.32 (2.26)	1.13 (1.04)
300	81.61 (0.74)	59.69 (2.93)	92.18 (3.21)	73.49 (0.54)	1.37 (3.97)	1.13 (1.17)
480	79.57 (2.49)	56.30 (2.72)	90.14 (3.61)	71.45 (0.54)	1.41 (1.58)	1.13 (2.0)

Table 6. Noise matrix parameters at different time shift in metal site 6 [mean (SD)].

n (min)	Leq (SD)	Lavg (SD)	Lmax (SD)	Lmin (SD)	Leq/Lavg (SD)	Lmax/Leq (SD)
60	88.52 (0.9)	71.21 (1.83)	101.69 (0.77)	78.22 (1.25)	1.24 (2.53)	1.15 (1.33)
180	83.75 (0.86)	63.29 (2.76)	96.92 (0.65)	73.44 (1.12)	1.32 (3.79)	1.16 (0.82)
300	81.53 (0.83)	59.61 (5.26)	94.70 (0.15)	71.23 (1.05)	1.37 (2.30)	1.16 (0.93)
480	79.49 (1.08)	56.22 (3.44)	92.66 (0.16)	69.18 (1.03)	1.41 (1.46)	1.17 (1.96)

Table7. Noise matrix parameters at different time shift in metal site 7 [mean (SD)].

n (min)	Leq (SD)	Lavg (SD)	Lmax (SD)	Lmin (SD)	Leq/Lavg (SD)	Lmax/Leq (SD)
60	88.47 (1.06)	71.16 (2.85)	100.63 (3.77)	80.92 (0.65)	1.24 (1.37)	1.14 (1.37)
180	83.70 (0.99)	63.24 (2.74)	95.86 (3.42)	76.15 (0.54)	1.32 (1.43)	1.15 (1.43)
300	81.48 (0.92)	59.56 (4.61)	93.64 (3.33)	73.93 (0.52)	1.37 (1.55)	1.15 (1.55)
480	79.44 (1.84)	56.17 (404)	91.60 (3.28)	71.89 (0.49)	1.41 (2.30)	1.15 (2.31)

The mean L_{avg} was 56.07dBA and the average L_{eq} was 79.33 dBA at 8 h. There was relatively higher difference in mean levels between values

Metal site 1 in this trade was a highly significant predictor for all six metrics in a. Differences in average metrics between each matrix at time interval 8 h were relatively small with the relationship between the L_{max}/ L_{eq} and L_{eq}/L_{avg} at 8h.

From figure 1 show that highly correlated L_{eq} (8h)–L_{avg} (8h) (r = 0.96) and L_{max} (8h)-L_{eq} (8h) was well correlated with (r = 0.88) and somewhat less well with L_{avg} (r = 0.77). Middle correlated L_{eq}/L_{avg} (8h)-Lmax/Leq (8h) (r= 0.43) the ratio metrics were poorly correlated with L_{max}- L_{eq}/L_{avg} (8h) (r= -0.08) and only slightly correlated with each other (r = 0.54).

From Table 2, we represented that noise parameters measurements on different times at 60, 180, 300, and 480 min (8 h) exposure levels that would be calculated using appropriate averaging equations. Over metal site 2, the L_{avg} were 17.33, 20.48, 21.94 and 23.29 dBA difference from L_{eq} at different time measurements from 60 min to 480 min <L_{eq}, while L_{max} was around 13.96 dBA higher than L_{eq} at different time measurements and 31.29, 34.44, 35.91 and 37.25 dBA difference from L_{avg} at each time intervals respectively, the exposure variability ratio metrics L_{eq}/L_{avg} was much higher at 480 min interval, as might be expected given the nature of their work. L_{max}/L_{eq} was around 1.15 for most time intervals. Among the highest ratio metrics, 1.39 for L_{eq}/L_{avg} and 1.17 L_{max}/L_{eq} at 480min, respectively.

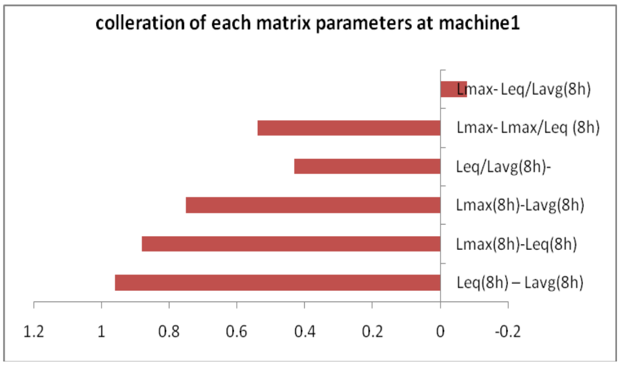

Figure 1. Relationship between each matrix in at metal site 1 at 480 min interval

The mean L_{avg} was 60.10 dBA and the average L_{eq} was 83.39 dBA at 8 h. There was relatively higher difference in mean levels between two parameters.

Metal site 2 in this trade was a highly significant predictor for all six metrics in Differences in average metrics between each matrix at time interval 8 h were relatively small with the relationship between the L_{max}/ L_{eq} and L_{eq}/L_{avg} at 8h.

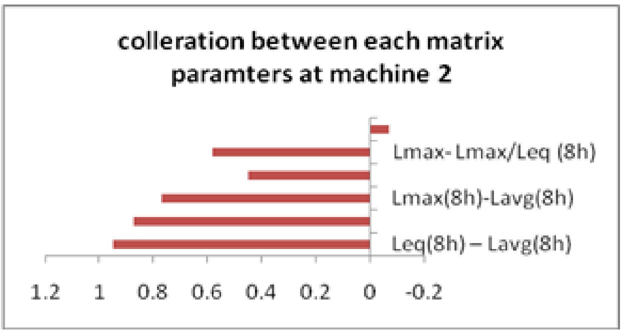

Figure 2. Relationship between each matrix in at metal site 2 at 480 min interval

From figure 2 show that highly correlated L_{eq} (8h)–L_{avg} (8h) (r = 0.95) and L_{max} (8h)-L_{eq} (8h) was well correlated with (r = 0.87) and somewhat less well with L_{avg} (r = 0.77). Middle correlated L_{eq}/L_{avg} (8h)-L_{max}/L_{eq} (8h) (r= 0.45) the ratio metrics were poorly correlated with L_{max}- L_{eq}/L_{avg} (8h) (r= -0.07) and only slightly correlated with each other (r = 0.58).

From Table 3, we represented that noise parameters measurements on different times at 60, 180, 300, and 480 min (8 h) exposure levels that would be calculated using appropriate averaging equations. Over metal site 3, the L_{avg} were 17.3, 20.44, 21.92 and 23.26 dBA difference from L_{eq} at different time measurements from 60 min to 480 min <L_{eq}, while L_{max} was around 8.58 dBA higher than L_{eq} at different time measurements and 25.94, 29.03, 30.5 and 31.85 dBA difference from L_{avg} at each time intervals respectively, the exposure variability ratio metrics L_{eq}/L_{avg} was much higher at 480 min interval, as might be expected given the nature of their work. L_{max}/L_{eq} was around 1.10 for most time intervals. Among the highest ratio metrics, 1.42 for L_{eq}/L_{avg} and 1.11 L_{max}/L_{eq} at 480min, respectively.

The mean L_{avg} was 55.02 dBA and the average Leq was 78.28 dBA at 8 h. There was relatively higher difference in mean levels between two parameters.

Metal site 3 in this trade was a highly significant predictor for all six metrics in Differences in average metrics between each matrix at time interval 8 h were relatively small with the relationship between the L_{max}/ L_{eq} and L_{eq}/L_{avg} at 8h.

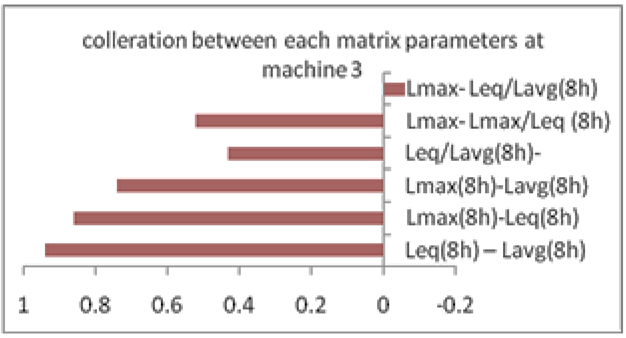

Figure 3. Relationship between each matrix in at metal site 3 at 480 min interval

From figure 3 show that highly correlated L_{eq} (8h)–L_{avg} (8h) (r = 0.94) and L_{max} (8h)-L_{eq} (8h) was well correlated with (r = 0.86) and somewhat less well with L_{avg} (r = 0.74). Middle correlated L_{eq}/L_{avg} (8h)-L_{max}/L_{eq} (8h) (r= 0.42) the ratio metrics were poorly correlated with L_{max}- L_{eq}/L_{avg} (8h) (r= -0.06) and only slightly correlated with each other (r = 0.52).

From Table 4, we represented that noise parameters measurements on different times at 60, 180, 300, and 480 min (8 h) exposure levels that would be calculated using appropriate averaging equations. Over metal site 4, the L_{avg} were 17.32, 20.47, 21.93 and 23.28 dBA difference from L_{eq} at different time measurements from 60 min to 480 min <L_{eq}, while L_{max} was around 4.11 dBA higher than L_{eq} at different time measurements and 21.43, 24.58, 26.04 and 27.39 dBA difference from L_{avg} at each time intervals respectively, the exposure variability ratio metrics L_{eq}/L_{avg} was much higher at 480 min interval, as might be expected given the nature of their work. L_{max}/L_{eq} was around 1.05 for most time intervals. Among the highest ratio metrics, 1.39 for L_{eq}/L_{avg} and 1.05 L_{max}/L_{eq} at 480min, respectively.

The mean L_{avg} was 59.48 dBA and the average L_{eq} was 82.76 dBA at 8 h. There was relatively higher difference in mean levels between two parameters. Metal site 4 in this trade was a highly significant predictor for all six metrics in Differences in average metrics between each matrix at time interval 8 h were relatively small with the relationship between the L_{max}/L_{eq} and L_{eq}/L_{avg} at 8h.

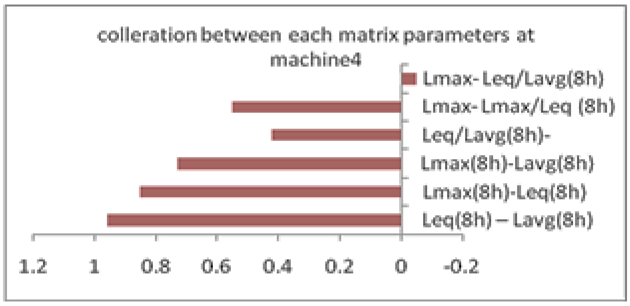

Figure 4. Relationship between each matrix in at metal site 4 at 480 min interval

From figure 4 show that highly correlated L_{eq} (8h)–L_{avg} (8h) (r = 0.96) and L_{max} (8h)-L_{eq} (8h) was well correlated with (r = 0.86) and somewhat less well with L_{avg} (r = 0.74). Middle correlated L_{eq}/L_{avg} (8h)-L_{max}/L_{eq} (8h) (r= 0.42) the ratio metrics were poorly correlated with L_{max}- L_{eq}/L_{avg} (8h) (r= -0.05) and only slightly correlated with each other (r = 0.55).

From Table (5, 6, and 7), We represented that noise parameters measurements on different times at 60, 180, 300, and 480 min (8 h) exposure levels that would be calculated using appropriate averaging equations. the L_{avg} were been given the same values in the previous tables difference from L_{eq} at different time measurements from 60 min to 480 min < L_{eq}, while L_{max} was higher than L_{eq} at different time measurements difference from L_{avg} at each time intervals respectively, the exposure variability ratio metrics L_{eq}/L_{avg} was much higher at 480 min interval, as might be expected given the nature of their work. L_{max}/L_{eq} was around 1.13 for most time intervals. Among the highest ratio metrics, for L_{eq}/L_{avg} and L_{max}/L_{eq} at 480min, respectively.

The mean L_{avg} and the average L_{eq} were higher values at 8 h. There was relatively higher difference in mean levels between two parameters.

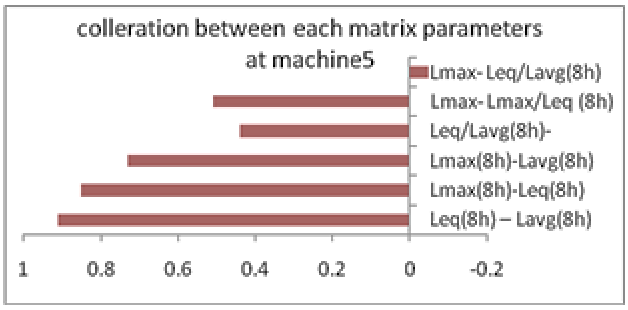

Figure 5. Relationship between each matrix in at metal site 5 at 480 min interval

Metal site 5, 6, and 7 in this trade was a highly significant predictor for all six metrics in Differences in average metrics between each matrix at time interval 8 h were relatively small with the relationship between the L_{max}/L_{eq} and L_{eq}/L_{avg} at 8h.

From figure 5 show that highly correlated L_{eq} (8h)–L_{avg} (8h) (r = 0.91) and L_{max} (8h)-L_{eq} (8h) was well correlated with (r = 0.85) and somewhat less well with L_{avg} (r = 0.73). Middle correlated L_{eq}/L_{avg} (8h)-L_{max}/L_{eq} (8h) (r= 0.44) the ratio metrics were poorly correlated with L_{max}- L_{eq}/L_{avg} (8h) (r= -0.05) and only slightly correlated with each other (r = 0.51).

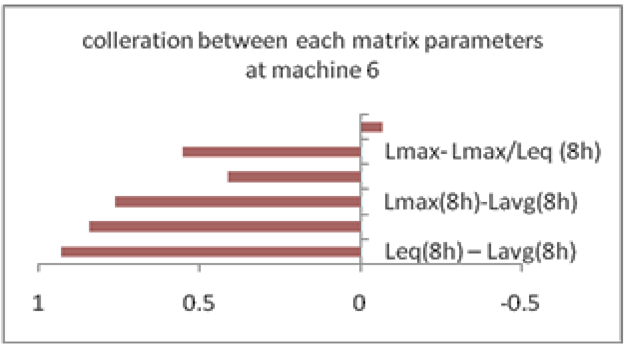

Figure 6. Relationship between each matrix in at metal site 6 at 480 min interval

From figure 6 show that highly correlated L_{eq} (8h)–L_{avg} (8h) (r = 0.93) and L_{max} (8h)-L_{eq} (8h) was well correlated with (r = 0.84) and somewhat less well with L_{avg} (r = 0.76). Middle correlated L_{eq}/L_{avg} (8h)-L_{max}/L_{eq} (8h) (r= 0.41) the ratio metrics were poorly correlated with L_{max}- L_{eq}/L_{avg} (8h) (r= -0.07) and only slightly correlated with each other (r = 0.55).

From figure 7 show that highly correlated L_{eq}(8h)–L_{avg}(8h) (r = 0.95) and L_{max}(8h)-L_{eq}(8h) was well correlated with (r = 0.85) and somewhat less well with L_{avg} (r = 0.73), middle correlated L_{eq}/L_{avg}(8h)-L_{max}/L_{eq}(8h) (r= 0.42). The ratio metrics were poorly correlated with L_{max}- L_{eq}/L_{avg}(8h) (r= -0.07) and only slightly correlated with each other (r = 0.52).

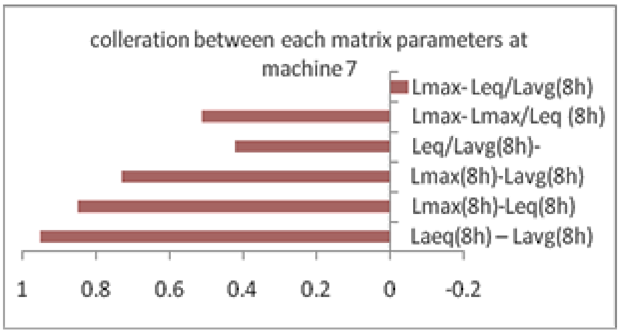

Figure 7. Relationship between each matrix in at metal site 7 at 480 min interval

From figure 8 show that highly correlated L_{eq}(8h)–L_{avg}(8h) (r = 0.92) and L_{max}(8h)-L_{eq}(8h) was well correlated with (r = 0.85) and somewhat less well with L_{avg} (r = 0.73), middle correlated Leq/Lavg(8h)-L_{max}/L_{eq}(8h) (r= 0.45). The ratio metrics were poorly correlated with Lmax- Leq/Lavg(8h) (r= -0.05) and only slightly correlated with each other (r = 0.55).

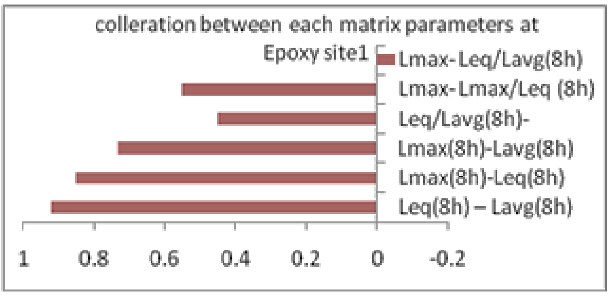

Figure 8. Relationship between each matrix in at Epoxy site 1 at 480 min interval

In epoxy site (Tables 8 and 9) can be represented for noise exposure of different noise matrix parameters on two different positions during different minutes, 60.180.300 and 480 min (8 h), the data were measured in two different positions with different activities.

Table 8. Noise matrix parameters at different time shift in Epoxy site 1 [mean (SD)].

n (min)	L_{eq} (SD)	L_{avg} (SD)	L_{max}(SD)	L_{min} (SD)	L_{eq}/L_{avg} (SD)	L_{max}/L_{eq}(SD)
60	77.01 (2.15)	59.74 (0.78)	81.71 (3.01)	72.95 (2.65)	1.29 (2.80)	1.06 (2.93)
180	72.23 (3.03)	51.82 (0.73)	76.93 (4.02)	68.17 (2.59)	1.39 (2.34)	1.07 (3.94)
300	70.01 (2.15)	48.14 (1.34)	74.71 (5.01)	65.95 (2.15)	1.45 (2.0)	1.07 (3.47)
480	67.97 (3.64)	44.75 (1.66)	72.71 (5.51)	63.91 (2.32)	1.52 (2.02)	1.07 (5.90)

From Table 9, we represented that noise parameters measurements on different times at 60, 180, 300, and 480 min (8 h) exposure levels that would be calculated using appropriate averaging equations. Over Epoxy site2, the L_{avg} were 17.24, 20.48, 21.86 and 23.20 dBA difference from L_{eq} at different time measurements from 60 min to 480 min $<L_{eq}$, while L_{max} was around 0.42 dBA slightly higher than L_{eq} at different time measurements 17.66, 20.81, 22.28 and 23.63 dBA difference from L_{avg} at each time intervals respectively, the exposure variability ratio metrics L_{eq}/L_{avg} was much higher at 480 min interval, as might be expected given the nature of their work. L_{max}/L_{eq} was around 1.01 for most time intervals. Among the highest ratio metrics, 1.56 for L_{eq}/L_{avg} and 1.01 L_{max}/L_{eq} at 480min, respectively.

The mean L_{avg} was 41.12 dBA and the average Leq was 64.32 dBA at 8 h. There was relatively higher difference in mean levels between two parameters.

From figure 9 show that highly correlated L_{eq}(8h)–L_{avg}(8h) (r = 0.93) and L_{max}(8h)-L_{eq}(8h) was well correlated with (r = 0.86) and somewhat less well with L_{avg} (r = 0.74), middle correlated L_{eq}/L_{avg}(8h)-L_{max}/L_{eq}(8h) (r= 0.45). The ratio metrics were poorly correlated with L_{max}- L_{eq}/L_{avg}(8h) (r= -0.05) and only slightly correlated with each other (r = 0.55).

Table 9. Noise matrix parameters at different time shift in Epoxy site 2 [mean (SD)].

n (min)	Leq (SD)	Lavg (SD)	Lmax (SD)	Lmin (SD)	Leq/Lavg (SD)	Lmax/Leq (SD)
60	73.36 (3.12)	56.12 (0.14)	73.78 (3.46)	72.90 (2.31)	1.31 (0.17)	1.01 (0.96)
180	68.58 (3.01)	48.20 (0.14)	69.01 (3.35)	68.13 (2.56)	1.42 (0.39)	1.01 (0.52)
300	66.37 (2.46)	44.51 (0.13)	66.79 (3.12)	65.91 (2.55)	1.49 (0.86)	1.01 (3.64)
480	64.32 (2.44)	41.12 (0.16)	64.75 (3.21)	63.87 (2.46)	1.56 (1.28)	1.01 (1.95)

In cutting site (Tables 10, 11, 12, 13 and 14) can be represented for noise exposure of different average noise matrix parameters on five machines during different minutes, 60.180.300 and 480 min (8 h), the data were measured at different activities.

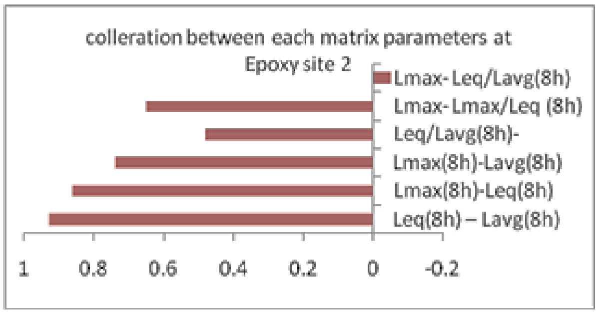

Figure 9. Relationship between each matrix in at Epoxy site 2 at 480 min interval

Table10. Noise matrix parameters at different time shift in cutting site at weighting lifting machine [mean (SD)].

n (min)	Leq (SD)	Lavg (SD)	Lmax (SD)	Lmin (SD)	Leq/Lavg (SD)	Lmax/Leq (SD)
60	86.17 (0.58)	68.87 (0.63)	87.05 (0.63)	86.17 (0.84)	1.25 (0.9)	1.01 (1.09)
180	81.40 (0.59)	60.95 (0.65)	82.8 (0.64)	81.40 (0.78)	1.34 (0.91)	1.01 (1.09)
300	79.18 (0.6)	57.26 (.054)	80.06 (0.58)	79.18 (0.79)	1.38 (1.11)	1.01 (0.17)
480	77.14 (0.61)	53.88 (0.63)	78.02 (0.68)	77.14 (0.8)	1.43 (0.97)	1.01 (1.11)

Table11. Noise matrix parameters at different time shift in cutting site at whipping machine [mean SD)].

n (min)	Leq (SD)	Lavg (SD)	Lmax(SD)	Lmin (SD)	Leq/Lavg (SD)	Lmax/Leq (SD)
60	88.29 (2.0)	70.98 (0.28)	89.28 (2.12)	88.28 (2.0)	1.14 (7.13)	1.01 (1.01)
180	83.52 (1.83)	63.06 (0.27)	84.51 (2.13)	83.50 (1.98)	1.32 (6.87)	1.01 (1.01)
300	81.30 (1.84)	59.38 (0.26)	82.29 (2.2)	81.29 (1.195)	1/37 (6.95)	1.01 (1.01)
480	79.26 (1.81)	55.99 (0.26	80.25 (2.12)	79.24 (1.87)	1.42 (6.89)	1.01 (1.01)

From Table 10, we represented that noise parameters measurements on different times at 60, 180, 300, and 480 min (8 h) exposure levels that would be calculated using appropriate averaging equations.

In Weighting lifting machine, the L_{avg} were 17.3, 20.45, 21.92 and 23.26 dBA difference from L_{eq} at different time measurements from 60 min to 480 min <L_{eq}, while L_{max} were around 1.4 and 0.88 dBA slightly higher than L_{eq} at different time measurements 18.18, 21.85, 22.8 and 24.14 dBA difference from L_{avg} at each time intervals respectively, the exposure variability ratio metrics L_{eq}/L_{avg} was much higher at 480 min interval, as might be expected given the nature of their work. L_{max}/L_{eq} was around 1.01 for most time intervals. Among the highest ratio metrics, 1.43 for L_{eq}/L_{avg} and 1.01 L_{max}/L_{eq} at 480min, respectively.

The mean L_{avg} was 53.88 dBA and the average Leq was 77.14 dBA at 8 h. There was relatively higher difference in mean levels between two parameters.

Table12. Noise matrix parameters at different time shift in cutting site at lathe machine [mean (SD)].

n (min)	Leq (SD)	Lavg (SD)	Lmax (SD)	Lmin (SD)	Leq/Lavg (SD)	Lmax/Leq (SD)
60	91.42 (0.2)	74.10 (0.33)	92.12 (0.08)	90.84 (0.13)	1.23 (0.07)	1.01 (0.13)
180	86.65 (0.1)	66.18 (0.54)	87.35 (0.09)	86.07 (0.11)	1.31 (0.12)	1.01 (0.13)
300	84.43 (0.09)	62.50 (0.21)	85.13 (0.09)	83.85 (0.15)	1.35 (0.11)	1.01 (0.13)
480	82.39 (0.02)	59.11 (0.17)	83.09 (1.01)	81.81 (0.14)	1.39 (0.06)	1.01 (0.13)

Table13. Noise matrix parameters at different time shift in cutting site at Forging machine [mean SD)].

n (min)	Leq (SD)	Lavg (SD)	Lmax (SD)	Lmin (SD)	Leq/Lavg (SD)	Lmax/Leq (SD)
60	91.72 (0.16)	74.40 (0.47)	92.29 (0.17)	91.19 (0.16)	1.23 (0.28)	1.01 (0.37)
180	86.95 (0.15)	66.48 (0.66)	87.52 (0.16)	86.42 (0.15)	1.31 (0.64)	1.01 (0.32)
300	84.74 (0.12)	62.80 (0.93)	85.30 (0.18)	84.20 (0.16)	1.35 (0.64)	1.01 (0.76)
480	82.69 (0.15)	59.41 (0.66)	83.26 (0.15)	82.16 (0.15)	1.39 (1.06)	1.01 (0.59)

Table14. Noise matrix parameters at different time shift in cutting site at Cutting machine [mean (SD)].

n (min)	Leq (SD)	Lavg (SD)	Lmax (SD)	Lmin (SD)	Leq/Lavg (SD)	Lmax/Leq (SD)
60	91.64 (0.35)	74.32 (2.52)	92.17 (0.37)	91.18 (0.37)	1.23 (1.48)	1.01 (0.64)
180	86.87 (0.23)	66.40 (2.15)	87.39 (0.31)	86.41 (0.33)	1.31 (2.08)	1.01 (0.57)
300	84.65 (0.25)	62.72 (3.17)	85.18 (0.25)	84.19 (0.31)	1.35 (1.67)	1.01 (0.49)
480	82.61 (0.24)	59.33 (1.38)	83.13 (0.24)	82.15 (0.30)	1.39 (1.33)	1.01 (0.52)

From figure 10 show that highly correlated $L_{eq}(8h)$–$L_{avg}(8h)$ (r = 0.97) and $L_{max}(8h)$-$L_{eq}(8h)$ was well correlated with (r = 0.89) and somewhat less well with L_{avg} (r = 0.78), middle correlated $L_{eq}/L_{avg}(8h)$-$L_{max}/L_{eq}(8h)$ (r= 0.45). The ratio metrics were poorly correlated with L_{max}- $L_{eq}/L_{avg}(8h)$ (r= -0.04) and only slightly correlated with each other (r = 0.56).

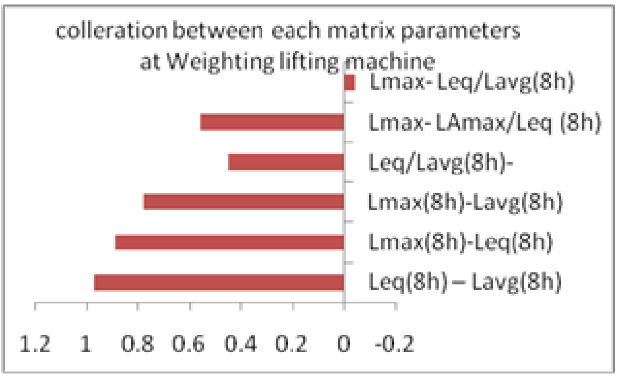

Figure 10. Relationship between each matrix in at weighting lifting machine at 480 min interval

From Table 11, we represented that noise parameters measurements on different times at 60, 180, 300, and 480 min (8 h) exposure levels that would be calculated using appropriate averaging equations. In Weighting lifting machine, the L_{avg} were 17.31, 20.46, 21.92 and 23.27 dBA difference from L_{eq} at different time measurements from 60 min to 480 min <L_{eq}, while L_{max} was around 0.99 dBA slightly higher than L_{eq} at different time measurements 18.18, 21.85, 22.8 and 24.14 dBA difference from L_{avg} at each time intervals respectively, the exposure variability ratio metrics L_{eq}/L_{avg} was much higher at 480 min interval, as might be expected given the nature of their work. L_{max}/L_{eq} was around 1.01 for most time intervals. Among the highest ratio metrics, 1.42 for L_{eq}/L_{avg} and 1.01 L_{max}/L_{eq} at 480min, respectively.

The mean L_{avg} was 55.99 dBA and the average L_{eq} was 79.26 dBA at 8 h. There was relatively higher difference in mean levels between two parameters

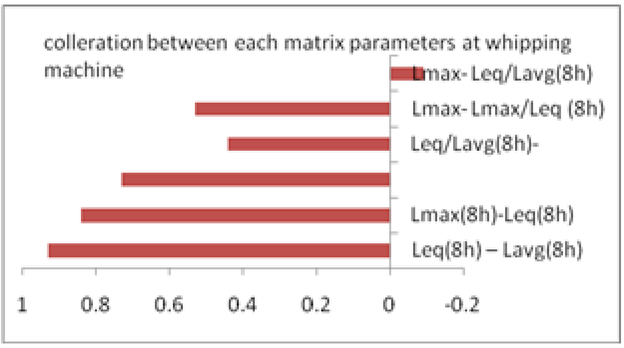

Figure 11. Relationship between each matrix in at whipping machine at 480 min interval

From figure 11 show that highly correlated $L_{eq}(8h)$–$L_{avg}(8h)$ (r = 0.93) and $L_{max}(8h)$-$L_{eq}(8h)$ was well correlated with (r = 0.84) and somewhat less well with L_{avg} (r = 0.73), middle correlated $L_{eq}/L_{avg}(8h)$-$L_{max}/L_{eq}(8h)$ (r= 0.44). The ratio metrics were poorly correlated with L_{max}- $L_{eq}/L_{avg}(8h)$ (r= -0.09) and only slightly correlated with each other (r = 0.53).

From Table (12, 13 and 14), we represented that noise parameters measurements on different times at 60, 180, 300, and 480 min (8 h) exposure levels that would be calculated using appropriate averaging equations. That can give the same result as in the previous tables in 10, 11 the L_{avg} were have been given values difference from L_{eq} at different time measurements from 60 min to 480 min <L_{eq}, while L_{max} was slightly higher than L_{eq} at different time measurements at each time intervals respectively, the exposure variability ratio metrics L_{eq}/L_{avg} was much higher at 480 min interval, as might be expected given the nature of their work. L_{max}/L_{eq} was around 1.01 for most time intervals. Among the highest ratio metrics, for L_{eq}/L_{avg} and Lmax/L_{eq} at 480min, respectively.

The mean L_{avg} was and the average L_{eq} were higher values at 8 h. There was relatively higher difference in mean levels between two parameters

From figure 12 show that highly correlated L_{eq}(8h)–L_{avg}(8h) (r = 0.93) and L_{max}(8h)-L_{eq}(8h) was well correlated with (r = 0.84) and somewhat less well with L_{avg} (r = 0.73), middle correlated L_{eq}/L_{avg}(8h)-L_{max}/L_{eq}(8h) (r= 0.42). The ratio metrics were poorly correlated with L_{max}- L_{eq}/L_{avg}(8h) (r= -0.09) and only slightly correlated with each other (r = 0.50).

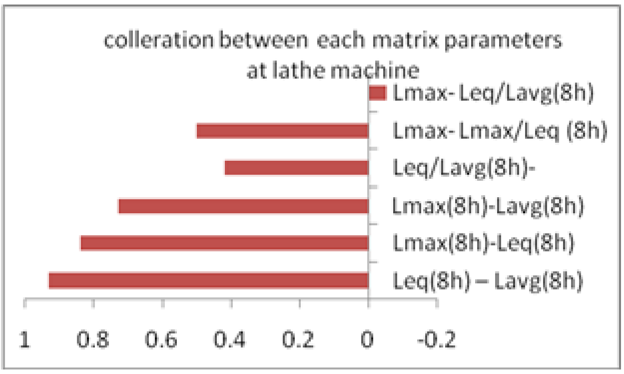

Figure 12. Relationship between each matrix in at Lathe machine at 480 min interval

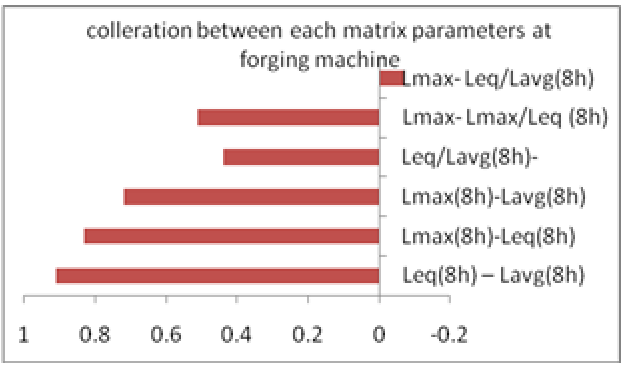

Figure 13. Relationship between each matrix in at forging machine at 480 min interval

From figure 13 show that highly correlated L_{eq}(8h)–L_{avg}(8h) (r = 0.93) and L_{max}(8h)-L_{eq}(8h) was well correlated with (r = 0.84) and somewhat less well with L_{avg} (r = 0.71), middle correlated L_{eq}/L_{avg}(8h)-L_{max}/L_{eq}(8h) (r= 0.42). The ratio metrics were poorly correlated with L_{max}- L_{eq}/L_{avg}(8h) (r= -0.07) and only slightly correlated with each other (r = 0.52).

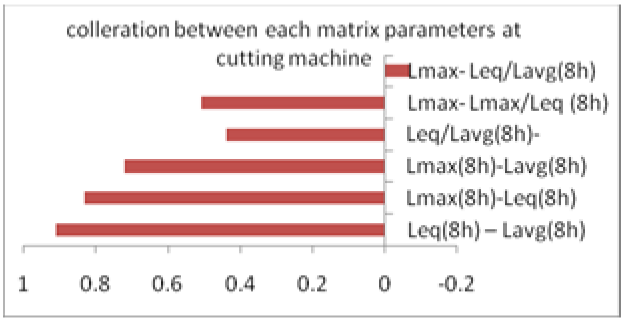

Figure 14: Relationship between each matrix in at cutting machine at 480 min interval

From figure 14 show that highly correlated L_{eq}(8h)–L_{avg}(8h) (r = 0.91) and L_{max}(8h)-L_{eq}(8h) was well correlated with (r = 0.83) and somewhat less well with L_{avg} (r = 0.72), middle correlated L_{eq}/L_{avg}(8h)-L_{max}/L_{eq}(8h) (r= 0.44). The ratio metrics were poorly correlated with L_{max}- L_{eq}/L_{avg}(8h) (r= -0.07) and only slightly correlated with each other (r = 0.51).

4. DISCUSSION

In the present analysis, several sources of data were utilized to estimate occupational noise exposure. The exposure estimates were based primarily on the reported experience of a group of 266 occupational activities with known potential for high noise exposure in Electrical factory.

The present data are similar to noise exposure levels of construction workers are typically in the range 85–90 dBA L_{eq}, as has been reported elsewhere [19, 20, 21 and 22]. In present data measurement L_{eq} such as in metal site and cutting side especially at high risk at 4800 min (8 h) exposure to workers in Electrical site

Summarizing exposure over time to capture the important characteristics associated with risk continues to constitute a challenging area of occupational exposure assessment and epidemiology. Even in the area of noise-induced hearing loss, in which basic exposure–response relationships for steady-state noise have been known for many years, and in which the importance of peak exposures is increasingly recognized, a summary metric for characterizing risk has not been adequately demonstrated. In this analysis, we have taken advantage of a large and well-documented dataset of integrated sound level meter measurements in the Electrical industry—an industry with high and extremely variable exposures—to explore relations between various exposure metrics**.** During exploration of the extensive accumulated dataset, numerous problems were identified, and the apparently erroneous data were either discarded or adjusted to conform to expected relationships. Two standard measures of average exposure level, the L_{eq}

and L_{avg}, were compared. Previous studies in construction [20], trucking [23] and fixed industry with variable noise levels [24] have shown average differences in mean L_{avg} and L_{eq} levels of over 6 dBA, but in present data are very higher over 17.0 dB at different time interval.

The fraction of the monitored population with exposures >85 dBA was also substantially increased using the L_{eq} metric in these previous studies. The primary difference between L_{eq} and L_{avg} is the exchange rate of 3 and 5 dB, respectively. Reviews of the literature on exchange rates generally indicate that although some hearing damage recovery may occur during intermittent quiet periods, there is no adequate scientific basis for the use of a 5 dB ER [25, 12 and 26]. While the 3 dB ER may be over-protective under some circumstances, the 5 dB ER will often underestimate risk. Nevertheless, the US OSHA continues to use a 5 dB ER and has rejected addressing this important issue in recent rulemaking proceedings for the construction industry [27]. In the current analysis, large differences in the absolute levels of L_{avg} and L_{eq} were observed; however, the two metrics were very highly correlated (r > 0.9). As a result, use of the L_{eq} or L_{avg} in an epidemiologic study should make very little difference in the slope of the exposure–response relationship although the risk at any particular exposure magnitude would be substantially different using one measure or the other.

In adopting a standard based on one metric, the data used to set the standard must be based on the same metric—especially when applied to industries with variable noise patterns. While the L_{eq} integrates short-term high levels on an equal energy basis, animal studies have demonstrated that peak levels above a 'critical level' of 120–135 dB [28, 29, 13, and 14] produce more damage than expected using the EEH. This critical level, which is not well established in humans, marks the transition from metabolic to direct mechanical damage to the hearing mechanism [30, 15].

Electrical workers are regularly exposed to peak noise levels <120 dB; in comparison the analysis of a subset of these data, with an average of 18 min per shift included peaks >140 dB [20]. Even if the L_{eq} underestimates the damage risk from high-level noise exposures, and needs augmentation with a peak metric, it is still more protective than the L_{avg} used by OSHA for all exposure scenarios.

Although peak exposures are common in some work settings, and exposure to impulse noise may be more damaging than longer exposure to lower level sounds of the same total energy, methods of integrating peak characteristics into exposure metrics for epidemiologic purposes have not been demonstrated.

Noise peaks are defined in terms of their amplitude, duration, and rise time, number of impulses and repetition rate, each of which affects the risk of hearing damage [31].

Existing exposure standards almost uniformly specify a peak limit of 140 dB, but the scientific evidence supporting this choice of levels is scant [12] and peak limits based solely on amplitude may be inadequate [32, 33]. Two models of hearing risk associated with peak noise exposures have been suggested. Price's Auditory Hazard Assessment Algorithm for the Human ear (AHAAH) is a mathematical model of the ear that incorporates spectral, amplitude and duration data into the exposure evaluation process and that has been validated for human exposures >130 dB [34]. Time or frequency domain kurtosis (the ratio of fourth moment to the second moment squared) Erdreich [35] has been used as a predictor of the magnitude and frequency distribution of noise induced hearing damage in animal models [36]. Kurtosis is attractive as an exposure metric because it represents a unified measure of the 'peakiness' of the distribution of a noise signal.

Despite the apparent utility of these two peak exposure models, however, both are currently most applicable to short term exposures—i.e. single gun shots or laboratory created exposure patterns—and require high-speed digital sampling. Their use in assessing long-term real-world occupational exposures is therefore limited. L_{max} was expected to address the 'peakiness' in the data, it was very highly correlated with L_{avg} and L_{eq} L_{avg} relationship (r of 0.91 and 0.88, respectively) and L_{max} is correlated with the ratio metrics.

Although this result was somewhat unexpected, it can be explained by the fact that the all three metrics are largely driven by the higher end of the exposure distribution due to exponential averaging [e.g. equation (1)]. To address the shortcomings of simple average metrics in a variable noise environment, two novel exposure metrics were derived. L_{eq}/L_{avg} was designed to address slightly variability over time by exploiting the difference between levels measured using the 3 and 5 dB exchange rates. L_{max}/L_{eq} also addresses without any variability at different time interval. While the two metrics are defined similarly, they appear to capture different information as they are poorly correlated with each other and uncorrelated with the average ratio metrics at 480min.

Most of Trade/tasks with smallest $L_{max}/L_{eq}$are generally those with high exposure to impact-type noise, i.e. in trade of cutting site at 60 min time interval that can give at L_{max} around 92.12 such as lathe, forging and cutting machines. Trade tasks with the highest levels of L_{eq}/L_{avg} are those which typically have highly ratio value at 480 min time interval at all of trade's sites with low exposures of L_{eq} at 8 hours due to big difference between L_{eq} and L_{avg} exposure levels**.** In order to assign exposure levels to subjects within an occupational cohort, exposure levels must be linked to the subjects' work histories via some intermediate variable. Linkage is commonly made using job title, as with a job exposure matrix [37].

More recently, exposures have been modeled based on a set of exposure determinants (i.e. job, factory, production rate) and linked via these same determinants in the work history [38]. A third approach, task-based exposure assessment, refines the job-based approach to capture the variability associated with varying distribution of time spent in individual tasks even by subjects within the same job title**.**

The approach has shown more promise when used to target high-hazard noise sources for exposure reduction efforts [39]. These three approaches were tested in the current dataset by splitting the data into model development and validation subsets, developing estimates in the training dataset and comparing these with the observed values in the validation subset.

The results are most graphically demonstrated in all trade at 480 min. The model of relationship between L_{eq} and L_{avg} are highly correlation, while L_{max} versus ration of L_{eq}/L_{avg} are very poor. While the metrics that described average exposure levels (L_{avg}, L_{eq}, L_{max}) were constructed so that they would decrease with longer periods of time, the variability metrics (L_{eq}/L_{avg}, L_{max}/L_{eq}) were calculated as simple averages. As a result, exposure response modeling could incorporate one of each type of metric—one to express exposure intensity and one to adjust for variability**.**

5. CONCLUSIONS

In this paper can be estimated correlation between the exposure metric used in Electrical site and the true, underlying metric. In our setting, assuming L_{eq} was the correct metric, very little attenuation would be expected by the use of L_{avg}, or even L_{max}.

On the other hand, if variability and peakiness are strong predictors of damage, beyond that associated with the average level, and then these considerably alter the observed relation between noise exposure and hearing damage within interval time of exposure.

The importance of this values of noise metrics result in application, such as the affect on the hearing conservation program for employees will be redefined and controls will be prescribed for employees by job title and for equipment operation level / process by task according to OSHA regulation that depend on values estimation as described before.

In addition, employee training will be updated to include noise awareness and perceptions, hearing protector fit and the importance of wearing hearing protection at all times necessary

REFERENCES

[1] Arezes, P. M., & Miguel, A. S. Hearing protection use in industry: The role of risk perception., *Safety Science, 43*(4), (2005), 253-267.

[2] CDC. NOISE AND HEARING LOSS PREVENTION. Retrieved January 06, 2016, from http://www.cdc.gov/niosh/topics/noise/stats.html (2015).

[3] Dunn, DE. Noise. In: Levy, BS. & Wegman, DH. Eds. Occupational Health: Recognizing and preventing work related disease and injury 4th Edition. Philadelphia: Lippincott Williams & Wilkins; (2000), P. 367-377.

[4] May, J. Occupational Hearing Loss. *American Journal of Industrial Medicine, 37*, 112-120 (2000).

[5] Aybek, A., Kamer, H. A., & Arslan, S. Personal noise exposures of operators of agricultural tractors. *Applied Ergonomics, 41*(2), (2010), 274-281.

[6] Fernandez, M. D., Quintana, S., Chavarria, N., & Ballesteros, J. A. Noise exposure of works of the construction sector. *Applied Acoustics, 70*, (2009), 753-760.

[7] Masterson, E. A., Themann, C. L., Luckhaupt, S. E., Li, J., & Calvert, G. M. Hearing difficulty and tinnitus among U.S. workers and non-workers in 2007. *Am. J. Ind. Med*. (2016).

[8] Ljungberg, J. K., & Neely, G. Stress, subjective experience and cognitive performance during exposure to noise and vibration. *Journal of Environmental Psychology, 27*(1), (2007), 44-54.

[9] Atherley GR, Martin AM. Equivalent-continuous noise level as a measure of injury from impact and impulse noise. *Ann Occup Hyg; 14*: (1971),11–23.

[10] Dancer A, Buck K, Parmentier G. et al. The specific problems of noise in military life. *Scand Audiol Suppl; 48*: (1998), 123–30.

[11] OSHA. Occupational noise exposure: hearing conservation amendment; final rule. Fed Reg. Washington, DC, US Department of Labor, Occupational Safety and Health Administration. 48: (1983), 738–85.

[12] NIOSH. Criteria for a recommended standard: occupational noise exposure. Cincinnati, OH: US Department of Health and Human Services/Centers for Disease Control, National Institute for Occupational Safety and Health (1998).

[13] Henderson D, Spongr V, Subramaniam M et al. Anatomical effects of impact noise. *Hear Res; 76*: (1994), 101–17.

[14] Levine S, Hofstetter P, Zheng XY et al. Duration and peak level as co-factors in hearing loss from exposure to impact noise. *Scand Audiol Suppl; 48*: (1998), 27–36.

[15] Lataye R, Campo P. Applicability of the L_{eq} as a damage-risk criterion: an animal experiment. *J. Acoust. Soc. Am.; 99*: (1996), 1621–32.

[16] Seixas N., Neitzel R., Sheppard L., Goldman B., Alternative Metrix for Noise Exposure Among Construction Workers, *Ann.Occup. Hyg*., Vol. 49, No. 6, PP. 493-502.

[17] ISO 9612 Acoustics- Determination of occupational noise exposure engineering method. International Standard, Second edition. Switzerland, (2009).

[18] Earshen J. Sound measurement: instrumentation and noise descriptors. In Berger E, Royster L, Royster J, Driscoll D, Layne M, editors. The noise manual. Fairfax, VA: *American Industrial Hygiene Association* (2000).

[19] Legris M, Poulin P. Noise exposure profile among heavy equipment operators, associated laborers, and crane operators. *Am Ind Hyg Assoc J; 59*: (1998), 774–8.
[20] Neitzel R, Seixas NS, Camp J, Yost M. An assessment of occupational noise exposures in four construction trades. *Am Ind Hyg Assoc J; 60*: (1999), 807–17.
[21] Seixas NS, Ren K, Neitzel R, Camp J, Yost M. Noise exposure among construction electricians. *Am Ind Hyg Assoc J; 62*: (2001), 615–21.
[22] Kerr M, Brosseau L, Johnson CS. Noise levels of selected construction tasks. *Am Ind Hyg Assoc J; 63*: (2002), 334–9.
[23] Seshagiri B. Occupational noise exposure of operators of heavy trucks. *Am Ind Hyg Assoc J; 59*: (1998), 205–13.
[24] Sriwattanatamma P, Breysse P. Comparison of NIOSH noise criteria and OSHA hearing conservation criteria. *Am J Ind Med; 37*: (2000), 334–8.
[25] Suter A.H. The relationship of the exchange rate to noise-induced hearing loss. Cincinnati, OH: Alice Suter and Associates (1992).
[26] ACGIH. 2001–2002 threshold limit values for chemical substances and physical agents and biological exposure indices (BEIs): noise. Cincinnati, OH: American Conference of Governmental Industrial Hygienists, (2001).
[27] OSHA Advance notice of proposed rulemaking: hearing conservation program for construction workers. Fed Reg 67. Washington, DC, US Department of Labor, Occupational Safety and Health Administration: 50610–8, (2002).
[28] Roberto M, Hamernik R, Salvi R Jet al. Impact noise and the equal energy hypothesis. *J Acoust Soc Am; 77:* (1985), 1514–20.
[29] Danielson R, Henderson D, Gartton MA et al. The importance of 'temporal pattern' in traumatic impulse noise exposures. *J Acoust Soc Am; 90*: (1991), 209–18.
[30] Price G. Implications of a critical level in the ear for assessment of noise hazard at high intensities. *J Acoust Soc Am; 69*: (1981),171–7.
[31] Henderson D., Hamernik R. P. Impulse noise: critical review. *J Acoust Soc Am; 80*: (1986), 569–84.
[32] McRobert H., Ward W.D. Damage-risk criteria: the trading relation between intensity and the number of non reverberant impulses. *J Acoust Soc Am; 53*: (1973), 1297–300.
[33] Eiber A. Mechanical modeling and dynamical behavior of the human middle ear. *Audiol Neurootol; 4*: (1999), 170–7.
[34] Price G. Auditory hazard units an index of risk from intense sounds. National Institute for Occupational Safety and health Practices Workshop: Impulsive Noise, Press. Cincinnati, OH (2003).
[35] Erdreich J. A distribution based definition of impulse noise. *J Acoust Soc Am; 79*: (1986), 990–8.
[36] Lei S-FA, Ahroon W, Hamernik R.P. et al. The application of frequency and time domain kurtosis to the assessment of hazardous noise exposures. *J Acoust Soc Am; 96*: (1994),1435–44.
[37] Goldberg M, Kromhout H, Guenel Pet al. Job exposure matrices in industry. *Int J. Epidemiol; 22(Suppl. 2)*: S10–S15 (1993).
[38] Burstyn I, Teschke K. studying the determinants of exposure: a review of the methods. *Am Ind Hyg Assoc J; 60*: (1999), 57–72.
[39] Stephenson M. Noise exposure characterization via task-based analysis. 23rdAnnual National Hearing Conservation Association conference, Cincinnati, OH. National Hearing Conservation Association (1995).