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ENVIRONMENTAL NOISE MEASUREMENT IN THE CITIES OF KRUŠEVAC AND TRSTENIK

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ABSTRACT

The paper analyzes the results of noise measurements in the environment in the city of Kruševac, for the winter period of 2024, based on the test report - noise measurement of the Institute for Public Health Kruševac, as an accredited testing laboratory, for the user of the Kruševac City Administration. The measurement was carried out in accordance with the current regulations, at twelve measuring points in Kruševac, in three time periods (day, evening and night). Also this paper describes the study of noise levels at 4 locations in the town of Trstenik, which was carried out during the 2024. Based on the obtained measurement results, an analysis of the same was carried out, a conclusion was drawn about noise level exceedances at the observed points and a proposal for improvement measures was given.

KEY WORDS: *noise, noise measurement, environment*

MERENJE BUKE U ŽIVOTNOJ SREDINI U GRADOVIMA KRUŠEVAC I TRSTENIK

SAŽETAK

Rad analizira rezultate merenja buke u životnoj sredini na području grada Kruševca, za zimski period 2024. godine, na osnovu izveštaja o ispitivanju – merenju buke Instituta za javno zdravlje Kruševac, kao akreditovane laboratorije za ispitivanja, za potrebe Gradske uprave Kruševca. Merenja su sprovedena u skladu sa važećim propisima, na dvanaest mernih mesta u Kruševcu, u tri vremenska intervala (dan, veče i noć). Takođe, u radu je prikazano istraživanje nivoa buke na 4 lokacije u opštini Trstenik, koje je sprovedeno tokom 2024. godine. Na osnovu dobijenih rezultata merenja urađena je analiza, donet zaključak o prekoračenju nivoa buke na posmatranim tačkama i dat predlog mera za unapređenje.

KLJUČNE REČI: *buka, merenje buke, životna sredina*

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INTRODUCTION

Noise is any unwanted sound that causes psycho-physiological sensations (disturbing, disturbing) by Praščević and Cvetković (2005) . Noise and sound have the same physical characteristics, but differ in that noise can have harmful effects on human health. According to the Mihajlov and others (2012) communal noise, i.e. noise in the environment, represents one of the main problems in urban areas. It is the noise generated by all sources found in the human environment, excluding workplace noise. People are exposed to this noise every day and it is one of the biggest problems of the human environment, which directly affects the quality of life. Communal noise comes from two main sources: outdoor and indoor noise sources. The main sources of noise in the human environment are: traffic, industry, construction and public works, recreation, sports and entertainment. The noise to which the inhabitants of modern cities are exposed has increased in the last thirty years by 50% or more, especially in urban and industrial environments by Bogdanović and Trajković (2016). The dominant source of noise in the environment is traffic (road, rail and airplane). Research by Mihajlov and others (2012) has shown that traffic noise causes a drop in real estate prices by about 5% on average and that in the period of economic development, this value can increase by up to 12%. It is estimated that in the countries of the European Union, about 20% of people live in zones where noise levels are unacceptable because they cause negative effects on human health, and about 40% of people live in the so-called „grey" zones where noise levels cause interference in human activities by Praščević and Cvetković (2005). According to some sources, it is estimated that around 120 million people are exposed to traffic noise levels higher than 55dB (A), while 50 million of them are exposed to noise levels higher than 65dB (A). A noise level above 55dB (A) causes discomfort, aggressive behavior and sleep disorders, constant exposure to a noise level above 65dB (A) can cause hypertension, and constant exposure to a noise level above 75dB (A) increases stress levels and increases the number of people with heart diseases and can lead to hearing damage by Mihajlov and others (2012). In Serbia, the analyzes often used data from countries with a similar volume of traffic, such as Greece, where about 20% of the population is exposed to a 24-hour communal noise level above 65 dB (A) by Jakovljević and Belojević (1998). Environmental noise is a significant problem in many countries, with negative effects on human health. According to Wim van Keulen's research (2022), noise pollution can cause anxiety during the day and sleep disturbances at night. Also, road traffic noise has been identified as the most common source of noise in the environment, which additionally contributes to overall health effects. In his work, Miladin Malešević (2016) points out that noise is one of the key permanent pollutants of the living and working environment in today's age, and emphasizes the importance of its detection, analysis and minimization. These findings point to the need for effective noise control measures to reduce its harmful effects on health and improve the quality of life in urban areas. Research (Casey and others, 2017; Menkiti and Agunwamba, 2015) suggests that noise pollution in the United States is the highest in low-income and racial minority neighborhoods, and noise pollution associated with household electricity generators is an emerging environmental degradation in many developing nations. Noise pollution affects both health and behavior. Unwanted sound (noise) can damage physiological health and mental health. Noise pollution is associated with several health conditions, including

cardiovascular disorders, hypertension, high stress levels, tinnitus, hearing loss, sleep disturbances, and other harmful effects. According to a research articles (Münzel and others, 2018; Kerns and the others, 2018; WHO 2018, 2019) across Europe, according to the European Environment Agency, it estimated 113 million people are affected by road traffic noise levels above 55 decibels, the threshold at which noise becomes harmful to human health by the WHO's definition. Sound becomes unwanted when it either interferes with normal activities such as sleep or conversation, or disrupts or diminishes one's quality of life. According to a 2024. review of the existing literature, noise pollution was associated with faster cognitive decline. Noise exposure in the workplace can also contribute to noise-induced hearing loss and other health issues. Occupational hearing loss is one of the most common work-related illnesses in the U.S. and worldwide ba Paul and the others (2019). It is less clear how humans adapt to noise subjectively. Tolerance for noise is frequently independent of decibel levels. Murray Schafer's soundscape research (2014) was groundbreaking in this regard. In his work, he makes compelling arguments about how humans relate to noise on a subjective level, and how such subjectivity is conditioned by culture. Schafer notes that sound is an expression of power in material culture. As such, fast cars or Harley Davidson motorcycles with aftermarket pipes tend to have louder engines not only for safety reasons, but for expressions of power by dominating the soundscape with a particular sound. Other key research (Central Pollution Control Board, 2018) in this area can be seen in comparative analysis of soundscape differences between Bangkok, Thailand, and Los Angeles, California, US. Based on Schafer's research, this study showed how soundscapes differ based on the level of urban development in the area. This study found that cities in the periphery have different soundscapes than inner city areas; findings tie not only soundscape appreciation to subjective views of sound, but also demonstrates how different sounds of the soundscape are indicative of class differences in urban environments. In 2023, the Egyptian National Research Center found that the average noise level in central Cairo was 90 decibels and that the noise never fell below 70 decibels. Noise limits set by law in 1994 are not enforced by The Daily Star (2024). In 2024, the World Hearing Index declared Cairo to be the world's second-noisiest city ba Egypt Independent (2024). Noise pollution is a major problem in India ba Business Standard India (2023). The government of India has rules and regulations against firecrackers and loudspeakers, but enforcement is extremely lax by Indian Central Pollution Control Board (2023). Awaaz Foundation is a non-governmental organization in India working to control noise pollution from various sources through advocacy, public interest litigation, awareness, and educational campaigns since 2003. Despite increased enforcement and stringency of laws now being practiced in urban areas, rural areas are still affected by Green Tribunal (2024). How noise emissions should be reduced, without the industry being hit too hard, is a major problem in environmental care in Sweden today. The Swedish Work Environment Authority has set an input value of 80 dB for maximum sound exposure for eight hours. In workplaces where there is a need to be able to converse comfortably the background noise level should not exceed 40 dB by Arbetsmiljövärkets Författningssamling (2020). The government of Sweden has taken soundproofing and acoustic absorbing actions, such as noise barriers and active noise control. When you hear loud sounds, a series of reactions occurs in your body. This is called the arousal response, and it can affect many different parts of your body. Your heart rate, blood pressure, and breathing rate go up. Your diges-

tion slows down. Your blood vessels tighten and your muscles tense. Together, these changes make you feel alert and ready to respond to a threat, even if you're not in any danger. The most common health problem that can result from noise pollution is noise-induced hearing loss (NIHL). You can get it when you're exposed to noise over a long period, or to very loud sounds for a short time. These sounds harm sensitive parts of your inner ear, causing NIHL. Noise has emerged as an important environmental risk factor in the WHO European Region, and public complaints about excessive noise are increasing. Studies have also documented health inequalities in noise exposure, that is, an association between exposure to harmful levels of noise and socioeconomic status. Excessive noise seriously harms human health and interferes with people's daily activities at school, at work, at home and during leisure time. It can disturb sleep; cause adverse cardiovascular, metabolic, psychophysiological and birth outcomes; lead to cognitive and hearing impairment; reduce performance; and provoke annoyance responses and changes in social behaviour. The most relevant sources of noise include means of transportation (for example, aircrafts, trains and motor vehicles), industry (for example, wind turbines), and leisure activities.

NOISE MEASUREMENT METHODOLOGY IN KRUŠEVAC

By measuring noise, it is necessary to determine three basic characteristics: noise volume, noise frequency spectrum and noise duration. The choice of appropriate measurement procedure, measurement parameter and measurement equipment depends on the noise characteristics by Cvetković (2005). The measurement of the noise level in the environment is carried out using the appropriate measurement methods, while respecting the existing regulations. The noise measurement was performed in accordance with the following regulations by B 08/24 (2024) :

- Law on the protection of noise in the environment (Sl. Glasnik RS 96/21),
- Rulebook on the conditions that must be met by the professional organization for noise measurement in the environment, the necessary documentation, the authorization procedure, the content of the authorization decision, as well as the content, scope and validity period of the noise measurement report (Sl. Glasnik RS 139/22),
- Rulebook on noise measurement methods, content and scope of reports on noise measurement in the environment (Sl. Glasnik RS 139/22),
- Regulation on noise indicators, limit values, methods for evaluating noise indicators, disturbance and harmful effects of noise in the environment (Sl. Glasnik RS 75/10).

Measurement methods by B 08/24 (2024) :

- SRPS ISO 1996-1:2019 Describing, measuring and evaluating noise in the environment
- Basic sizes and assessment procedures,
- SRPS ISO 1996-2:2019 Describing, measuring and evaluating noise in the environment,
- Determination of sound pressure level.

When measuring, you should use devices that meet ISO standards. Before and after the measurements, calibration of the measuring device should be carried out. The measuring devices used in noise measurement are: sound level meter/filters, condenser microphone, acoustic calibrator and digital thermohygroanemometer. The manufacturer, types, serial numbers, device characteristics and calibration data are listed in detail in the Noise Measurement Report by B 08/24 (2024). The locations where the measurement is performed are chosen according to the regulations from the Regulation on noise indicators, limit values, methods for evaluating noise indicators, disturbance and harmful effects of noise in the environment (Sl. glasnik RS br. 75/10). Within the locality, measurement points are selected in accordance with the Rulebook on noise measurement methods, content and scope of reports on noise measurement (Official Gazette of the RS No. 72/10). All the obtained information is needed to implement the basic procedures of noise management, assessment of the state of the noise level and assessment of the harmful effects of noise on humans. In this paper, an analysis of the results of noise measurements in the environment in the city of Kruševac, for the winter of 2024, was made, based on the report on the investigation - noise measurement of the Institute for Public Health Kruševac by B 08/24 (2024). The measurement was carried out at twelve measuring points in Kruševac.

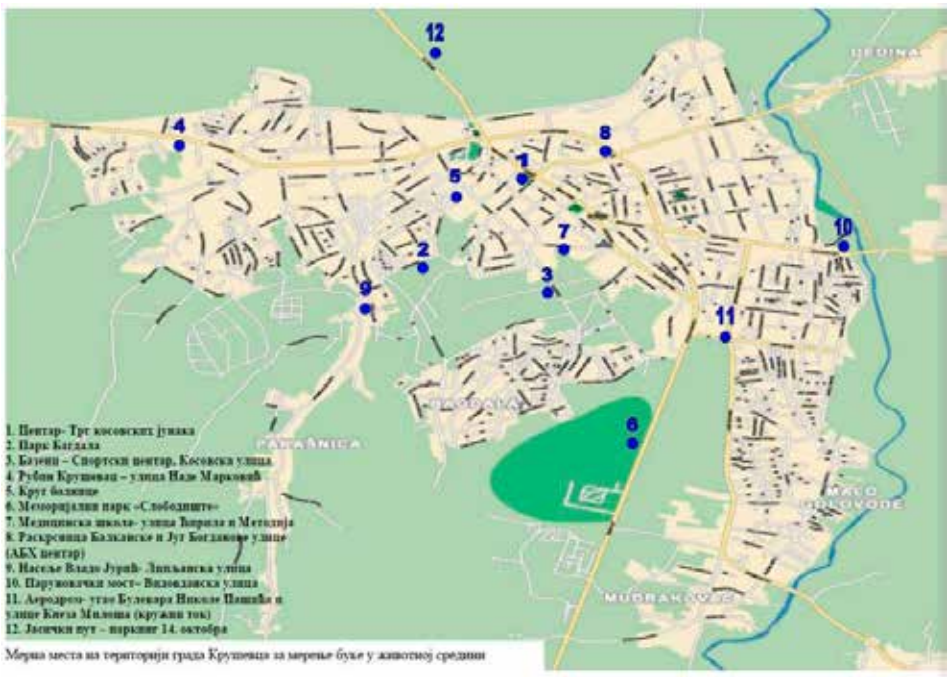

Figure 1. Measuring points on the territory of the city of Kruševac for measuring noise in the environment by B 08/24 (2024)

The classifications of the mentioned measuring points are as follows:

1. city center, craft, trade, administrative-administrative zone with apartments, zones along highways, highways and city roads (day and evening 65dB, night 55dB)

2. areas for rest and recreation, hospital zones and convalescent centers, cultural and historical sites, large parks (day and evening 50dB, night 40dB)
3. business-residential areas, commercial-residential areas and children's playgrounds (day and evening 60dB, night 50dB)
4. city center, craft, trade, administrative-administrative zone with apartments, zones along highways, highways and city roads (day and evening 65dB, night 55dB)
5. areas for rest and recreation, hospital zones and convalescent centers, cultural and historical sites, large parks (day and evening 50dB, night 40dB)
6. city center, craft, trade, administrative-administrative zone with apartments, zones along highways, highways and city roads (day and evening 65dB, night 55dB)
7. tourist areas, camps and school zones (day and evening 50dB, night 5dB)
8. city center, craft, trade, administrative-administrative zone with apartments, zones along highways, highways and city roads (day and evening 65dB, night 55dB)
9. clean residential area (day and evening 55dB, night 45dB)
10. city center, craft, trade, administrative-administrative zone with apartments, zones along highways, highways and city roads (day and evening 65dB, night 55dB)
11. city center, craft, trade, administrative-administrative zone with apartments, zones along highways, highways and city roads (day and evening 65dB, night 55dB)
12. city center, craft, trade, administrative-administrative zone with apartments, zones along highways, highways and city roads (day and evening 65dB, night 55dB)

The measurement was carried out in two series of measurements, at six measuring points each, in three different time intervals:

- daily period 06:00-18:00, 08.12.2024.
- evening period 18-22h, 08 December 2024.
- night period 22:00-06:00, 08 and 09 December 2024.

Within the day and night time interval, two measurements were performed and the measurement interval was 10 minutes. During the daytime period, the measurement was carried out between 08:30 and 10:30 and 12:00 and 14:00. During the evening period, the measurement was carried out between 20:00 and 22:00. During the night period, the measurement was performed in the period 22:00 - 00:00 and 00:00 - 02:00. A total of five measurements were performed in the first series of measurements. In the second series of measurements, the measurement was performed at the other six measurement points, in three different time intervals:

- daily period 06:00-18:00, 13 December 2024.
- evening period 18-22h, 13 December 2024.
- night period 22:00-06:00, 13 and 14 December 2024.

Also, within the day and night time interval, two measurements were performed and the measurement interval was 10 minutes. During the daytime period, the measurement was carried out in the period 09:30 - 11:30 and 12:00 - 14:00. During the evening period, the measurement was carried out between 19:30 and 21:30. During the night period, the measurement was performed in the period 22:00 - 00:00 and 00:00 - 02:00. In the second series of measurements, a total of five different measurements were performed. The mea-

surement results are also influenced by the meteorological conditions in the observed measurement period, which is detailed in the Report on testing - noise measurement by B 08/24 (2024) and shows that weather conditions could not threaten the reliability of the measurements. At the first measuring point (picture 2), the measurements were taken on the plateau in front of the „Rubin" hotel from the green area at a distance of about 20m from the middle of the road. This measuring point is located in the very center of the city, in the vicinity are multi-storey business buildings. Noise originates from traffic, sound systems in the square and activities of citizens.

Figure 2. Measuring point - Center [6]

Figure 3. Measuring site – Bagdala Park [6]

At the second measuring point (Figure 3), the measurements were taken in the park where the restaurant is located, which is surrounded by traffic lanes on three sides. The noise mainly originates from traffic, and partly from the activities of citizens.

At the third measuring point (picture 4), the measurements were taken in front of the fence of the tennis court complex. Along the street there are buildings with one or more floors with bars. Noise originates mainly from traffic and music from nearby restaurants.

Figure 4. Measuring point - Pools [6]

Figure 5. Measuring place – Rubin Kruševac [6]

At the fourth measuring point (Figure 5), the measurements were taken in front of the main gate of the Rubin factory. On both sides of the street there are residential buildings and shops, ground or one-story. Noise mainly comes from traffic.

At the fifth measuring point (Figure 6), the measurements were taken in the hospital grounds, 10m from the parking lot. The noise comes from vehicles entering the hospital grounds.

Figure 6. Measuring point - hospital circuit [6]

Figure 7. Measuring place - Memorial Park "Slobodište" [6]

At the sixth measuring point (Figure 7), the measurements were taken in the "Slobodište" memorial park, at a distance of about 15 m from the center of the road. There are no residential buildings nearby. The noise originates from the traffic from Bruski road.

At the seventh measuring point (Figure 8), the measurements were taken in the parking lot of the Sports Hall, next to the "Dragomir Marković" elementary school, on a green area at a distance of 15m from the middle of the road. On both sides of the street there are one-story and multi-story buildings of different purposes. Noise originates from traffic and citizen activities.

Figure 8. Measurement site - Medicine School [6]

Figure 9. Measuring place - ABH center [6]

At the eighth measuring point (Figure 9), the noise originates from the traffic of a large number of light and heavy vehicles, due to the intersection where cars come from four directions, and there is also a traffic circle. On one side of the intersection is the yard of the barracks, and on the other three residential buildings with several floors and ground-floor buildings with bars.

At the ninth measuring point (Figure 10), measurements were taken from the green area between residential buildings number 48 and 50, at a distance of 20m from the middle of the street. There are residential buildings with several floors in the area. The noise comes from traffic.

Figure 10. Measuring place - Vlado Jurić Settlement [6]

Figure 11. Measuring point –Parunovac bridge [6]

At the tenth measuring point (Fig. 11), measurements were taken from a green area at a distance of about 15 m from the middle of a very busy road with two double lanes. The measuring point is at a distance of 30m from the Parunovačko bridge, across the street from the Jet Petrol gas station. In the surroundings there are buildings with bars, single-storey and multi-storey. The noise comes from traffic.

Figure 12. Measuring place - Airport [6]

Figure 13. Measuring point – Jasika road [6]

At the eleventh measuring point (picture 12), measurements were taken from a green area at a distance of about 20m from the center of the roundabout at the corner of Nikola

Pašić Boulevard and Kneza Miloša Street. The measuring point is located at the intersection of two very busy roads. There are multi-storey residential buildings in the area. The noise comes from traffic.

At the twelfth measuring point (picture 13), the measurements were taken from the green area between the parking lot of the "14. Oktobar" factory and Jasički puta, at a distance of about 20m from the middle of the two-lane road. The noise comes from traffic.

RESULTS AND DISCUSSION OF NOISE MEASUREMENT METHODOLOGY IN KRUŠEVAC

The measurement results are shown in table 1, and the graphical representation of the spectral analysis, for the measurement location Rubin Kruševac - Street Nade Marković, 08 December 2024 in the period 08:41:17 - 08:51:17 (I measurement), in Figure 14. Detailed graphical representations of all spectral analyzes are given in the Report on testing - noise measurement.

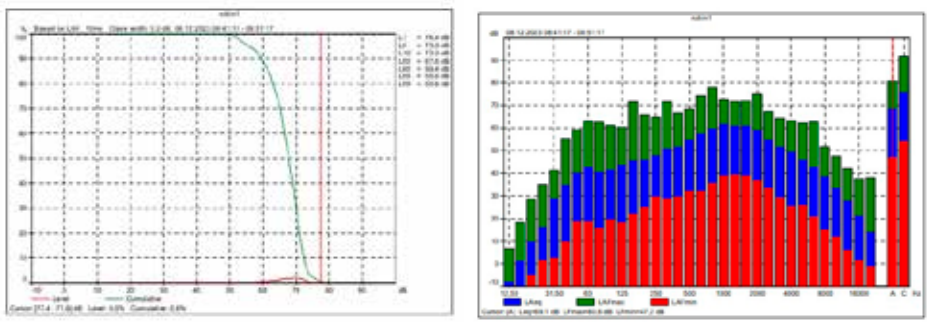

Figure 14. Measuring place – Rubin Kruševac [6]

Table 1. Measurement results in Kruševac [6]

Measuring point (average number of light/heavy vehicles per hour)		Measured noise level values in dB (A) Measurement method: SRPS ISO 1996-1:2019, SRPS ISO 1996-2:2019						
		day		night	Permitted noise level	night		Permitted noise level
		I measurement	II measurement	III measurement		IV measurement	V measurement	
1. Center (726/14)	**LAeqT**	**63**	**60**	**61**	**65 dB**	**60**	**57**	**55 dB**
	LAFmax	89	76	82	/	79	73	/
	LAFmin	51	53	49	/	51	46	/
2.Park Bagdala (12/0)	**LAeqT**	**42**	**41**	**39**	**50 dB**	**45**	**41**	**40 dB**
	LAFmax	58	58	54	/	72	60	/
	LAFmin	30	32	31	/	32	27	/
3. Pools (501/6)	**LAeqT**	**65**	**66**	**65**	**60dB**	**63**	**59**	**50 dB**
	LAFmax	82	82	81	/	78	77	/
	LAFmin	41	47	46	/	38	33	/

4. Rubin (690/32)	**LAeqT**	**69**	**71**	**69**	**65 dB**	**67**	**65**	**55 dB**
	LAFmax	81	88	83	/	85	79	/
	LAFmin	48	56	48	/	47	37	/
5. Hospital Circle (12/0)	**LAeqT**	**51**	**52**	**47**	**50 dB**	**46**	**37**	**40 dB**
	LAFmax	73	74	72	/	77	52	/
	LAFmin	40	44	36	/	34	34	/
6. Slobodište (436/29)	**LAeqT**	**62**	**61**	**61**	**65 dB**	**57**	**54**	**55 dB**
	LAFmax	77	74	78	/	71	75	/
	LAFmin	51	43	42	/	32	28	/
7. Medical school (228/2)	**LAeqT**	**53**	**57**	**54**	**50 dB**	**53**	**51**	**45 dB**
	LAFmax	71	76	80	/	70	71	/
	LAFmin	42	47	42	/	40	37	/
8. ABH center (780/36)	**LAeqT**	**68**	**67**	**62**	**65 dB**	**62**	**56**	**55 dB**
	LAFmax	85	92	77	/	86	76	/
	LAFmin	55	52	47	/	43	37	/
9. Settlement Vlado Jurić (6/0)	**LAeqT**	**46**	**58**	**46**	**55dB**	**47**	**45**	**45 dB**
	LAFmax	61	79	65	/	64	58	/
	LAFmin	40	38	39	/	38	42	/
10. Bridge (399/28)	**LAeqT**	**63**	**63**	**62**	**65 dB**	**61**	**57**	**55 dB**
	LAFmax	80	77	80	/	75	78	/
	LAFmin	50	49	43	/	46	36	/
11. Airport (502/36)	**LAeqT**	**63**	**65**	**64**	**65 dB**	**60**	**60**	**55 dB**
	LAFmax	77	78	78	/	74	74	/
	LAFmin	52	58	46	/	43	43	/
12. Road (476/26)	**LAeqT**	**67**	**67**	**64**	**65 dB**	**63**	**60**	**55 dB**
	LAFmax	78	88	79	/	76	75	/
	LAFmin	52	52	43	/	43	41	/

For the first measuring point (Center), the area of the city center, the determined noise levels are equal to the equivalent levels and amounted to 62dB during the day, 61dB in the evening, and 60dB at night. It was determined that the noise level was exceeded during the night, which was up to 5dB. Noise levels during the day and evening do not exceed the limit values. During the measurements, it was determined that the noise in the environment is a continuous flow and that most of it originates from traffic, the sound system in the square and the activities of citizens. For the second measurement site (Bagdala Park), the determined noise levels are equal to the equivalent levels and were up to 41dB during the day, 38dB in the evening, and up to 45dB at night. It was determined that the noise level was exceeded during the night, which was up to 5dB. Noise levels during the day and evening do not exceed the limit values. During the measurements, it was determined that the noise in the environment is a non-continuous flow and that most of it originates from vehicles and the activities of citizens. For the third measurement site (Pools), the established noise levels are equal to the equivalent levels and amounted to 66dB during the day, 65dB in the evening, and 63dB at night. The noise level was exceeded in all periods. The

exceedance during the day was up to 6 dB, during the evening up to 5 dB, and during the night up to 1 dB. During the measurement, it was determined that the noise in the environment is a continuous flow and that it mostly originates from traffic and the surrounding catering facilities. For the fourth measurement site (Rubin Kruševac), the determined noise levels are equal to the equivalent levels and were up to 71dB during the day, 69dB in the evening, and up to 67dB at night. The noise level was exceeded in all periods. The excess during the day was up to 6dB, during the evening up to 4dB, and during the night up to 12dB. During the measurements, it was determined that the noise in the environment is a continuous flow and originates from traffic. For the fifth measurement site (Hospital Circle), the determined noise levels are equal to the equivalent levels and were up to 51dB during the day, 47dB in the evening, and up to 46dB at night. It was determined that the noise level was exceeded during the day and at night, which was up to 1dB during the day, and up to 6dB during the night. Noise levels during the evening do not exceed the limit values. During the measurements, it was determined that the noise in the environment is a non-continuous flow and that most of it originates from vehicle traffic in the hospital area. For the sixth measurement site (Slobodište), the determined noise levels are equal to the equivalent levels and amounted to 62dB during the day, 61dB in the evening, and 57dB at night. It was determined that the noise level was exceeded during the night, which was up to 2dB. Noise levels during the day and evening do not exceed the limit values. During the measurements, it was determined that the noise in the environment is a non-continuous flow and that most of it originates from traffic. For the seventh measurement site (Medicine School), the determined noise levels are equal to the equivalent levels and amounted to 57dB during the day, 54dB in the evening, and 53dB at night. The noise level was exceeded in all periods. The exceedance during the day was up to 7dB, during the evening up to 4dB, and during the night up to 8dB.. During the measurement, it was determined that the noise in the environment is a non-continuous flow and that most of it originates from traffic and the activities of citizens. For the eighth measurement site (ABH center), the determined noise levels are equal to the equivalent levels and amounted to 68dB during the day, 62dB in the evening, and 62dB at night. It was determined that the noise level was exceeded during the day and at night, which was up to 3dB during the day, and up to 7dB during the night. Noise levels during the evening do not exceed the limit values. During the measurements, it was determined that the noise in the environment is a continuous flow and originates from traffic. For the ninth measurement site (Settlement Vlado Jurić), the established noise levels are equal to the equivalent levels and amounted to 58dB during the day, 46dB in the evening, and 47dB at night. It was determined that the noise level was exceeded during the day and at night, which was up to 3dB during the day, and up to 2dB during the night. Noise levels during the evening do not exceed the limit values. During the measurements, it was determined that the noise in the environment is a non-continuous flow and that it originates mainly from traffic and the activities of citizens. For the tenth measurement site (Parunovac bridge), the determined noise levels are equal to the equivalent levels and amounted to 63dB during the day, 62dB in the evening, and 61dB at night. It was determined that the noise level was exceeded during the night, which was up to 6dB. Noise levels during the day and evening do not exceed the limit values. During the measurements, it was determined that noise in the environment is a continuous flow and that most of it originates from traffic. For the eleventh measurement site (Airport), the

determined noise levels are equal to the equivalent levels and amounted to 65dB during the day, 64dB in the evening, and 60dB at night. It was determined that the noise level was exceeded during the night, which was up to 5dB. Noise levels during the day and evening do not exceed the limit values. During the measurements, it was determined that noise in the environment is a continuous flow and that most of it originates from traffic. For the twelfth measurement site (Jasika road), the determined noise levels are equal to the equivalent levels and amounted to 67dB during the day, 64dB in the evening, and 63dB at night. It was determined that the noise level was exceeded during the day and at night, which was up to 2dB during the day, and up to 8dB during the night. Noise levels during the evening do not exceed the limit values. During the measurements, it was determined that the noise in the environment is a continuous flow and originates from traffic. In the rest and recreation area, hospital areas, cultural and historical localities (measuring points 2 and 5), significant noise exceedances were measured at night in both measuring points and at measuring point 5 during the day. In the school zone (measuring site 7), large noise excesses were measured in all measurement periods. In the residential area (measuring site 9), noise exceedances were measured during the day and at night. In the zone of the business-residential area, shopping and children's playground (measuring point 3), noise exceedances were measured in all measurement periods. In the zone of the city center with residential zones, zones along traffic roads (measuring points 1, 4, 6, 8, 10, 11 and 12), noise exceedances were measured during the day at measuring points 4, 8 and 12, and in the evening at measuring point 4, as well as at night at all measuring points.

In order to achieve the goal of reducing communal noise levels and protect people's health, it is necessary to implement some measures:

- first determine the so-called black, gray and white acoustic zones,
- in relation to the control group (white acoustic zone of the city), the impact of traffic noise on the health of people living in black acoustic zones should be examined,
- tighten the control of compliance with regulations on diverting heavy vehicles to the bypass around the city and prohibiting the traffic of such vehicles through the city zone,
- control the noise emitted by motor vehicles during technical inspection and in daily traffic,
- improve the traffic infrastructure, expand the network of streets with automatic traffic regulation,
- introduce timers on traffic lights that last longer than 1 minute,
- install green protective belts of different woody and bushy species along traffic roads.

NOISE MEASUREMENT IN THE TRSTENIK

Measurement of noise in the town Trstenik was carried out in accordance with the regulations of the Republic of Serbia during the winter 2024, with the use of modern equipment. Measurement methods are applied in accordance with: SRPS ISO 1996-1- Description, Measurement and Evaluation of Noise in the Environment Basic Sizes and Procedures for Evaluation and SRPS ISO 1996-2 Describing, measuring and evaluating noise

in the environment Determination of noise levels in the environment. The calibration was performed before and after the measurement series, and the extended measurement uncertainty (for 95% confidence level) was ± 5% and with FAST dynamic characteristic. The instrument was used for measuring broadband variabled noise. Measured physical size was an equivalent continuous sound level (Leq) with done spectral terrestrial analysis. Data processing and verification of input parameters was carried out using software programs BZ5503 and Noise Explorer 7815. The results of the test only refer to the measured measuring points in the measurement terms. Based on the Regulation on Noise Indicators, Limit Values, Methods for Assessment of Indicators of Noise, Disturbance and Harmful Effects of Noise in the Environment a classification of measuring points and measuring points has been performed. Selected measuring points were:

1. AMSS Crossroads – settled at the entrance to Trstenik. It is categorized as: city center, craft, commercial, administrative zone with apartments, zones along highways, main and urban roads (belt exposed to direct noise from the main road, 25m width, on both sides of the road (allowed noise level – day and evening 65 dB, night 55 dB) Measurement was carried out from the yard of the Auto-Moto Association of Serbia, in the vicinity of the intersection of two very busy streets, surrounded by residential buildings and noise from traffic.
2. Center – Square- settled in front of the Municipality building. It is categorized as: business-residential and commercial-residential area with children's playground; belt exposed to direct noise: from the main road at a depth of 25 to 50 meters, with noisy streets at a depth of 25m on both sides of the road (allowed noise level - day and evening 60 dB, night 50 dB). The space is connected to multi-store buildings. Noise originates from traffic and citizenship activities.
3. Prva petoletka – surroundings of the mechanical industry. It is categorized as: City center, craft, commercial, administrative-upravna zone with apartments, zone along highways, main and city roads (belt exposed to direct noise from the main road, 25m width, on both sides of the road) day and night 65 dB, night 55 dB; areas for rest and recreation, hospital zones and rest areas, cultural and historical sites, large parks (dosing noise: day and night 50 dB, night 40 dB). The measurement was done in front of the factory's main gate. The street is surrounded by terraced and one-storey residential buildings. Noise originates mainly from traffic.
4. Health Center "MD Sava Stanojevic" – area is classified in the category: recreation and recreation areas, hospital zones and rest areas, cultural and historical sites, large parks (dosing noise - day and night 50 dB, night 40 dB). The measurements were made in the compound of the Health Center "MD Sava Stanojevic" in Vuka Karadzic Street, on the green area in front of emergency aid. The street is decorated with terraced and multi-storey buildings for different purposes. The noise comes from traffic and citizens' activities. During measurement time (09:00, 11:00, 20:00, 22:00 and 00:00 hours) at all locations, weather conditions could not endanger the reliability of the measurement (the temperature was ranged from 18°C to 25°C, wind was NW with velocity from 2.9 m/s to 3.7 m/s, humidity of air was from 53% up to 83%, and the atmosphe pressure was ranged from 999.8 mb to 1000.3 mb).

In Table 2, data collected from measuring points can be seen. The graphical presentation of the spectral analysis is also shown (in the terrestrial range from 12.5 Hz to 50 Hz and from 10.000 Hz to 16.000 Hz, which is outside the scope of accreditation, ie outside the indicated terrestrial ranges with central frequencies values from 50Hz to 10.000Hz given in the SRPS ISO 1996-2 method).

Figure 15. Measuring points - AMSS and Center, Health center and Prva petoletka [8]

Conclusions were drawn for each measuring point:

1. Measuring point 1 – AMSS For the area located along main and urban roads with a residential area, the measured noise values were up to 59 dB for a day 55dB in the evening and for night up to 54dB. There were no overruns over the day and evening, even during the night. During the measurement it was found that noise has a continuous flow in the environment and that it originates from traffic. The average number of vehicles on the measuring intervals was 302 light and 15 heavy vehicles per hour.
2. Measuring point 2 – Center For the city center area, located along urban roads with a residential area, the measured values of the external noise were up to 59 dB for a day, 57dB for evening and for night 54 dB. There were no overruns over the day and evening, but during the night there were overruns of up to 4 dB. During the measurement, it was found that the noise in the environment is a continuous flow

and that it mostly originates from traffic. The average number of vehicles on the measuring place was: light 82 and 2 heavy per hour.

3. Measuring point 3 - Prva petoletka For the area located along main and urban roads with residential areas, the measured noise values were up to 66 dB for a day, 62 dB for evening and for night up to 65 dB. Exceeding the noise level during the day was up to 1 dB, during the evening there was no overrun, and during the night there were overruns of up to 10 dB. During the measurement it was found that noise in the environment is a continuous flow and that it originates from traffic. The average number of vehicles on the measuring site was 196/15 light and weight per hour, retrospectively.
4. Measuring point 4 - Health Center For a space surrounded by medical objects, the measured external noise values were up to 56 dB for a day, for the evening 50 dB and 50 dB for the night. Exceeding the noise level during the day was up to 6 dB, during the evening there was no overrun, and during the night there were overruns of up to 10 dB. During the measurement, it was found that the noise in the environment has a non-continuous flow and that most of it originates from traffic. The average number of vehicles on the measuring place was 91/1- light and weight per hour, retrospectively.

Table 2. Measurement results in Trstenik [8]

Measuring point (average number of light/heavy vehicles per hour)		Measured noise level values in dB (A) Measurement method: SRPS ISO 1996-1:2019, SRPS ISO 1996-2:2019						
		day		night	Permitted noise level	night		Permitted noise level
		I measurement	II measurement	III measurement		IV measurement	V measurement	
1. AMSS (302/15)	**LAeqT**	**57**	**59**	**55**	**65 dB**	**54**	**52**	**55 dB**
	LAFmax	75	78	71	/	66	70	/
	LAFmin	45	44	42	/	38	38	/
2.Center (82/2)	**LAeqT**	**59**	**56**	**57**	**60 dB**	**54**	**53**	**50 dB**
	LAFmax	79	72	73	/	66	69	/
	LAFmin	49	44	50	/	43	45	/
3. P. Petoletka (196/15)	**LAeqT**	**65**	**66**	**62**	**65 dB**	**65**	**57**	**55 dB**
	LAFmax	87	91	81	/	87	45	/
	LAFmin	43	42	37	/	32	31	/
4. H. Center (91/1)	**LAeqT**	**56**	**53**	**50**	**50 dB**	**50**	**48**	**40 dB**
	LAFmax	72	68	68	/	71	74	/
	LAFmin	47	43	37	/	32	33	/

In the zones located along the main and city roads, in the zones exposed to direct noise from the main road, measuring points 1 and 3, exceedances of noise levels were measured during the night measurement periods at measuring point 3. In the business and residential area, in the zones exposed to direct noise from noisy streets, measuring point 2, exceedances of noise levels were measured during the night measurement periods. In the zone surrounded by healthcare facilities, rest and recreation zones, hospital zones and convalescent

homes, schools, cultural and historical sites, measuring point 4, increased noise levels were measured during the day and evening, as well as significantly increased noise levels during the night. The noise level exceedances in Trstenik at the observed points during the day were up to 6 dB (A), during the evening up to 3 dB (A), and during the night there were exceedances of up to 12 dB (A). Of the observed measuring points, the location where the smallest oscillations were recorded in the daytime, evening and nighttime measurement regime was the measuring point Centar. The location where the highest noise levels of 64 dB were measured in the daytime, 63 dB in the evening and 57 dB in the nighttime period was the measuring point Prva Petoletka. The location in Trstenik where the lowest noise levels were measured with 55 dB in the daytime, 53 dB in the evening and 48 dB in the nighttime period was the measuring point Health Center.

Proposal for measures:

1. Determine the so-called black, gray and white acoustic zones.
2. Examine the impact of traffic noise on the health of people living in black acoustic zones compared to the control group (white acoustic zone of the city).
3. Implement stricter control of compliance with regulations on the redirection of heavy vehicles to roads around the city, i.e. the prohibition of the traffic of such vehicles through the city zone.
4. Insist on the control of noise emitted by motor vehicles during technical inspection and in everyday traffic.
5. Continue to expand the network of streets with automatic traffic regulation and synchronization of traffic lights on individual directions.
6. Introduce timers at traffic lights that last longer than 1 minute, especially at intersections with major roadway significance.
7. Planning and installation of green protection belts and the arrangement of multi-storey plantations of various woody and shrubby species (sycamore (Acer platanoides L.), linden (Tilia sp.), Berlin poplar (Populus x berolinensis Dipp.), pedunculate oak (Quercus robur L.), hornbeam (Carpinus betulus L.), Canadian poplar (Populus canaden-sis Asch.), birch (Betula verrucosa Ehrh.), etc.) and evergreen shrubs (Viburnum rhytiphyllum) along busy roads, in order to reduce the level of municipal noise.

CONCLUSION

Exceeding the noise level in the territory of the city of Kruševac at the observed locations in the month of December was up to 7 dB (A) during the day, up to 5 dB (A) in the evening, and up to 13 dB (A) during the night. Of the observed measurement points, the smallest oscillations in the day, evening and night measurement mode are at the measurement point Center. The highest noise levels of 71 dB during the day, 69 dB during the evening and 67 dB during the night were measured at the Rubin measuring site. The lowest noise levels of 41 dB during the day and 38 dB in the evening were measured at the Bagdala Park measurement site, and 37 dB at night at the Hospital Circle measurement site. Noise in the environment at the observed measurement points mainly comes from traffic, and to some extent from the activities of citizens during the night time measure-

ment periods. These measured values of noise in the environment, especially exceedances during the night, can adversely affect people's rest and general health, especially if the noise is long-lasting. This research showed that the level of noise in the municipality of Trstenik is not within the allowed limits. Measured noise values in the environment, with overruns especially during night, may adversely affect the rest and general health of people, especially if their effect is of a more recent character. From results it could be concluded: in zones along main and city roads, significant overruns of noise level were measured for night measurement at the measuring point 3. In the business-residential area, (measuring point 2) noise levels exceeded allowed level during nighttime measuring. In the zone surrounded by health facilities and recreation areas, (measurement place 4), overruns were measured during the day and overnight, The location where the smallest oscillations are recorded is the measurement place Center. The overload level of noise on observed points were up to 6dB(A) during the evening and up to 10 dB (A) during the night and Noise in the environment, at the observed points, originates from traffic (buses, heavy trucks and light vehicles). Further research should inspect deeper connections between noise and health problems of the population. In the meantime, in order to improve managing noise levels, it is necessary to: identify the so-called black, gray and white acoustic zones; carry out a sharper control of redirecting heavy vehicles to the roads around the city, increase control of the noise emitted by motor vehicles during the technical inspection and daily traffic; continue with extending the network of streets with automatic traffic regulation and synchronization of traffic lights in certain directions; introduce time pieces on traffic lights that last more than 1 minute, especially at intersections with magistral significance; plan the installation of green and protective belts and arrange multi-storey plantations of various woody along traffic roads in order to reduce the level of municipal noise. All of this would significantly affect the quality of people's lives and reduce the subsequent costs of remedying the effects of noise.

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