# STUDY OF OCCUPATIONAL HEALTH SAFETY IN STEEL RE-ROLLING MILL WITH REFERENCE TO HIGH NOISE LEVEL AND TEMPERATURE

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## ABSTRACT

*This study was conducted to assess the exposure to noise and temperature in a steel re- rolling mill. The measured noise and temperature values were then compared with international standards set by Occupational Safety and Health Administration (OSHA). Our results indicate that temperature level was high at two places of the mill i.e. furnace and re-rolling mill sections with the average value of 67 °C and 39°C respectively, which exceeds OSHA limit of 25-30 °C for comfortable working temperature. The average noise level at furnace section was satisfactory but that at the re-rolling mill was found to be 102 dB, whereas OSHA has set the limit to be 92 dB for 6 hours work shift. A pair-wise t-test indicated that the noise level at all factory zones was significantly different than that of administration section with a p-value < 0.0001. The re-rolling noise level was found to be extremely significant, followed by furnace and unloading section. Likewise the indoor factory heat level is also significant from outside air temperature. The interview survey revealed that the workers exposed to these chronic conditions in the factory are suffering from post work irritability, headache, fatigue, eye infection and heat exhaustion. It was therefore, recommended that the Pakistan Environmental Protection Agency (PEPA) should strictly implement and follow-up on the occupational safety laws, adopt shift rotation and ensure reduction in the length of exposure of each worker i.e. 1.5 to 2 hours instead of 6 hours work in these working conditions.*

**KEYWORDS:** *Noise, Occupational health & Safety, Shift rotation, Steel Mill Temperature, Shift rotation, Steel-Mill*

## INTRODUCTION

Occupational health and safety has been the subject of interest worldwide. To protect labor from industrial hazards, various safety guidelines have been set up worldwide. The famous one is Occupational Safety and Health Administration (OSHA). For body protection, appropriate clothing, glasses, boots etc are suggested. Similarly various devices such as ear plug and ear muff are used against unavoidable noise[1]. The loss of hearing is a common complaint about the exposed workers. Besides hearing loss, workers may exhibit sleep disturbance, annoyance, mental strain and cardiovascular disease[2],[3],[4].

As a standard safety procedure, working for 8 hours under normal noise levels of 85 dB is safe. The duration of occupational exposure should be reduced if the noise level exceeds the normal levels. For instance, at an exposure level of 88 dB, noise, the suggested guideline exposed duration is 4 hours. If that level reaches to 91 dB, the exposure time is reduced to 2 hours only[5].

Elevated temperature is another significant source of occupational health hazard which is often ignored. Workers in many industries are continuously exposed to high degrees of temperature which could impact their well-being and health. The increased in level of temperature has got negative effect on health and worker's efficiency[6]. In some industries (like textile mill), the workers don't face the twin problems of noise and elevated temperature. But in industries like steel mill, both noise and high-temperature pose occupational health risks. Their combined effect harms human body. The health risk of the exposed worker to the combined effect of heat and noise would be expected to be greater than exposure to any of these two attribute alone.

Response to heat of a human body varies from person to person. Normal body temperature is 37$^{o}$C. Ambient air temperature range from 20-26$^{o}$C is the most comfortable for a human being. Discomfort starts at above 36$^{o}$C. The body responses in the form of sweating, that leads to dehydration and regular intake of water is desirable[7].

The twin problems of chronic noise and heat exposure put workers in steel mill at health risk. There

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is also an element of discomfort and effect on workers' overall well being involved. Although working continuously under elevated levels of heat and noise is underestimated by the owners and regulatory agencies; it is undesirable, unsafe as well as hazardous. There is strong evidence on how exposure to noise and heat could affect human health. A health risk study conducted by Melamed and Bruhis[8] found that under conditions of chronic noise exposure at the end of the work shift the workers exhibited high levels of accumulated fatigue and post work irritability. Attenuating the noise reaching the eardrum by 30 to 33 dB, by fitting the same workers with earmuffs for a period of 7 working days, resulted in a significant improvement in both psychological and physiological stress reactions.

Although the Pakistan Environmental Protection Agency (PEPA) has become more effective due to recent decentralization from the federal government, the issue of occupational health and safety is often not well entertained. The strong hold of the industry in the country often leads to occupational health safety violations hence putting workers at risk. It is therefore a matter of serious environmental concern. The current study was, therefore, conducted to evaluate the exposure to noise and temperature conditions of the workers in a steel rerolling factory and record workers safety concerns so that suggestions could be made to the PEPA. Steel rolling mill was selected because it apparently does not contribute to any major environmental concern (e.g. chemical effluents or air emissions). That is probably one of the reasons why it is often ignored for its safety violations. Most of the workers in this factory belong to low income families for whom earning bread for their family is important at any cost.

## METHODS

Temperature and Noise measurements: Temperature was measure in degree Celsius ($^0$C) by using a Hygrotherm (Thermo/ Hydgro meter), Model No. TH03-China, with a temperature recording capability of 10 $^0$C to 60 $^0$C. Noise in dB was recorded using a sound level meter model Cole Parmer-USA, SL-4001. For both, temperature and noise level measurement, the factory was divided into six zones/sections (Figure 1).

For noise meter two modes were used i.e. Normal mode and Maximum hold mode. The former characteristic is simulated as "Human Ear Listing" response while the later mode stored the maximum value that occurs occasionally.

For workers health risk assessment from occupational noise and heat. In total there were 95 workers working in different zone of the mill, out of which 50% workers were interviewed through a structured questionnaire. The workers were selected through random sampling in each zone of the factory. The mill owners and management team members were also interviewed.

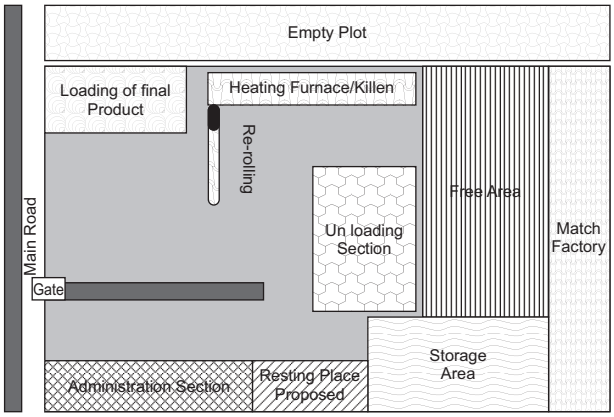


Figure 1: Layout of various zones in the Steel re-rolling mill

## DATA ANALYSIS

Data was analyzed using statistical analysis software. A paired t-test was performed for both the summer and winter ambient air pairing with factory temperature data. The mill noise at various zones was also compared with each other using a paired t-test. Linear regression analysis of the data was also done and correlation coefficient $R^2$ value was determined.

For temperature and heat data collection, six zones were identified in the steel mill. These zones included; the administration section, unloading section, furnace section, steel re-rolling mill section, storage section and loading section. All these locations are sketched in Figure. 1. Selected locations in each zone of the steel mill were visited numerous time for data collection. Readings were taken at 10 minute interval (for 8 hours) in duplicates at each zone separately. Each reading was recorded for 2 minutes duration. Noise was recorded at an approximate distance of 7.5 meters from the source.

A number of meetings were conducted with various stake holders of the factory, including the owner,

administrative staff and exposed workers. They were interviewed through a structured questionnaire. Interviews were conducted with the administration and other staff of the industry.

A questionnaire was also prepared to collect data regarding the adverse impacts of working in elevated temperature and noise conditions. The aim of those meetings and interviews was to record their concerns and viewpoints on the overall occupational safety as well as health hazard to the workers due to elevated noise and heat exposure.

## RESULTS AND DISCUSSION

### NOISE EXPOSURE LEVELS IN THE MILL

The average noise level in the mill ranged from 67.22 – 102.00 dB (with the lowest in the administration section and highest in the re-rolling section (Table 1). The administration section is comparatively comfortable with an average noise level of 67.22±4.45 dB. On normal mode noise level fluctuated between 58.20 - 71.10 dB. In the administration section the maximum hold reached up to 89.70 dB only for a short period of time. Overall working in the administration section was safe in terms of safety standards, as the noise level is within the tolerable limits (Table. 1).

**Table 1: Showing the recorded Noise level (dB) at different sections in the steel mill**

| Different Mill Sections | Detection Mode | Maximum | Minimum | Average | Standard Deviation |
|---|---|---|---|---|---|
| Administration | Maximum Hold | 89.70 | 72.10 | 82.42 | 6.11 |
| | Normal Mod | 71.10 | 58.20 | 67.22 | 4.45 |
| Unloading | Maximum Hold | 95.60 | 86.90 | 90.38 | 2.63 |
| | Normal Mod | 82.30 | 69.60 | 75.78 | 3.70 |
| Furnace | Maximum Hold | 98.30 | 85.30 | 94.95 | 4.33 |
| | Normal Mod | 84.10 | 71.00 | 75.85 | 3.42 |
| Re-rolling mill | Maximum Hold | 110.30 | 90.10 | 102.69 | 8.67 |
| | Normal Mod | 99.30 | 92.60 | 95.22 | 2.14 |
| Storage | Maximum Hold | 90.10 | 81.60 | 87.42 | 2.46 |
| | Normal Mod | 81.40 | 71.20 | 74.23 | 3.45 |
| Loading | Maximum Hold | 96.50 | 85.20 | 91.78 | 3.97 |
| | Normal Mod | 71.10 | 71.10 | 76.77 | 3.35 |

This was considered as yardstick in order to statistically compare with the noise in other zones. Pair-wise comparison was done, and the mean, standard error, and p-value were calculated by conducting a pair-wise t- test. The following pairs of data were compared; Admin-unloading, admin-loading, admin- storage, admin-furnace and admin- re-rolling (Table2). Results of the statistical analysis show that all the difference in each comparison is statistically significant at 95% confidence interval and at p value $\alpha = 0.05$. But a closer look at the data indicates that some differences are extremely significant, for instance the admin- re-rolling is very significant with a p value= $1.9E^{-09}$, predicting that the noise level at re-rolling zone is very high than the normal. Likewise the unloading and furnace section are also very significant (Table2).

**Table2: Statistical Analysis of the Noise and Temperature Levels measured in various zones of the factory**

| | Admin | storage | loading | furnace | unloading | Re-rolling |
|---|---|---|---|---|---|---|
| Mean | 67.21 | 74.23 | 76.76 | 75.85 | 75.77 | 95.21 |
| Standard Error | 19.76 | 11.88 | 11.21 | 11.69 | 13.70 | 4.57 |
| t Stat | | 7.53 | 4.53 | 6.56 | 7.08 | 22.01 |
| P-value at 95 % CI | | 0.00085 | 0.000040 | 0.000020 | 0.000011 | 1.90E-10 |

The second comfortable zone is the storage section. In this section the ingot and fuel are stored temporarily. Reading taken at maximum hold ranged between 81.60-90.10 dB with an average of 87.42±2.46 dB. While reading taken at normal mode ranged from 71.20-81.40 dB with an average of 74.23±3.45 (Table 1). This zone is noisy in comparison with the administration section and standard working hours of OSHA. Loading and unloading is an occasional activity of the mill. Therefore, workers in these section have enough intervals to take rest.

The furnace area is one of the busiest and noisiest places in the mill. The maximum hold reading recorded here range from 85.30 to 98.30 dB with an average of 94.95±4.33 dB. The maximum hold is occasional and affecting the workers temporally. Normal mode results range from 84.10 to 71.00 dB with an average of 75.85 ± 3.42 dB. This range seems comparatively comfortable but as temperature in this section is high and can affect worker negatively, as discussed in the subsequent section. Re-rolling section is the busiest section. The noise level started at 90.10 dB and reached up to 110.30 dB at maximum hold mode. At normal mode the noise level ranged from 92.30 to 99.30 dB with an average of 95.22±2.14 dB. As the ingot* is red-hot and can damage

* Ingot is a block of raw-iron, typically 0.5 to 1.0 meter long.

the workers, extreme precautionary measures are required. In this section the workers not only need safety measures but also needed to make their stay short.

The steel re-rolling area could be categorized as the nosiest place in the mill. The noise level recorded in the re-rolling zone exceeds the OSHA as well as Pakistan National Environmental Quality standards (Pak-NEQS). Moreover workers in the re-rolling and furnace sections of the mill seldom get break during their 8 hour shift. In steel re-rolling mill the workers sometime, observe a short break of 15 to 30 minutes for lunch and prayer have to work continuously and cautiously. By doing so, they increase their exposure level as well as duration to the elevated levels of noise and heat.

According to the OSHA a level of 90 dB should be considered the maximum limit for noise with continuous exposure over 8 hours[9]. Likewise, the permissible limit for noise set by Pakistan National Environmental Quality Standard is 85 dB with a distance of 7.5 meter from the source of noise[10]. In steel re-rolling section the workers are at a $\leq$ 0.5 meter distance to source. According to standards set by OSHA, a worker can be exposed to 92 dB for 2 hours of duty[11]. If OSHA guideline values were followed strictly, in steel re-rolling mill, the recommended continuous exposure time will be 2-4 hours. Sriwattanatamma and Breysse,[12] compared to the recommended noise level set by National Institute for Occupational Safety and Health (NIOSH) and the U.S. Occupational Safety and Health Administration (OSHA). According to them the standard of 90dB is not that effective and recommended the standard of 85 dB set by NIOSH[12].

The results from our interviews with the workers show that the workers are not in good shape of health.

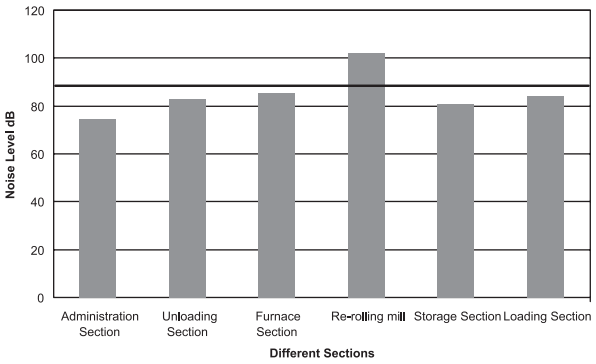


Figure. 2: Twelve hours noise level recorded at different zones of the Factory

A linear regression of the noise levels recorded at various sections of the factory verses the number of visits each worker makes to a hospital or a doctor resulted in a correlation coefficient of 0.6339. Given the fact that the heat in the furnace also contributes to the illness of the workers, this may be considered as a strong correlation (Figure. 3).

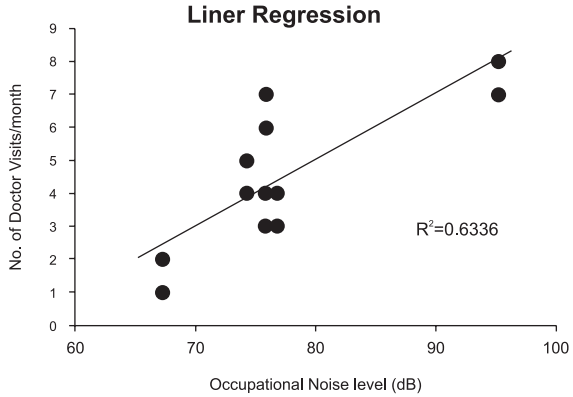


Figure 3: Correlation between occupational nose level and number of doctor's visits

## TEMPERATURE

Temperature ranged from 16°C to as high as 81°C in various sampled locations of the mill. The most comfortable working environment temperature according to OSHA is from 25°C to 30°C.The highest temperature of 56°C was recorded at the furnace section. Again, the furnace and re-rolling mill sections were critical areas where higher temperature values were recorded.

Temperature variations occur with change in season. The ambient air temperature in the surrounding of the mill range between 35-49 °C during summer months (May-Sept), whereas temperature of 21-26 $^{o}$C is usually recorded during the months of October-April (Figure. 4).

The heat inside the factory during winter and summer were pair-wise compared with the ambient air temperature recorded during summer and winter. The results showed a statistically significant difference at p value = 0.05, indicating that the factory temperatures remains high during summer and winter (Table 3).

**Table3: Statistical Analysis of the measured Air temperature in and outside of the factory**

| Group | Summer air temp | Summer indoor factory | Winter air temp | Winter indoor factory |
|---|---|---|---|---|
| Mean | 29.33 | 37.46 | 23.65 | 30.68 |
| SD | 9.96 | 10.27 | 11.31 | 12.45 |
| Standard Error of Means | 2.07 | 2.14 | 2.35 | 2.59 |
| T-value | 10.78 | | 16.86 | |
| p-value at 95 % CI | < 0.0001 | | < 0.0001 | |

The average daily ambient air temperature ranged between 14.0 – 40.4 °C and 5.0 – 35.5 °C in summer and winter respectively. The corresponding factory temperature ranges were 15.0 – 46 and 4 - 42.8 °C respectively for summer and winter. By comparing with the standard set by OSHA, 7.00 am to 9 am in summer and 1.00 am to 11.00 am in winter are comfortable (Figure. 4). In this way winter is comparatively comfortable for four hours only, while the working hours in summer are only 2.

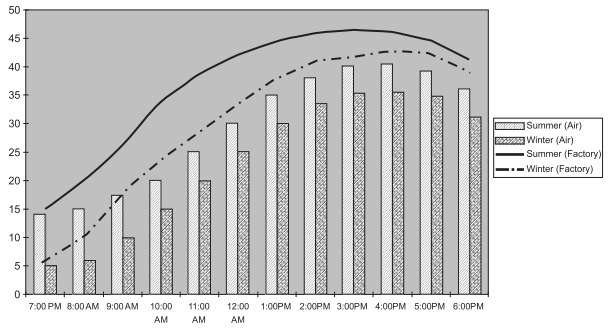


Figure. 4: Daily average temperature during duty hours

If the industry follows OSHA guidelines, the worker will work for two hours. In this way for eight hours shift the industry need to arrange four sub-shifts of two hours duration. This arrangement will add to the product cost. Another option is to rotate worker from noisy and hot area to other parts of the factory with less noise and temperature. In this way the factory will be running continuously with less input costs in terms of labor and minimum health hazard.

According to the interviews conducted with the administration and owners, if they follow the OSHA rules regulation, the mill will go in loss as they have to arrange a big number of workers with different shift ranging from 2-4 hours in summer and 4-6 hours in winter. This was discussed with workers also, and it was found out that, in summer they needed one hour rest after one hour work, while in winter the interval should be two hours. Another possibility explored during interview survey was that in summer they should be shifted to loading or storage section after one hour interval and in winter after two hours interval. In such situation they can resume their duty in furnace and re-rolling section after three hours in summer and two hours in winter. In this way they will work for two hours in furnace and re-rolling section and for 6 hours in other zones of the mill. While in winter, a worker will work for four hours in furnace and re-rolling section and four hours in other section of the mill.

## CONCLUSIONS

From the overall discussion, it is concluded that elevated noise and exposed heat conditions pose a cumulative negative effects on workers. Chronic occupational exposure to both heat and high noise level can badly affect the workers health.

The workers engaged in re-rolling and furnace sections are more prone to noise-induced hearing loss and thermal effects (due to prolonged stay) as compared to workers of other sections. It is recommended that there is a strong need to implement the standard of working hours as well as heat stress and noise control measures.

Strictly following OSHA regulations will mean that the owners/ management will have to take measures to ensure that a particular worker in the furnace and re-rolling section is exposed for not more than 2 hours. The workers who were interviewed were not happy with the chronic exposure to noise and heat. For owners on the other hand it's economically costly to decrease the work duration of the workers. There is a need to introduce certain preventive measures to the workers e.g. making it mandatory for each worker to wear ear plugs. These can be managed through workers rotation at different duty places. It is therefore recommended that government and industrial management should introduce separate guidelines/ standards for such industries having both, noise and temperature hazard for protecting health of the industrial workers against the elevated temperature and noise level exposure along with proper implementation.

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