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Investigation of diurnal road traffic noise in Makurdi metropolis, Benue State, Nigeria

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Abstract

Road traffic noise is the main source of noise in cities and is considered not only an environmental problem but also a threat to public health. This study assessed diurnal road traffic noise levels and their correlation with traffic flow characteristics in Makurdi metropolis, aiming to determine the extent of noise pollution and suggest solutions. Five locations in Makurdi metropolis were selected for this study. Results from the study revealed that the mean equivalent continuous noise level (L_{eq}), noise pollution level (L_{NP}), traffic noise index (TNI), and noise climate (NC) ranged from 68.65 to 70.46 dBA, 62.90 to 67.64 dBA, 16.98 to 31.13 dBA, and -2.18 to -6.33 dBA respectively during dry season, while the mean L_{eq}, L_{NP}, TNI and NC ranged from 65.83 to 70.72 dBA, 56.71 to 67.62 dBA, 3.87 to 29.99 dBA and -3.10 to -9.12 dBA respectively during wet season. The L_{eq} values exceeded the 60 dBA limit stipulated by National Environmental Standards and Regulations Enforcement Agency (NESREA) but were mostly below the 70 dBA limit recommended by World Health Organisation (WHO) except in few locations where the noise levels were slightly above WHO prescribed limit. It is recommended that public awareness campaigns on the harmful effects of road traffic noise be created by relevant agencies.

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1. Introduction

Noise is an unpleasant sound that creates annoyance and interferes with conversation, teaching-learning processes, disturbs sleep, reduces work efficiency, causes stress and other challenges to public health [1]. Noise may also be considered as the wrong sound in the wrong place at the wrong time [2]. The noise received by humans depend on some factors such as age, gender and mood of the individual [3].

Noise pollution is a broad environmental problem that affects millions of people all over the world [4]. The effects of noise on people in developing countries are as widespread as those in developed countries, and the long-term effects are the same [5, 6]. In Nigeria, like other African or underdeveloped nations, noise pollution is a common problem, however, the campaign (if there is any) against it, is not strong. A greater percentage of people do not consider noise as a pollutant and take it as part of normal life [3].

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The negative health effects of noise can be categorized into two based on its duration and volume. These are, auditory effects, also known as physical effects such as hearing defects, and non-auditory effects which are associated with physiological effects such as high blood pressure, irregularity of heart rhythms and peptic ulcers; psychological effects such as mental disorders, sleeping disorders, irritability and stress; and performance related effects such as decline in productivity and misunderstanding what is heard [7].

Noise can emanate from various sources such as transport systems, industrial activities, construction sites and recreational activities. The increasing urbanization and industrialization of societies have escalated the problem [4]. It is a well-known fact that traffic noise is the number one contributor to the overall noise pollution scenario [8]. Studies have revealed that more than 70% of the total noise is generated by vehicles [9, 10]. Urban traffic noise is one of the most critical types of noise and is normally considered more interfering than the other types of noise [11].

Traffic noise problem is caused by various kinds of vehicles such as motorcycles, tricycles cars, buses, trucks and heavy vehicles. It is a combination of the noise produced by vehicle engines, exhaust and tyres. Traffic noise is also elevated by defective mufflers or other faulty parts of vehicles. Conditions like a steep incline which causes heavy labouring of vehicle engines also complicates traffic noise [12]. The physical characteristics of the road surface play a major role in determining traffic noise output. Well-maintained, smooth-surfaced roads are less noisy compared to those with cracked, damaged and patched surfaces [13].

Several studies have reported that road traffic noise in most Nigerian cities exceed the stipulated standard limits. A study conducted by Oluwasegun *et al*. [14] in Ikeja metropolis on road traffic noise pollution and impacts on residents of Ikeja Local Government Area of Lagos State, Nigeria revealed that the average maximum values of equivalent continuous noise level (L_{Aeq}) at the road junctions/roundabouts, busy roads, parks/garages were found to be 90.50, 88.10 and 88.80 dB(A), respectively. These noise levels were far above the recommended limits of 70 and 60 dB(A) by the World Health Organization (WHO) and National Environmental Standards and Regulations Enforcement Agency (NESREA), respectively. Similarly, a study conducted in Nigeria by Akpen *et al*. [15] in Makurdi metropolis indicated that the road traffic noise levels in all the sampled locations at various distances exceeded the WHO stipulated limit of 70 dB by 0.73 to 3.09 dB(A). In another research on noise pollution measurements and possible effects on public health in Ota Metropolis, Nigeria by Oguntunde *et al*. [16], it was found that the mean noise levels ranged from 90.60 to 90.78 dB(A) which are far above the WHO recommendations. Also, the assessment of noise pollution levels at major motor parks in Port Harcourt metropolis, Rivers State, Nigeria was conducted by Udeh and Egwoha [17]. The study established that the noise levels were above the permissible limit by NESREA for residential and business locations. Again, a study carried out by Ede *et al*. [18] in motor parks at Izuchukwu junction and its axis in Nnewi, Anambra State, Nigeria revealed that, the average noise levels of the studied motor parks was 77.70 dB which surpassed the WHO and NESREA recommended permissible limits. In the same light, a study conducted by Ekom *et al*. [4] in selected highways and motor parks in FCT Abuja, Nigeria found that, the daytime noise levels of highways and motor parks were 81.50 and 76.10 dB(A), respectively, which exceeded WHO and NESREA permissible limits.

Annual Average Daily Traffic (AADT) is the total number of vehicles traversing a roadway in a year divide by 365 days. It is a metric generally used in transportation planning and engineering. The American Association of State Highways and Transport Officials (AASHTO) in 1992 released the AASHTO Traffic Data Programs which identified a way of Producing AADT without seasonal biases or day-of-week biases by creating "average of averages". Today, newer advances from traffic data providers have made it possible to calculate AADT by side of the road, day of the week and by time of the day [19]. This study was deemed necessary to assess the diurnal road traffic noise level in Makurdi metropolis in order to determine the extent of environmental pollution from the noise and suggest possible solutions that will attenuate the problem. The study further attempts to investigate the correlation between L_{eq} and traffic flow characteristics. The AASHTO guidelines were adopted in this study to compute the average traffic data for each study location in the study area.

2. Materials and methods

2.1. Study area

Makurdi metropolis is the study area. It is the capital of Benue State in the central part of Nigeria called Middle Belt. The town is located between Latitudes 7°38′ and 7°50′ N, and Longitudes 8°24′ and 8°38′ E [20]. It is traversed by the second largest river in the country, the River Benue. The town is strategically located on the North-South transportation network by road and by rail, respectively, between Nasarawa and Enugu States [21] with a landmass of about 800 km^2 and an estimated population of 367,588 people according to the National population census data of 2006 [22]. The area has two distinct seasons; the dry and wet seasons. The dry season starts in November and usually ends by March, while the wet season is from April to October with a mean annual rainfall ranging from 1200 to 2000 mm [23]. Temperature in Makurdi is however, generally high all over the year [20]. The average daily temperature varies between 21 and 37°C [24, 25]. Relative humidity fluctuates with seasons, reaching its mean monthly peak of about 92% in the wet season [26]. SRS Junction, Wurukum Roundabout, Balcony Junction, High Level Roundabout, and Ankpa Ward Junction were selected for this research. These locations were selected based on the fact that they are critical to traffic flow in the study area. Table 1 shows the geographical coordinates and elevations of the study locations which were obtained using a Global Positioning System (GPS) device, while Figure 1 represents the geographical map of the study area indicating the study locations.

Table 1: Geographical coordinates and elevations of the study locations.

S/No.	Location	Location code	Lat. (N)	Long. (E)	Elevation (m)
1.	SRS Junction	SRSJ	7.761425°	8.557624°	134
2.	Wurukum Roundabout	WRA	7.727667°	8.546663°	76
3.	Balcony Junction	BJ	7.700994°	8.537742°	92
4.	High Level Roundabout	HLRA	7.718076°	8.529509°	92
5.	Ankpa Ward Junction	AWJ	7.722313°	8.507453°	94

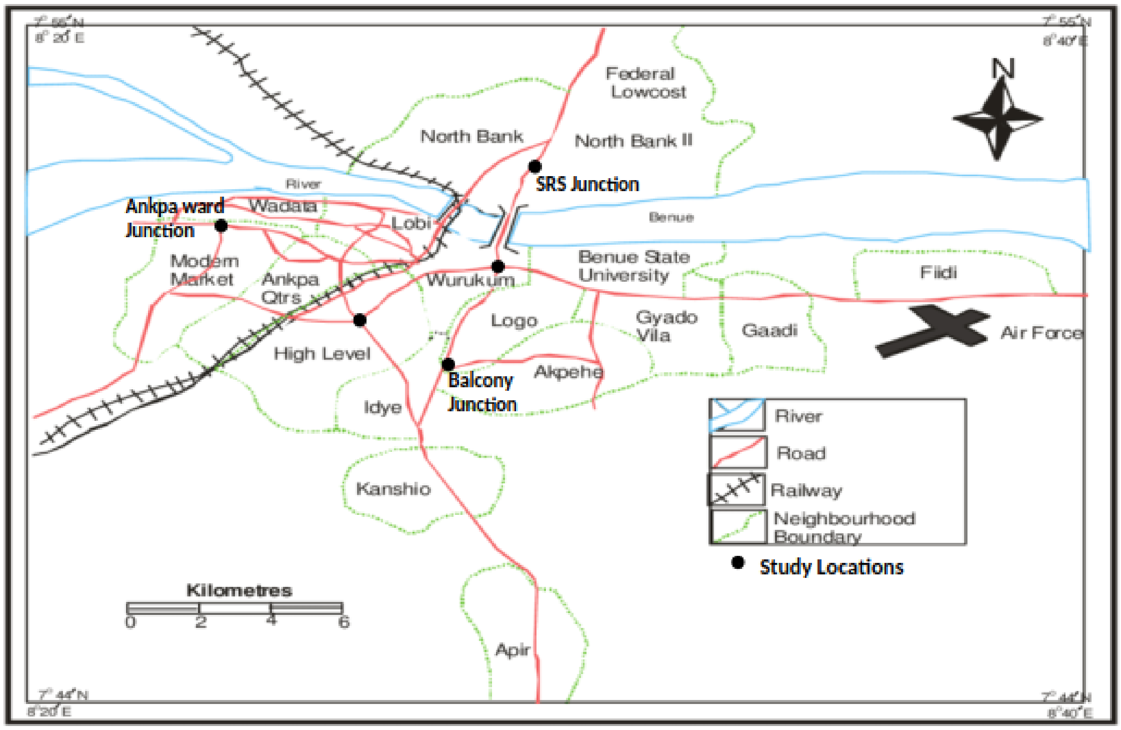


Figure 1: Geographical map of Makurdi metropolis.

2.2. Methods

2.2.1. Measurement of sound pressure level

The decibel (dB) scale is commonly used to measure sound. The decibel is the logarithmic ratio of one pressure to another [27]. The sound pressure level (L_p) in decibels is defined as [28–30]:

$$L_p = 20\log_{10}\left(\frac{p}{p_0}\right), \tag{1}$$

where p is the root-mean-square sound pressure in Newton per square meter and p_0 is the standard reference sound pressure; 2×10^{-5} Pa or 20μPa which corresponds to the threshold of human hearing.

2.2.2. Equivalent continuous noise level

The equivalent continuous noise level (L_{eq}) is the steady sound pressure level which over a given period of time has the same total energy as the actual fluctuating noise [29, 31–33]. It is given by [33–36]:

$$L_{eq} = 10\log_{10}\frac{1}{N}\left[10^{L_{p1}/10} + 10^{L_{p2}/10} + \cdots 10^{L_{pN}/10}\right], \tag{2}$$

where $L_{p1}, L_{p2}, L_{p3}, \ldots, L_{pN}$ are individual sound pressure level readings in dB(A) and N is the number of measurements in the assessed time.

2.2.3. Noise pollution level

The noise pollution level (L_{NP}) is a noise indicator which considers the L_{eq} and the magnitude of time variation in the noise level. It can be calculated using the expression [13, 32, 37–40]:

$$L_{NP} = L_{eq} + (L_{10} - L_{90}), \tag{3}$$

where L_{10} and L_{90} represent the noise levels exceeded for 10% and 90% of the measurement time, respectively.

2.2.4. Traffic noise index

Traffic noise index (TNI) is a measure of public annoyance caused by traffic noise and it is expressed as [38, 39, 41–43]:

$$TNI = 4(L_{10} - L_{90}) + L_{90} - 30, \tag{4}$$

where 30 is the correction factor.

2.2.5. Noise climate

Noise climate (NC) is the range over which sound levels vary in an interval of time and is given by [14, 38, 39, 41, 42, 44]:

$$NC = L_{10} - L_{90}. \tag{5}$$

2.3. Traffic flow characteristics

The relationship among speed, flow rate and density gives the traffic flow characteristics.

2.3.1. Traffic density

Traffic density, k, is the number of vehicles per unit length of roadway and is given by [19, 45, 46]:

$$k = \frac{n}{L}, \tag{6}$$

where n is the number of vehicles and L is the length of roadway in kilometers (km).

2.3.2. Traffic flow rate

The traffic flow rate, q, is the number of vehicles passing a certain cross-section during a specified period of time and is expressed as [19, 45, 47]:

$$q = \frac{n}{t}, \tag{7}$$

where t is the time interval in hours (hrs). The flow rate can be likened to the discharge or the flux of a stream. The maximum possible flow rate of any road is called its capacity.

2.3.3. Space mean speed

The space mean speed, V_s is the average speed of vehicles over a given road segment [20]. It is also defined as the quotient of traffic flow rate and traffic density [19, 46–48], that is:

$$V_s = \frac{q}{k}. \tag{8}$$

If all vehicle speeds are measured over the same length of roadway, i.e. $L = L_1 = L_2 = L_3 = \ldots = L_n$, then V_s is expressed as [19, 45, 46]:

$$V_s = \frac{L}{\frac{1}{n}\sum_{i=1}^{n} t_i}, \tag{9}$$

where L is the length of roadway under study in kilometers (km) and t_i is the time interval of the i^{th} vehicle in hours (hrs).

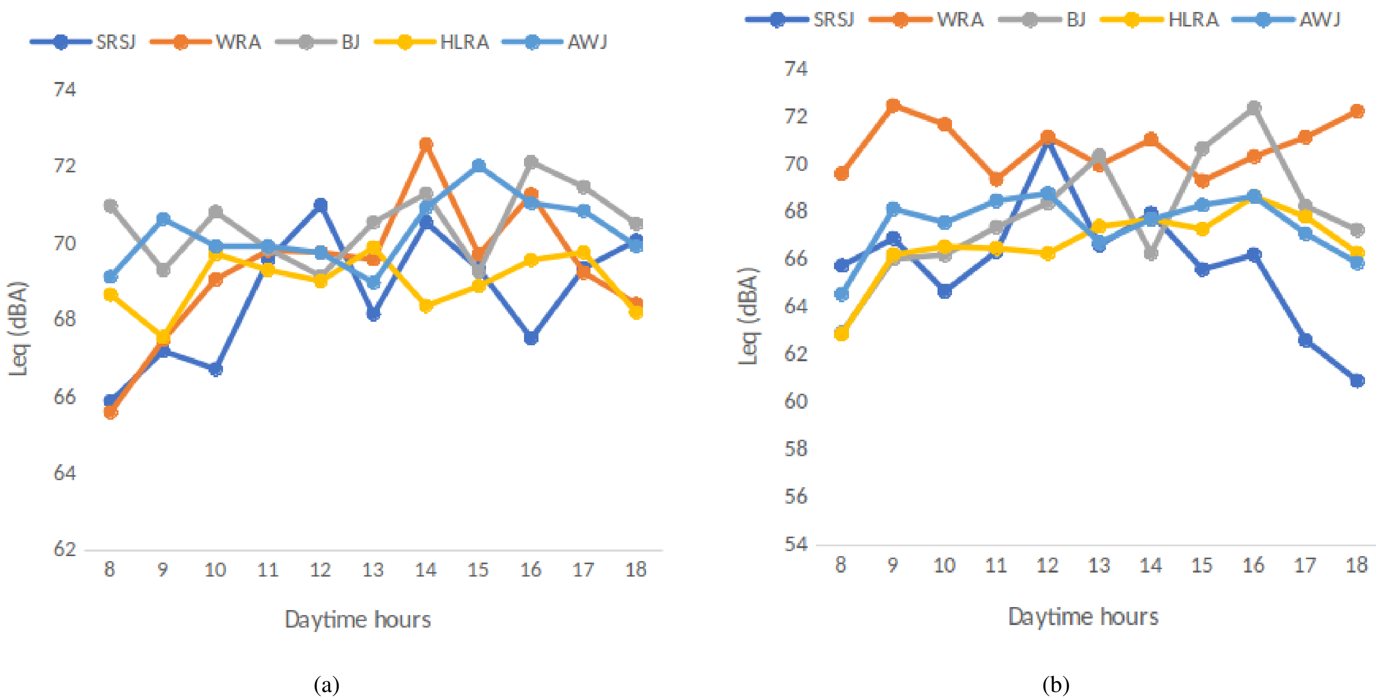


Figure 2: Diurnal variation of equivalent continuous noise levels (L_{eq}) across the study locations for (a) dry season and (b) wet season.

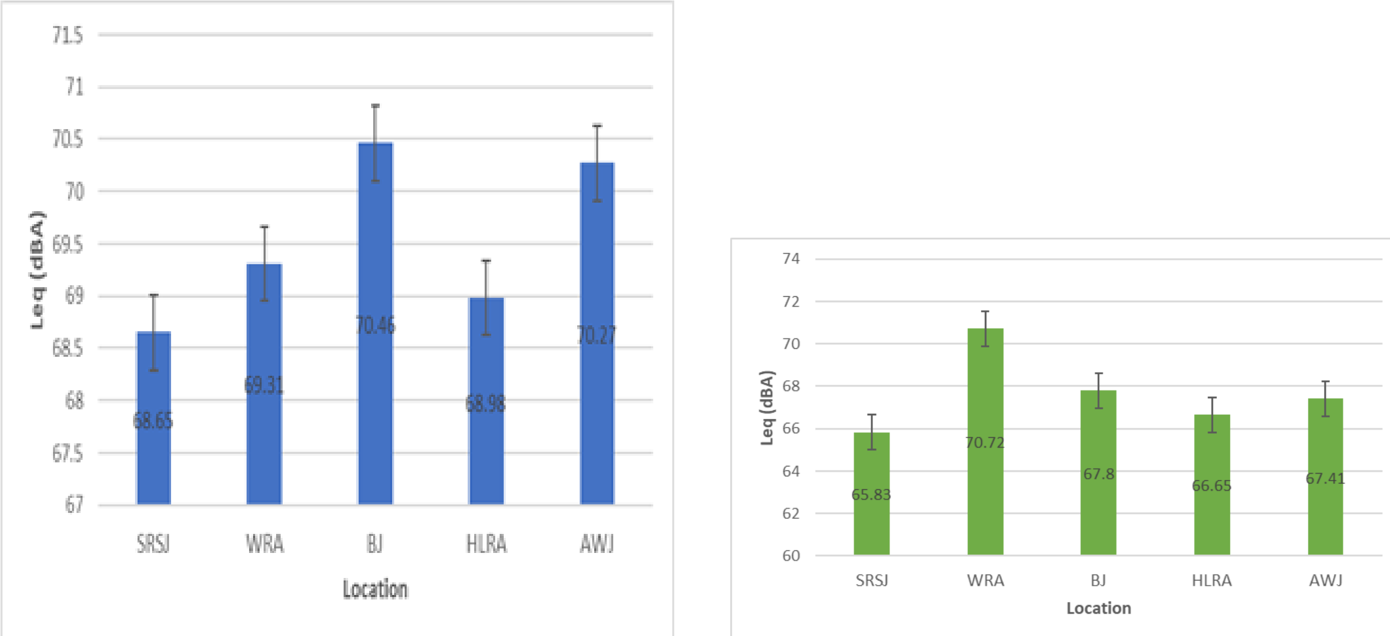
2.4. Measurement of road traffic sound pressure level and traffic count

A microprocessor digital sound level meter, model SL-5858 was used for measuring the road traffic sound pressure level. The meter was mounted on a stand at a height of 1.5 m above ground level. Measurements were taken at a distance of at least 3.5 m away from any reflecting surface to avoid the effect of sound reverberation. The meter was positioned at a distance of 1.5 m from the edge of road shoulder. Readings from the meter at each study location were recorded from 7:00 am to 6:00 pm on each day in every 10 minutes and the hourly equivalent continuous noise levels were computed for each study location.

Closed-Circuit Televisions commonly known as CCTV cameras were mounted on separate stands and positioned beside the roadway at the selected locations to capture the passing vehicles from 7:00 am to 6:00 pm on each day. The devices were positioned where there was free flow of traffic. The CCTVs were linked to mobile phones through Wi-Fi for monitoring to ensure exact coverage of the targeted area and to ensure that nobody tampers with them. Each CCTV was powered by a 20000 mAh power bank. A 4 m length of road section was marked on each roadway and the number of vehicles crossing the marked sections was recorded. The CCTVs were placed at each leg of the roundabouts and junctions to record incoming vehicles only. The hourly number of vehicles for each day was later extracted by replaying the videos from the CCTVs via laptop on slow motion and the hourly average number of vehicles for each study location was computed. The road traffic sound pressure measurements and the traffic counts were conducted at 2 busy roundabouts and 3 busy junctions (cross intersections) in Makurdi metropolis for 5 days (i.e Mondays, Wednesdays, Fridays, Saturdays and Sundays) at each study location from November to December, 2022 and from August to September, 2023 marking the dry and wet season periods, respectively. All measurements at a particular study location were carried out concurrently.

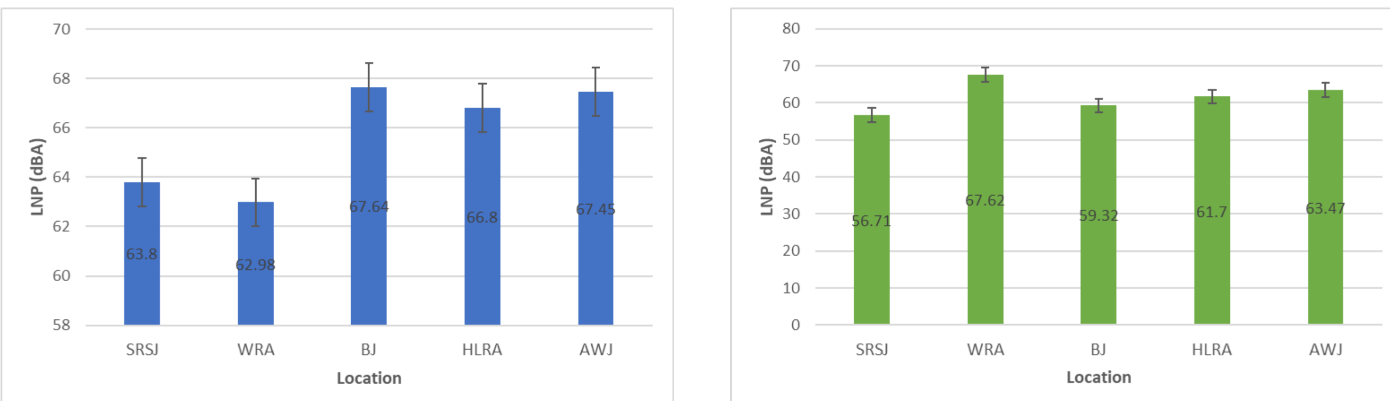
3. Results

The values of road traffic sound pressure level (L_p) obtained from field measurement were used to calculate the equivalent continuous noise level (L_{eq}), the noise pollution level (L_{NP}), the traffic noise index (TNI), and the noise climate (NC) using equations (2), (3), (4), and (5), respectively. Similarly, the traffic density (k), traffic flow rate (q), and space mean speed (V_s) were obtained from the number vehicles (n) using equations (6), (7), and (9), respectively. Figures 2a and 2b represent the diurnal variation of L_{eq} across the study locations for dry and wet seasons, respectively, while Figures 3a and 3b, 4a and 4b, 5a and 5b, and 6a and 6b illustrate the diurnal variation of mean L_{eq}, L_{NP}, TNI, and NC respectively across the study locations for dry and wet seasons. The acronyms SRSJ, WRA, BJ, HLRA, and AWJ stand for SRS Junction, Wurukum Roundabout, Balcony Junction, High Level Roundabout, and Ankpa Ward Junction, respectively. Again, Tables 2 and 3 present a summary of mean n, k, q, and V_s across the study locations during dry and wet seasons, respectively, whereas Figures 7 to 11 display the diurnal variation of L_{eq} with n, k, q, and V_s at each study location during dry and wet seasons.



(a) (b)

Figure 3: Mean equivalent continuous noise levels (L_{eq}) across the study locations for (a) dry season and (b) wet season.



(a) (b)

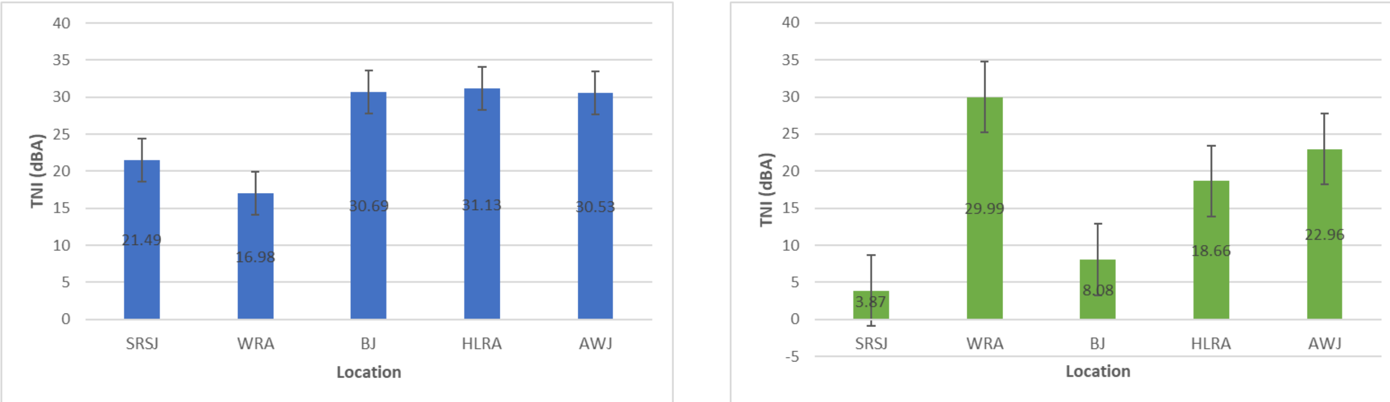
Figure 4: Mean L_{NP} across the study locations for (a) dry season and (b) wet season.

Table 2: Summary of mean n, k, q, and V_s across the study locations during dry season.

Location	n	k (veh/m)	q (veh/hr)	V_s (km/hr)
SRS Junction	3133	783	3133	16.39
Wurukum Roundabout	7881	1970	7881	41.23
Balcony Junction	3520	880	3520	18.42
High Level Roundabout	4658	1165	4658	24.37
Ankpa Ward Junction	4634	1158	4634	24.25

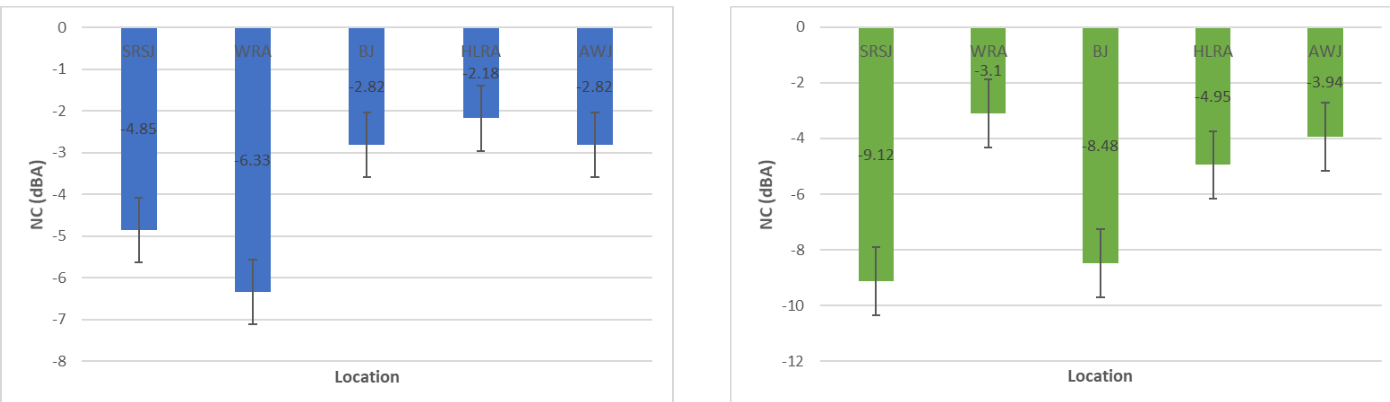
4. Discussion

Figure 2a and 2b revealed a significant variation in the noise levels of the various locations at different times of the day which confirm a trend of inconsistent variation in the noise levels. From Figure 3a, the mean L_{eq} values of 68.65, 69.31, 70.46, 68.98, and 70.27 dBA were obtained at SRS Junction, Wurukum Roundabout, Balcony Junction, High Level Roundabout, and Ankpa Ward Junction, respectively, with a minimum mean L_{eq} of 68.65 dBA and a maximum mean Leq of 70.46 dBA recorded at SRS and Balcony



(a) (b)

Figure 5: Mean TNI across the study locations for (a) dry season and (b) wet season.



(a) (b)

Figure 6: Mean NC across the study locations for (a) dry season and (b) wet season.

Table 3: Summary of mean n, k, q, and V_s across the study locations during wet season.

Location	n	k (veh/m)	q (veh/hr)	V_s (km/hr)
SRS Junction	2522	631	2522	13.19
Wurukum Roundabout	7729	1933	7729	40.44
Balcony Junction	2924	731	2924	15.30
High Level Roundabout	4655	1164	4655	24.36
Ankpa Ward Junction	3994	999	3994	20.90

Junctions, respectively during dry season, whereas mean L_{eq} values of 65.83, 70.72, 67.80, 66.65, and 67.41 dBA were recorded at SRS Junction, Wurukum Roundabout, Balcony Junction, High Level Roundabout, and Ankpa Ward Junction, respectively during wet season as illustrated in Figure 3b, with minimum and maximum mean L_{eq} values of 65.83 and 70.72 dBA obtained at SRS Junction and Wurukum Roundabout, respectively. This implies that the people living, working or trading around these locations are exposed to noise levels of 68.65 to 70.46 dBA or more every day. These noise levels surpass the 60 dBA limit stipulated by NESREA but are slightly below the 70 dBA limit recommended by WHO except at Balcony Junction and Ankpa Ward Junction during dry season and Wurukum Roundabout during wet season where the noise levels are slightly above the WHO recommended limit. The noise levels in both seasons indicate that people who spend most of their time in these locations are liable to be affected by health conditions associated with exposure to noise pollution.

The mean noise pollution level (L_{NP}) values of 63.80, 62.98, 67.64, 66.80, and 67.45 dBA were recorded at SRS Junction, Wurukum Roundabout, Balcony Junction, High Level Roundabout and, Ankpa Ward Junction, respectively during dry season as displayed in Figure 4a, with Wurukum Roundabout and Balcony Junction having the minimum (62.90 dBA) and maximum (67.64 dBA) L_{NP}, respectively. Figure 4b presents the mean L_{NP} at the study locations during wet season. From the figure, SRS Junction,

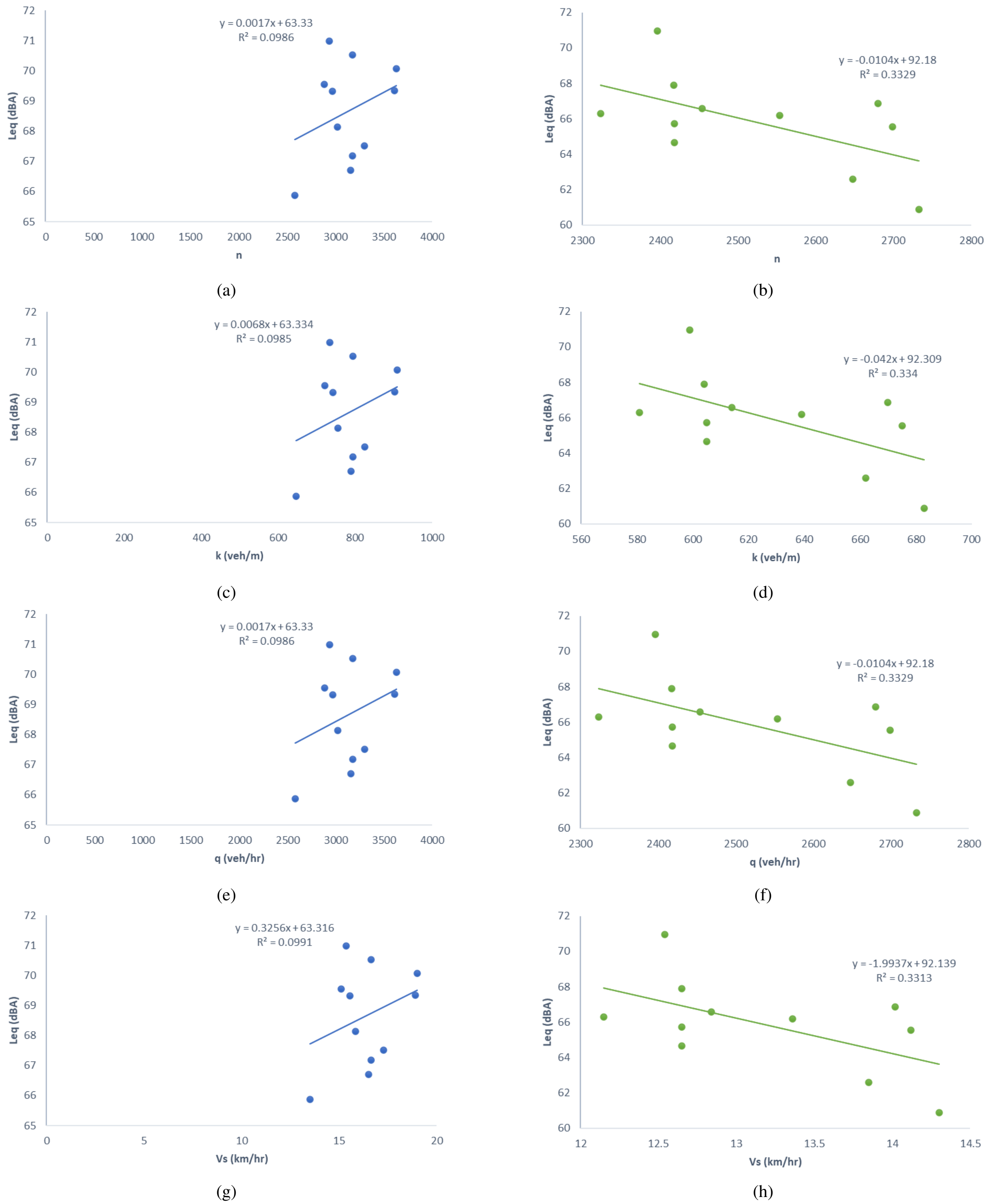


Figure 7: Diurnal variation of L_{eq} with n, k, q, and V_s at SRS Junction during (a) dry season and (b) wet season.

Wurukum Roundabout, Balcony Junction, High Level Roundabout, and Ankpa Ward Junction had mean L_{NP} of 56.71, 67.62, 59.32, 61.70, and 63.47 dBA, respectively, with SRS Junction and Wurukum Roundabout having minimum and maximum mean L_{NP} values

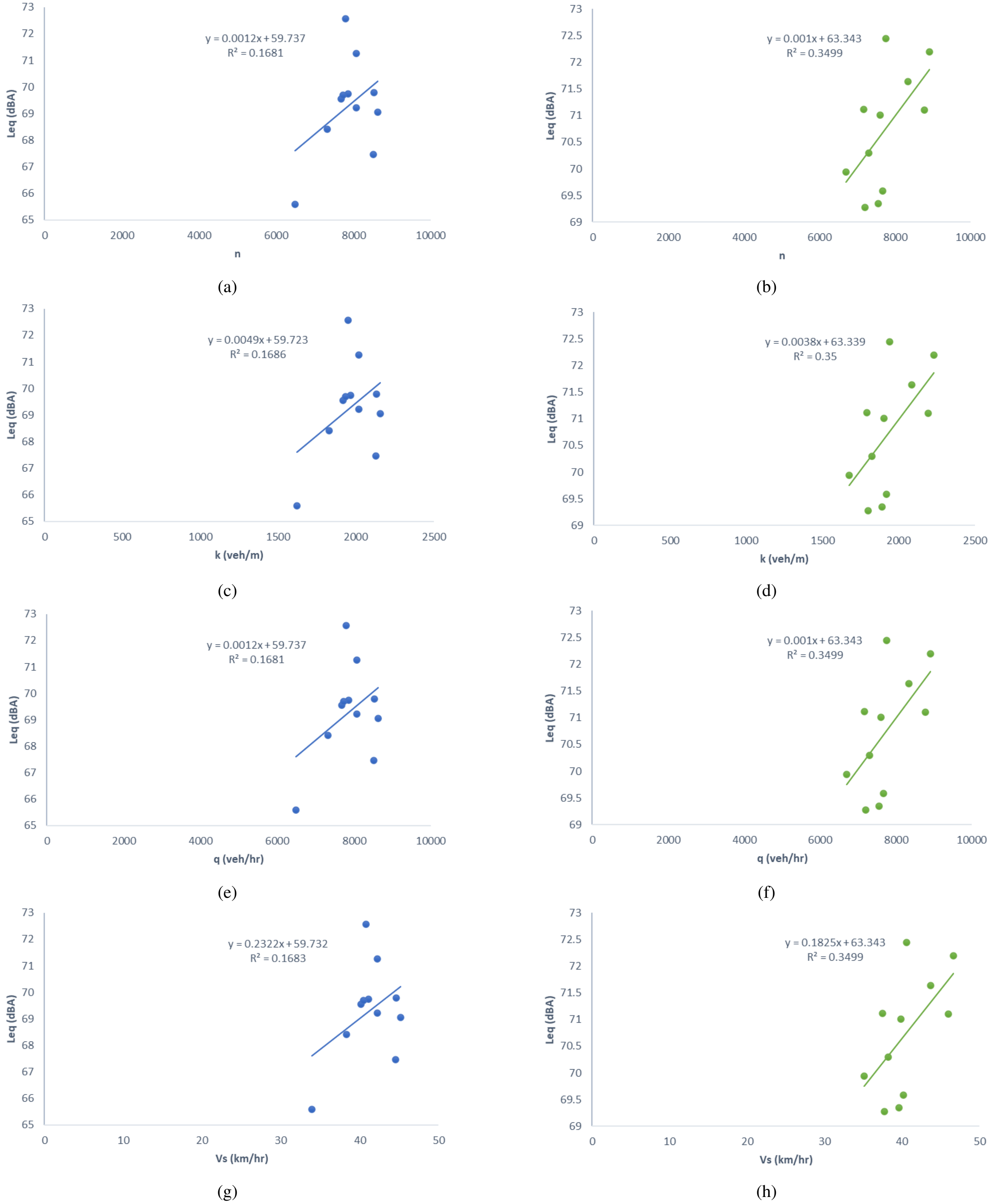


Figure 8: Diurnal variation of L_{eq} with n, k, q, and V_s at Wurukum Roundabout during (a) dry season and (b) wet season.

of 56.71 and 67.62 dBA, respectively.

Figures 5a and 5b illustrate the mean traffic noise index (TNI) across the study locations during dry and wet seasons, respectively.

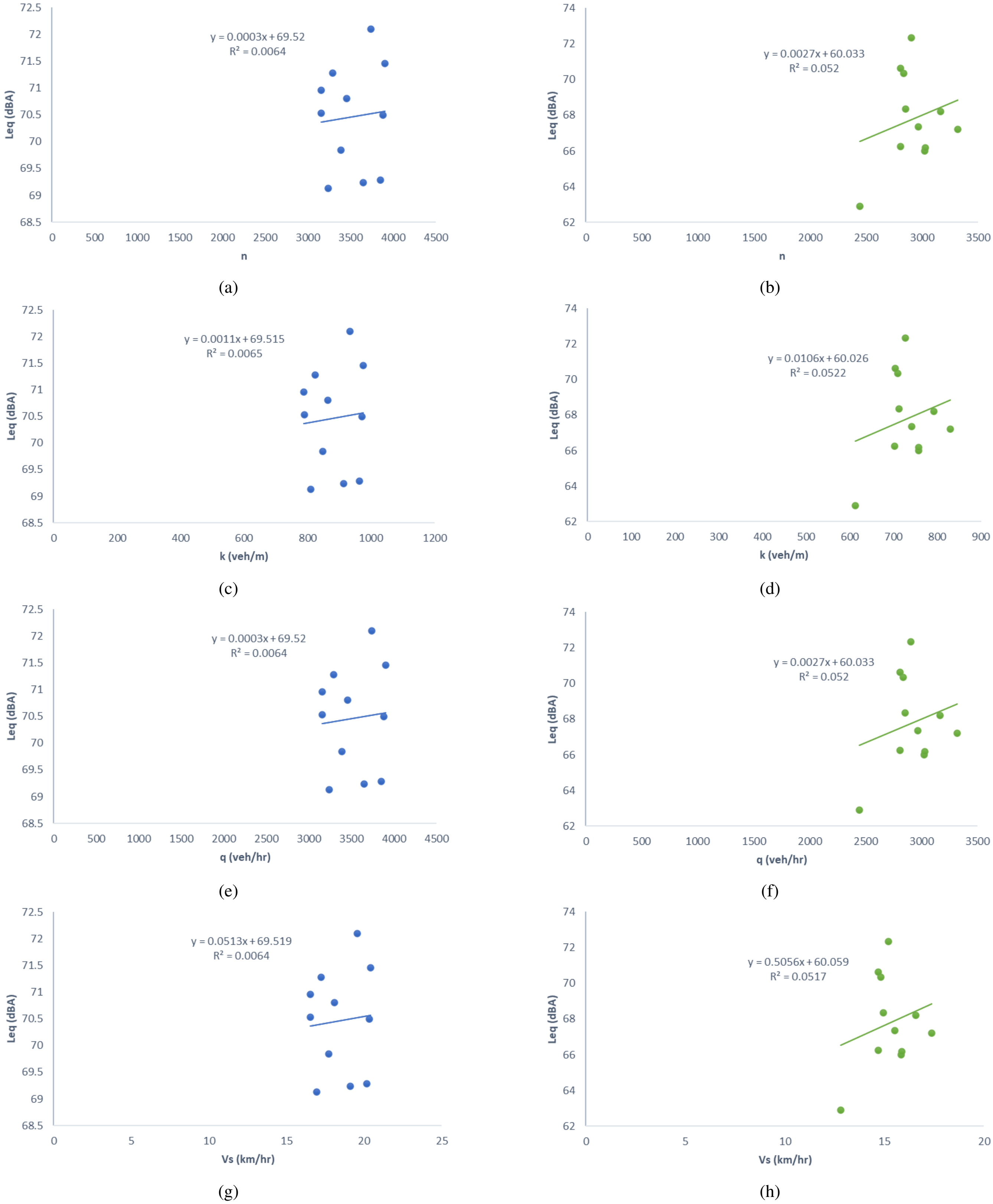


Figure 9: Diurnal variation of L_{eq} with n, k, q, and V_s at Balcony Junction during (a) dry season and (b) wet season.

It can be observed from Figure 5a that mean TNI of 21.49, 16.98, 30.69, 31.13, and 30.53 dBA were found at SRS Junction, Wurukum Roundabout, Balcony Junction, High Level Roundabout, and Ankpa Ward Junction, respectively during dry season. The

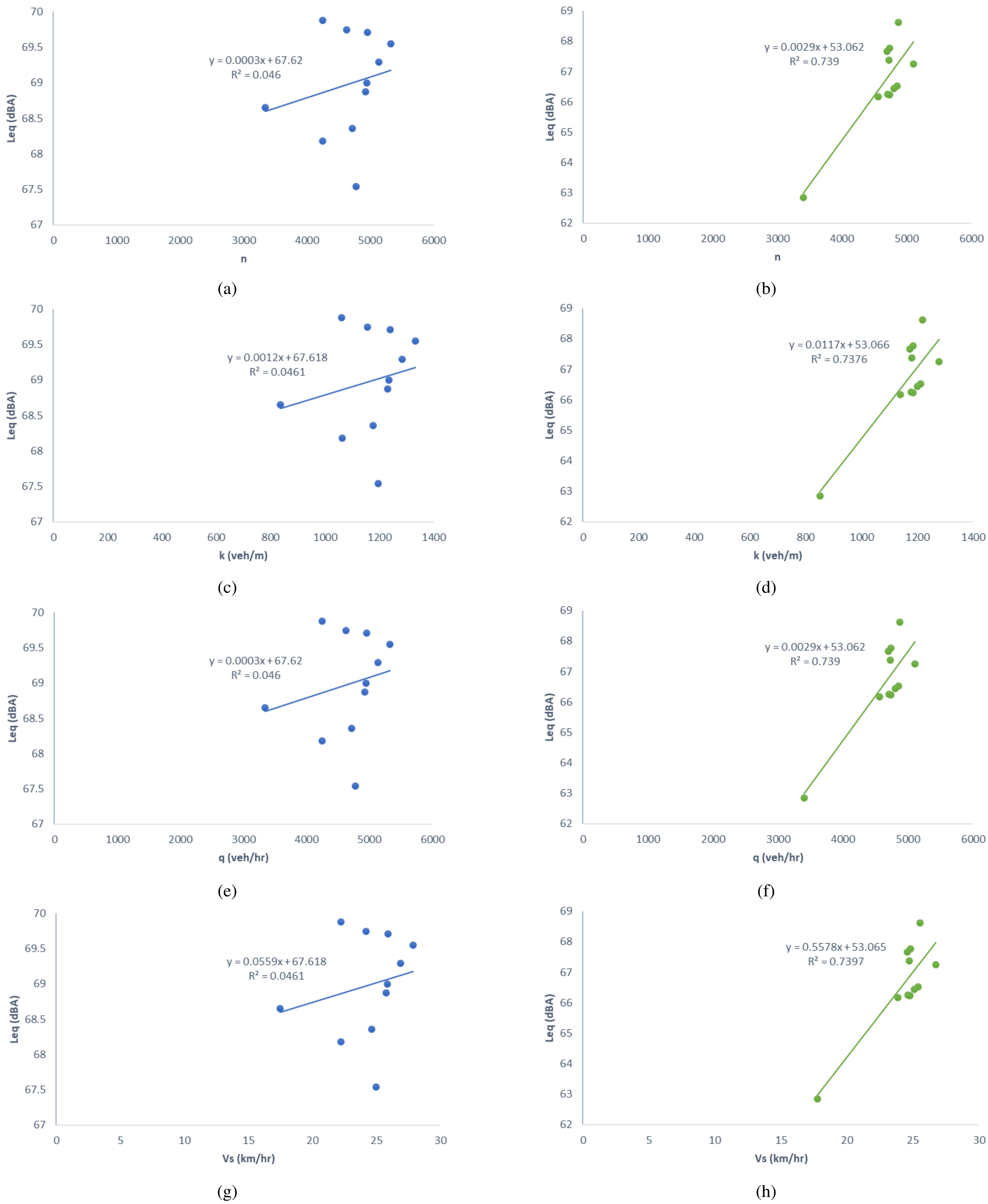


Figure 10: Diurnal variation of L_{eq} with n, k, q, and V_s at High Level Roundabout during (a) dry season and (b) wet season.

minimum and maximum mean TNI values of 16.98 dBA and 31.13 dBA were observed at Wurukum and High Level Roundabouts, respectively. This indicates that Wurukum and High Level Roundabouts had the lowest and highest annoyance response due to traffic

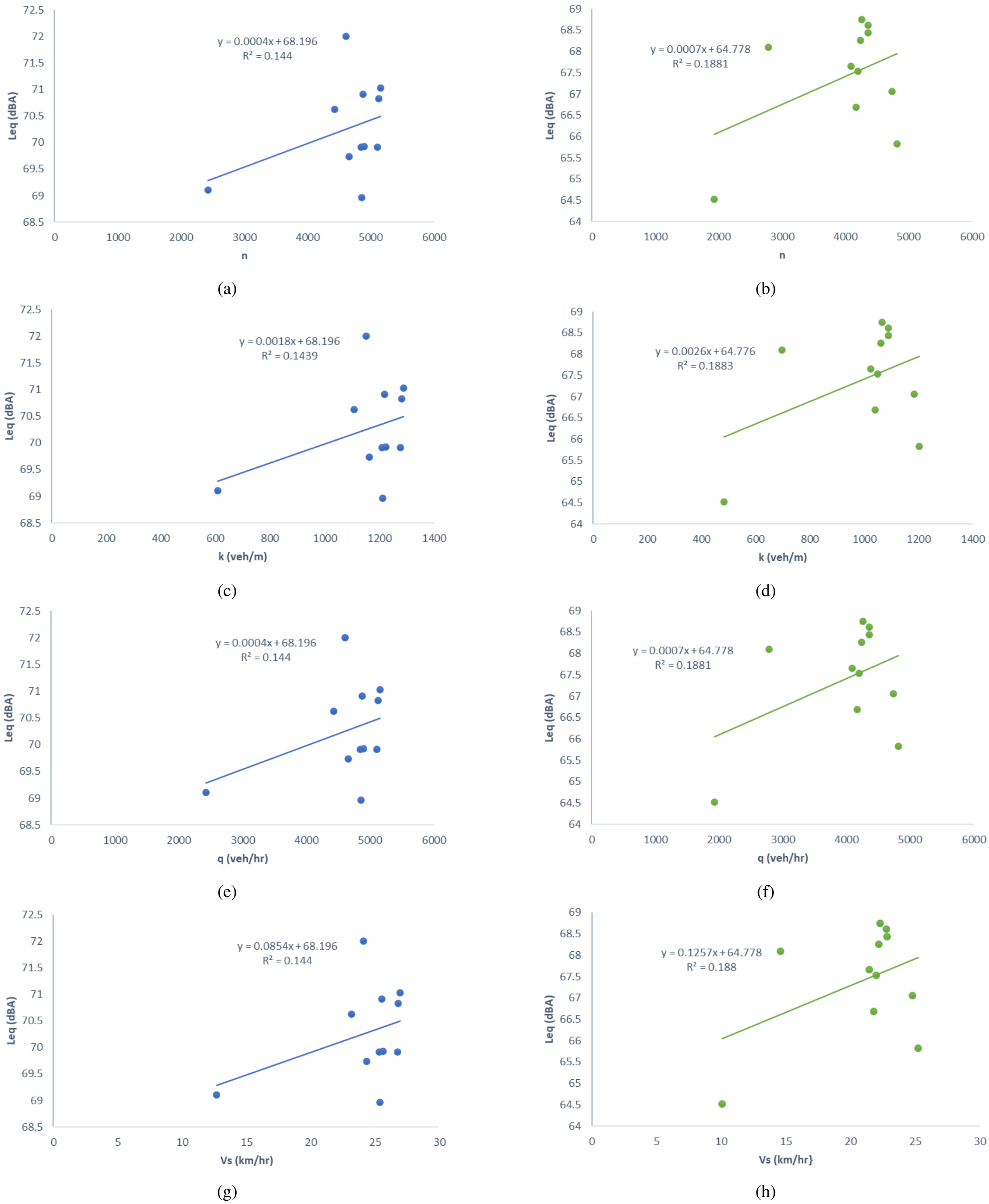


Figure 11: Diurnal variation of L_{eq} with n, k, q, and V_s at Ankpa Ward Junction during (a) dry season and (b) wet season.

noise, respectively during dry season. On the other hand, Figure 5b shows that mean TNI values of 3.87, 29.99, 8.08, 18.66, and 22.96 dBA were obtained at SRS Junction, Wurukum Roundabout, Balcony Junction, High Level Roundabout and, Ankpa Ward

Junction, respectively during wet season. The minimum and maximum mean TNI values of 3.87 and 29.99 dBA were found at SRS Junction and Wurukum Roundabout, respectively. This means that SRS Junction and Wurukum Roundabout had the lowest and highest annoyance response due to traffic noise, respectively during wet season.

The variation of noise climate at each study location is illustrated in Figures 6a and 6b. The mean noise climate (NC) of SRS Junction, Wurukum Roundabout, Balcony Junction, High Level Roundabout, and Ankpa Ward Junction was found to be -4.85, -6.33, -2.82, -2.18 and, -2.82 dBA, respectively during dry season as shown in Figure 6a, with minimum (-2.18 dBA) and maximum (-6.33 dBA) mean NC values obtained at Wurukum and High Level Roundabouts, respectively. Figure 6b depicts that SRS Junction, Wurukum Roundabout, Balcony Junction, High Level Roundabout, and Ankpa Ward Junction had mean NC values of -9.12, -3.10, -8.48, -4.95, and -3.94 dBA, respectively during wet season. The minimum (-3.10 dBA) and maximum (-9.12 dBA) mean NC occurred at Wurukum Roundabout and SRS Junction, respectively. The noise climate values at the study locations indicate relatively low variation in noise intensity with climate.

Similarly, the variation of L_{eq} with n, k, q, and V_s for each study location during dry and wet seasons is depicted in Figures 7 to 11. The results indicate an increasing trend in the variation of L_{eq} with n, k, q, and V_s at the study locations except SRS Junction (Figure 7) which exhibits a reversed trend during the wet season period. The decreasing trend observed at SRS Junction could be attributed to wind flow variation. Sound waves travelling in the wind direction produce higher sound levels in that direction, while those travelling in the opposite direction produce lower sound levels in that direction [49]. The variation at SRS Junction during wet season could also be due to the fact that the sound level meter recorded the maximum noise level produced at any instant. For instance, if a car, bus, van, motorcycle and heavy vehicle are passing simultaneously, then the maximum noise level produced at that instant will be recorded for the major type of vehicle. Hence, it is impossible to get the contribution of noise level offered by each type of vehicle at that point however, the total number of vehicles passing by the place are counted. Note that the number of vehicles is a major determining factor of the traffic density (k), traffic flow rate (q), and space mean speed (V_s) hence, n varies directly with k, q, and V_s i.e, n icreaseses as k, q, and V_s increases and vice versa. A summary of mean n, k, q, and V_s at each study study location during dry and wet seasons is presented in Tables 2 and 3, respectively. We observed from Tables 2 and 3 that minimum mean n, k, q, and V_s of 3133, 783 veh/m, 3133 veh/hr, and 16.39 km/hr were, respectively, found at SRS Junction during dry season, whereas maximum mean n, k, q, and V_s of 7881, 1970 veh/m, 7881 veh/hr, and 41.23 km/hr were respectively recorded at Wurukum Roundabout in the same season. The wet season results on the other hand indicate that minimum mean n, k, q, and V_s of 2522, 631 veh/m, 2522 veh/hr, and 13.19 km/hr were found respectively at SRS Junction, while maximum mean n, k, q, and V_s of 7729, 1933 veh/m, 7729 veh/hr, and 40.44 km/hr were observed respectively at Wurukum Roundabout. The minimum and maximum mean n, k, q, and V_s were recorded at SRS Junction and Wurukum Roundabout respectively in both seasons.

5. Conclusion

An investigation of diurnal road traffic noise levels and their correlation with traffic flow characteristics in Makurdi metropolis was conducted in order to ascertain the extent of environmental pollution from the noise and suggest possible solutions that will attenuate the problem. The results of the study disclosed that the mean L_{eq}, L_{NP}, TNI, and NC ranged from 68.65 to 70.46 dBA, 62.90 to 67.64 dBA, 16.98 to 31.13 dBA, and -2.18 to -6.33 dBA respectively during dry season, while the mean L_{eq}, L_{NP}, TNI, and NC ranged from 65.83 to 70.72 dBA, 56.71 to 67.62 dBA, 3.87 to 29.99 dBA, and -3.10 to -9.12 dBA respectively during wet season. The results across the study locations in both seasons revealed that the minimum (65.83 dBA) and maximum (70.72 dBA) mean L_{eq} were both recorded in the wet season. The results also indicated that a minimum mean L_{NP} of 56.71 dBA was observed during the wet season, whereas a maximum mean L_{NP} of 67.64 dBA was recorded during the dry season. The TNI results showed that the wet and dry seasons recorded the minimum and maximum mean TNI of 3.87 and 31.13 dBA, respectively. Similarly, the minimum (-2.18 dBA) and maximum (-9.12 dBA) mean NC were observed during the dry and wet seasons respectively across the study locations. The L_{eq} values when compared with the National Environmental Standards and Regulations Enforcement Agency (NESREA) and the World Health Organisation (WHO) standards indicated that the values obtained in both seasons were above the 60 dBA limit stipulated by NESREA but below the 70 dBA limit recommended by WHO except in two locations during dry season and one location during wet season where the L_{eq} values were slightly above the WHO prescribed limit. These noise levels indicate that people living, working or trading around these locations are liable to be affected by health conditions associated with exposure to noise pollution. The variation of L_{eq} with n, k, q, and V_s across the study locations showed that L_{eq} increases with increasing n, k, q, and V_s in almost all the locations for both seasons except at SRS Junction where a reversed trend was observed during the wet season. A summary of mean n, k, q, and V_s at each study location indicated that the minimum and maximum mean n, k, q, and V_s were recorded at SRS Junction and Wurukum Roundabout respectively in both seasons. It is recommended that public awareness campaigns on the negative impact of road traffic noise be created by relevant environmental stakeholders and noise pollution regulatory agencies. The road network in Makurdi metropolis should be expanded and overpasses be constructed at Wurukum and High Level roundabouts. These overpasses should be constructed using low noise pavements such as porous asphalt. Also, heavy penalties and fines should be imposed on road users for reckless blasting of horns, sirens and playing of loud music, and people who spend most of their time in the study locations should adopt the use of earmuffs as an interim measure.

Data availability

Data will be made available upon reasonable request from the corresponding author.

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