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Measurement of Noise Levels: An Observational Study in Engineering Laboratories

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Abstract

The current study determines the sound levels observed in the engineering laboratories at the Institute of Chemical Engineering and Technology, University of the Punjab, Lahore, Pakistan. The objective of the study was to measure sound-levels of different engineering laboratories during specified time periods and compare them with OSHA standards. The sound-level parameters were investigated in five of the main laboratories. The time weighted average (TWA) and equivalent continuous sound level (L_{eq}) values were observed at different times and compared with the OSHA standards. The TWA in all the laboratories was estimated to be 65.75 dBA which are within the international OSHA standards for noise however a considerable number of sound-levels in different laboratories were slightly higher than the accepted standards. This study is useful for chemical engineering institutes and laboratories as the laboratory equipment are the same in the common domain. More studies should be undertaken, as background noise and noise coming from the laboratory equipment can not only cause hearing problems but may also lead to miscommunication and difficulties in performing routine laboratory tasks.

Keywords: *Noise, Sound-level, Polymer, OSHA, Standards, Laboratory, TWA, L_{eq}.*

1. Introduction:

Sound is defined as airborne vibration appreciable to the ear. Sound loud enough to cause harm is called noise, without considering its other characteristics [1]. Noise is a type of pollution because it can cause hearing deterioration and psychological stress. It can bring about nuisance, sleep disturbance, heart diseases and cognitive problems that are determined by noise exposure and degree of habituation [2].

The magnitude of the noise depends upon the sound power. Sound power Level (SWL) is the acoustical energy generated by the sound source, and is an absolute value. Reference power level normally used is 10-12 watts [3]. The loudness of the sound is determined from pressure within the sound wave. The sound pressure level (SPL) depends upon the distance from the source and the acoustic characteristics of the area in which it is located. Sound pressure levels are measured in decibels (dB), which are a logarithmic unit of the ratio of the calculated sound pressure to a reference sound pressure of 0.0002 dynes/cm^2 or microbars. Overall sound levels are measured in dB(A). The 'A' specifies that the response of the sound level meter is adjusted to a certain degree to trigger the

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response of the human ear [4].

Many studies are being conducted, highlighting the problem of occupational noise [5]. As many kinds of practical applications and technical research activities are conducted in laboratories, there is a need to investigate the sound levels in them. The recommended upper level of noise for speech to be intelligible is 55 dB(A). Typical problem occurring in laboratories due to noise is misunderstanding among staff members when hearing each other. Other problems occurring from noise include hear loss, stress, anxiety, fatigue and high blood pressure [6].

Noise in the laboratory is due to a combination of external and internal sources. Many of the internal sources of noise come from laboratory equipment. Occupational Safety and Health Administration (OSHA) has set acceptable standards for levels of noise in the workplace. According to OSHA's Noise standard (29 CFR 1910.95), employers are required to have a hearing conservation program if employees are exposed to a time-weighted average (TWA) noise level of 85 decibels (dBA) or higher in an 8-hour work period of a 40-hour work shift [7]. Although the sound levels in most laboratories are underneath the threshold level that causes hearing problems, laboratory noise can become quite loud. The practical work encompassing incubators, large analyzers, refrigerators, heaters, fans, fume hoods, washers, centrifuges, stirrers, motors and compressors, all significantly contribute to the noise level [8, 9]. Laboratory work encompasses unskilled, skilled and precision work [10]. The maximum permissible noise level for unskilled work is 80 decibels (dBA), for skilled work 75 decibels (dBA) and for precision work 70 decibels (dBA) [11]. So, care should be taken not to exceed the limits of at least 70 decibels (dBA)

(See Figure 1: *Noise Standards in Laboratory*).

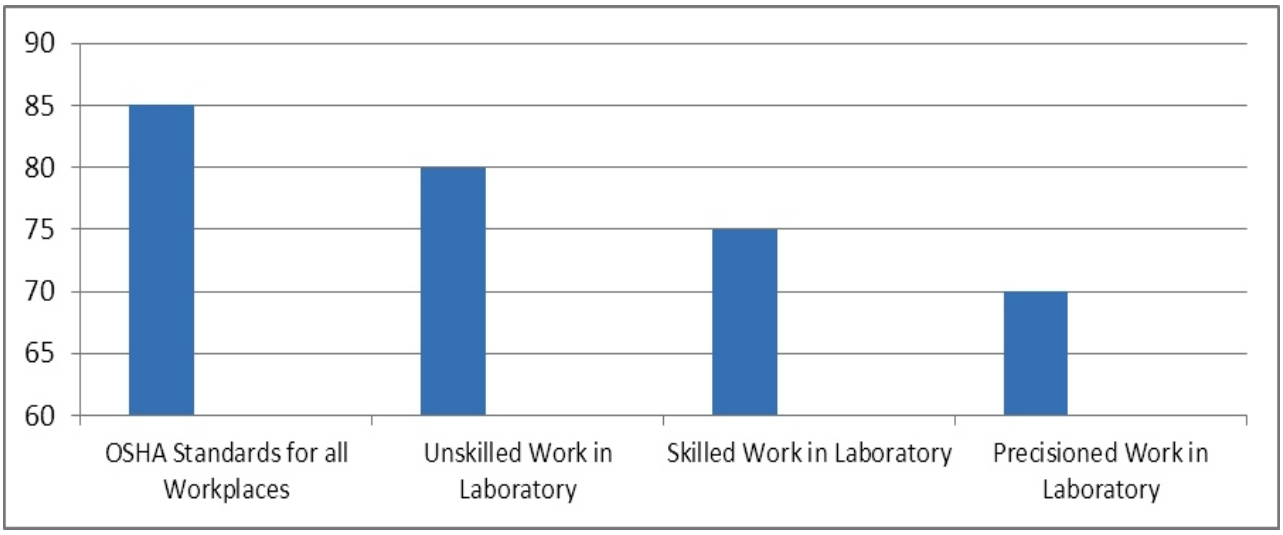

Figure 1: Noise Standards in Laboratory

Some papers have been published showing the sound-levels at different workplaces. The few articles that are published show, that most noise levels in laboratories of different types are within the OSHA standards of 85 decibels, however care should be taken for some noise-producing instruments that may take the sound threshold beyond recommended limits [12, 13, 14].

The objective of the study was to measure sound-levels of different engineering laboratories during specified time periods and comparing them with OSHA standards.

2. Materials and Methods:

The study was conducted from February 2019 to July 2019 at University of the Punjab, Lahore, Pakistan. The sound levels were taken in five of the

main laboratories at the Institute of Chemical Engineering and Technology, University of the Punjab, Lahore, Pakistan. Each laboratory had different instruments, as shown in Table 1: *Instruments in Laboratories*. The readings were taken at eight different times of the day, in the morning from 9:00 AM to evening till 5:00 PM.

Table 1: Instruments in Laboratories

LAB Number	INSTRUMENTS
LAB A (Polymer Engineering[a])	Thermogravimetric Analyzer, Thermo-mechanical Analyzer, Dynamic Mechanical Analyzer, Differential Thermal Analyzer, Differential Scanning Calorimeter, Air Compressor, Nitrogen Gas Cylinder, Air Filters, Water Chiller, Rheometer, Phase Sequence Relay.
LAB B (Polymer Engineering[b])	Universal Testing Machine, Fourier Transform Infrared Spectroscope, Tubular Impact Tester, Pendulum Impact Tester, Hardness Tester, Barcoal Tester, Mandrel Bending Tester.
LAB C (Polymer Engineering[c])	Pilot Plant, Hot Plate with Magnetic Stirrer, Water Distillation Unit, Electrical Generator, Compressor, Ball Mills, Attritor, High Speed Paint Mixture.
LAB D (Mineral Processing)	Jaw Crusher, Kneader Mixer for Paste, Kneader Mixer for Dry Solids, Disc Mill, End Runner Mill, Pebble Mill, Hammer Mill, Magnetic Separator, Pan Granulator, Sieve Shaker
LAB E (Instrumentation Processing Center)	Manometer, Level Control Unit, Flow control Unit, Pressure Control Unit, Temperature Control Unit, Weight Tester, Liquid Level System.

The recordings were taken by a digital sound-level meter, model dsl-331. The measuring height was fixed at about 1.5 meters above the ground level. The readings were taken at minimum level (L_{min}), maximum level (L_{min}) and equivalent sound level (L_{eq}) as parameters. The device was calibrated, with respect to the standard instructions, ranging 30 - 130 decibels (dBA), microphone ½ inch electric-condenser type with accuracy of +/- 1.5 dB. For the measurement of noise level, the device was set to A-weighting as it is considered to be of sensitive frequency for any sound level.

The time weighted average (TWA) of sound levels during the 8-hour work period is calculated using the following calculation: [15]

$$TWA = 16.61(\log D) + 90 \quad \text{---------- (1)}$$

'D' is noise dose given by:

$$D = C/T \quad \text{---------- (2)}$$

'C' is total length of the working day and 'T' is reference duration given by:

$$T = 8/2^{(L-90)/5} \quad \text{---------- (3)}$$

'L' is sound level at a specific time period.

3. Results and Discussion:

Majority of the equivalent sound level (L_{eq}) readings were within the region of 60 70 decibels (dBA). The mean L_{eq} level of all the readings was calculated to be *64.94 dBA*. The maximum L_{eq} was observed in Lab D (Mineral Processing) with *72.65 dBA*. Sound levels were highest during 11-12 AM with an average L_{eq} of *72.06 dBA*. The comparison of measurements for laboratories, time and place are given in Table 2: *Recordings at different time and place (dBA).*

Table 2: Recordings at different time and place (dBA)

Time	Lab A			Lab B			Lab C			Lab D			Lab			Mean
	L_{min}	L_{max}	L_{eq}	L_{min}	L_{max}	L_{eq}	L_{min}	L_{max}	L_{eq}	L_{min}	L_{max}	L_{eq}	L_{min}	L_{max}	L_{eq}	L_{eq}
9-10 AM	53.1	58.2	*55.65*	62.5	67.6	*65.05*	56.3	60.6	58.45	62.4	76.3	*69.35*	62.3	70.4	*66.35*	***62.97***
10-11 AM	54.3	58.6	*56.45*	63.2	66.8	*65.00*	60.6	67.4	64.00	68.4	80.3	*74.35*	62.3	71.4	*66.85*	***65.33***
11-12 AM	53.8	88.5	*71.15*	53.2	78.3	*65.75*	58.2	71.8	65.00	82.3	100.4	*91.35*	62.1	72.0	*67.05*	***72.06***
12-1 PM	52.0	58.3	*55.15*	54.1	59.5	*56.80*	58.1	66.2	62.15	82.2	86.4	*84.30*	61.5	67.2	*64.35*	***64.55***
1-2 PM	53.3	63.4	*58.35*	54.0	60.1	*57.05*	57.4	68.0	62.70	62.6	71.3	*66.95*	62.9	69.6	*66.25*	***62.26***
3-4 PM	55.3	77.6	*66.45*	53.5	74.3	*63.90*	63.4	79.1	71.25	61.4	68.5	*64.95*	60.6	78.7	*69.65*	***67.24***
4-5 PM	53.4	58.6	*56.00*	53.8	59.0	*56.40*	65.6	69.7	67.65	60.2	67.2	*63.70*	66.8	72.3	*69.55*	***62.66***
5-6 PM	56.0	60.7	*58.35*	54.0	58.1	*56.05*	60.2	68.8	64.50	62.3	70.2	*66.25*	63.0	71.1	*67.05*	***62.44***
Mean	**53.90**	**65.49**	***59.69***	**56.04**	**65.46**	***60.75***	**59.98**	**68.95**	**64.46**	**67.73**	**77.58**	***72.65***	**62.69**	**71.59**	***67.14***	***64.94***

*Green = Less than 70 dBA. *Yellow = 70 - 75 dBA. *Orange = 75 - 80 dBA;
*Dark Orange = 80 - 85 dBA. *Red = Greater than 85 dBA

The time weighted average (TWA) of all the laboratories was estimated to be *65.75 dBA*. The maximum TWA was observed in Lab D (Mineral Processing) with *79.88 dBA*. The TWA of all the laboratories individually and combined are given in Table 3: *Time weighted average of Labs (dBA).*

Table 3: Time weighted average of Labs (dBA)

Laboratories	Time Weighted Average (TWA)
Lab A	62.26
Lab B	61.92
Lab C	65.37
Lab D	79.88
Lab E	67.33
All Laboratories	*65.75*

It was also noticed that few machines in particular created a lot of noise and exceeded the 85 dBA level; these included hammer mill (100.4 dBA), air compressor (88.5 dBA) and jaw crusher (86.4 dBA) (Figure 2: *Noise Producing Equipment*).

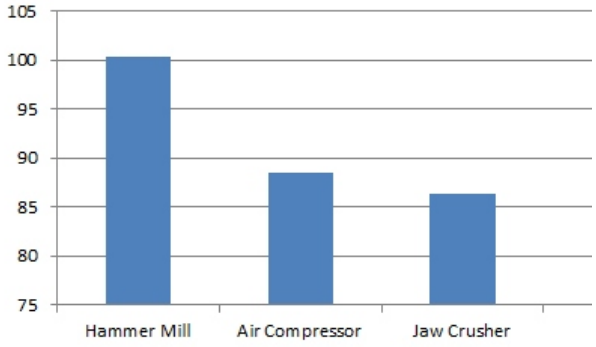

Figure 2: Noise Producing Equipment

On applying ANOVA analysis and comparing the sound-levels in the five laboratories, significant difference ($P < 0.05$) was observed with P-value recorded at 0.0006. Details are given in Table 4*: Comparison using different variables***.** This is due to significant differences observed between Lab A vs D and Lab B vs D; comparison is shown in Table 5: Post-Hoc Tukey HSD Results in different Labs. On comparing sound-level values with respect to different time rates, no significant difference was observed with P-value at 0.4116.

Table 4: Comparison using different variables

Comparison	Test Analysis Type	Sound-level type	P-value	Result
Comparison among all Laboratories	ANOVA Test	L_{eq}	0.0006	Significant
Comparison at different Rates in Time	ANOVA Test	L_{eq}	0.4116	Not

Table 5: Post-Hoc Tukey HSD Results in different Labs

Laborator Pairs	Tukey HSD Q	P-value	Inference
Lab A vs B	0.5064	0.8999947	Not Significant
Lab A vs C	2.2862	0.4969499	Not Significant
Lab A vs D	6.2115	0.0010053	Significant
Lab A vs E	3.5687	0.1084882	Not Significant
Lab B vs C	1.7798	0.6943583	Not Significant
Lab B vs D	5.7051	0.0024705	Significant
Lab B vs E	3.0623	0.2166331	Not Significant
Lab C vs D	3.9252	0.0628334	Not Significant
Lab C vs E	1.2824	0.8881365	Not Significant
Lab D vs E	2.6428	0.3529326	Not Significant

4. Conclusions:

The results concluded that most of the readings were within the generally acceptable OSHA standards for noise of 85 decibels (dBA). However, taking into account the precision physical work, there were a considerable number of values that exceeded the 70 decibels (dBA) limit. Also, it was observed that specific instruments in particular created more noise than others. So, caution to noise levels should be observed by laboratory colleagues and management, especially when skilled or precision physical work is being undertaken in the laboratory. This study is useful for chemical engineering institutes and laboratories as the laboratory equipment are the same in the common domain.

Following recommendations are useful and should be taken in order to limit sound-levels in laboratories; these include separating noise producing equipment from the laboratory to a different location, placing compressors and loud equipment in an isolated room, acoustical treatment on ceilings, using personal protective equipment (ear muffs / ear plugs) and avoiding loud conversations. OSHA's hearing conservation program is devised to protect workers from hearing impairment resulting from significant occupational noise exposures even if the person is exposed to such noise levels during his/her entire working life. It deals with monitoring sound-levels, initial/annual

training, selecting hearing protection devices, audiometric testing and records management.

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