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TRAFFIC NOISE EXPERIENCED ON BUSES, TRAMS AND CARS IN THE URBAN AGGLOMERATION OF THE CITY OF KATOWICE

Summary. Transport noise is one of the biggest problems faced by urban agglomerations. Therefore, more and more activities are being undertaken related to its reduction. The article attempts to investigate the noise level on public transport vehicles, buses, trams and passenger cars, from the passenger's perspective. The assessment is based on the results of field tests. The study considered wheeled and rail vehicles, including a new generation of buses and tramways, as well as a car subjected to many years of operation. The research was carried out in the city of Katowice. The conducted experiment showed comparable high values for recorded volume levels on trams and buses, as well as a relatively low noise level in the passenger car.

Keywords: traffic noise, urban agglomeration, transport

1. INTRODUCTION

When, in 2004, Poland decided to join the EU, it had to face many restrictive assumptions on the part of every other country belonging to it. Most areas of human life are

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regulated, including those that are intended to improve quality of life in urban agglomerations [10,16].

Great importance is placed on reducing noise, which is a burdensome environmental and anthropogenic factor, which can negatively impact the experience of city life among residents and visitors. Noise is an indispensable phenomenon related to the development of public spaces in cities and communication within them. It can be divided according to source, i.e., communication noise, industrial noise, communal noise, domestic noise and the resultant work environment [14,15,18,23].

Noise is an undesirable excess of emitted sound, which has a nagging or even harmful effect on human health. This nuisance is related to the characteristic features of the sound, i.e., the frequency and intensity of the propagating acoustic waves. We may talk about this harmfulness when we are exposed to prolonged exposure to the noise source, when the amplitude of the sound increases to the upper limit, i.e., about 102 W/m^2 (pain limit), in which the sound is not an aural impression but perceived as pain [23].

The human hearing system is designed to receive a sound wave, which is directed to the eardrum and introduced to vibrations. These vibrations pass successively between the ossicles, hammer, anvil and stapes, which bring fluid into the worm tube, in turn irritating the cilia of the receptor cells and causing electrical impulses. Using the auditory nerve, they reach the centre of hearing in the cerebral cortex. There, they are read and interpreted [3].

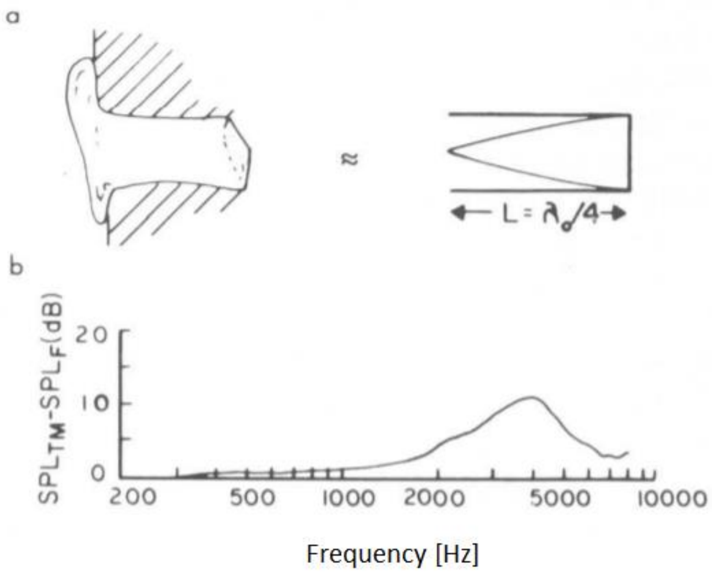

Figure 1. Hearing wire (a) and sound pressure level (SPL) gain diagram in the ear canal (b) [23]

The human hearing organ (Figure 1) processes sounds with frequencies in the 16-20,000 Hz range. The best audible frequencies are those in the 1,000-4,000 Hz range. At a young age, we are able to receive these frequencies. As we get older, the body lowers the upper limit of the sound reception, such that high-frequency sounds are no longer heard (at which point, the best-heard sounds are those in the 1,000-3,000 Hz range).

The threshold for audible levels is 0 dB, while the maximum intensity of an audible sound is that with a 140 dB measure (the higher value causes pain, which is related to the damage inflicted on the spiral organ). The division of the noise level due to nuisance from the sound reception (Table 1) is as follows:

- <35 dB: this sound volume is harmless to people, but it can be burdensome during work that requires us to focus
- 35-75 dB: this volume is bothersome, makes it difficult to understand the speech of the person standing next to the hearer and eliminates the rest of the nervous system from the human nervous system
- 70-85 dB: this causes gradual damage to the hearing organ
- 85-130 dB: this damages people’s hearing, contributes to diseases of the nervous system and does not allow the speech of a person standing next to the hearer to be understood
- 130 dB: this sound permanently damages human hearing and enhances the vibrations of internal organs [4]

Tab. 1

The scale of subjective nuisance from communication noise [8]

Onerousness	**L_{Aeq} (dB)**
Small	<52
Average	52-62
Large	63-70
Very large	>70

Traffic noise is mainly related to vehicle traffic. The most noticeable noise of this kind is found in highly developed anthropogenically agglomerations, where the communication diversity along the routes used by cars, trams and railways has been extended. The article presents an analysis of noise that affects passengers in a passenger car, bus and tram, which represent the main sources of public transport in Polish agglomerations [2].

2. RESEARCH PLAN

The aim of the study is to analyse the occurring noise in public transport vehicles from the passenger’s perspective. The experiment was carried out in accordance with the PN-90/S-04052 standard with an acceptable noise level inside the vehicle using the SON-50 integral sound level meter.

The technical data for the SON-50 are as follows:

- Microphone: WK-21, capacitive, polarized
- Time characteristics: SLOW, FAST
- Filters: centre frequencies: 31.5÷8 kHZ
- Measuring range: 20-135 dBA

The measurements were carried out on Correction Curve A and the FAST dynamic characteristic. The device was placed on the seat where the passenger would sit. The tests were carried out over a period of time, in which individual vehicles overcame the route between the selected stops in three measuring rounds [21].

The objects subjected to sound intensity testing were respectively:

- Volvo 7900 series hybrid bus
- Tram with Konstal 105N HF series wagon
- Renault car

Measurements on three types of public transport were performed in Katowice on the route between Katowice Zawodzie Łączna and Katowice Zawodzie Pętla.

Fig. 2. Route between Katowice Zawodzie Łączna and Katowice Zawodzie Pętla
Source: Google Maps

Noise was checked at bus stops when people were allowed onto vehicles, at the time of starting, during the route between stops, and during stopping at the next stop. The measurements were carried out on the section between one stop and the next on three occasions. The noise level results were convergent, according to PN-90/S-04052, where the noise of public transport cannot be higher than 85 dB/A.

Tab. 2

Technical data of tested vehicles

Technical data	Bus	Tram	Car
Dimensions	Length: 18 m Width: 2.55 m Height: 3.28 m	Length: 13.5 m Width: 2.35 m Height: 3.35 m	Length: 4.209 m Width: 1.777 m Height 1.457 m
Engine, drive	High-pressure: Volvo D5K 240, four-cylinder in-line engine, 240HP Electric: Volvo I-SAM, 150 kW/1,200 Nm	Asynchronous AC drive	Petrol: 115 km
Additional data	Exhaust system: One-piece silencer. Under normal driving conditions, the DPF is self-regenerating without driver intervention.	Weight: 16,500 kg Maximum speed: 70 km/h	Drive type: for the front axle

The tests were carried out in the city between 10.00 and 12.00; hence, the maximum value of vehicle speed did not exceed 50 km/h. The meter was placed on the passenger seat in order to measure the passenger's driving comfort. The study took into account the travel time of a given route by a public transport vehicle [1].

3. RESEARCH RESULTS

The bus (Volvo hybrid bus; see Figure 3) considered during the test is a relatively new vehicle, as it was produced in 2016. The largest noise values were observed at the moment of leaving and at arriving the bus stop. Nevertheless, the noise level did not exceed the values included in the PN-90/S-04052 standard, especially since this noise came from the passenger compartment in which it was tested and was thus also related to conversations of other vehicle passengers and other disturbances. On the scale for the subjective feeling of comfort (Table 1), the nuisance from feeling noise was high [2,5,7,20].

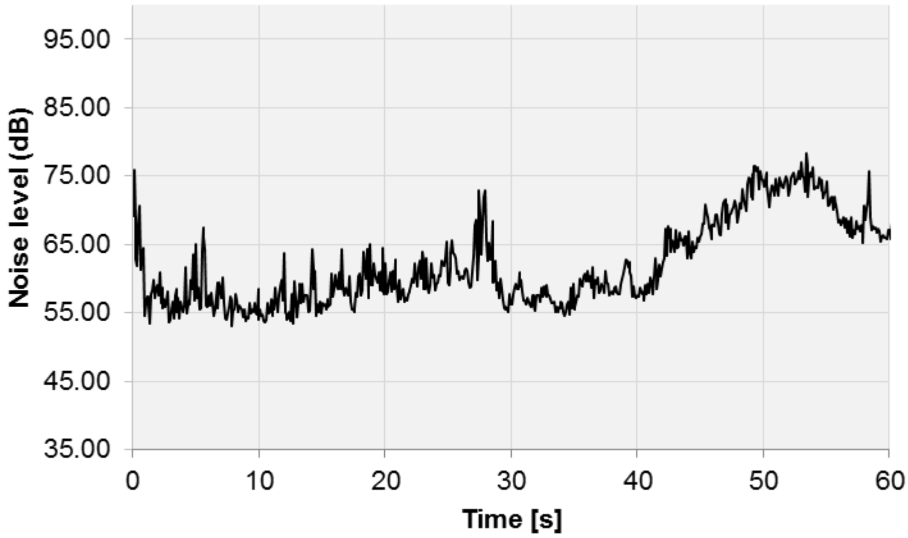

Fig. 3. Averaged (average of three attempts for the Volvo hybrid bus) noise level in the public bus from the perspective of the time between the two stops

The tram considered by the test was manufactured in 2007; thus, it was a relatively new communication vehicle. We observed the highest noise level while driving. Throughout the route, we could observe a more or less constant noise value without major amplitudes. As can be seen on the graph, the values for most of the road oscillated in the 75-85 dB value range (Figure 4), which gave us a value within the standard's range; but, for our auditory system, it was tiring and it is not recommended for places with such fixed noise values [9,11,12,17].

The noise level was examined in the passenger space, such that human factors were also superimposed on its reception. According to the scale of the subjective feeling of comfort, driving a tram with such a noise level is very burdensome for the passenger. However, in our case, this evaluation fell within the range of the PN-90/S-04052 standard [1,7,19,21].

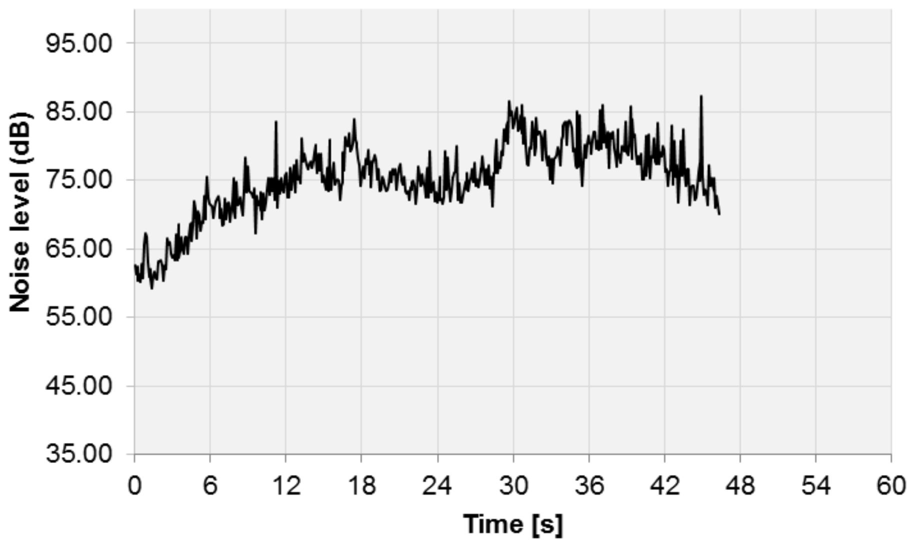

Fig. 4. Averaged (average of three attempts for tram with a Konstal 105N series wagon) noise level on the public bus from the perspective of the time between the two stops

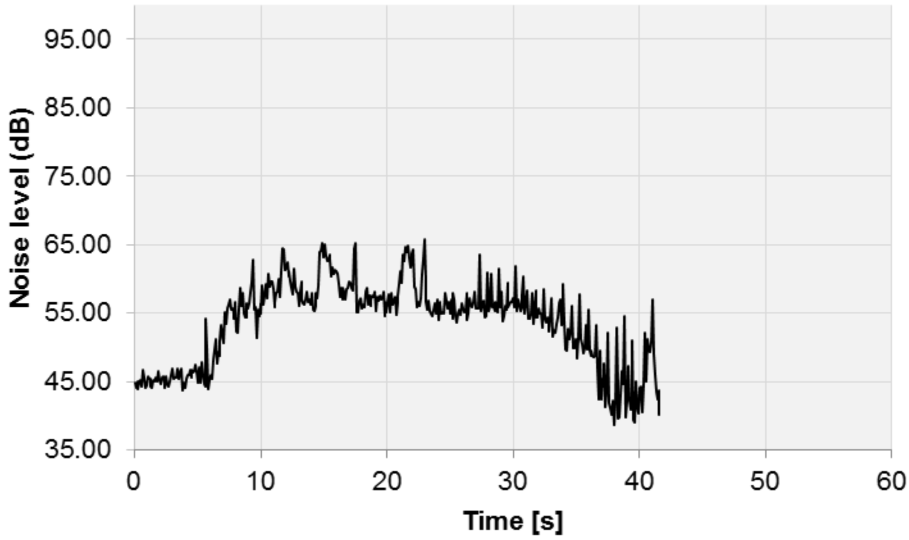

Fig. 5. Averaged (average of three attempts for the Renault car) noise level on the public bus from the perspective of the time between the two stops.

The passenger car was constructed in 2004 and had a long service life. Nevertheless, the vehicle did not exceed 70 dB. As can be seen on the graph, the noise level fluctuated in the 55-65 dB value range. The highest noise level occurred when the vehicle accelerated. The passenger should not feel too tired from the route due to being exposed to the significant effects of the sounds reaching him/her. This is also connected to the fact that we did not deal with the load related to the additional noise caused by other passengers when driving the car. The test was carried out from the passenger's perspective in the front cabin of the vehicle [7,13,19].

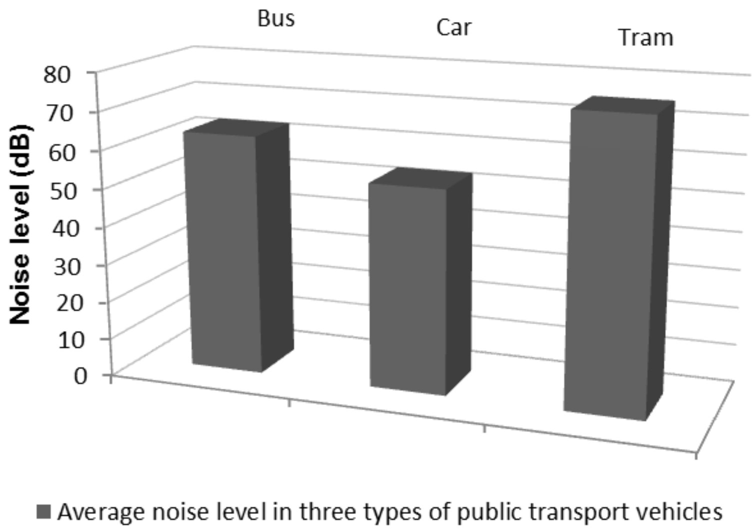

Fig. 6. Average noise level in three types of vehicles: bus, passenger car, tram

The graph shown in Figure 6 presents the averaged noise values for individual vehicles on the same section of the route. As can be seen, the largest load, in terms of arrival noise, is experienced by a passenger taking a tram ride, in which the average was ≈75 dB. The least annoying noise was from the passenger car (≈54 dB).

4. CONCLUSIONS

Due to the fact that everybody is exposed to noise, one should be aware that it can have harmful effects in terms of the length of exposure to the sound reaching us. For the heavily urbanized and anthropogenically used area of the city in which the study was conducted, traffic noise is noise that dominates over other sources. In the conducted experiment, it can be observed that it did not exceed the established norms, but it was onerous and permanent, which would affect the state of our physical and mental health [6].

In order to eliminate the nuisance of traffic noise and ‘mute’ the city, in addition to the standard processes, the following is advised: capturing vehicles exceeding the noise level, checking technical conditions, i.e., the value of tyre pressure, introducing alternative public transport vehicles. In recent years, many innovative, pro-ecological approaches to reducing or almost eliminating noise levels and reducing the amount of exhaust gases have been developed, such as airborne gondolas, trams and electric vehicles. Introducing them involves huge financial resources; but, in the years to come, we should feel a difference in the quality of air and a reduction or almost total reduction in the level of transport noise in the city.

The noise level of vehicles in comparison with earlier models in the context of public transport has decreased. The introduction of appropriate standards and initiatives by the countries in the EU community has also had an impact on reducing noise nuisance, especially for the benefit of passengers. Companies producing vehicles are employing increasingly well-educated acoustics that work on soundproofing sounds emanating from vehicles. More and more attention is being focused on driving comfort because increased comfort when using public transport will mean an increase in the number of passengers.

The fight against noise has begun, and every step of the way we hear about the further development of innovative ideas. Everything indicates that, in the next few years, the noise level will change positively, such that not only will the imposed standards be met, but also the needs of the typical passenger.

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