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Assessment of Noise Pollution of Kolkata Metro Railway System and Its Impact on Urban Receptors- A Case Study

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Abstract— An assessment of noise quality was conducted at underground and overground metro stations, within the metro rakes (AC and Non-AC), and at an institutional building near an elevated metro corridor to assess the exposure of the Kolkata Metro Railway System. The present study was conducted at different hours (peak and non-peak hours) for different types of rake (AC and Non-AC) movement. Different noise descriptors including A-weighted equivalent noise (L_{eq}), statistical noise (L_{10}, L_{50}, L_{90}), noise climate (NC), traffic noise index (TNI), two-hour noise dose (%ND), and corresponding time-weighted average (TWA) were calculated under the purview of the present study. Pearson's correlation was performed between all noise descriptors to investigate the relation between them. Scatter plot analysis was conducted between L_{10} and %ND. In the case of all study duration, all noise descriptors mostly exceeded FTA prescribed noise standard, along with 2-hr TWA which exceeded the OSHA guidelines of 100 dB for both AC and Non-AC rakes. On the other hand, at underground and overground metro stations, within metro rakes (except at day peak hours within AC coach), and at the school building, the mean value of traffic noise index (TNI) exceeded 74 dB (A), the threshold of over criterion. The study results indicate that Non-AC rakes are more annoying than AC rakes. In all the study units, L_{eq} was influenced by L_{10}, which originates from pressure honking. There is a very strong relationship observed between L_{10} and % ND. This study proposes that noise barriers should be installed at underground and overground metro stations, along the stretches of overground metro track, within metro rakes for developing the acoustic quality of the Kolkata Metro Railway System and the areas of its immediate vicinity.

Index Terms— Equivalent noise, Statistical noise level, Noise climate, Traffic Noise Index, Time-weighted average, Noise Dose

I. INTRODUCTION

Noise is a term, which comes from the word *"nausea"*, which means unwanted sound. The environment surrounding us is getting affected by various forms of pollution. Among them, noise pollution is considered to be a major one. Noise is originated from various sources, transmitted by a medium (usually air), which finally makes physiological and psychological impacts on receptors [2][6][12][15]. Environmental noise is generated by different anthropogenic activities, especially from the urban areas and the development of transport and industry. Nowadays noise-related problem is a major environmental issue even in developed countries.

In an era of enhancing urbanization, the traffic population is increasing rapidly. From 2001 to 2011, the observed Compound Annual Growth Rate (CAGR) of the traffic population was approximately 9.9% [17]. The noise originating from the Mass Rapid Transit System (MRTS) also induces some adverse impacts on the environment. Various parts of rail produce different types of noise under moving or stationary conditions (not in dead conditions). Under moving conditions noise is generated from rail-wheel interaction, whistle, and some aerodynamic noise sources (viz. whooshing noise) particularly when the locomotive moves within a tubular structure. In the case of over-ground metro railway, railway noises may be generated from the locomotive engines, noise coming from the wheels turning on the railroad track and some sorts of noise may come from outside activities. The train may also employ horns, whistles, bells, and other noisemaking devices for both communication and warning. Trains given forward by electric traction engines and controlled by high-speed electronic inverters can produce a whining noise. Other than the above-mentioned noise sources of the metro railway system noise originating from the visual and audio announcement, advertisement, and warning system can contribute to a significant amount of environmental noise pollution. There are numerous numbers of people avail this metro railway system for their daily commuting as a fast movement option from one place to another compared to other modes of transport. During this travel period, people have been exposed to a high level of noise pollution originating from metro railway movement within metro rakes (AC rake & Non-AC rake), at the metro station, and the places in the immediate vicinity of the metro track. Although rail traffic noise is considered less annoying than road traffic and aircraft noise, rail noise has some adverse impacts on human health [14].

Short-term and long-term exposure to such high noise pollution from underground and over-ground metro railway pose cardiovascular disease in humans and increased the

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chances of coronary artery diseases [2]. It decreases the working efficiency of a man and produces an adverse effect on the concentration of a man. It can affect a pregnant woman and interfere with the sleep structure of a human being. In the study of Vogiatzis (2012) it was observed that for protecting the sensitive cultural receptors from the noise impact of the Athens metro extension to Piraeus, some preventive measures were adopted by the authorities [18]. Consequently, the installation of tracks and special track work on a floating slab was prescribed to reduce ground-borne noise. In the study of Mohanan et al. (1989) on Kolkata metro railway, ventilation system, announcements, television, passengers, auxiliary rail equipment, rail and wheel contact, the propulsion system and aerodynamics of the train, etc. were identified as potential noise sources, both in underground and overground stations [11]. However, overground stations were also affected by outside vehicular noise and other human activities. In this study, A-weighted background noise for both underground stations was measured at 59 dB (A) at the south end of the platforms and 69 dB (A) at the midpoint of the platform on the mezzanine level. The study of noise impact assessment of mass rapid transit systems for Delhi city concluded the increase in noise levels due to elevated metro rail corridors in different places in Delhi city [4]. India's first underground Kolkata Metro Railway is now moving both underground and over-ground, starting from Noapara metro railway station to Kavi Subhash metro railway station (Near New Garia) over the entire route length of 27.22 km (en.m.wikipedia.org). After Mahanayak Uttam Kumar (Tollygunj) station, the remaining part of the metro track is laid on an elevated metro rail corridor. In the immediate vicinity of this metro track, there are several commercials and residential and institutional places. Noise originating from the continuous movement of the metro railway system is severely hampered the environmental quality of those places. There are very limited studies that addressed the environmental quality degradation by metro railway system in Indian perspective and as well as the entire world. In this present study, an assessment of noise quality within metro railway rakes and noise exposure of the students and workers of a school in the immediate vicinity of the over-ground metro railway track was undertaken to ascertain the potential impacts of metro railway noise.

II. RESEARCH METHODOLOGY

The entire study design consists of a selection of study areas, the procedure adopted to conduct this study including study duration and in-depth idea for analyzing study observations.

A. Site Selection

The present study was carried out inside both the AC and Non-AC metro rakes, at the metro platform (both underground stations (e.g. Belgachia (22.6060° N, 88.3864° E) and Shyambazar (22.6006° N, 88.3703° E)) and overground station (e.g. Dumdum (22.6215° N, 88.3928° E) and Netaji (28.6960° N, 77.1526° E))) and at a school building (22.4857° N, 88.3422° E) near the elevated metro track for assessing the exposure of metro noise (Fig . 1). These underground and overground metro platforms were considered under the purview of this study based on the high number of commuters in those stations.

(a) Kolkata Metro Route

(b) Noise study area at school

Fig. 1 Noise study area

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B. Field Measurement

A noise study at each location was conducted with the help of Bruel and Kzaire (Type-2) sound level meter (CESVA, SC160) (Fig . 2), mounted at 1.5 m above the ground on a tripod stand and 1.2 m distances from the nearest sound reflective surfaces (e.g. body of the metro rakes, walls and column of metro platforms and building indoor walls, doors, and windows, etc.) as per the guidelines of Central Pollution Control Board (CPCB, 2000), Part-1 and Part-2 of the ISO 1996 standards over the period of October 2015 to May 2016 with 1 s resolution [3].

Fig.2 Noise measurement process

The background noise for all these stations and metro rakes was monitored both at day-time (6:30 AM to 8:30 AM) on Sunday and nighttime (12:00 AM to 2:00 AM) when all the major noise producing sources (here, metro operations) were absent. In this study, noise quality monitoring was conducted at all noise monitoring stations at day-time peak hour (8:00 AM to 10:00 AM), day-time non-peak hour (1:00 PM to 3:00 PM), night-time peak hour (5:00 PM to 7:00 PM) and night-time non-peak hour (7:45 PM to 9:45 PM) on every weekday. Metro rakes were counted by visual observations at different study hours. The instrument was calibrated before each measurement. In the first phase of the present study, a noise quality assessment was conducted to investigate the average noise exposure of the commuters in the Kolkata Metro Railway System at each monitoring station and within metro rakes. On the other hand at the school premises, a noise study was conducted for assessing short term and long term noise exposure for metro movement (AC and Non-AC rakes) through an elevated metro track adjacent to the school building at peak and non-peak hours of the day during examination hours to avoid the influence of anthropogenic noise.

To describe noise quality A-weighted equivalent noise levels (L_{eq}), statistical noise level (L_{10}, $L_{50,}$ and L_{90}) noise climate (NC), traffic noise index (TNI), % noise doses (%ND), and 8-hr time-weighted average (TWA) were also calculated to assess the extent of noise exposure of the passengers, students, and school workers to the metro railway noise.

C. Data analysis

After extracting raw noise data from the sound level meter (SLM), the logarithmic average of sound pressure level on an hourly basis was carried out with the following equation:

$$L_{eq} = 10 \times log \sum_{i=1}^{n} f_i \left(10^{\frac{Li}{10}}\right) \quad (1)$$

Where L_{eq} is the A-weighted equivalent noise level, f_i is the time fraction and L_i is the noise level at each time fraction.

To quantify noise annoyance related parameters in ambient and indoor environment noise climate (NC) and traffic noise index (TNI) were evaluated by the following equations:

$$NC = L_{10} - L_{90} \quad (2)$$

$$TNI = 4 \times NC + L_{90} - 30 \quad (3)$$

Where L_{10} and L_{90} indicate the noise level equal to or exceeds 10% and 90% of the total noise study duration respectively.

As per the Occupational Safety and Health Administration (OSHA) and World Health Organisation (WHO), % noise dose (%ND) and time-weighted average (TWA) were computed, as the indicators to describe the noise exposure of indoor and outdoor workers and other public [13][19].

$$\%ND = 100 \times (\sum_{i=1}^{n} \frac{C_i}{T_i} \quad (4)$$

$$T_i = \frac{8}{2^{\frac{Li-90}{ER}}} \quad (5)$$

$$TWA = 16.61\ log_{10}\left({}^{ND}/_{100}\right) + 90 \quad (6)$$

In equation (4) C_i is the actual time exposed to a noise level and T_i is the time allowed to be exposed to that noise level. In equation (5), Li is the noise level exposed in dB (A).

Descriptive statistical analysis of all the noise descriptors was carried out to find out the status of noise quality and its corresponding exposure to receptors. Pearson’s correlation analysis was performed by SPSS (v 20) software to find out the relationship between different noise descriptors with NC, and TNI. Scatter plot analysis was also conducted for investigating the influence of honking component L_{10} in % ND.

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III. Results and Discussion

A. *Status of the noise pollution of the study unit*

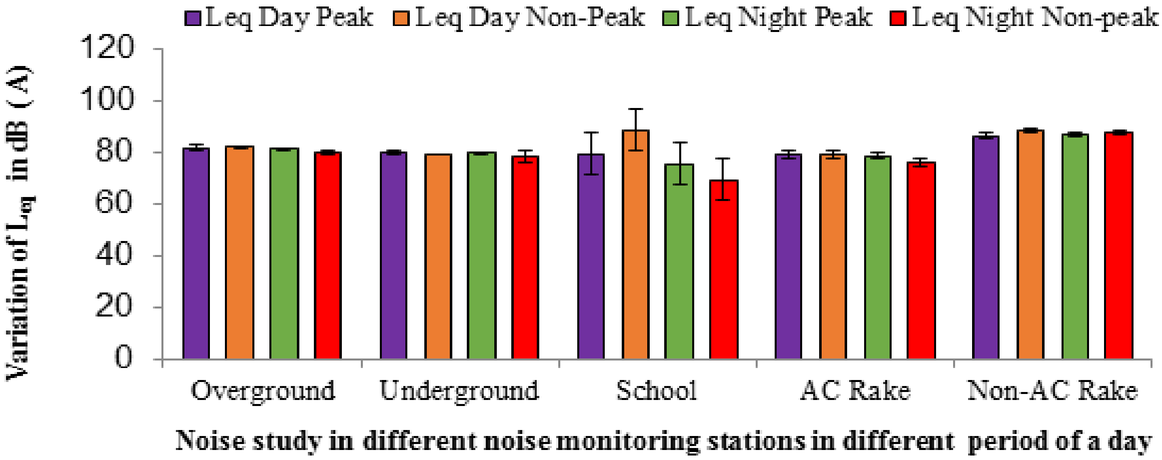

Fig.3 Diurnal variation of equivalent noise level (L_{eq}) in dB(A) in the different noise study areas

In above Fig. 3, the A-weighted equivalent noise level (L_{eq}) at the first floor level of the school building within the classroom was observed at 79.40 dB(A), 75.50 dB(A), 88.40 dB(A), and 69.40dB(A) at day-peak, day non-peak, night-peak, night non-peak hour respectively for the movement of metro rakes. On the other hand, under the moving condition within the metro rakes, for AC rakes A-weighted equivalent noise level (L_{eq}) was observed at 78.9 dB(A),94.8 dB(A),119.6 dB(A), and 65.8 dB(A) at day peak, day non-peak, night-peak, night non-peak hour respectively and for Non-AC rakes, it was 86.3 dB(A),88.18 dB(A),86.63 dB(A) and 87.63 dB(A) at day peak, day non-peak, night peak, night non-peak hour respectively. In the case of all study areas, L_{eq} exceeded the Federal Transit Administration (FTA) day-night noise level standard of 55 dB (A) for safe listening [4]. These findings are almost related to the observations of Garg et al. (2011) for mass rapid transit system noise pollution in Delhi city and Mohanan et al.(1989) for Kolkata metro railway [4][11]. In the case of underground stations incoming and outgoing rake starting and stopping operations, rail-wheel interaction, ventilation system, public redressal system and fans mounted in the basement columns, and other anthropogenic activities induced these noise levels. Except for the ventilation systems, all the potential noise sources of underground stations along with outside vehicular activities led to increasing the noise level in overground stations. Within the metro rakes rattling of doors and windows, air inhaling system, aerodynamic noise, and sweep of wall-mounted fans (in the Non-AC rakes) are the main sources of noise. But, in the case of the school building, a major portion of the noise originated from metro movement through an adjacent Highline. Other than metro noise, school workers' and students' activities, outdoor traffic movement are also the reasons for the degradation of the acoustic quality of that school. In this study, we observed daytime background noise levels of 44.35 dB (A), 70.8 dB(A), 53.2 dB(A,) and nighttime background noise levels of 48.65 dB(A), 66.35 dB(A), 39.6 dB(A) at the underground and overground metro station and school building respectively. Maintenance works of metro tracks and other anthropogenic activities are responsible for this background noise at metro stations. But, in the case of school buildings outside vehicular activities and people's conversations are the main key factors of these background noise levels. This observation is almost similar to the study output of Mohanan et al. (1989) for metro stations [11]. On the other hand, within empty rakes under stationary conditions, observed background noise was 59.8 dB(A) for Non-AC coaches and 62.6 dB(A) for AC coaches due to the maintenance works at metro rakes and other anthropogenic and maintenance activities at metro car shed are responsible for these background noise levels. In the case of Non-AC rakes, Mohanan et al. (1989) also observed a background noise level of 56 dB (A) [11].

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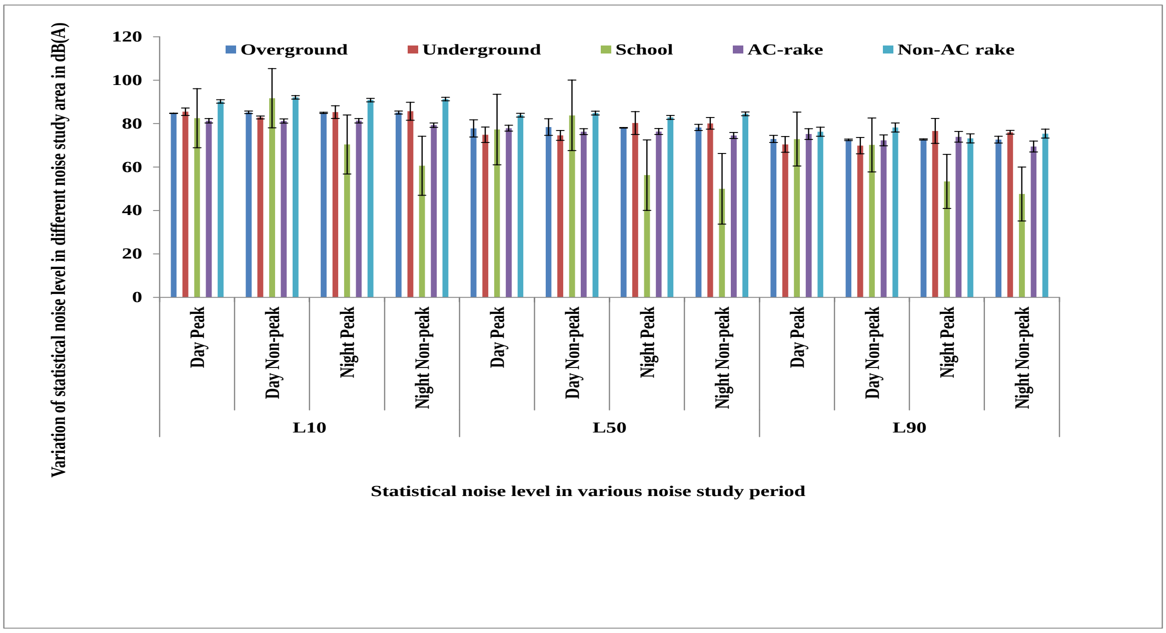

Fig.4 Diurnal variation of the statistical noise level in dB (A) in different noise study areas

In this Fig .4, it is indicated that the peak noise level (L_{10}) exceeded the Federal High Way Administration; USA (FHWA) prescribed permissible noise level of 55 dB (A) in the school during every observation period except night non-peak hours. It may be concluded that due to metro whistle or honking event, an alert system for class ending and other activities inside the school at day peak and day non-peak, and night peak hour. But, in the case of night non-peak hours, metro horn, outside vehicular and anthropogenic activities could be the reason for that high level of L_{10} [16]. On the other hand, median noise (L_{50}) and background noise level (L_{90}) were also exceeded 55 dB (A) at every study hour, except L_{90} at night non-peak hours within the allowable limit of Federal High Way Administration; USA (FHWA) [16]. This may be attributed to the fact that due to different categories of metro operations through the elevated metro railway track at every study hour, different activities within school premises by the students and staff and outside traffic movement could be the precursor for this high level of L_{50} and L_{90}. But, at the night non-peak hours when the metro frequency was less and no other activities inside school premises may be the reason for an acceptable level of L_{90}. But, in the case of other study areas L_{10}, L_{50} and L_{90} exceeded the Federal Transit Administration (FTA) day-night noise level standard of 55 dB (A) for safe listening [11].

B. Exposure assessment of metro noise pollution

To investigate the metro noise exposure % noise dose (ND) and time-weighted average (TWA) were calculated based on Occupational Safety Health Administration (OSHA) guidelines (www.osha.gov).

In this following Fig .5 it is indicated that, within AC and Non-AC rakes at different periods, both noise dose (%ND) and time-weighted average (TWA) exceeded the Occupational Safety Health Administration (OSHA) guidelines 1-hour time-weighted average (TWA) of 105 (A). These findings can be attributed to the fact that prolonged exposure to these high levels of noise dose can lead to several health ailments for daily commuters, specially noise-induced hearing loss (NIHL) [5].

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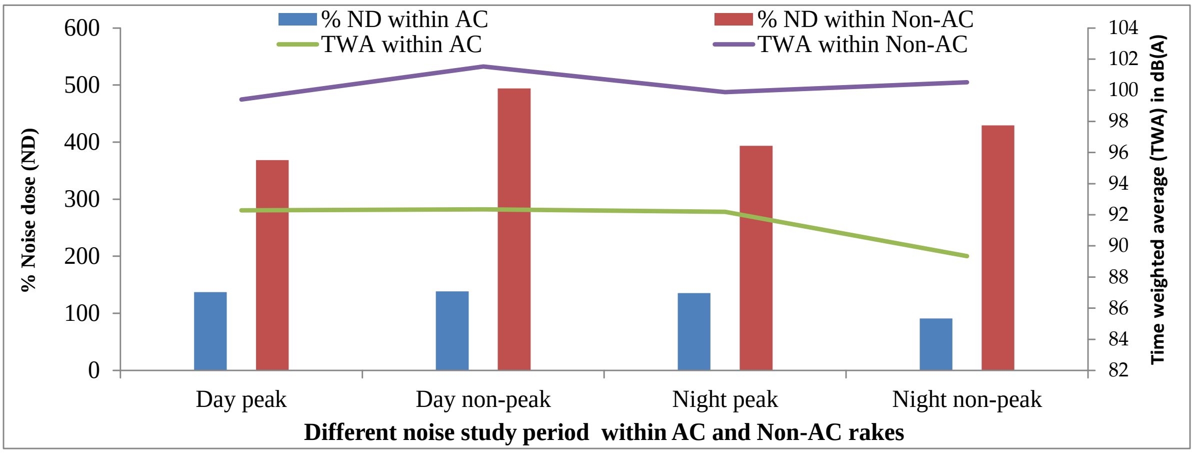

Fig. 5 Variation in % noise dose (ND) and time-weighted average (TWA) in dB(A) at different times of day within different metro rakes (AC and Non-AC)

Due to random movement of metro rakes (both AC and Non-AC) within the underground, overground metro stations, door, window operations, the rattling of exhaust fans, and other mechanical noises from vestibules impose a significant high level of % noise dose (ND) and time-weighted average (TWA) (Fig .6), which exceeded the prescribed limit of % noise dose and time-weighted average (TWA) of the Occupational Safety Health Administration (OSHA) that 400 % noise dose for the 2-hour time-weighted average (TWA) of 100 dB (A) respectively.

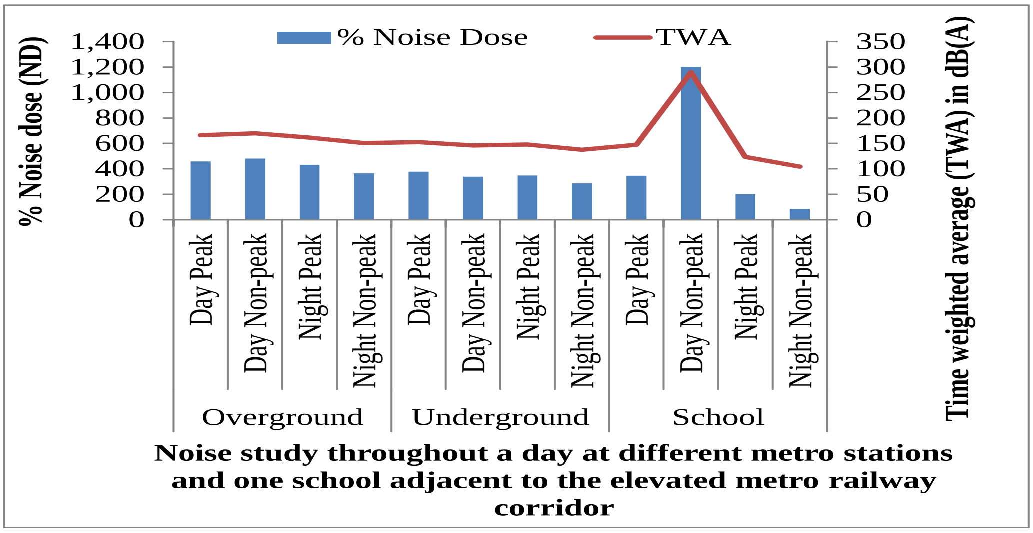

Fig.6 Variation in % noise dose (ND) and time-weighted average (TWA) at different times of day at overground metro stations, underground metro stations, and school building

Long-term exposure to this high level of noise pollution zone can impose detrimental health effects on daily passengers, railway police forces, and other metro workers including auditory problems [5]. On the other hand, Fig . 6 reveals that due to frequent movement of AC and Non-AC rakes within elevated metro corridor adjacent to the school building, different anthropogenic activities within school premises and outside and outdoor traffic causes serious degradation of the acoustic quality of school premises. In the above analysis of % noise dose (ND) and time-weighted average (TWA) (Fig. 6) over the period of two hours at the first floor level of that school building at day-peak, day-non-peak, night-peak, and night-non-peak hours during the examination period of that school are 345.07 %, 1201.60 %, 200.96 %, and 86.27 % respectively. In this case, 2-hour time-weighted average (TWA) at day-peak, day-non-peak, night-peak, and night-non-peak hours within the school building are 147.32 dB(A), 289.59 dB(A), 123.38 dB(A) and 104.33 dB(A) respectively. This observation indicates that the 2-hour time-weighted average exceeded the Occupational Safety Health Administration (OSHA) which is the 2-hour time-weighted average (TWA) of 100 dB (A) for all monitoring duration [5].

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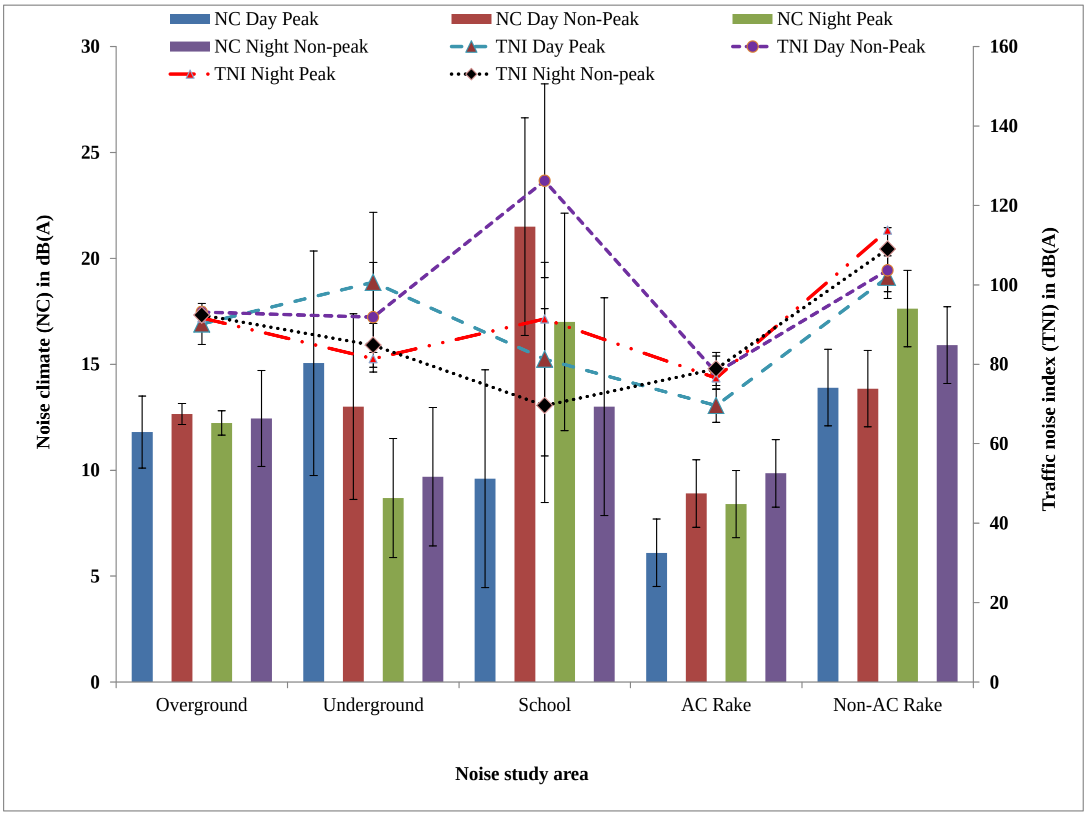

Fig.7 Variation of noise climate (NC) and traffic noise index (TNI) in different noise study areas within different study duration

In this case (Fig . 7), the observed noise climate (NC) and traffic noise index (TNI), were very high at all study durations ranging from 6.1 ± 1.59 dB(A) to 21.5 ± 5.14 dB(A) and 69.6 ± 4.19 dB(A) to 126.2 ± 24.4 dB(A) which were exceeded the allowable limit of less annoyance, that is, 74 dB(A) traffic noise index (TNI), except at day peak study hour within AC metro rakes [10].

C. Railway traffic attributes

Pie-chart percentage distribution of metro rakes on overall railway traffic at each study hour indicates that, in all study areas, Non-AC rakes contribute a major portion of metro railway traffic flow at every study hour except day peak hour. At day peak hours AC rakes contribute 54.55% of railway traffic flow (Fig.8).

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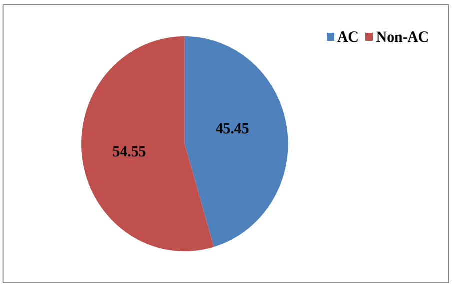
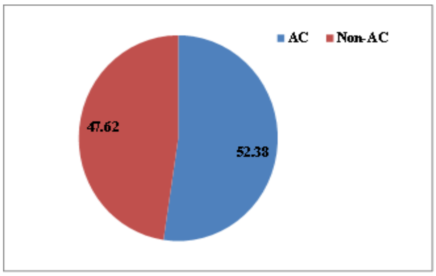


(a)



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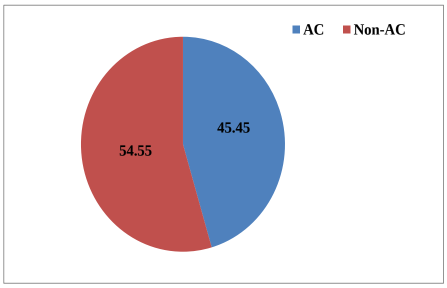

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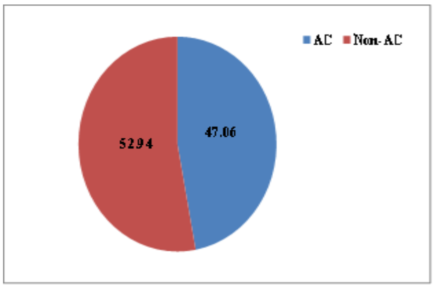

(d)

Fig.8 Hourly percentage contribution of AC and Non-AC rakes on the total number of railway traffic flow at day peak (a), day non-peak (b), night peak (c), and night non-peak (d) hours respectively

D. Statistical analysis of noise descriptors

To quantify the relationship between noise descriptors, Pearson's correlation analysis was conducted between the observed noise descriptors.

Table 1 Correlation statistics between noise descriptors for overground metro stations

	L_{eq}	L_{10}	L_{50}	L_{90}	NC	TNI
L_{eq}	1.00					
L_{10}	0.94	1.00				
L_{50}	0.965*	0.82	1.00			
L_{90}	0.92	0.75	0.992**	1.00		
NC	-0.83	-0.60	-0.95	-0.979*	1.00	
TNI	-0.78	-0.52	-0.91	-0.957*	0.996**	1.00

In this Table 1, Pearson's correlation analysis between all noise descriptors concludes that there is a very high statistically significant positive correlation on exists between L_{eq} and L_{10} (p=0.94), L_{50} (p=0.965), and L_{90} (p=0.92). It signifies that L_{eq} was influenced by peak noise (L_{10}), median noise (L_{50}), and background noise (L_{90}). A very high positive statistically significant correlation exists between L_{50} and L_{90} (p=0.968). A Linear proportional relationship exists between L_{50} (median noise) and L_{90} (background noise). It signifies that median noise (L_{50}) was influenced by background noise (L_{90}). But, noise climate (NC) and traffic noise index (TNI) were negatively influenced by equivalent noise (L_{eq}).

In Table 2, a very high statistically significant positive correlation exists between L_{eq} and L_{10} (p=1.00). A very high statistically significant positive correlation exists between L_{50} and L_{90} (p=0.92). A Linear proportional relationship exists between L_{50} and L_{90}. It signifies that increase in median noise

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Table 2 Correlation statistics between noise descriptors for underground metro stations

	L_{eq}	L_{10}	L_{50}	L_{90}	NC	TNI
L_{eq}	1.00					
L_{10}	1.00**	1.00				
L_{50}	0.62	0.61	1.00			
L_{90}	0.40	0.39	0.92	1.00		
NC	0.04	0.05	-0.70	-0.90	1.00	
TNI	0.20	0.21	-0.59	-0.82	0.988*	1.00

(L_{50}) is influenced by background noise (L_{90}). A very high statistically significant negative correlation exists between L_{90} and NC (p=-0.90). An inversely proportional relationship exists between L_{90} and NC. It signifies that an increase in background noise (L_{90}) is responsible for the decrease in NC. Very high statistically significant positive correlation exists between noise climate (NC) and traffic noise index (TNI) (p=0.988). A Linear proportional relationship exists between noise climate (NC) and traffic noise index (TNI). It signifies that an increase in noise climate (NC) is responsible for the increase in traffic noise index (TNI).

Table 3 Correlation statistics between noise descriptors for Non-AC metro rakes

	L_{eq}	L_{10}	L_{50}	L_{90}	NC	TNI
L_{eq}	1.00					
L_{10}	0.966*	1.00				
L_{50}	0.79	0.64	1.00			
L_{90}	0.60	0.51	0.87	1.00		
NC	-0.26	-0.15	-0.72	-0.93	1.00	
TNI	-0.12	0.00	-0.63	-0.86	0.989*	1.00

Pearson's correlation analysis (Table 3) of noise descriptors for Non-AC metro rakes reveals that a very high statistically significant positive correlation exists between L_{eq} and L_{10} (p=0.966). A very high statistically significant positive correlation exists between L_{50} and L_{90} (p=0.087). A Linear proportional relationship exists between L_{50} and L_{90}. It signifies that the increase in median noise (L_{50}) is influenced by background noise (L_{90}). A very high statistically significant negative correlation exists between L_{90} and noise climate (NC) (p=-0.90). An inversely proportional relationship exists between L_{90} and noise climate (NC). It signifies that an increase in background noise (L_{90}) is responsible for the decrease in noise climate (NC). A very high statistically significant positive correlation exists between noise climate (NC) and traffic noise index (TNI) (p=0.989). A Linear proportional relationship exists between noise climate (NC) and traffic noise index (TNI). It signifies that an increase in noise climate (NC) is responsible for the increase in traffic noise index (TNI).

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Table 4 Correlation statistics between noise descriptors for AC metro rakes

	L_{eq}	L_{10}	L_{50}	L_{90}	NC	TNI
L_{eq}	1.00					
L_{10}	0.970*	1.00				
L_{50}	0.82	0.85	1.00			
L_{90}	0.81	0.90	0.958*	1.00		
NC	-0.61	-0.66	-0.951*	-0.90	1.00	
TNI	-0.46	-0.52	-0.88	-0.81	0.984*	1.00

In Pearson's correlation analysis (Table 4) of noise descriptors for AC, metro rakes conclude that a very high statistically significant positive correlation exists between L_{eq} and L_{10} (p=0.970). A very high statistically significant positive correlation exists between L_{50} and L_{90} (p=0.958). A Linear proportional relationship exists between L_{50} and L_{90}. It signifies that the increase in median noise (L_{50}) is influenced by background noise (L_{90}). A very high statistically significant negative correlation exists between L_{90} and NC (p=-0.90) and L_{50} and noise climate (NC) (p=-0.951). An inversely proportional relationship exists between noise climate (NC) with L_{50} and L_{90}. It signifies that an increase in background noise (L_{90}) is responsible for the decrease in NC. Very high statistically significant positive correlation exists between noise climate (NC) and traffic noise index (TNI) (p=0.984). A Linear proportional relationship exists between noise climate (NC) and TNI. It signifies that an increase in noise climate (NC) is responsible for the increase in traffic noise index (TNI).

Table 5 Correlation statistics between noise descriptors for school buildings due to the movement of AC and Non-AC rakes

	L_{eq}	L_{10}	L_{50}	L_{90}	NC	TNI
L_{eq}	1.00					
L_{10}	0.979*	1.00				
L_{50}	0.93	0.983*	1.00			
L_{90}	0.83	0.93	0.968*	1.00		
NC	0.59	0.41	0.27	0.04	1.00	
TNI	0.92	0.82	0.72	0.54	0.86	1.00

In this above Table 5, Pearson's correlation analysis of noise descriptors of school buildings concludes that a very high statistically significant positive correlation exists between L_{eq} and L_{10} (p=0.979), and L_{50} (p=0.958). A Linear proportional relationship exists between L_{10} and L_{50} with L_{eq}. It signifies that an increase in peak (L_{10}) and median noise (L_{50}) influence the equivalent noise (L_{eq}). Here, in this case, it is indicated that background noise (L_{90}) is also influenced by peak (L_{10}) and median noise (L_{50}). A high statistically significant positive correlation exists between noise climate (NC) and traffic noise index (TNI) (p=0.86). A Linear proportional relationship exists between noise climate (NC) and TNI. It signifies that an increase in noise climate (NC) is responsible for the increase in traffic noise index (TNI).

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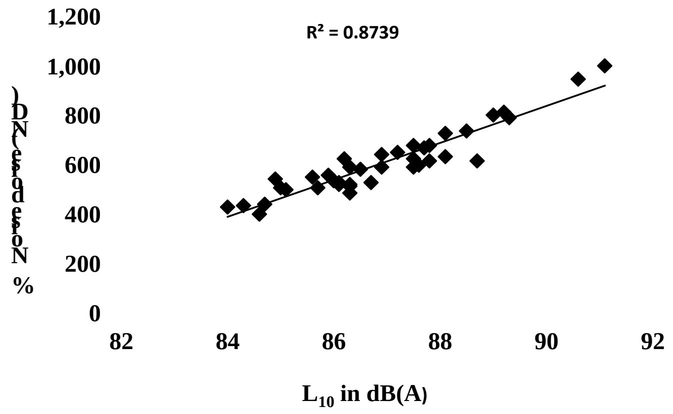

Fig.9 Scatter plot analysis between L_{10} and % ND in the case of overground metro

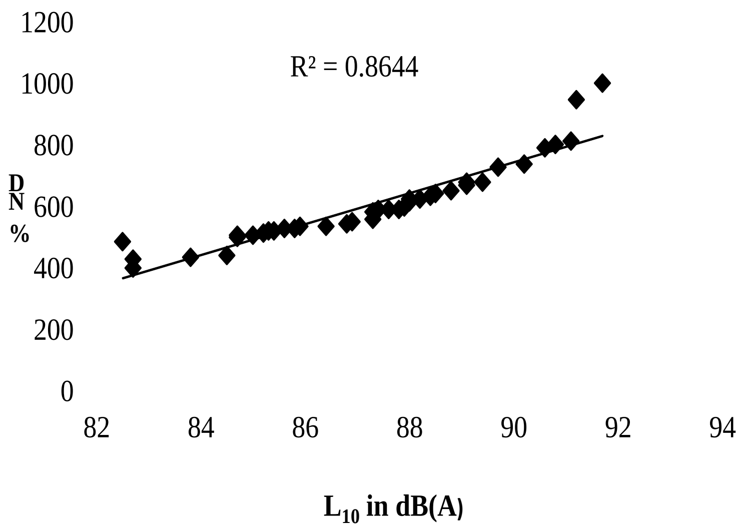

Fig.10 Scatter plot analysis between L_{10} and % ND for the underground metro station

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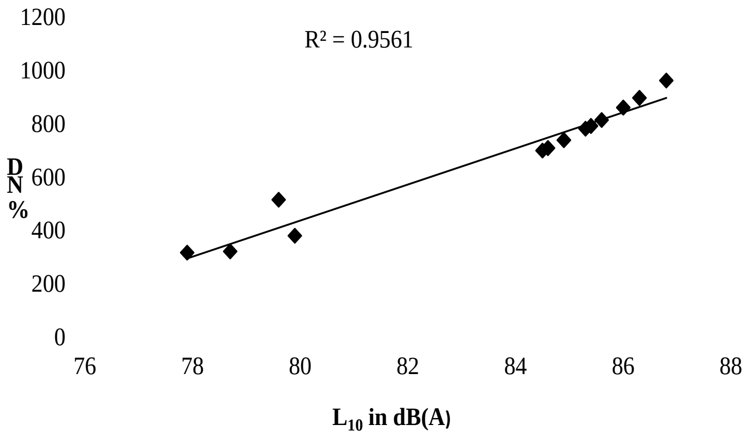

Fig.11 Scatter plot between %ND and L_{10} for AC rakes

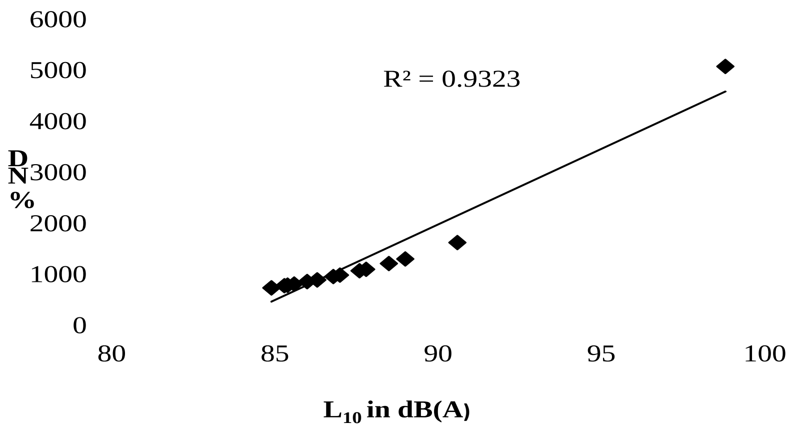

Fig.12 Scatter plot between % ND and L_{10} for Non-AC rakes

Scatter plot analyses (Fig. 9, Fig. 10, Fig. 11, Fig. 12) were performed between %ND and average L_{10} for all the study units, to predict % noise dose (ND) based on L_{10}. In the case of overground, underground metro stations, AC, Non-AC metro rakes, and school buildings very strong relationship between L_{10} and %ND was observed, where, R^2 are 0.87, 0.86, 0.956, 0.93, 0.95 respectively. These findings conclude that there is a very strong relationship exists between L_{10} and % ND for all study locations.

IV. CONCLUSION

It appears from the present study that for each study duration, different noise descriptors, including A-weighted equivalent noise level (L_{eq}), statistical noise level (L_{10}, L_{50}, L_{90}), and noise exposure related parameters noise climate (NC), traffic noise index (TNI), noise dose (% ND) and 2-hours' time-weighted average (TWA), at every study elements were observed very high. Here, the peak noise component (L_{10}) imposes some strong influence on noise dose (%ND), which originates from pressure honking. This observation concludes that the acoustic quality of all considering study areas is mostly affected by Non-AC metro rake movement which was more annoying than AC metro rakes. Due to the ageing of those Non-AC rakes, improper maintenance of Non-AC metro rakes and no existing noise insulation techniques at noise propagation medium were key precursors of this alarming acoustic degradation of all study units. Prolonged exposure to this high level of noise pollution can cause several health ailments to the receptors of different ages. This study proposed that noise barriers should be installed at underground, overground metro stations and along the stretches of overground metro track near the school building and some noise absorption materials may also be introduced in the metro stations, the body of the metro rakes (more specifically in metro doors and windows) and at school

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building for minimizing the adverse effect of noise level generated from the movement of the metro railway system. Receptors may use ear-plug for receiving low noise energy. Some epidemiological studies including noise annoyance study, audibility measurement, cardiovascular and sleep structure evaluation may be conducted on people of different ages and genders, who are consistently exposed to this high level of noise pollution to assess the extent of health effects due to that metro railway movement.

CONFLICT OF INTEREST

The present study declares that there is no conflict of interest.

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REFERENCES

[1] Babisch,W., Cardiovascular effects of noise. NoiseandHealth, vol.13(52),pp201,2011. http://doi.org/10.4103/1463-1741.80148,.
[2] Croy, I., Smith, M.G. and Waye, K.P., Effects of train noise and vibration on human heart rate during sleep: an experimental study. BMJ open, vol.3(5),e002655,2013. http://dx.doi.org/10.1136/bmjopen-2013-002655.
[3] Central Pollution Control Board-CPCB,The Noise Pollution (Regulation and Control) Rules,2000.
[4] Garg, N.; Sharma, O.; Maji, S.,Noise impact assessment of mass rapid transit systems in Delhi city, Indian Journal of Pure and Applied Physics, vol.49,pp257-262,2011.http://nopr.niscair.res.in/handle/123456789/11315.
[5] Gershon, R.R., Neitzel, R., Barrera, M.A. and Akram, M., Pilot survey of subway and bus stop noise levels. Journal of Urban Health, vol.83(5),pp802,2006.https://doi.org/10.1007/s11524-006-9080-3.
[6] Hammer, M.S., Swinburn, T.K. and Neitzel, R.L., Environmental noise pollution in the United States: developing an effective public health response. Environmental health perspectives, vol.122(2),pp115-119,2014.https://doi.org/10.1289/ehp.1307272.
[7] International Organization for Standardization-ISO, 1996-1.Acoustics—Description, Measurement and Assessment of Environmental Noise. Basic Quantities and Assessment Procedures: Part 1, Switzerland,2003.
[8] International Organization for Standardization-ISO, 1996-2. Acoustics—Description and Measurement of Environmental Noise: Acquisition of Data Pertinent to Land Use: Part 2; Switzerland, 1998.
[9] KolkataMetro.Wikipedia.https://en.wikipedia.org/w/index.php?title=Kolkata_Metro&oldid=791035155 (accessed 20th October, 2020).
[10] Ma, G., Tian, Y., Ju, T. and Ren, Z., Assessment of traffic noise pollution from 1989 to 2003 in Lanzhou city. Environmental monitoring and assessment, vol.123(1-3),pp413-430,2006.https://doi.org/10.1007/s10661-006-1494-6.
[11] Mohanan, V., Sharma, O. and Singal, S.P., A noise and vibration survey in an underground railway system. Applied acoustics, vol.28(4),pp 263-275,1989.https://doi.org/10.1016/0003-682X(89)90084-4.
[12] Münzel, T., Gori, T., Babisch, W. and Basner, M., Cardiovascular effects of environmental noise exposure. European heart journal., vol.35(13),pp829-836,2014.https://doi.org/10.1093/eurheartj/ehu030.
[13] Occupational Safety and health Administration-OSHA-2019. Occupational Noise Regulations-1910.85. Available at https://www.govinfo.gov/content/pkg/CFR-2010-title29-vol5/pdf/CFR-2010-title29-vol5-sec1910-95.pdf (accessed 26.10.2020).
[14] Pultznerova, A., Eva, P., Kucharova, D. and Argalasova, L.,Railway noise annoyance on the railway track in northwest slovakia. Noise &health, vol.20(94),pp90,2018. https://dx.doi.org/10.4103%2Fnah.NAH_59_17.
[15] Recio, A., Linares, C. and Díaz, J., System dynamics for predicting the impact of traffic noise on cardiovascular mortality in Madrid. Environmental Research., vol.167, pp499-505,2018.https://doi.org/10.1016/j.envres.2018.07.021.
[16] Research Designs and Standards Organisation, Ministry of Railways, India-RDSO,Metro Rail Transit System: Guidelines for Noise and Vibrations; Track Design Directorate, CT-38,2015.
[17] Solanki, H.K., Ahamed, F., Gupta, S.K. and Nongkynrih, B., Road transport in Urban India: Its implications on health. Indian journal of community medicine: official publication of Indian Association of Preventive & Social Medicine, vol.41(1),pp16,2016.http://doi.org/10.4103/0970-0218.170959.
[18] Vogiatzis, K., Environmental ground borne noise and vibration protection of sensitive cultural receptors along the Athens Metro Extension to Piraeus. Science of the Total Environment, vol.439,pp230-237,2012.https://doi.org/10.1016/j.scitotenv.2012.08.097.
[19] World Health Organisation-WHO,Noise exposure limit for children in recreational settings: review of available evidence,2018.

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