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Analysis of the effectiveness of track lubricators in selected locations in Wrocław

Abstract: Due to the growing problem of the negative impact of noise, an attempt was made to reduce it by installing track lubricators in several locations in Wroclaw. The article presents the results of measurements in selected tram loops before and after the installation of track lubricators. The collected data were compiled and analyzed together with an indication of the further direction of research.

Keywords: Noise; Lubricator; Tram loop

Introduction

We commonly encounter noise caused by transportation, industrial activities, and recreational pursuits. In large cities, it is therefore present in almost every situation (Table **1**) – whether at work, during travel, on a walk, or at home. Due to its negative effects, it is classified as one of the major pollutants of the natural environment. When noise intensity exceeds 55 dB, the first negative impacts on humans begin to appear, such as sleep disturbances and hyperactivity.

The range of sound intensity is defined by the threshold of audibility (0 dB) and the pain threshold (130 dB).

Tab. 1. Sound Levels in Example Situations [6]

Type of Sound (Noise)	**Type of Sound (Noise)**
Threshold of audibility	0
Gentle breeze and rustling leaves	15 – 20
Whispered conversation	20
Average noise in an apartment	40
Quiet street, normal conversation	40 - 45
Loud conversation	60
Street noise, tram	70
Heavy traffic, motorcycle engine	80 – 85
Pneumatic hammer (at a distance of 2 m)	90
Express train (at a distance of 10 m)	100
Disco, rock concert	100 – 120
Propeller aircraft	120
Threshold of pain	130

Particularly troublesome noise in cities is tram noise, caused by tribological processes [16]. To reduce this type of noise, the following actions are undertaken:

- Rail grinding on tram lines,
- Track tamping,
- Wheel turning,
- Replacement of worn-out tram wheels,
- Installation of lubricators,
- Construction of low acoustic barriers,

- Modernization of tracks.

Studies conducted so far have shown not only the overall effectiveness of tram lubricators but also additional benefits, including reduced wear of rails and wheel rims on tram bogies [1]. This is particularly important as it minimizes costs associated with rail surfacing, track repairs, and wheel and rim replacement [4].

Both national and international publications cover topics such as reviews of lubricants [3, 5], methods of controlling lubrication systems [2, 13], and analysis of noise reduction effectiveness [12]. Due to the varied tram fleets selected individually by municipal operators, the actual effectiveness of track lubricators can only be determined based on measurements conducted at specific locations.

Case Study: Noise Reduction Through Installation of Track Lubricators on Tram Loops in Wrocław

The tram transport system in Wrocław is the oldest electric tram system in Poland, servicing 22 daytime lines. The city's tram tracks and infrastructure are managed by Miejskie Przedsiębiorstwo Komunikacyjne Sp. z o.o.

Currently, the following tram types are in operation in Wrocław:

- Konstal 105NaWr,
- Protram 204 WrAs,
- Protram 205 WrAs,
- Skoda 16T,
- Skoda 19T,
- PESA 2010 NW,
- Moderus MF 19 AC,
- Moderus MF 24 AC,
- Moderus LF07AC.

Due to identified noise exceedances in the areas of selected tram loops and numerous complaints from residents, a decision was made to install track lubricators.

On March 31, 2021, the tram track operator in Wrocław announced a tender for the preparation of design documentation and the installation of automatic track lubricators on six tram loops in Wrocław.

The client required the installation of track lubricators in the following quantities and locations:

- Leśnica Loop – single-track lubricator,
- Kromera Loop – double-track lubricator,
- Sępolno Loop – single-track lubricator and double-track lubricator,
- Księże Małe Loop – single-track lubricator,
- Klecina Loop – double-track lubricator,
- Oporów Loop – single-track lubricator and double-track lubricator.

On May 12, 2021, bids were opened. Following the tender process, the company LWZ Sp. z o.o. was selected. Lubricators from SmarTech were installed at the designated loops.

According to the tender documentation, the installed lubricators are adapted for use with biodegradable greases that do not increase the braking distance of trams. The client approved a biodegradable calcium-based grease produced from a mixture of synthetic ester oil and vegetable oil. According to the manufacturer, the grease currently in use is intended for the through lubrication of rail infrastructure in railway and urban tram systems, as well as for lubricating machinery and equipment operated in forested areas, water intakes, etc., where there is a potential risk of environmental contamination.

Measurement Methods

For each loop, a graphical schematic was created indicating the measurement point. The microphone was positioned, whenever possible, at the same distance from the track throughout the route requiring measurement. In each case, the sound analyzer was placed at a height of approximately 1.5 meters above ground level.

During measurements, efforts were made to eliminate the influence of interfering sounds, including noise generated by vehicle traffic. As a result, measurements were primarily conducted during evening or early morning hours.

Equipment Used

The measurements were conducted using a sound level meter from the manufacturer Norsonic, model Nor145, provided by Systemy Pomiarowe Sp. z o.o. The Nor145 sound analyzer is a precision class 1 sound level meter (highest accuracy class) compliant with IEC 61672, IEC 61260, DIN 45657, ANSI S1.4, ANSI S1.11, and ANSI S1.43 standards. Before each measurement cycle, the meter was calibrated using a four-range Nor1256 class 1 calibrator.

Comparison of Results

Klecina Loop

The loop consists of two tracks (Fig. **1**). For the purposes of this article, they have been designated as "Track No. 1" and "Track No. 2." The platform for disembarking passengers and the platform for boarding passengers were also identified. The section marked in red between points A and B was the subject of acoustic research. The measurement position was located at point C.

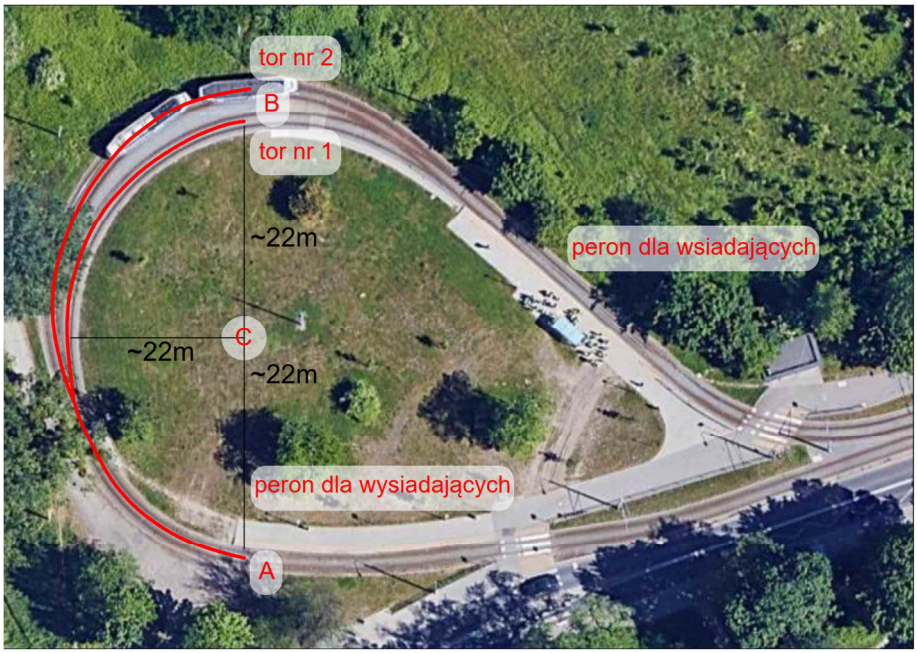
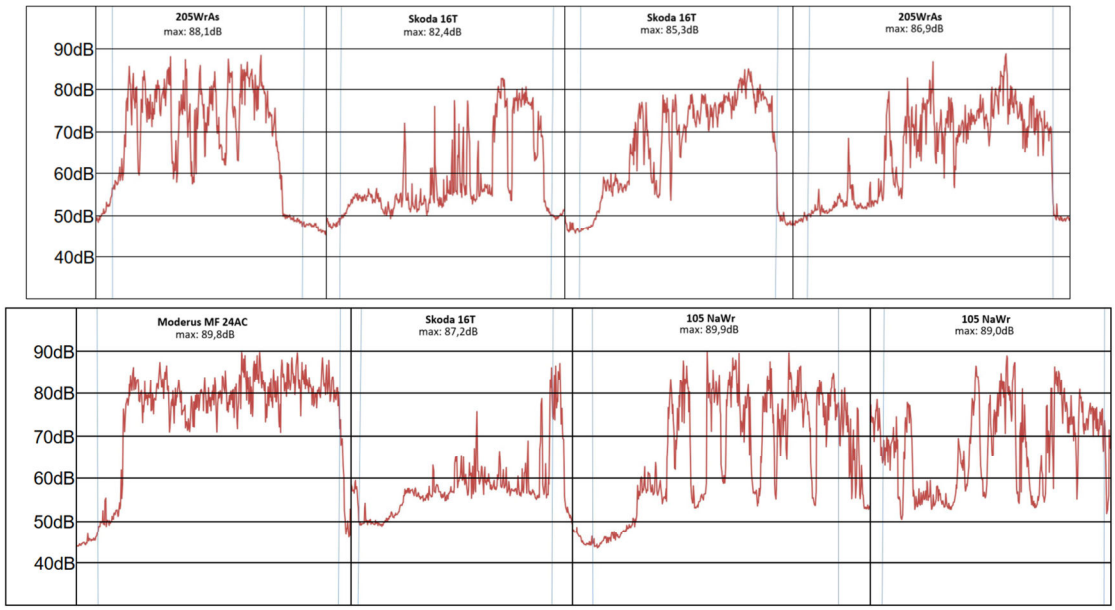


Fig. **1**. Klecina Loop

The acoustic measurements were conducted on the following dates:

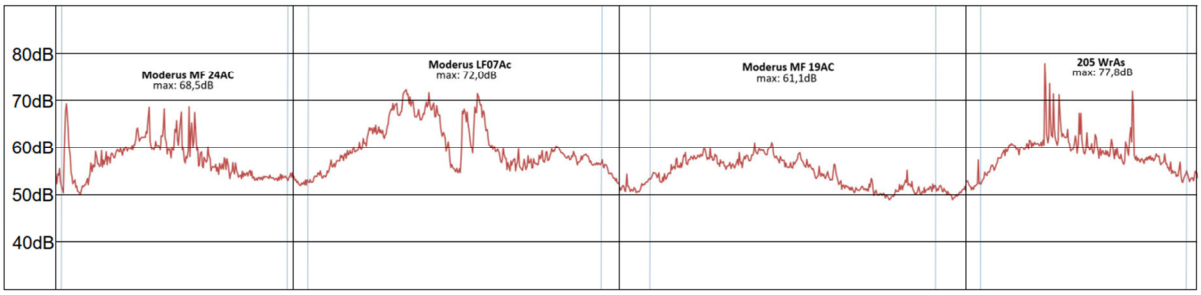
- 27.09.2021 – Before the installation of lubricators.
- 09.09.2022 and 12.09.2022 – After the installation of lubricators.

For the measurements carried out on 27.09.2021, the results obtained are shown in Fig. **2**.



2. Measurement Results on 27.09.2021

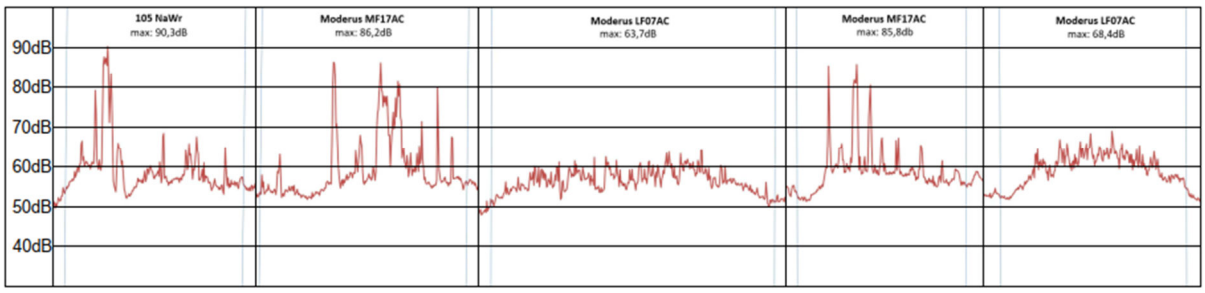
For the measurements conducted on 09.09.2022, the results are presented in Fig. **3**.



3. Measurement Results on 09.09.2022

On 09.09.2022, discrepancies in the tram fleet compared to the fleet operating on 27.09.2021 were identified.

As a result, additional measurements were conducted on 12.09.2022 to obtain further comparative results (Fig. **4**).



4. Measurement Results on 12.09.2022.

Table **2** presents the tram fleet recorded during the three measurement days. Shaded fields indicate the same fleet operating on the same tracks.

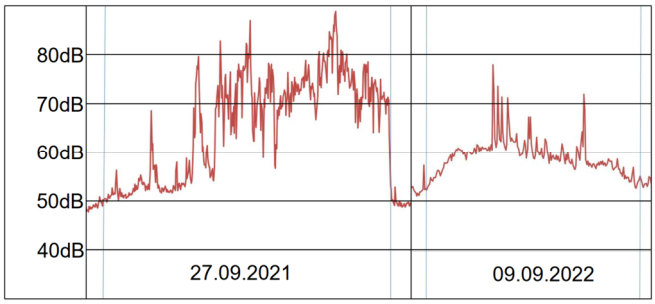
Tab. 2. Summary of Tram Fleet, Measurements on 27.09.2021, 09.09.2022, and 12.09.2022

Tram Fleet Recorded in 2021		Tram Fleet Recorded in 2022			
Measurement on 27.09.2021		Measurement on 09.09.2022		Measurement on 12.09.2022	
Track No. 1	Track No. 2	Track No. 1	Track No. 2	Track No. 1	Track No. 2
205WrAs	205WrAs	Moderus LF07AC	Moderus MF24AC	Moderus LF07AC	105NaWr
Moderus MF24AC	Skoda 16T	205WrAs	Moderus MF19AC		Moderus MF17AC
Skoda 16T	Skoda 16T				
	105NaWr				
	105NaWr				

Thanks to the summary, it can be concluded that only models 205WrAs and 105NaWr can be compared. Track No. 1 and Track No. 2 are characterized by different curve radii. Therefore, the comparison could only be made for the same tram model traveling on the same track.

In this case, the comparison was made for the 205WrAs model on Track No. 1 and the 105NaWr model on Track No. 2.

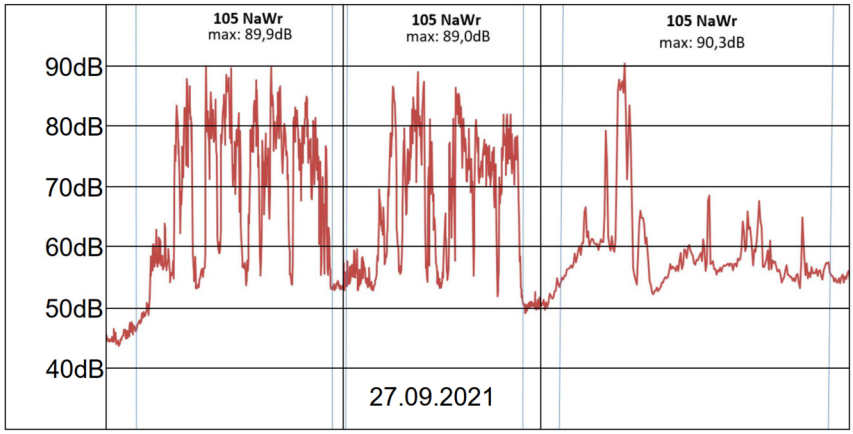
The charts (Fig. **5**) present the acoustic measurement results for the 205WrAs vehicle on the section from the disembarking stop to the stop on Track No. 1.



5. Comparison of Acoustic Measurement Results at Klecina Loop on 27.09.2021 and 09.09.2022 for Model 205WrAs on Track No. 1

During the measurement on 27.09.2021, the highest recorded value was 86.9 dB, while on 09.09.2022, the highest recorded value was 77.8 dB. The acoustic background for both days was similar, at approximately 48 dB. As shown in the charts, the installed lubricators reduced the noise by 9.1 dB.

Fig. **6** Acoustic Measurement Results for Model 105NaWr on the Section from the Disembarking Stop to the Stop on Track No. 2



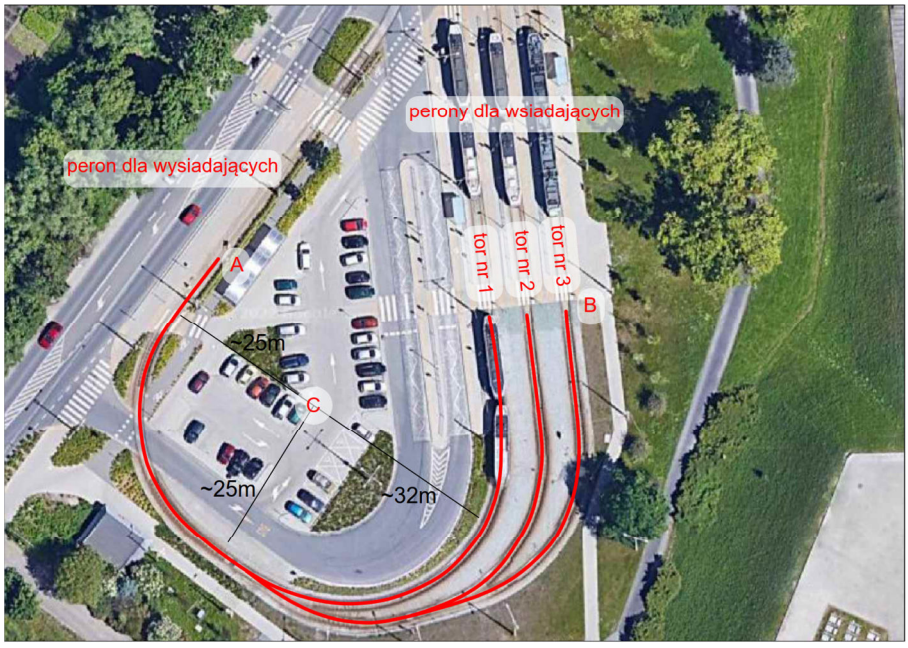
6. Comparison of Acoustic Measurement Results at Klecina Loop on 27.09.2021 and 12.09.2022 for Model 105NaWr on Track No. 2

For the two measurements conducted on 27.09.2021, the highest recorded value was 89.9 dB, whereas for the measurement on 12.09.2022, the highest recorded value was 90.3 dB.

Despite the installation of track lubricators, a higher value was recorded. Due to its momentary nature, it can be assumed that this increase was caused by a change in the switch position (impact of switch components against each other). Beyond this incidental spike, attention should be drawn to the overall flattening and smoothing of the chart obtained during the measurements on 12.09.2022.

Oporów Loop

The loop consists of three tracks, as shown in Fig. **7**. For the purposes of this article, they have been designated as "Track No. 1," "Track No. 2," and "Track No. 3". The platform for disembarking passengers and the platform for boarding passengers were also identified. The section marked in red between points A and B was the subject of acoustic research. The measurement position was located at Point C.



7. Oporów Loop

Acoustic Measurements were conducted on the following dates:

- 24.09.2021 and 25.09.2021 – Before the installation of lubricators.
- 14.10.2022 – After the installation of lubricators.

The Table **3** would list the recorded tram fleet for the three measurement days, including specific tram models operating on each track. Shaded fields highlight cases where the same tram fleet operated on the same tracks across the dates.

Tab. 3. Summary of Tram Fleet, Measurements on 24.09.2021, 25.09.2021, and 14.10.2022

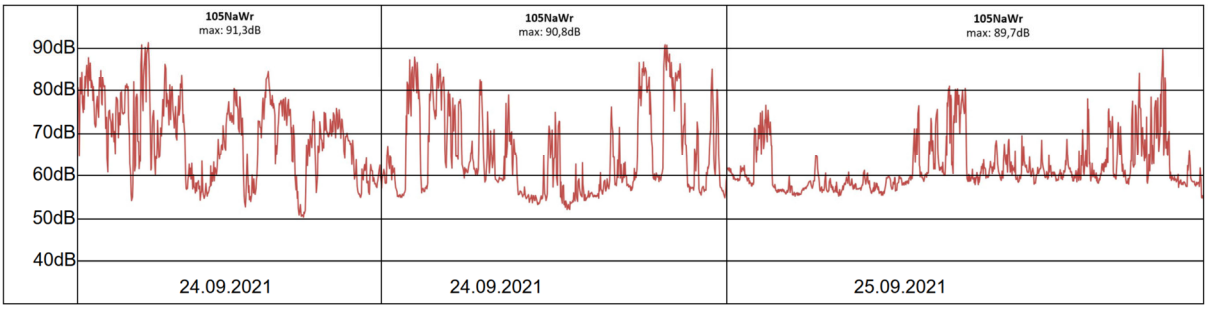
Tram Fleet Recorded in 2021						Tram Fleet Recorded in 2022		
Measurement on 24.09.2021			Measurement on 25.09.2021			Measurement on 14.10.2022		
Track No. 1	Track No. 2	Track No. 3	Track No. 1	Track No. 2	Track No. 3	Track No. 1	Track No. 2	Track No. 3
105NaWr	Moderus MF19AC	105NaWr	105NaWr	Moderus MF24AC	105NaWr	105NaWr	204WrAs	205WrAs
105NaWr	Moderus MF24AC	105NaWr	Moderus MF24AC	Skoda19T	Moderus MF24AC	105NaWr	105NaWr	Moderus MF19AC
205WrAs	Skoda19T	Moderus MF19AC		Moderus MF24AC	105NaWr	105NaWr		
	PESA 2010NW	Moderus MF24AC		105NaWr				
				Skoda16T				

Thanks to the summary, it can be observed that only model 105NaWr and Moderus MF19AC can be compared. Tracks 1, 2, and 3 are characterized by different curve radii. Therefore, the comparison could only be made for the same tram model traveling on the same track.

In this case, the comparison was made for:

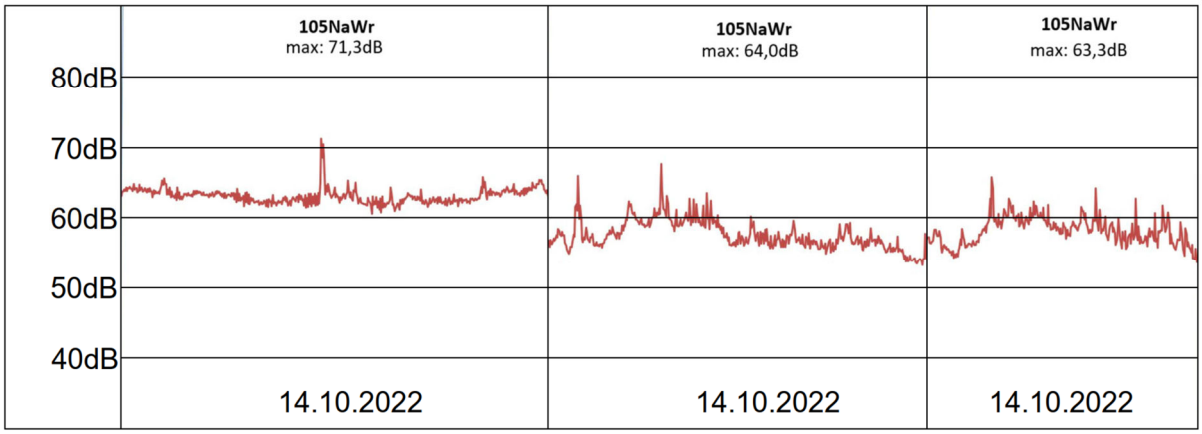
- Model 105NaWr on Track No. 1,
- Model 105NaWr on Track No. 2,
- Model Moderus MF19AC on Track No. 3.

The charts (Fig. **8**) present the acoustic measurement results for the 105NaWr vehicle on the section from the disembarking stop to the stop on Track No. 1.



8. Comparison of Acoustic Measurement Results at Oporów Loop on 24.09.2021 and 25.09.2021 for Model 105NaWr on Track No. 1

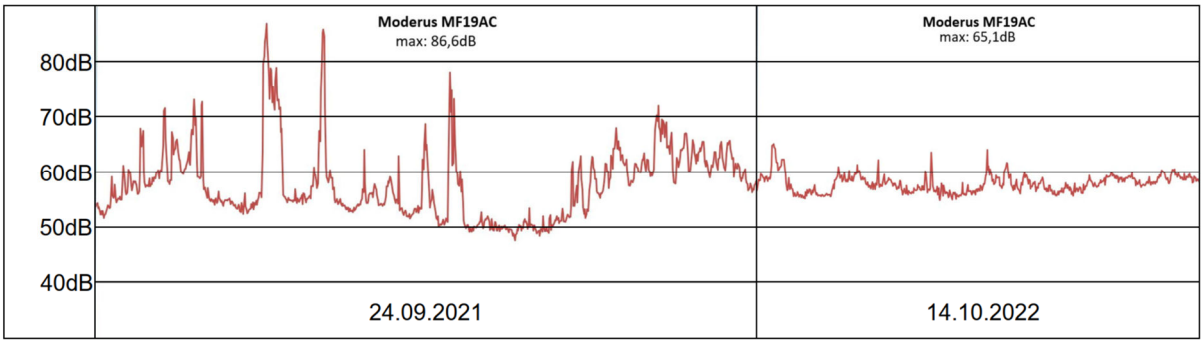
During the measurements conducted on 24.09.2021 and 25.09.2021, the highest recorded values were: 91.3 dB, 90.8 dB, and 89.7 dB (Fig. 9).



9. Comparison of Acoustic Measurement Results at Oporów Loop on 14.10.2022 for Model 105NaWr on Track No. 1

For the measurements conducted on 14.10.2022 for the 105NaWr model on Track No. 1, the following highest values were recorded: 71.3 dB, 64.0 dB, and 63.3 dB. From the charts (Fig. **9**), it can be concluded that the installed lubricators reduced the noise by as much as 20 dB for the 105NaWr model on Track No. 1.

The charts (Fig. **10**) present the combined acoustic measurement results for the Moderus MF19AC vehicle on the section from the disembarking stop to the stop on Track No. 3.

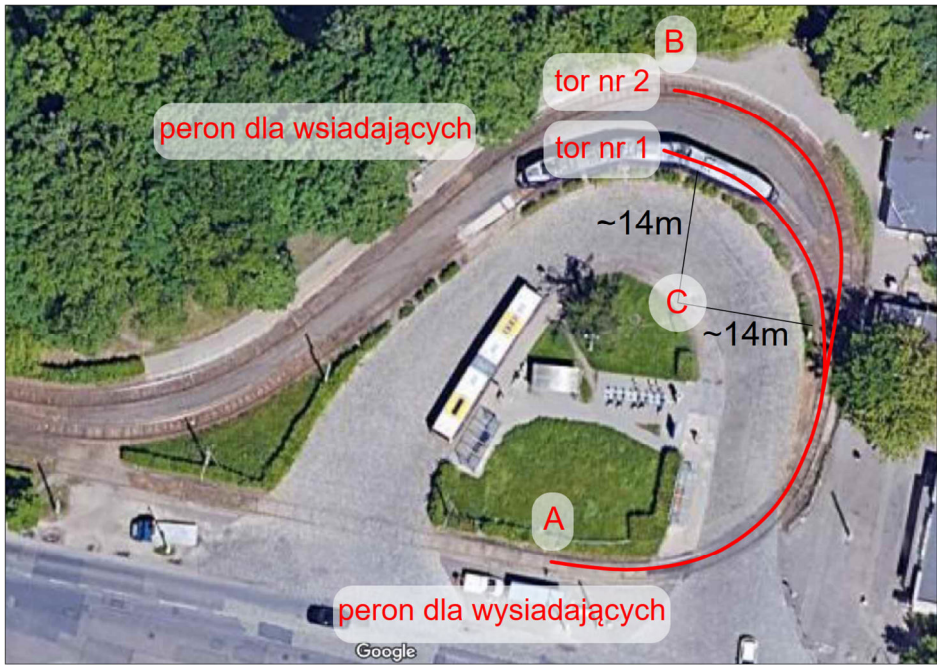


10. Comparison of Acoustic Measurement Results at Oporów Loop on 24.09.2021 and 14.10.2022 for Model Moderus MF19AC on Track No. 3

During the measurements conducted on 24.09.2021, the highest recorded value was 86.6 dB, while on 14.10.2022, the highest recorded value was 65.1 dB. From the charts, it can be concluded that the installed lubricators reduced noise by 21.5 dB for the Moderus MF19AC model on Track No. 3.

Sępolno Loop

The loop consists of two tracks, as shown in Fig. **11**. For the purposes of this article, they have been designated as "Track No. 1" and "Track No. 2". The platform for disembarking passengers and the platform for boarding passengers were also identified. The section marked in red between points A and B was the subject of acoustic research. The measurement position was located at Point C.



11. Sępolno Loop

Acoustic Measurements were conducted on the following dates:

- 25.09.2021 – Before the installation of lubricators.
- 16.10.2022 – After the installation of lubricators.

The Table **4** presents the tram fleet recorded during the three measurement days. Shaded fields indicate the same tram fleet operating on the same tracks. This table would include the tram models, their operation on specific tracks, and any other relevant data from the specified measurement days.

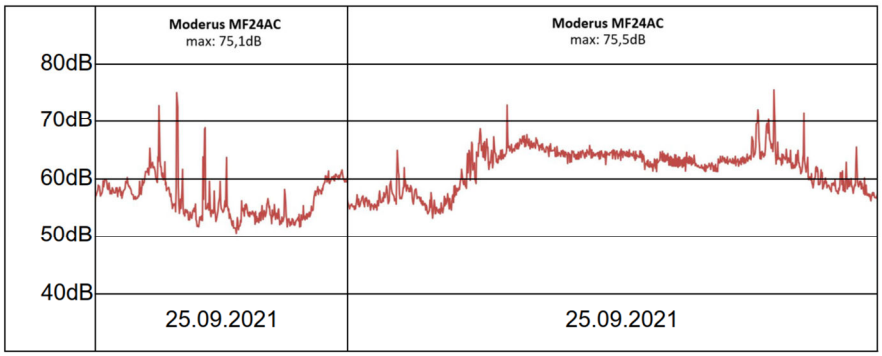
Tab. 4. Summary of Tram Fleet, Measurements on 27.09.2021, 09.09.2021, and 12.09.2021

Tram Fleet Recorded in 2021		Tram Fleet Recorded in 2022	
Measurement on 25.09.2021		Measurement on 16.10.2022	
Track No. 1	Track No. 2	Track No. 1	Track No. 2
Skoda19T	PESA 2010NW	Moderus LF07AC	Moderus LF07AC
Skoda19T	Moderus MF24AC	Moderus LF07AC	Moderus LF07AC
Skoda19T	105NaWr	Moderus LF07AC	Moderus LF07AC
Skoda19T	204WrAs	Moderus LF07AC	Moderus MF19AC
Skoda19T	PESA 2010NW		Moderus MF24AC
Skoda19T	Skoda16T		Moderus MF24AC
	105NaWr		Moderus MF17AC
	Skoda19T		
	PESA 2010NW		
	Moderus MF24AC		
	PESA 2010NW		

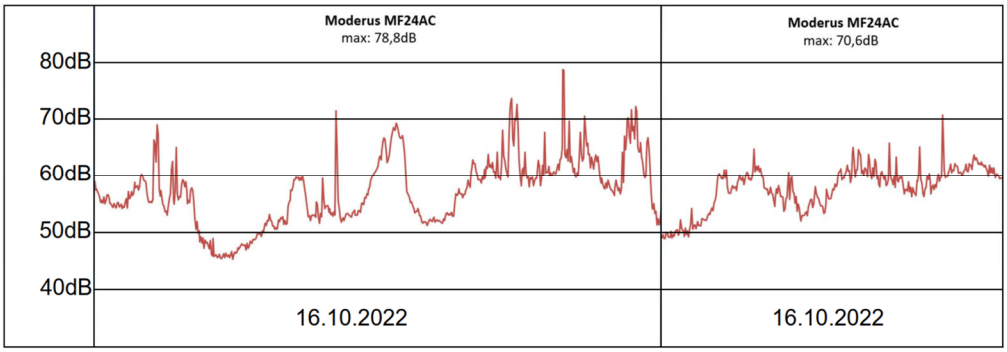
Thanks to the summary, it can be observed that only the Moderus MF24AC model could be compared. Tracks 1 and 2 have different curve radii, so the comparison was limited to the same tram model operating on the same track. In this case, the Moderus MF24AC model on Track No. 2 was analyzed.

An additional challenge during the measurements was the fact that the timetables for Sępolno Loop had almost entirely replaced older tram models with the latest fleet.

The charts (Figs. **12** and **13**) present the acoustic measurement results for the Moderus MF24AC vehicle on the section from the disembarking stop to the stop on Track No. 2.



12. Comparison of Acoustic Measurement Results at Sępolno Loop on 25.09.2021 for Model Moderus MF24AC on Track No. 2



13. Comparison of Acoustic Measurement Results at Sępolno Loop on 16.10.2022 for Model Moderus MF24AC on Track No. 2

During the measurements on 25.09.2021, the highest recorded value was 75.5 dB, while on 16.10.2022, the highest recorded value was 78.8 dB. From the charts, it can be concluded that the installed lubricators did not reduce noise levels for the Moderus MF24AC model on Track No. 2.

Due to the inability to compare measurement results on Track No. 1 and for other tram models on Track No. 2, the effectiveness of the installed lubricators cannot be definitively ruled out.

Summary

This study focuses on the comparison and analysis of acoustic measurement results conducted before and after the installation of track lubricators at Klecina Loop, Oporów Loop, and Sępolno Loop.

The analysis demonstrates the effectiveness of the installed lubricators at Klecina Loop and Oporów Loop. However, no improvement was observed for Sępolno Loop.

The findings confirm that the installation of track lubricators was a justified action. Further acoustic analysis across the city is suggested, as well as implementing similar solutions in areas particularly problematic for the surrounding environment. This is crucial for enhancing the quality of life for residents near these loops and for users temporarily present in these areas.

To ensure accurate measurements, arrangements should be made with the operator to use the same tram models before and after the installation of lubricators. To eliminate additional variables, consistent tram speeds should also be ensured. According to current regulations in Wrocław, the maximum speed in the studied areas (near switches) should be:

- Up to 15 km/h on straight entry switches (with locked points) and on exit switches.

- Up to 10 km/h on curved entry switches.

Additionally, acoustic measurements should be performed under analogous atmospheric conditions, including pressure, temperature, and wind speed.

It is therefore recommended that future measurements account for all the variables mentioned above.

Acknowledgments

I would like to extend my gratitude to Systemy Pomiarowe Sp. z o.o., which provided the Nor145 sound analyzer by Norsonic, along with the Nor1256 Class 1 four-range calibrator, for the purpose of these measurements on multiple occasions.

Source materials

[1] Bąkowski H., Wójtowicz A.: Oszczędności wynikające ze smarowania obrzeży kół w łukach o różnym promieniu. „TTS Technika Transportu Szynowego", Tom R. 20, nr 2-3, str. 58-61, 2013.
[2] Belikov A., Kreknin K., Matsuk Z., Protsiv V. Lubricants for rail transport liquid (plastic) for friction pair "wheel - rail" (2022) Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, (1), pp. 63 - 68, Cited 0 times. DOI: 10.33271/nvngu/2022-1/063.
[3] Clayton, Peter et al. "Laboratory assessment of lubricants for wheel/rail applications." Lubrication Engineering 45, 501-506, 1989.
[4] Deak V.: Zmniejszanie hałasu podczas jazdy tramwajów po łuku – system smarowania obrzeży kół. Technika Transportu Szynowego 7-8/2004.
[5] Eadie, Donald & Oldknow, Kevin & Santoro, Marco & Kwan, Gene & Yu, Marcia & Lu, Xin. Wayside gauge face lubrication: How much do we really understand?. Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit. 227, 245-253, 2013. 10.1177/0954409712459306.
[6] http://geoportal.wroclaw.pl/www/old/mapa-akustyczna.shtml#halas.
[7] https://www.zdium.wroc.pl/torowiska-tramwajowe/.
[8] Polska Norma PN-ISO-1:1999 „Akustyka. Opis i pomiary hałasu środowiskowego. Podstawowe wielkości i procedury".
[9] Rozporządzenie Ministra Środowiska z dnia 14 czerwca 2007 r. w sprawie dopuszczalnych poziomów hałasu w środowisku (Dz. U. Nr 120, poz. 0826).
[10] Rozporządzenie Ministra Środowiska z dnia 29 lipca 2004 r. w sprawie dopuszczalnych poziomów hałasu w środowisku (Dz. U. Nr 178, poz. 1841).
[11] Rozporządzenie Ministra Środowiska z dnia 4 czerwca 2007 r. w sprawie ustalania wartości wskaźnika hałasu LDWN.
[12] Tellado N., Aspuru I., Eguiguren J.L. Importance of lubrication position on squeal noise mitigation (2006) EURONOISE - The 6th European Conference on Noise Control: Advanced Solutions for Noise Control, pp. 6P, 2006.
[13] Temple, P. D., Harmon, M., Lewis, R., Burstow, M. C., Temple, B., & Jones, D. Optimisation of grease application to railway tracks. Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, 232(5), 1514-1527, 2018. doi:10.1177/0954409717734681.
[14] Ustawa z dnia 27 kwietnia 2001 r. „Prawo Ochrony Środowiska" (Dz.U. Nr 62, poz. 627) wraz z późniejszymi zmianami.
[15] Ustawa z dnia 28 lipca 2005 r. o lecznictwie uzdrowiskowym, uzdrowiskach, i obszarach ochrony uzdrowiskowej oraz gminach uzdrowiskowych (Dz. U. Nr 167, poz. 1399).
[16] Zariczny, J., & Grulkowski, S. Efektywność działania smarownic a redukcja hałasu generowanego na łukach linii tramwajowych. Technika Transportu Szynowego, R. 15 (nr 9=184), 43-45, 2009.