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Measurement and Analysis of Noise Levels from Loudspeakers on Public Transportation in Kupang, East Nusa Tenggara

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ABSTRACT

The government is very concerned about the threshold value of human hearing that causes permanent noise-induced hearing loss (NIHL), such as noise caused by public transportation (bemo) in Kupang. This research aims to increase the awareness of the bemo user in Kupang to prevent hearing loss due to noise from bemo audio devices. Noise measurements due to public transportation are usually carried out outside the vehicle, for example, on the street, but in this study, measurements were carried out inside the vehicle (bemo). Data was obtained from (1) Data on sound intensity in public transport taken manually using a Sound Pressure Level (SPL) meter and (2) Data on the working hours of the drivers taken manually by asking how long they drive in a day. The results of $L_{eq}(1 \text{ minute})$ of each route and the average of $L_{eq}(5 \text{ minutes})$ of eight routes showed a sound intensity above the threshold set by the government, i.e., 70 dB. Routes 1 and 3 are bemo routes that need attention because they have maximum sound intensity of more than 100 dB and are included in the Very Loud category. Meanwhile, the other routes are included in the Loud category. Furthermore, the average time a driver stays in a bemo daily is 13.5 hours, which concluded that all drivers are at risk of hearing loss. Therefore, special attention is needed from the government because this can result in driver hearing loss.

Keywords: Bemo; Kupang; Noise-induced hearing loss; Public transportation; Sound intensity

Pengukuran dan Analisis Tingkat Kebisingan dari Pengeras Suara pada Angkutan Umum di Kupang, Nusa Tenggara Timur

ABSTRAK

Pemerintah memperhatikan nilai ambang batas pendengaran manusia yang dapat mengakibatkan gangguan pendengaran akibat kebisingan permanen, seperti kebisingan yang disebabkan oleh angkutan umum (bemo) di Kupang. Penelitian ini bertujuan untuk meningkatkan kewaspadaan pengguna bemo di Kupang dalam mencegah terjadinya gangguan pendengaran akibat kebisingan dari speaker pada bemo. Pengukuran kebisingan pada angkutan umum biasanya dilakukan di luar kendaraan, misalnya di jalan raya, namun pada penelitian ini pengukuran dilakukan di dalam kendaraan (bemo). Data diperoleh dari (1) Data intensitas suara pada angkutan umum yang diambil secara manual dengan menggunakan *Sound Pressure Level* (SPL) meter dan (2) Data jam kerja pengemudi yang diambil secara manual dengan menanyakan berapa lama mereka berkendara dalam sehari. Hasil $L_{eq}(1 \text{ minute})$ untuk masing-masing rute dan rata-rata $L_{eq}(5 \text{ minute})$ untuk delapan trayek menunjukkan intensitas suara berada di atas ambang batas yang ditetapkan pemerintah, yaitu sebesar 70 dB. Rute 1 dan 3 merupakan rute bemo yang perlu mendapat perhatian karena memiliki intensitas suara maksimal lebih dari 100 dB dan masuk dalam kategori Sangat Keras. Sementara itu, rute lainnya masuk dalam kategori Keras. Lebih lanjut, rata-rata waktu pengemudi berada di dalam bemo setiap hari adalah 13,5 jam, yang berarti semua pengemudi berisiko mengalami gangguan pendengaran. Oleh karena itu, perlu adanya perhatian khusus dari pemerintah karena hal ini dapat mengakibatkan gangguan pendengaran pada pengemudi.

Kata kunci: Bemo; Kupang; Gangguan pendengaran akibat kebisingan; Angkutan umum; Intensitas suara

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INTRODUCTION

Noise-induced hearing loss (NIHL) is a decrease in the function of the sense of hearing or deafness due to noise that exceeds the threshold value for human hearing (Natarajan *et al.*, 2023; Setyawan, 2021). Decreased hearing function or deafness in humans due to noise occurs due to permanent damage to the stereocilia (part of the inner ear). According to the National Committee for the Prevention of Hearing Loss and Deafness, in 2014, Indonesia had the highest cases of noise-induced hearing loss in Southeast Asia, with 16.8% of the total population. The hearing loss occurs due to loud noises produced in the workplace, including the factory, public transportation, street, etc. (Septiana & Widowati, 2017). Of 100 public transportation drivers in Lahore city, 65% had NIHL, 25% had normal hearing threshold, and 10% had disabling hearing loss (Aslam *et al*., 2008). NIHL will give the impression of permanent sensorineural deafness so that the only treatment that can be given is supportive and preventive management (Astuti *et al*., 2023; Silva *et al*., 2020), not just for adults, but also for neonatal (Yasmeen *et al*., 2020). Therefore, acting against noise sources that can cause hearing loss is necessary.

The threshold value of human hearing can be measured in the same way as sound intensity, which is measured in decibels (dB). However, to imitate the characteristics of human hearing, the measuring instrument of a Sound Pressure Level (SPL) meter has a filter called an A-weighted filter, with a frequency response shown in Figure 1, with the unit used is dBA (A-weighted decibel). For example, a typical conversation has an intensity of 60-70 dBA; in a cinema, it is 74-104 dBA; in motor vehicles, it is 80-110 dBA; concerts/sporting events are 94-110 dBA; sirens are 110-129 dBA and fireworks festivals of 140-160 dBA (National Institute on Deafness and Other Communication Disorders, 2022). The human sense of hearing can generally hear up to 70 dBA for a long time without experiencing damage (National Institute on Deafness and Other Communication Disorders, 2022), beyond which the sense of hearing can experience hearing loss due to noise (noise-induced hearing loss/NIHL) (Zhou *et al*., 2020).

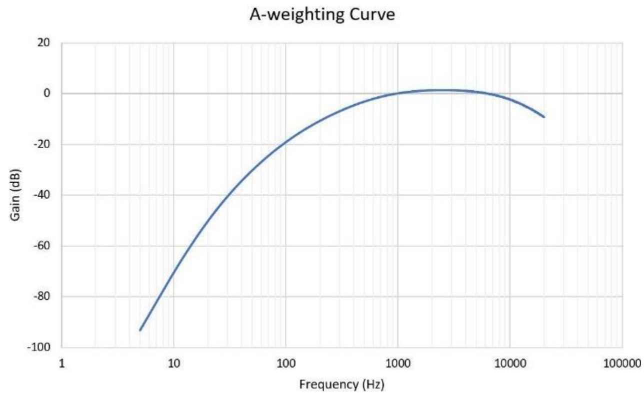

Figure 1. Frequency Response of A-Weighted Filter

Several previous studies have been conducted to analyze noise levels in a location, for example, in a university campus environment (Ahmad *et al*., 2018). The results obtained in this research show that the average noise level in the Semarang University campus environment is above 55 dB. Based on this research, it was concluded that the noise level at the University of Semarang needed to be within the standards set by the government. Apart from that, research on noise levels was also carried out on roads (Balirante *et al*., 2020; Devia, 2023; Heriyatna, 2017), in schools (Hardiani *et al*., 2022; Kurnia *et al*., 2022), in the textile industry (Sumardiyono *et al*., 2023). The results of research on noise levels also carried out in public transportation in Manado City showed that 49% of public vehicles had noise above the threshold (Liono *et al*., 2020). Research conducted on public transit in the City of Toronto stated that the highest average noise level was on the subway platform, followed by the subway and buses. Followed by the tram, and the lowest was inside the vehicle (Yao *et al*., 2017).

Because the damage from hearing loss due to noise is permanent, the government pays close attention to the regulations regarding hearing threshold value through The Minister of Health Regulation 78 of 1987 concerning Noise Related to Health. These regulations regulate the maximum permitted noise limits. Noise levels are divided into several zones. Zone A is intended for research sites, hospitals, and health or social care areas, with recommended noise levels ranging from 35-45 dB; Zone B is intended for housing, educational, and recreational areas, with a recommended noise level of around 45-55 dB; Zone C is intended for trading offices, markets, with a recommended noise level of about 50-60 dB; and Zone D is intended for industrial environments, factories, train stations, terminals, with recommended noise levels ranging from 60-70 dB (Menteri Kesehatan Republik Indonesia, 1987). In line with these regulations, the Decree of the Minister of Environment 48 of 1996 concerning Noise Level Standards also limits noise in trade and service areas, industry, recreation, and sea ports to a maximum of 70 dBA (Menteri Negara Lingkungan Hidup Republik Indonesia, 1996). In more detail, Minister of Manpower Regulation 5 of 2018 concerning Occupational Safety and Health in The Work Environment regulates daily exposure times at specific noise intensities in dBA (Menteri Ketenagakerjaan Republik Indonesia, 2018). For example, if the exposure time per day is 8 hours, then the noise intensity is 85 dBA. The higher the exposure time per day, the higher the noise intensity.

However, all parties have yet to implement government noise intensity regulations, including transportation. Transport noise appears to have more impact on health in those who are noise-sensitive (Welch *et al*., 2023) —for example, the phenomenon of public transportation in Kupang. Public transportation in Kupang, commonly called bemos, is known as a "walking discotheque" because of the flashing lights and noisy audio equipment (Semiun, 2018). Based on the total travel time, the maximum noise intensity that bemo passengers can accept before triggering hearing loss can be determined. The damage caused by noise-induced hearing loss is gradual (National Institute on Deafness and Other Communication Disorders, 2022), so many people are only aware of it once a particular medical check is carried out. Furthermore, hearing loss due to noise can affect the acceptance of official jobs, for example, for TNI/Police candidates and official schools in specific ministries.

Although it is suspected that the most significant noise source is from audio devices, it does not rule out the possibility that car engines and the surrounding environment also increase the intensity of noise received by passengers. Data on the passengers' average travel time is also needed so that it can be known whether the duration of the noise that occurs has an impact that can cause hearing problems for passengers. The other data is the results from passengers and drivers, who are expected to find a middle point where public transport can still be attractive to passengers without the risk of hearing loss due to noise.

After the data is obtained, the necessary actions can be formulated for public transportation with excessive noise intensity. The action in question can be an outreach to public transport users and drivers to create regional regulations related to noise intensity on public transport. Furthermore, it can provide input for public transport drivers to maintain passengers' interest in public transport without risking hearing damage.

This research aims to analyze the sound intensity of bemo users (passengers and drivers) in Kupang. It is important, so that they can increase their awareness to prevent hearing loss due to the noise originating from bemo audio devices. Therefore, it is crucial to collect data on sound intensity in bemos in Kupang City, average travel time taken by passengers, and a short survey of passengers and public transport drivers are needed. The method for collecting sound intensity data in public transportation is taken manually using SPL meters on several bemos in operation.

RESEARCH METHOD

Generally, the type of bemos in Kupang is "mikrolet" of various years of manufacture, with 12 passengers. Bemo has two cabins, namely the front and the passenger cabins. The front cabin has two doors on the left and right. The driver's seat and steering wheel are on the right, while the passenger seat is on the left. The passenger cabin door is a double-fold door. Bemo in NTT has colorful, striking, and unique decorations. Figure 2 shows one example of bemo. All bemos, on average, have audio devices to play music. The music player is on the front dashboard, while the amplifier and other audio amplifiers are under the dashboard. Meanwhile, the speakers are placed under the passenger seats. Figure 3 shows the speakers under the passenger seats.

Figure 2. Bemo in Kupang

Figure 3. The Speakers

Figure 4 shows the route taken by the route 1 and Table 1 shows eight bemo routes in Kupang. From the 22 bemo routes in Kupang, this research will take eight routes as samples: routes 1, 2, 3, 5, 6, 7, 10, and 27. For example, route 1 with the route of Terminal Kota Lama - Kuanino, Oepura, Sikumana - Terminal Kota Lama takes 18 km with estimated travel time of 49 minutes. From the eight routes, they have an average distance of 18.825 km with an average total travel time of 47.25 minutes (Manu, 2016).

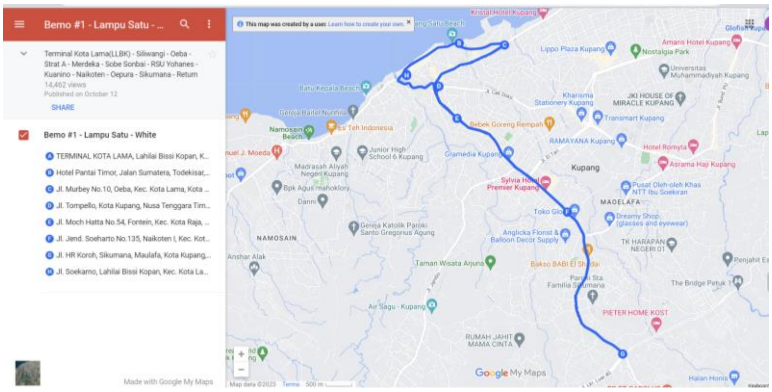

Figure 4. The Route of Bemo Route 1

Table 1. List of Eight Bemo Routes in Kupang (reprocessed from (Admin, 2020)

Route Number	Route	Distance (km)	Estimated Travel Time (minutes)	Source
1	Terminal Kota Lama - Kuanino, Oepura, Sikumana - Terminal Kota Lama	18	49	https://www.google.com/maps/d/viewer?mid=1nhl5kldKNbWRJuhvPNZdQeyun374FOVP&ll=-10.182291018394206%2C123.59454000000001&z=14
2	Terminal Kota Lama - Polda NTT, Pasar Inpres dan Oepura - Terminal Kota Lama	18,4	49	https://www.google.com/maps/d/viewer?mid=1e8bgTv0_XjhSQ4ijGtqdGj3WScyNvtPx&ll=-10.182356823665529%2C123.59500730000002&z=14
3	Terminal Kota Lama - Kuanino Bawah, Perempatan, Bakunase - Tedis - Terminal Kota Lama	17	38	https://www.google.com/maps/d/viewer?mid=1Lw0EjUklKnQjvd-JPr2IAzTPyhx-juhP&ll=-10.18994123769282 5%2C123.58474275000002&z=13
5	Terminal Kota Lama -SMP 2 Kupang, SMA 1 Kupang, Oebobo, Oeba - Terminal Kota Lama	20,2	54	https://www.google.com/maps/d/viewer?mid=1sBUdXl_W1yhMat6rAdSvHjACvTvWChox&ll=-10.182367324507947%2C123.594595&z=14
6	Terminal Kota Lama - SMP 2 Kupang, SMA 1 Kupang, Transmart, Ramayana Kupang, Oebufu - Terminal Kota Lama	20,1	51	https://www.google.com/maps/d/viewer?mid=1Z4VYQkDWOla1_EEqj9SQTyYyaIS6SkVT&ll=-10.165975162963713%2C123.60463500000002&z=14
7	Jl. H.R Koroh - Kantor Walikota - Jl. H.R Koroh	21,7	51	https://www.google.com/maps/d/viewer?mid=1yltrAUnEkUEm1NZgz6qTLyVwrBXHU7os&ll=-10.179876223712148%2C123.61549500000002&z=13
10	Terminal Kota Lama - Ina Boi, Lippo Mall, Kantor Walikota, Bundaran PU - Terminal Kota Lama	16,2	40	https://www.google.com/maps/d/viewer?mid=1x7d0SfVCZ5R1yJ7j8YEfTKMABNAFnBm8&ll=-10.156855102194363%2C123.60135500000001&z=14
27	RS W.Z. Yohanes - Kuanino, Kantor Walikota - RS W.Z. Yohanes	19	46	https://www.google.com/maps/d/viewer?mid=1i10DHCqbfk3-wCzhC0OQ06MCvn3y3CZj&ll=-10.165345281591064%2C123.60463500000002&z=14
	Average	18,825	47,25	

This research consists of three stages, i.e., data acquisition, data processing, and data analysis. Figure 5 shows the research method. In data acquisition, data was obtained from

(1) Data on sound intensity in public transportation measured manually using an SPL meter inside the bemo, and (2) Data on drivers' working hours taken by asking how long the driver drives in a day so that the exposure time experienced by drivers to noise can be known.

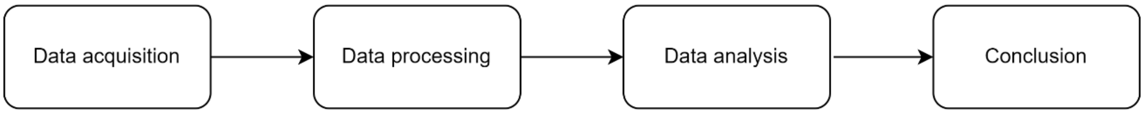

Figure 5. Research Method

Data was taken from eight public transport routes with collection times carried out four times which were considered representative, namely 07.00 (representing the period of 06.00-09.00), 10.00 (representing the period of 09.00-12.00), 13.00 (representing the period of 12.00-15.00), and 16.00 (representing the period of 15.00-18.00). Figure 6 shows the data acquisition. The sound intensity was taken inside the bemo. The SPL meter is carried by the person sitting in the bemo, where the loudspeaker is placed under the seat.

Figure 6. Data Acquisition

In data processing, the data logger from the sound level meter is taken. Table 2 shows the example of data logger. Finally, in data analysis, the data logger is analyzed using noise intensity calculations by (SNI) 7231:2009 and Decree of Minister of Environment 48/MENLH/11/1996. Noise level measurement for n hours with minimum data collection for m measurements over a specific period can be determined using Equation (1).

$$L = 10 \log \frac{1}{n}\left(\sum_{i=1}^{m} t_i * 10^{0.1*L_i}\right) \text{dB} \quad (1)$$

where L is the measurement at a particular time (dB), t_i is the measurement time, dan L_i is the noise level at a specific time (dB) (Rusmayanti *et al.*, 2021).

Table 2. Example of data logger

RecNo	MeaValue	Weight	Time	Date
0	712	A	16:32:04	07/09/2023
1	711	A	16:32:05	07/09/2023
2	711	A	16:32:06	07/09/2023
3	688	A	16:32:07	07/09/2023
4	645	A	19:00:24	25/09/2023
5	515	A	19:00:25	25/09/2023
6	515	A	19:00:26	25/09/2023
7	455	A	19:00:27	25/09/2023
8	693	A	11:52:40	27/09/2023
9	692	A	11:52:41	27/09/2023
10	692	A	11:52:42	27/09/2023
…	…	…	…	…

RESULTS AND DISCUSSION

The samples are taken from eight bemo routes. Sound intensity measurements were carried out inside the bemo every 10 seconds for five minutes so that 30 data were obtained from each time interval, each bemo route. An example of sound intensity data on Lamp 1, totaling 30 data, is shown in Figure 6. The sound intensity ranges between 70-100 dB. Data collection was carried out four times, i.e., at 07.00 (representing 06.00-09.00), at 10.00 (representing 09.00-12.00), at 13.00 (representing 12.00-15.00), and at 16.00 (representing 15.00-18.00). Table 3 shows the average, minimum, and maximum sound intensity values for each route number in four interval times.

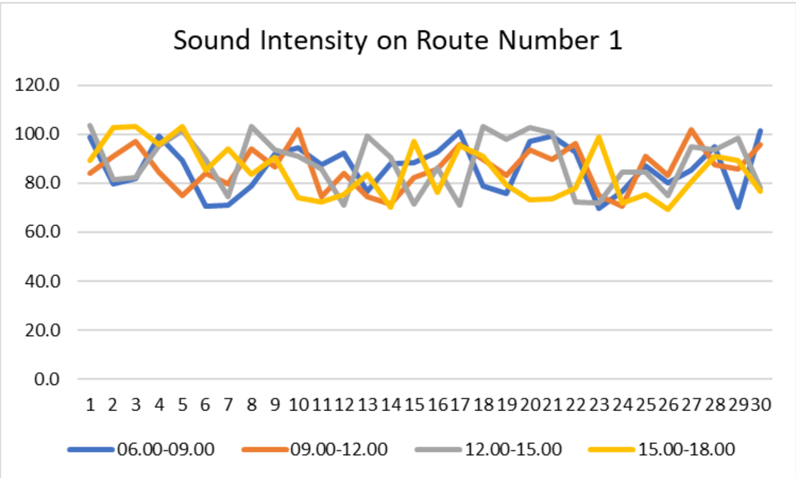

Figure 6. Sound Intensity on Route Number 1

Table 3. Sound Intensity in dB for Each Route in Kupang

Route Number	Sound Intensity (dB)											
	06.00-09.00			09.00-12.00			12.00-15.00			15.00-18.00		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
1	86.3	69.7	101.5	86.3	70.6	101.9	88.2	71.0	103.3	84.6	69.2	103.2
2	78.5	71.2	90.3	80.8	71.3	90.3	80.6	71.6	90.3	81.1	71.6	90.4
3	85.5	74.9	100.0	88.8	75.6	101.9	89.8	75.0	101.4	89.1	75.0	100.6
5	78.1	62.1	89.6	75.1	62.2	89.9	76.6	63.4	90.1	74.0	61.5	89.4
6	79.6	69.5	91.1	80.5	68.8	91.6	81.3	69.8	90.7	81.6	71.9	91.8
7	85.3	76.1	92.5	84.7	75.6	92.0	82.9	75.5	92.0	83.7	75.8	91.9
10	82.3	73.5	91.0	81.1	72.9	89.8	81.8	72.9	91.1	80.2	73.2	89.8
27	79.2	71.5	90.6	83.3	71.0	93.4	82.5	71.5	93.4	82.7	71.3	93.4

Figures 7 and 8 show the average and maximum sound intensity values for eight bemo routes in Kupang. Those figures show that the sound intensity of eight bemo routes in Kupang, namely routes 1, 2, 3, 5, 6, 7, 10, and 27, is above the threshold determined by the government, i.e., 70 dB. There were no significant differences in data collection for the time intervals sampled, i.e., 06.00-09.00, 09.00-12.00, 12.00-15.00, and 15.00-18.00. In particular, for Routes 1 and 3, the sound intensity reaches a maximum of over 100 dB.

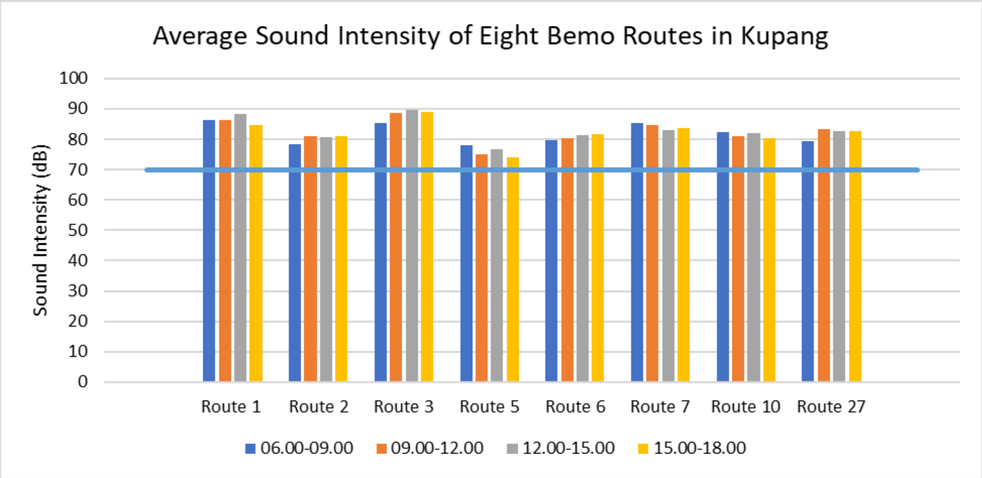

Figure 7. Average Sound Intensity for Eight Bemo Routes in Kupang

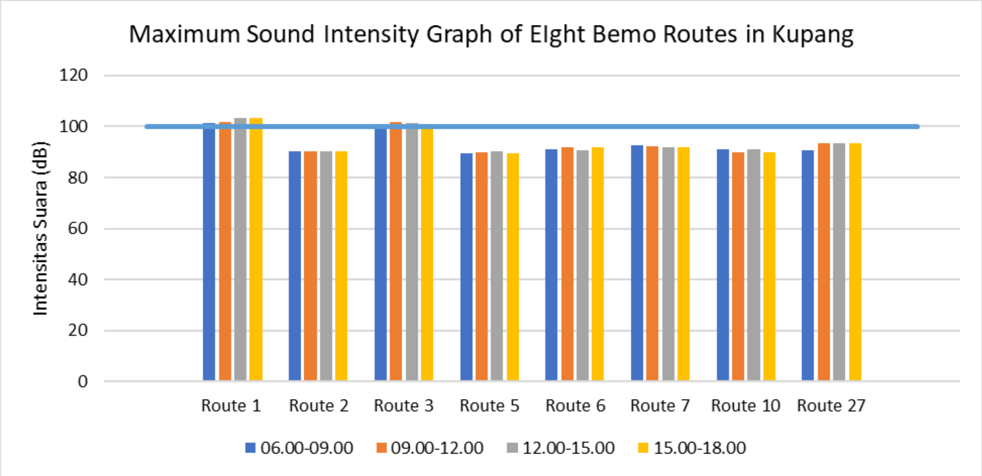

Figure 8. Maximum Sound Intensity for Eight Bemo Routes in Kupang

The analysis was conducted using a descriptive method. Descriptive analysis aims to describe the conditions in the field with explanations and analysis based on research data. L_{eq} is the equivalent or measured noise level of each measurement time expressed in dBA units. This L_{eq}value is then compared with the threshold set by the government. Research data is processed by finding the Equivalent Continuous Sound Level (L_{eq}) for each measurement time.

Data was collected every 10 seconds for five minutes, resulting in 30 data for each time interval and each route. Each data represents the sound level for the i^{th} 10 seconds. The calculation of $L_{eq}(1\text{ minute})$ is based on these data, as seen in Equation (2). Tables 4 to 11 provide an example of how to calculate $L_{eq}(1\text{ minute})$ for a five-minute period, for all routes in the time interval of 06.00-09.00.

$$L_{eq}(1\text{ minute}) = 10\log\frac{1}{60}\left((10^{0.1L_1} + 10^{0.1L_2} + \cdots + 10^{0.1L_6})5\right)dB \quad (2)$$

Table 4. $L_{eq}(1\text{ minute})$ Calculation Results for Route 1 (06.00-09.00)

	10th seconds	**20th seconds**	**30th seconds**	**40th seconds**	**50th seconds**	**60th seconds**	$L_{eq}(\mathbf{1\ minute})$
1st minute	98.8	79.5	81.8	99.1	89.1	70.8	91.4
2nd minute	71.2	78.8	91.6	94.3	87.4	92.1	87.3
3rd minute	76.7	87.9	88.5	92.5	101.0	78.7	91.2
4th minute	75.6	97.0	99.3	92.6	69.7	76.7	91.1
5th minute	87.2	80.0	85.3	95.0	70.1	101.5	91.8

Table 5. $L_{eq}(1\text{ minute})$ Calculation Results for Route 2 (06.00-09.00)

	10th seconds	**20th seconds**	**30th seconds**	**40th seconds**	**50th seconds**	**60th Seconds**	$L_{eq}(\mathbf{1\ minute})$
1st minute	73.1	81.2	84.3	73.9	81.8	72.7	77.1
2nd minute	83.9	78.8	90.3	82.4	78.2	82.0	81.8
3rd minute	73.5	76.6	72.2	77.8	82.7	72.0	74.6
4th minute	80.1	73.3	71.3	83.0	89.8	79.0	80.6
5th minute	77.9	85.3	71.2	71.3	76.8	78.6	76.6

Table 6. $L_{eq}(1\text{ minute})$ Calculation Results for Route 3 (06.00-09.00)

	10th seconds	**20th seconds**	**30th seconds**	**40th seconds**	**50th seconds**	**60th seconds**	$L_{eq}(\mathbf{1\ minute})$
1st minute	75.0	81.0	84.8	82.3	84.2	94.3	84.8
2nd minute	91.5	80.9	78.9	93.1	79.4	74.9	85.0
3rd minute	83.3	83.2	85.1	83.6	92.0	100.0	90.2
4th minute	98.2	82.0	95.5	94.8	91.6	92.3	91.4
5th minute	78.7	78.3	77.1	89.4	77.5	81.1	80.2

Table 7. L_{eq}(1 minute) Calculation Results for Route 5 (06.00-09.00)

	10th seconds	**20th seconds**	**30th seconds**	**40th seconds**	**50th seconds**	**60th seconds**	L_{eq}**(1 minute)**
1st minute	86.2	77.8	62.1	73.0	69.0	72.1	76.4
2nd minute	88.3	88.1	67.4	84.1	82.9	79.7	82.0
3rd minute	77.6	76.1	67.0	80.3	85.4	66.9	76.7
4th minute	75.3	80.0	63.8	86.0	85.4	85.6	80.2
5th minute	77.5	89.6	77.9	88.4	72.5	77.7	81.8

Table 8. L_{eq}(1 minute) Calculation Results for Route 6 (06.00-09.00)

	10th Seconds	**20th seconds**	**30th seconds**	**40th seconds**	**50th seconds**	**60th seconds**	L_{eq}**(1 minute)**
1st minute	73.4	75.4	84.2	83.4	85.5	75.0	78.9
2nd minute	88.9	89.6	91.1	72.1	69.5	80.0	84.1
3rd minute	89.9	89.7	78.4	83.7	70.6	74.3	82.8
4th minute	83.0	71.3	87.5	73.1	69.8	87.8	80.7
5th minute	72.7	70.9	91.0	69.7	77.4	78.8	80.8

Table 9. L_{eq}(1 minute) Calculation Results for Route 7 (06.00-09.00)

	10th seconds	**20th seconds**	**30th seconds**	**40th seconds**	**50th seconds**	**60th seconds**	L_{eq}**(1 minute)**
1st minute	80.9	89.7	86.1	86.8	79.5	76.9	82.4
2nd minute	88.1	76.1	77.0	84.9	89.2	89.9	83.8
3rd minute	90.9	89.2	89.5	76.5	80.6	82.7	84.4
4th minute	88.1	92.5	89.1	88.1	83.2	78.0	85.4
5th minute	89.4	92.0	92.1	80.7	86.3	85.8	86.2

Table 10. L_{eq}(1 minute) Calculation Results for Route 10 (06.00-09.00)

	10th seconds	**20th seconds**	**30th seconds**	**40th seconds**	**50th seconds**	**60th seconds**	L_{eq}**(1 minute)**
1st minute	86.0	74.4	87.0	78.2	77.9	88.6	81.7
2nd minute	83.0	74.1	78.2	91.0	90.5	73.5	83.5
3rd minute	79.0	80.5	81.2	90.7	89.4	79.1	83.1
4th minute	80.8	80.3	86.2	87.9	79.9	78.1	80.8
5th minute	84.5	76.6	77.4	90.8	81.7	81.1	81.9

Table 11. L_{eq}(1 minute) Calculation Results for Route 27 (06.00-09.00)

	10th Seconds	**20th seconds**	**30th seconds**	**40th seconds**	**50th seconds**	**60th seconds**	L_{eq}**(1 minute)**
1st minute	72.4	82.5	83.7	85.5	71.5	79.5	78.7
2nd minute	90.6	79.2	80.0	73.7	71.9	73.9	80.6
3rd minute	82.8	89.4	74.1	86.5	87.3	80.7	82.6
4th minute	74.7	76.3	78.8	88.1	73.2	84.3	79.5
5th minute	74.3	72.1	73.2	86.8	73.6	75.0	77.0

Furthermore, the formula shown in Equation (3) calculates $L_{eq}(5\ \text{minutes})$. Table 12 shows the overall $L_{eq}(5\ \text{minutes})$ for each bemo route in all periods. According to Decibel Pro, the sound intensity level can be divided into seven categories, which are shown in Table 13 (Decibel Pro, 2024). Bemos with Routes 1 and 3 showed high L_{eq} values for all time intervals, i.e., above 90 dB, which are included in the very loud category. Meanwhile, the other routes are included in the loud category. The highest $L_{eq}(5\ \text{minutes})$ in Routes 1, 2, 5, 10, and 27 occurred in 12.00-15.00, while Routes 3, 6, and 7 occurred in 09.00-12.00.

$$L_{eq}(5\ \text{minutes}) = 10\log\frac{1}{5}\left((10^{0.1L_1} + 10^{0.1L_2} + \cdots + 10^{0.1L_6})1\right)dB \qquad (3)$$

Table 12. $L_{eq}(5\ \text{minutes})$ Calculation Results for Eight Routes in All-time Ranges

Route Number	06.00-09.00	09.00-12.00	12.00-15.00	15.00-18.00	Average of $L_{eq}(5\ \text{minutes})$
1	90.8	90.0	93.8	91.7	91.6
2	78.9	80.8	81.6	80.8	80.5
3	88.0	92.4	92.1	91.3	90.9
5	80.0	79.1	80.4	77.3	79.2
6	81.8	82.4	81.5	82.1	82.0
7	84.6	84.8	82.7	83.3	83.8
10	82.3	80.5	82.5	80.0	81.3
27	80.1	83.8	84.1	83.3	82.8

Table 13. Category for Sound Intensity

Noise Level (dBA)	Category
20	Faint
30 – 40	Soft
50 – 60	Moderate
70 – 80	Loud
90 – 110	Very loud
120	Uncomfortable
130 – 140	Painful and dangerous

Sound intensity above the threshold can cause hearing problems, especially for bemo drivers. Table 14 shows a driver's average time in a bemo every day. From the eight routes taken, the drivers spent about 13.5 hours. According to Decibel Pro, the maximum exposure time (in an 8-hour working day) is shown in Table 15 (Decibel Pro, 2024). It can be concluded that all drivers are at risk of hearing loss.

Table 14. Average Driver Time in Bemo per Day

Route Number	Average Time/Day
1	15 hours
2	15 hours
3	14 hours
5	14 hours
6	14 hours
7	12 hours
10	12 hours
27	12 hours

Table 15. Maximum Exposure Time

Noise level (dBA)	Number of Hours
85	8 hours (wearing hearing protection in the workplace is mandatory)
88	4 hours
91	2 hours
94	1 hour
97	30 minutes
100	15 minutes

CONCLUSION

From the results of $L_{eq}(1\ \text{minute})$ of each route and the average of $L_{eq}(5\ \text{minutes})$ of all routes, the sound intensity of the eight bemo routes, i.e., routes 1, 2, 3, 5, 6, 7, 10, and 27, showed a sound intensity above the threshold, i.e., 70 dB. Bemos with Routes 1 and 3 showed high L_{eq} values for all time intervals, i.e., above 90 dB, which are included in the very loud category. Meanwhile, the other routes are included in the loud category. Furthermore, from the graph of maximum sound intensity for eight bemo routes in Kupang, Route 1 with the route of Kota Lama Terminal - Kuanino, Oepura, Sikumana - Kota Lama Terminal and Route 3 with the route of Kota Lama Terminal - Kuanino Bawah, Perempatan, Bakunase - Tedis - Kota Lama Terminal are bemo routes that need more attention. Both routes have a maximum sound intensity of more than 100 dB. Meanwhile, the average time a driver stays in a bemo daily is 13.5 hours. The number of hours shows that the drivers are at risk of hearing loss. Therefore, special attention is needed from the government because this can result in driver hearing loss.

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