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“Statistical Analysis Noise Pollution in Jaipur City during Pre and Post COVID-19 Pandemic”

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ABSTRACT
Exposure to noise pollution for an extended period of time can result in annoyance, sleep disturbances, hypertension, psychological illnesses, and hormonal dysfunction. Noise pollution is a new environmental issue that is becoming increasingly prevalent. The noise that is produced by the traffic on roads is one of the forms of noise pollution that has a substantial impact on the quality of urban settings. Taking into consideration the recent implementation of the COVID-19societal lockdown, the purpose of this study is to investigate the effects of the lockdown on the changes in noise pollution levels before, during, and after the lockdown phase in various residential, commercial, industrial, and silence zones within the city of Jaipur City. With the exception of the commercial zone, all of the other monitoring stations had reported sound levels that were significantly higher than the prescribed noise limits that were established by the Central Pollution Control Board (CPCB) of India. This was the case despite the fact that a significant reduction in noise levels was noticed during the lockdown. Furthermore, the findings suggested that significant enhancements in health benefits could be detected throughout the lockdown time, which was significantly superior than the pre-lockdown and unlock periods. A number of solutions for reducing noise are also presented, and it is possible that these strategies will pave the way for the development of noise control measures at the regional and municipal levels.
Keywords:-Hormonaldys function, commercial, monitoring, strategies, implementation, psychological

I. INTRODUCTION

The growing body of data implies that the majority of the cities in India are at risk of experiencing increased noise exposure, which can have detrimental consequences on both the physical and mental health of individuals. On the other hand, the recent implementation of theCOVID-19 societal lockdown has resulted in a significant decrease in the volume of motor traffic and social gatherings all over the world. The purpose of this study is to investigate the changes in noise pollution levels before, during, and after the lockdown phase of the COVID-19 lockdown in various residential, commercial, industrial, and quiet zones of the city of Jaipur City. This is done in an effort to gain a more in-depth understanding of the effects that the lockdown has had on the levels of noise pollution. The purpose of this study is to investigate the changes in noise levels that occur during the various phases of lockdown, to investigate the noise exceedance levels that occur in various zones, to investigate the potential impact that noise may have on health outcomes such as annoyance and sleep disturbance, and to propose effective noise mitigation strategies in order to reduce the overall negative effects that noise has on physical health.

II. METHODOLOGY

1.1. Characteristics of the study area

The city of Jaipur, which is the capital of the Indian state of Rajasthan, is situated in the vicinity of the Arawali hills. The coordinates of its location are 26.5 degrees north and 75.5 degrees east. It has a population of 3.4 million people (according to the Census of 2011) and is one of the cities in India that is expanding at the quickest rate. It is the tenth largest city in India, and it covers an area of 467 square kilo metres. There are 15 satellite towns that are included in the broader metropolitan region of Jaipur, which encompasses a total area of 2940 square kilometers and has a population of 4.45 million persons. It is possible to divide the city of Jaipur into eight geographical zones, 91 wards, and 61 localities1. The city's economic growth is mostly driven by the city's education system, commercial sector, and tourism industry. Additionally, it is commonly referred to as the "Pink City" due to the fact that it is one of the most famous tourist sites in India. This is because of the historical value and architecture that

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it possesses. Walled city is the location of the majority of the traditional economic activity, including retail trade and the production of jewellery. The vast majority of the city's manufacturing facilities are situated in the surrounding territories, particularly in the southern and western regions of the city. The city that is enclosed by walls has a population density that is significantly higher than 75,000 people per square kilometre. This is because the economic activities are concentrated in a high concentration. One may see the city of Jaipur depicted in Fig.

Fig. Map of Jaipur city

In order to explore the impacts of noise exposure during the various phases of lockdown, a total of six sampling locations were evaluated. These locations corresponded to residential, industrial, commercial, and silent zones within the city of Jaipur. The information regarding the locations of the noise monitoring stations is shown in Table1, and Figure1 illustrates the geographic distribution of the stations.

Table-Location details of the soundstations in Jaipur City

Location ID	**Zone**	**Sampling locations**
1	Silence Zone(Location I)	Garden behind Governor House, Civil Line
2	Silence Zone (Location II)	Santokba Durlabhji Memorial Hospital (Jaipur)
3	Residential Zone (Location I)	Nagar Nigam Office Patel Marg Mansarovar
4	Residential Zone(Location II)	Science Park Shastri Nagar
5	Commercial Zone(Location I)	Gali No.3 Raja Park
6	Industrial Zone(Location I)	Sita Pura Jaipur

Over the course of twenty-four hours, beginning in January 2020 and continuing through July2020, data on sound levels were collected. This was done to cover the entire phase, which included before lockdown, during lockdown, and during unlock phase.

Noise assessment analysis

To analyze the noise pollution level, noise percentiles values (that is L10, L50 and L90) were calculated by using noise level data and these percentiles values were used to evaluate the noise pollution indices (Pathak etal, 2008: Robinson,1971).Hourly noise data were analyzed to obtain the equivalent sound level (Leq) for all the days of a month corresponding to specific hour.

On the other hand, L10, L50, L90, and NC each stand for the level of sound that exceeds 10% of the totaltime of measurement, the level of sound that exceeds 50% of the whole time of measurement, the level of sound that exceeds 90% of the total time of measurement, the equivalent noise level, and the noise pollution level, respectively. represents the equivalent effect of noise coming from different sources and of varying intensities (Robinson, 1971; Newman et.al., 1985).

$$NC = L10 - L90$$

$$Leq = L50 + (NC)^2/60$$

During the various stages of the COVID-19 lockdown, a descriptive analysis is carried out on the sound levels that were measured in the locations that were considered for having sound monitoring. Different land-use patterns, including residential, industrial, commercial, and silent zones, are taken into consideration when evaluating the changes in sound levels that occur throughout the pre-lockdown, lockdown, and unlock phases. The t-test, which compares the means of two samples, and the F-test, which compares the variances of samples, are utilized in order to find any potential changes in the sound levels that may occur during lockdown periods. Additionally, an analysis of variance (ANOVA) test is carried out for samples that are more than two in number. Ata significant level, each of these analyses is carried out.

III. RESULTS AND DISCUSSION

The findings and the subsequent discussion

Alterations in sound levels as a result of the many human activities on land. In total, six different locations were chosen for the purpose of conducting sound level measurements. These locations correspond to residential, industrial, commercial, and silent zones. The data on the equivalent continuous sound level were averaged over a period of one hour (represented by Leq), and the monthly variation of the data according to the various types of land use is shown inFigure2.

There is a discernible pattern in the overall sound levels during the various periods of lockdown, despite the fact that there is a significant difference in the monthly sound levels that may be detected according to the various types of land usage. In particular, the data that was processed between the 25th of March and the 31st of May 2020 (the time when India declared a nationwide lockdown) can be related to the "during lockdown" phase. On the other hand, the period of time that occurred before the 25th of March 2020 and after the 31st of May 2020 is defined as the "before lockdown" phase and the "unlock phase," respectively, in this study. In spite of the fact that the equivalent sound levels for all zones fall within the range of 55–75 decibels before to the lockdown period, the range experienced a significant decrease to 29–45 decibels during the lockdown period, and then progressively increased to 41–76decibels (Fig.).

The results of the analysis of variance (ANOVA) test indicated that there were no significant changes in Leq between January and February (before lockdown) and between June and August (unlock phase) for both residential zones. This was in reference to the monthly differences in the equivalent sound levels. Furthermore, during the lockdown period, statistical tests with regard to residential zones were unable to be carried out because there was a lack of data pertaining to residential zones during the month of May. Before lockdown period, Leq data of all the five months (January, February, March, June, July or August) revealed significant differences in Leqforindustrial[$F_{stat}=8.56>F_{cri}=2.45, p<0.001$],commercial[$F_{stat}=15.82>F_{cri}=2.45, p < 0.001$], and silence (location I) [$F_{stat} = 25.16 > F_{cri} = 2.45$, $p < 0.001$] zones, the only exception being location II of the silence zone where no statistical difference could be observed [$F_{stat}=1.02<F_{cri} =2.45$, $p =0.40$].

During the unlock phase, it was observed that there were statistical differences in the monthly data, but only for industrial [$F_{stat}=23.35>F_{cri}=3.13, p<0.01$] and location I of the silence zone [$F_{stat} = 3.13 > F_{cri} = 2.71$, $p < 0.05$]. On the other hand, the t-test for sample means indicated that there were statistical differences during the lockdown phase for all land use types.

The equivalent sound level data were further grouped into three categories (according to before lockdown, during lockdown, and unlock phase) for the purpose of gaining a better understanding of the changes in sound level that occurred as a result of the nationwide lockdown in India. This was done despite the fact that differences in monthly Leq data were observed for different zones. The following table provides a summary of the statistical properties of Leq during the various phases of shutdown for all types of land use situations.

By comparing the mean Leq values, it is possible to notice a discernible decrease in sound levels during the lockdown phase, which gradually

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increased after the lockdown portion of the experiment. The similar pattern is observed across all different kinds of land use. It has been discovered that the reduction in mean Leq is greatest in location I of the residential zone, which accounts for 29% of the total. This is followed by a reduction of 23% in location II of the residential zone and location II of the silent zone, and a reduction of 17% in position I of the silence zone. On the other side, it was discovered that the reduction in Leq was 8% for the industrial zone and 14% for the commercial zone, respectively.

Contrarily, as compared to the sound levels that were present during the lockdown phase, the sound levels that were present during the unlock phase were found to be 21% higher in the quiet zones and location II of the residential zone. In addition to this, it

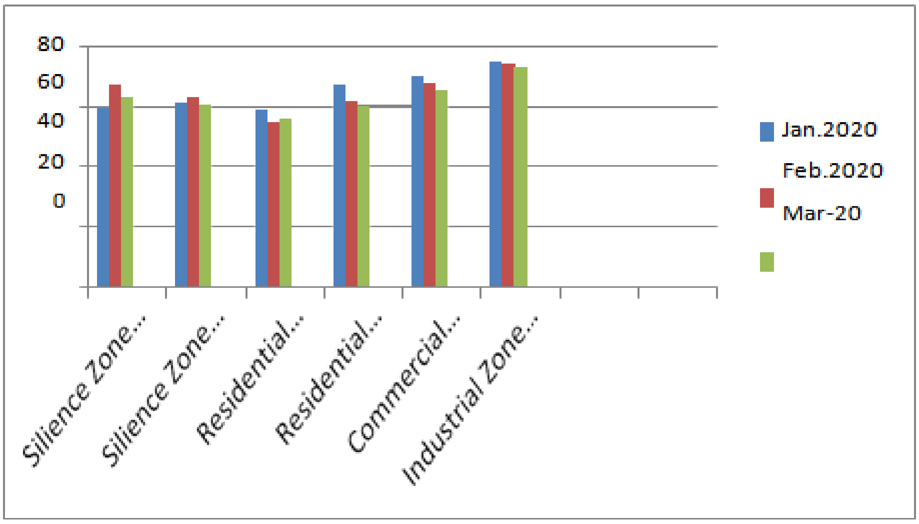

Fig.(a):Pre Lockdown (Before Lockdown)

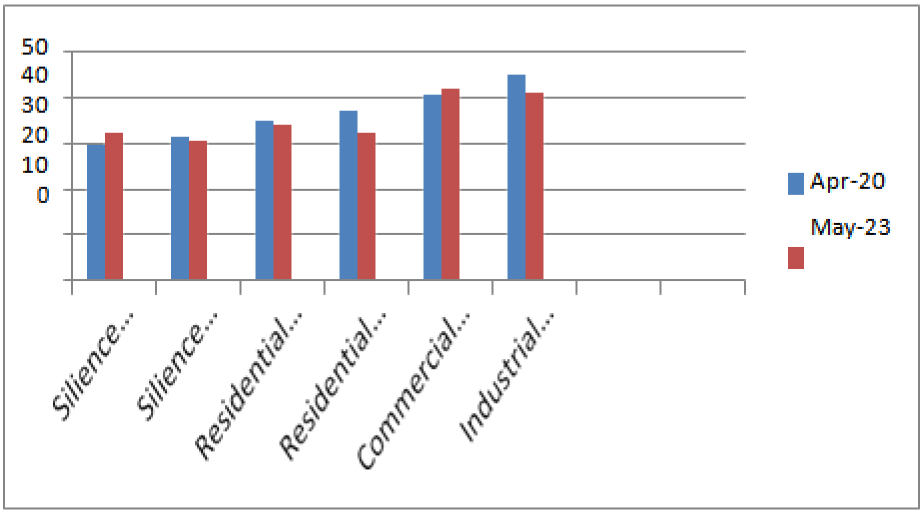

Fig.(b):During Lockdown

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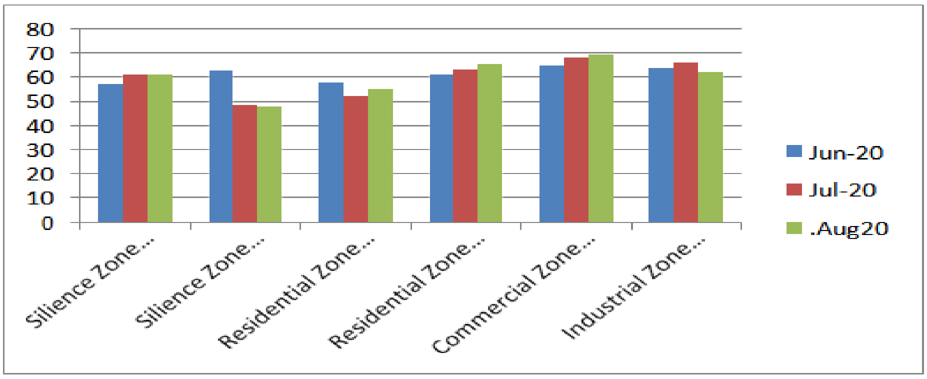

Fig.(c):Post Lockdown (After Lockdown)

increased by 32 percent in location I of the residential zone, where as the increment was determined to be smaller in the industrial zone (16 percent) and the commercial zone (9 percent), respectively. These results indicate that the reduction in sound levels during lockdown was considerably higher in residential (23 dB and 13 dB in location I and II, respectively) and silence (8dBinlocation I and 18d Bin location II) zones than that of industrial and commercial zones (6 dB reduction in both the cases). There is no doubt that this may be ascribed to the significant decrease in traffic, the severe limitation of individuals' mobility, and the closure of businesses, the effects of which could be noticed in residential and silent zones. On the other hand, in order to speed up the operation of manufacturing units and prevent a short age of any essential commodities, the movement of trucks and other categories of good's vehicles between states and within states was allowed. As a consequence of this, the reduction in sound level in the industrial zone was not found to be substantially significant.

In order to acquire deeper insights into the statistical significance of identical sound levels during various phases of lockdown, a t-test was carried out for the purpose of comparing the means of two samples (Table). As was to be predicted, significant differences in mean Leq were found between the data that corresponded to before the lockdown period and the data that corresponded to during the lockdown phase for all types of land use. With regard to the Leq data that was belonging to during the lockdown and unlock period, same observations were obtained in each and every instance. This unequivocally demonstrates that the sound level in each and every zone experienced a significant decrease when the lockdown was in effect. It is also interesting to note that there were no significant differences in the sound levels that could be observed before lockdown and during the unlock phase for residential, industrial, commercial, and silence zones. This is an indication of normal traffic operations during the unlock phase after the four phases of the nationwide lockdown in India (beginning on the 25th of March 2020 and ending on the 31st of May 2020).

Table
Statistical summary of Leq during different phases of lockdown

(A) Before lockdown

Location	Min	Mean	Median	Max
Residential I	54.29	79.57	85.26	104.00
Residential II	39.03	55.40	59.99	67.71
Industrial	48.26	70.27	72.23	88.56
Commercials	38.93	44.83	44.85	56.00
Silence I	38.94	46.57	46.07	54.41
Silence II	45.71	75.71	83.13	101.27

(b)During lockdown

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Location	**Min**	**Mean**	**Median**	**Max**
Residential I	44.27	56.19	55.45	72.73
Residential II	37.82	42.66	42.09	51.00
Industrial	53.45	64.19	62.12	76.64
Commercials	37.71	38.55	38.34	39.85
Silence I	37.71	38.55	38.35	39.85
Silence II	40.75	57.79	56.65	78.11

(C)After lockdown

Location	**Min**	**Mean**	**Median**	**Max**
Residential I	51.54	74.04	80.91	85.06
Residential II	38.59	51.86	55.73	63.07
Industrial	54.02	74.71	79.80	86.44
Commercials	38.89	42.24	42.13	45.33
Silence I	39.80	46.49	47.11	51.61
Silence II	43.37	69.07	76.05	85.52

Table t-stat results of Leq during different phases of lockdown

Residential I	Before	8.30 (p <0.001)	Significant	**1.98 (p =0.09)**	Notsignificant
	During			−6.37 (p < 0.001)	Significant
Residential II	Before	6.26 (p <0.001)	Significant	**1.40 (p =0.08)**	Notsignificant
	During			−4.94 (p < 0.001)	Significant
Industrial	Before	2.80 (p <0.01)	Significant	**−1.61 (p = 0.06)**	Notsignificant
	During			−4.43 (p < 0.01)	Significant
Commercials	Before	10.17 (p <0.001)	Significant	1.57 (p =0.09)	Notsignificant
	During			−9.05 (p < 0.001)	Significant
Silence I	Before	13.13 (p <0.001)	Significant	**0.09 (p =0.46)**	Notsignificant
	During			-12.65(p <0.001)	Significant
Silence II	Before	4.73 (p <0.001)	Significant	**1.49 (p =0.07)**	Notsignificant

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	During			3.00	(p <0.01)	Significant

IV. CONCLUSIONS

This study attempted to investigate to what extent the corona virus lockdown has impacted exposure to noise pollution levels and public health outcomes in the city of Jaipur City. The behavioral shifts in transport sector and the societal lockdown has impacted positively on local and regional environmental pollution levels. In this regard, this study provided an understanding of monthly sound level patterns, time wise variations in sound data, changes in sound levels during different phases of lockdown, and possible public health risks due to prolonged exposure to noise pollution. The magnitude of changes in sound levels in the residential, industrial, commercial and silence zones are examined in the pre-lockdown, lockdown and after lockdown phase.

Our results indicated a significant reduction in sound levels at all the six sound monitoring stations during lockdown phase as compared to that of pre-lockdown and unlock phases. The reduction was much higher in the residential and silence zones than that of industrial and commercial zones. Concerning day and night time sound equivalent levels, the sound levels during daytime were found to be considerably higher than night time in all the zones. The night time sound equivalent dropped by an average of 9dB during lockdown while the average reduction was by almost 15dB in the pre-lockdown and unlock phase in all the considered zones. Considering the limits recommended by the Central Pollution Control Board (CPCB) of India, except for commercial zone, all other monitoring stations had reported sound levels quite higher than the recommended noise limits. exceedance of standard noise limits even during lockdown period, while it reached 100% in the pre-lockdown and unlock phase. This is indeed a subject of serious concern as continuous exposure to noise can have a long-term impact on person's health and well-being such as annoyance and sleep disturbance.

Although the Jaipur Junction and Industrial Aria locations indicated sound levels exceeding the recommended noise limits most of the times during all phases of lockdown, the impact of road traffic noise on risk of high annoyance and sleep disturbance was found to be lower during lockdown as compared to that of prelockdown and unlock phase. Results of this work indicated that prominent improvements in health benefits could be observed in the lockdown period, much better than the pre-lockdown and unlock phase. This suggests that strict noise pollution mitigation strategies and suitable policy measures could provide public health benefits and provide an overall sustainable transport infrastructure. In light of this, several possible noise mitigation strategies such as promoting sustainable mode of transport, adoption of green space, adequate road infrastructure and development of a sound monitoring network in the local and regional level were also indicated in this work.

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