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# METHODS OF EXPERIMENTAL RESEARCH OF NOISE POLLUTION FROM ROAD TRANSPORT AND ACOUSTIC PARAMETERS OF NOISE PROTECTION SCREENS

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**Abstract.** A review of scientific work on the main sources of noise from road transport and its impact on human health. Measures to reduce the level of noise load on the environment are analyzed.

It is established that in projects of construction and reconstruction of highways measures of reduction of noise loading of motor transport on adjoining territories to highways, especially within settlements, should be considered.

The method is given and experimental measurements of noise load from highways to the adjacent territories depending on the distance from the noise source to the residential area are carried out. It was found that the equivalent sound level in the area adjacent to the residential area, at a distance of 2 m is 74.4 dBA, and the maximum sound level – 78.0 dBA. When measuring the noise characteristics at a distance of 1 m in front of the noise shield, the equivalent sound level was 88.6 dBA, and the maximum sound level was 103.9 dBA. At a distance of 2.4 m from the noise shield, the equivalent sound level was 70.7 dBA, and the maximum sound level was 89.8 dBA.

It was found that during the experimental measurements at a distance of 19.5 m from the existing highway and at a distance of 2 m from residential buildings, the measured equivalent noise level exceeded the established normative value by 19.4 dBA, and the measured maximum noise level exceeded the established normative value by 8.0 dBA.

Experimental measurements of acoustic efficiency parameters of noise protection screens were performed. It is established that noise protection screens are effective means of reducing the noise transport load on the environment. At a distance of 2 m from the noise protection screen, the acoustic efficiency of the screen is 11-16 dBA.

**Key words:** highway, noise load, experiment, noise protection screens.

**Introduction.** Significant increases in the intensity of traffic, increasing the power of car engines and increasing speeds of road transport cause acoustic pollution. It should be noted that today noise pollution has become one of the main polluters of the environment. It should be noted that all organs of the human body react negatively to the increase in noise levels in the environment. According to the World Health Organization (WHO), constant man-made noise disrupts a person's psychological comfort, and also leads to various diseases, not only of the hearing aid, but also of the nervous and cardiovascular systems [1]. In the countries of the European Union, much attention is paid to reducing the noise level from road transport in the environment. This problem is solved when designing the construction and reconstruction of roads. Noise protection measures are planned in the settlements adjacent to the highway: additional landscaping, noise protection screens, etc.

**The problem and its relevance.** The noise load from road transport is influenced by many factors. Some of them are the technical condition of the road surface and terrain, others the performance of cars.

Vehicle noise is mainly caused by three factors: exhaust pipes, vehicle engines and tires that interact with the road surface. Each of these factors reproduces sound energy, which, in turn, is a source of moving and vibrating sound waves – fluctuations in atmospheric pressure. These sound pressure fluctuations are usually reflected in the sound pressure and are measured in micronewtons per 1 $m^2$ ($\mu N/m^2$) or in micropascals ($\mu Pa$). Usually the sound pressure is in the range from 20 to 200 $\mu Pa$. Due to this scatter, the sound pressure is measured on a logarithmic scale (Fig. 1). On this scale, a value of 0 dB is equal to a sound pressure level (SPL) of 20 μPa and corresponds to the hearing threshold for most people. The value of 140 dB is equal to SPL 2×108 μPa and is the threshold of pain for most people.

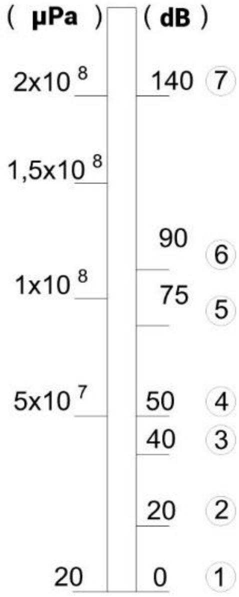



Fig. 1. Scale of sound levels: 1 – limit of audibility; 2 – rustling of leaves; 3 – "sleeping" area at night; 4 – restaurant without music; 5 – continuous traffic flow at a distance of 30 m; 6 – jet aircraft at an altitude of 300 m; 7 – pain threshold

To express the energy of sound, or the pressure of sound in SPL, or in dB, the following equation is used:

$$SPL = 10xLg(P/P\,ref)^2, \tag{1}$$

where P – is the sound pressure; Pref – sound pressure equal to 20 μPa.

It should be noted that the trajectory of sound propagation is different. It depends on the presence of obstacles.

The next characteristic of sound is amplitude, or volume. Sound sources produce sound energy, which, in turn, creates micro fluctuations in atmospheric pressure.

Another characteristic of sound is its frequency, or tonality, measured in Hz, or the period of oscillations per second.

Thus, the sound impression received by a person is greatly influenced by a person's condition: fatigue, previous irritation with sound, simultaneous sound of other sources (so-called masking) and much more. In addition, at sufficiently large amplitudes of sound in the human auricle there are nonlinear distortions: higher harmonics in the case of sinusoidal tone, higher harmonics and combination tones in non-sinusoidal tone.

Therefore, the development of methods for estimating and reducing traffic noise from highways to the environment and conducting experimental measurements of noise load when moving cars is an urgent task of research.

**Analysis of recent research and publications.** In research works [2, 3] the results of research on noise reduction through the use of improved geometric shape of the car tires and improved road surface design are presented. However, it should be noted that road safety should be ensured first of all when developing measures to reduce noise load.

In [4] it is noted that the level of noise load on the environment depends on the temperature and humidity parameters of the environment. It is established that with increasing temperature and humidity, the speed of sound increases [5].

In addition, it was noted in [6] that, depending on atmospheric conditions, the sound level can vary between 6–10 dB.

Numerous studies of the influence of pavement materials on noise characteristics have been carried out in [3]. It was found that a thin smooth layer of bitumen reduces the noise level by 4-5 dBA compared to the noise level on roads with ordinary asphalt pavement.

However, in [4] it was noted that a smooth road surface reduces the noise level, but does not ensure the safety of cars in wet weather.

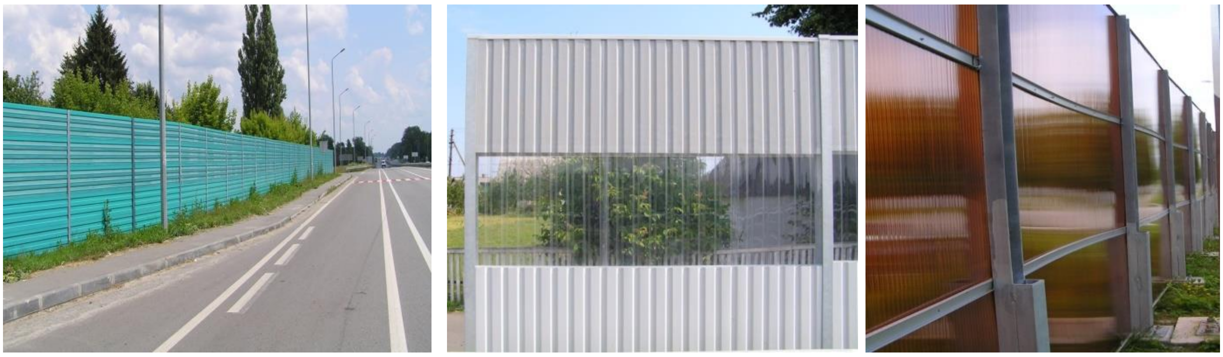
In scientific works [7–9] the issues of selection of optimal parameters and materials of noise protection screens and their efficiency of application on highways are considered. The issues of visual perception of the screen by road users and their integration with the surrounding areas are presented.

Therefore, the development of the transport network requires the development of effective measures to reduce noise pollution. Therefore, the topic of scientific work is relevant and timely.

**The aim of research** is the development of a method for experimental assessment of the noise load of roads on the environment and measurements of noise load depending on the technical condition of roads and parameters of noise screens.

**Research methodology.** Experimental studies of noise pollution on the environment were conducted in areas of roads that are close to settlements. The noise characteristics of the traffic flow were determined before the noise protection screen and at a distance of 2 m after it. In addition, the maximum and equivalent sound levels were determined in the settlement area, which is close to the highway. The measurement was performed 2 m before the fence of the house, if any, or 2 m before the house at a height of 1.2-1.5 m from the surface level. Also, the measurement method involved determining the temperature, humidity and wind direction, atmospheric pressure and air velocity; traffic intensity and traffic flow composition; number of lanes; the distance from the axis of the extreme lane (noise source) to the noise shield; height and technical condition of the screen; the distance from the noise source to the measuring point in the residential area and the profile of the highway at the place of measurement.

The type of noise protection screens on which measurements were made, located on the Kyiv-Chop highway, is shown in Fig. 2. They have the following physical characteristics: the material from which the screens are made – steel sheet (perforated), plastic (transparent or translucent of different colors); screen height – from 2.5 m to 3.9 m.



a) b) c)

Fig. 2. Noise protection screens on the Kyiv-Chop highway:
a – steel perforated sheet; b – screen with a transparent part (157 km, Berezivka village, Kyiv region); c – plastic screen (238 km, Zhytomyr region)

The following equipment was used to measure the noise of traffic flows: Octave 110A № AO60114 noise meter, electronic weather station type WM-918, wing anemometer, ASO-3 and roulette.

The estimated equivalent noise level from the traffic flow at a distance of 7.5 m from the axis of the nearest lane of the paved highway is determined by the formula:

$$L = 50 + 8,8 \lg N, \qquad (2)$$

where L – is the equivalent noise level of dBA; N – perspective traffic intensity, bus/hour.

The value of the equivalent (energy) sound level LA, dB is determined by the formula:

$$L_A = 10\lg\left[\frac{1}{T_m}\int_0^{T_m}\left(\frac{p_A(t)}{p_0}\right)^2 dt\right], \quad (3)$$

where $p_A(t)$ – sound pressure, which changes over time, measured with the frequency response "A" of the noise meter, PA ; $p_0$ – threshold value of pressure equal to $2\cdot10^{-5}$ Па; $T_m$ – duration of noise measurement, min.

The width of the interval of sound levels must be less than or equal to 5 dBA. Average sound level $L_i$ in $i$ – intervals of sound levels are determined by the formula:

$$L_i = \frac{L_í + L_â}{2}, \quad (4)$$

where $L_í$ – the lower limit of the interval of sound levels, dBA; $L_â$ – the upper limit of the interval of sound levels, dBA.

**Results of experimental measurements of noise load from highways.** Measurements of noise characteristics of traffic flow were carried out on the highway of Zhytomyr region. Schematic situational plan of the area where measurements were carried out on the highway Kyiv-Chop km 238 + 740 is shown in Fig. 3.

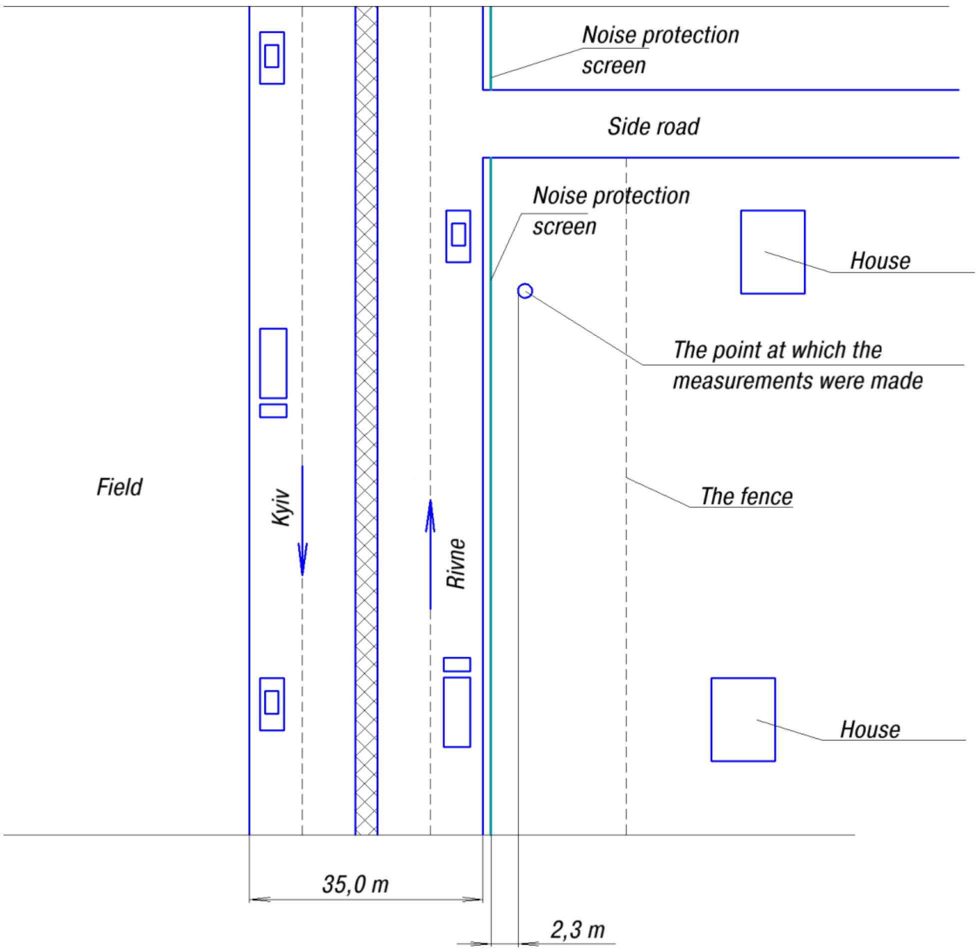



Fig. 3. Schematic situational plan of the section of the Kyiv-Chop highway km 238 + 740

The results of experimental measurements of the acoustic efficiency of noise protection parameters of screens located on the roads of Zhytomyr region are given in Table. 1.

Table 1 – The results of experimental measurements of the characteristics of noise protection screens

| Name of the highway service | Section of the highway with Noise protective screen, km | Length of Noise protective screen, м | Eq. noise level before Noise protective screen, dBA | Eq. noise level at a distance of 2 m per Noise protective screen, dBA | Efficiency, dBA |
|---|---|---|---|---|---|
| Zhytomyr region (to the right) | 237+920 – 238+685 | 765 | 87 | 71 | 16 |
| | 238+740 – 238+780 | 40 | 84 | 72 | 12 |
| | 238+830 – 238+880 | 50 | 86 | 74 | 12 |
| | 239+375 – 239+450 | 75 | 86 | 73 | 13 |
| | 239+520 – 239+580 | 60 | 85 | 72 | 13 |
| | 239+610 – 239+670 | 60 | 85 | 72 | 13 |
| | 239+680 – 239+740 | 60 | 86 | 73 | 13 |
| | 239+870 – 239+930 | 60 | 84 | 71 | 13 |
| | 246+920 – 247+020 | 100 | 85 | 70 | 15 |
| | 247+040 – 247+110 | 70 | 85 | 71 | 14 |
| | 247+190 – 247+150 | 60 | 86 | 72 | 13 |
| | 247+260 – 247+315 | 55 | 86 | 74 | 12 |
| | 247+780 – 247+840 | 60 | 86 | 74 | 12 |
| | 247+850 – 247+885 | 35 | 84 | 73 | 11 |
| | 248+210 – 248+325 | 115 | 84 | 70 | 14 |
| | 248+345 – 248+390 | 45 | 85 | 73 | 12 |
| | 248+470 – 248+520 | 50 | 86 | 74 | 12 |
| | 248+560 – 248+650 | 90 | 84 | 69 | 15 |
| | 248+665 – 248+715 | 50 | 84 | 72 | 12 |
| | 248+722 – 248+920 | 198 | 86 | 70 | 16 |
| | 248+990 – 249+090 | 100 | 86 | 71 | 15 |
| | 250+096 – 250+180 | 84 | 85 | 71 | 14 |
| | 250+220 – 250+500 | 280 | 86 | 70 | 16 |
| | 250+650 – 251+420 | 770 | 85 | 69 | 16 |
| | 251+530 – 251+590 | 60 | 84 | 72 | 12 |
| Zhytomyr Region (to the left) | 247+010 – 247+110 | 100 | 84 | 69 | 15 |
| | 247+130 – 247+230 | 100 | 85 | 70 | 15 |
| | 247+440 – 247+500 | 60 | 85 | 73 | 12 |
| | 247+977 – 248+010 | 33 | 85 | 74 | 11 |
| | 248+420 – 248+750 | 330 | 86 | 71 | 15 |

The results of experimental studies have shown that the equivalent sound level in the area adjacent to the residential area, at a distance of up to 2 m is 74.4 dBA, and the maximum sound level – 78.0 dBA.

When measuring the noise characteristics at a distance of 1 m in front of the noise shield, the equivalent sound level was 88.6 dBA, and the maximum sound level was 103.9 dBA. At a distance of 2.4 m from the noise shield, the equivalent sound level was 70.7 dBA, and the maximum sound level was 89.8 dBA.

Table 1 shows that the acoustic efficiency of noise protection screens on the highway in the Zhytomyr region is 11-16 dBA.

During the experimental measurements at a distance of 19.5 m from the existing highway and at a distance of 2 m from residential buildings: the measured equivalent noise level exceeded the set normative value by 19.4 dBA, and the measured maximum noise level exceeded the set normative value by 8.0 dBA.

**Conclusions.** As a result of experimental measurements of noise load from roads in the surrounding area, the following conclusions can be drawn:

1. The task of reducing the impact of road traffic noise on the environment should be considered in projects for the construction and reconstruction of roads.

2. The analysis of the characteristics of noise protection screens on the Kyiv-Chop highway in Zhytomyr region made it possible to establish that the acoustic efficiency of noise protection screens is 11-16 dBA.

3. It was established that the equivalent sound level in the area adjacent to the residential area, at a distance of up to 2 m was 74.4 dBA, and the maximum sound level – 78.0 dBA.

## References

[1] SHumove zabrudnennya. [Online]. Available: https://uk.wikipedia.org/wiki/%D0%A8%D1%83%D0%BC%D0%BE%D0%B2%D0%B5_%D0%B7%D0%B0%D0%B1%D1%80%D1%83%D0%B4%D0%BD%D0%B5%D0%BD%D0%BD%D1%8F.

[2] C. G. Gordon, W. J. Galloway, B. A. Kugler, D. L. Nelson, *NCHRP Report 117: Highway Noise*. A Design Guide for Highway Engineers. HRB, National Research Council, Washington, D.C., 1971.

[3] G. Fleming, E. Gregg, Rickley, *Performance Evaluation of Experimental Highway Noise Barriers*. Report No. DOT-VNTSC-FHWA-94-16 and FHWA-RD-94-093. Cambridge MA: John A. Volpe National Transportation Systems Center, 1994.

[4] D. Banerjee, "Ambient Noise Level around an integrated Iron & Steel works", *Bulletin of National Institute of Ecology*, 32(4), pp.144–146, 2006.

[5] G. Fleming, E. Gregg, Rickley, *Parallel Barrier Effectiveness: Dulles Noise Barrier Project*. Report No. FHWA-RD-90-105and DOT-TSC-FHWA-90-1. Cambridge MA: U.S. Department of Transportation, John A. Volpe National Transportation Systems Center, Acoustics Facility, 1990.

[6] A. Ahmed, M. A. Fahim, & H. S. Seddeq, "Noise prediction for outdoor cooling systems; case study", *Journal of American Science,* 6(11), pp. 899–905, 2010.

[7] Highway Noise Barriers: Performance, Maintenance and Safety (Video). Cambridge, MA: John A. Volpe National Transportation Systems Center, 1996.

[8] Summary of Noise Barriers Constructed By December 31, 2010. – Washington, DC: U.S. Department of Transportation, 2012.

[9] Highway Noise Barrier Design Handbook. Prepared by Gregg G. Fleming, Harvey S. Knauer, Cynthia S.Y. Lee, Soren Pedersen, 2000.

[10] S. Castineira-Ibanez, *Characterization of an Acoustic Barrier Made up of arrangements of Multi-Phenomena Cylindrical scatterers based on Fractal Geometries Euronoise*. Prague, 2012.

[11] G. Jonasson Hans, *Nord 2000. New Nordic prediction method for rail traffic noise*, SP Hallbar Samhallsbyggnad, Ljud och vibration. Storeheier, Svein, SINTEF, 2001 DOI:10.1006/jsvi.1996.0268.

[12] Pachaivannan Partheeban, Krishnamurthy Karthik, Partheeban Navin Elamparithi, Krishnan Somasundaram, Baskaran Anuradha, "Urban road traffic noise on human exposure assessment using geospatial technology", *Environmental Engineering Research,* 27(5), 210249, 2022.

[13] L. Maine, L. Sharma, D. Franzen, "Use of corn height measured with an acoustic sensor improves yield estimation with ground based active optical sensors", *Computers and Electronics in Agriculture*, 2016. DOI:10.1016/j.compag.2016.04.016.

[14] D. Kapski, V. Kasyanik, O. Lobashov, A. Volynets, O. Kaptsevich, A. Galkin, "Estimating the Parameters of Traffic Flows on the Basis of Processing of Localization Data on the Movement of Vehicles", *Communications-Scientific letters of the University of Zilina*, 21(2), pp. 89-99, 2019.

[15] M. Gallo, *A piecewise-defined function for modelling traffic noise on Urban Roads*. MDPI, 2020, DOI:10.3390/infrastructures5080063.

[16] M. Melnyk, M. Lobur, I. Vasyliuk, V. Mazur, N. Hemich, "The mathematical model of length defining position of dominated noise source in traffic flow", Proc. of the XI Intern. Conf. on the experience of designing and application of CAD systems in microelectronics (CADSM'2011). Lviv – Polyana: Publishing House Vezha & Co, 2011.

[17] R. K. Mishra, M. Parida, S. Rangnekar, "Evaluation and analysis of Traffic Noise Along Bus Rapid Transit System Corridor", *International Journal of Environmental Science and Technology*, 2010. DOI:10.1007/BF03326183.

[18] M. Maghrour Zefreh, A. Torok, "Theoretical comparison of the effects of different traffic conditions on Urban Road Traffic Noise", *Journal of Advanced Transportation*, 2018. DOI:10.1155/2018/7949574.

[19] I. M. Beca, M. Iliescu, "The Sunet System for Monitoring Noise Pollution in Cluj-Napoca", *Romanian Journal of Transport Infrastructure*, 6(2), pp. 33-44, 2017.

## МЕТОДИКА ЕКСПЕРИМЕНТАЛЬНИХ ДОСЛІДЖЕНЬ ШУМОВОГО ЗАБРУДНЕННЯ ВІД АВТОМОБІЛЬНОГО ТРАНСПОРТУ ТА АКУСТИЧНИХ ПАРАМЕТРІВ ШУМОЗАХИСНИХ ЕКРАНІВ

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**Анотація.** Проведено огляд наукових робіт стосовно основних джерел шумового навантаження від автомобільного транспорту та його вплив на стан здоров'я людей. Проаналізовано заходи зниження рівня шумового навантаження на оточуюче середовище.

Встановлено, що у проєктах будівництва і реконструкції автомобільних доріг повинні розглядатися заходи зменшення шумового навантаження автомобільного транспорту на прилеглі території до автомобільних доріг, особливо у межах населених пунктів.

Наведено методику та проведено експериментальні вимірювання шумового навантаження від автомобільних доріг на прилеглі території у залежності від відстані від джерела шуму до житлової зони. Встановлено, що еквівалентний рівень звуку на ділянці прилеглій до житлової зони, на відстані до 2 м становить 74,4 дБА, а максимальний рівень звуку – 78,0 дБА. При вимірюванні шумових характеристик на відстані 1 м перед шумозахисним екраном еквівалентний рівень звуку становив 88,6 дБА, а максимальний рівень звуку – 103,9 дБА. При відстані до шумозахисного екрану 2,4 м еквівалентний рівень звуку складав 70,7 дБА, а максимальний рівень звуку – 89,8 дБА.

Встановлено, що при експериментальних вимірюваннях на відстані 19,5 м від існуючої автомобільної дороги та на відстані 2 м до житлової забудови виміряний еквівалентний рівень шуму перевищував встановлене нормативне значення на 19,4 дБА, а виміряний максимальний рівень шуму перевищував встановлене нормативне значення на 8,0 дБА.

Проведено експериментальні вимірювання параметрів акустичної ефективності шумозахисних екранів. Встановлено, що шумозахисні екрани є ефективними засобами зменшення шумового транспортного навантаження на навколишнє середовище. При відстані 2 м від шумозахисного екрану акустична ефективність екрану становить 11–16 дБА.

**Ключові слова**: автомобільна дорога, шумове навантаження, експеримент, шумозахисні екрани.

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