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APPLICATION OF INDICATORS IN NOISE CONTROL

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Jelena Malenović-Nikolić, Bojana Zlatković, Uglješa Jovanović

University of Niš, Faculty of Occupational Safety, Niš, Serbia

ORCID iDs:	Jelena Malenović-Nikolić	https://orcid.org/0000-0002-1965-080X
	Bojana Zlatković	https://orcid.org/0000-0001-8051-1510
	Uglješa Jovanović	https://orcid.org/0000-0003-3204-6276

Abstract. *Indicators provide a foundational basis for offering essential data and describing changes in the environment at national, regional, or local levels. An indicator created to highlight the cause of change, the consequences of changes, the state of the environment, or the significance of implementing protective measures may be considered relevant for research. An adopted indicator, as part of the National List of Indicators, forms the basis for developing strategies, creating national policies, and establishing legal norms. Serbia's National List of Environmental Indicators includes two noise indicators, which belong to the sixth thematic section and are classified as indicators of state. The overall noise indicator, designated as 6.40 and part of the sixth thematic section entitled "State", describes noise disturbance over a 24-hour period, including the day-evening-night segments. According to the regulation, the day period lasts from 6 AM to 6 PM, the evening period from 6 PM to 10 PM, and the night period from 10 PM to 6 AM. The night noise indicator, also under the "State" category, with the designation 6.41, specifically describes noise disturbance during the night period (10 PM to 6 AM). This paper analyzes the use of indicators in noise control at both local and national levels. The use of indicators in noise control is a significant prerequisite for systematically and internationally accepted determination of the state of the environment, and for creating conditions to compare noise level values on an international level. Indicators are based on highly reliable data, which must be monitored in accordance with statistical correctness and internationally recognized methodology. The value of these indicators, published in the Report on the State of the Environment, becomes publicly available and is subject to comparative analysis.*

Key words: *indicators, control, measurement range, the environment*

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Corresponding author: Jelena Malenović-Nikolić
University of Niš, Faculty of Occupational Safety, Čarnojevića 10A, 18000 Niš, Serbia
E-mail: jelena.malenovic@znrfak.ni.ac.rs

1. INTRODUCTION

Noise indicator values signal improvements or deteriorations of the state of the environment and are considered as either ecological or professional indicators, depending on research needs. Noise monitoring should be conducted with the proper selection of measurement locations while considering existing data and information about identified problems.

The Regulation on the National List of Environmental Indicators of the Republic of Serbia [1] stipulates that noise control is conducted based on two indicators. These indicators are expressed in decibels (dB) and are used to determine the state of the environment, develop strategic noise maps, and plan preventive and corrective protection measures.

2. NOISE INDICATORS WITHIN THE NATIONAL LIST OF ENVIRONMENTAL INDICATORS

According to the Law on Environmental Noise Protection [2], local self-government units are responsible for financing and conducting noise monitoring within their territories.

Figures 1 and 2 show the territories (local self-governments and agglomerations) for which noise monitoring data are reported.

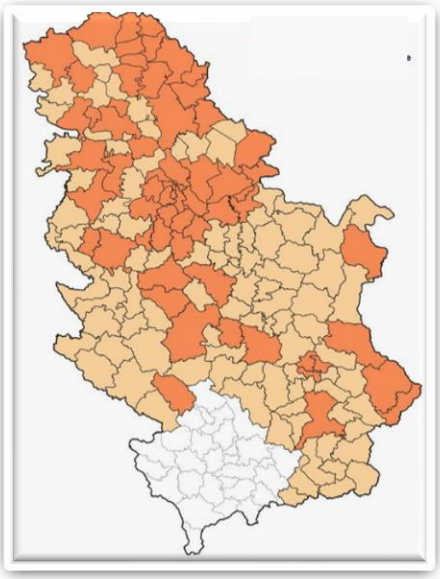

Fig. 1 Reporting of noise monitoring by the local self-governments in 2021 [3]

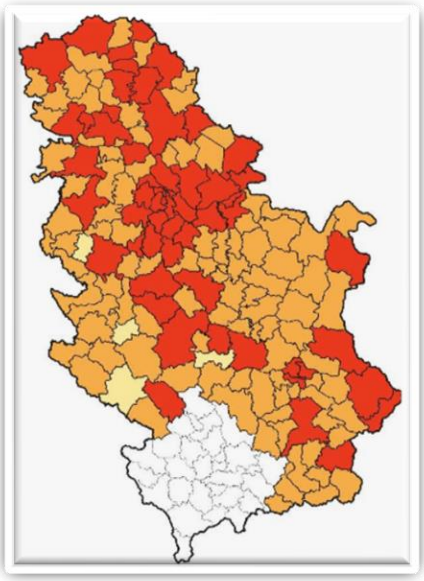

Fig. 2 Reporting of noise monitoring by the local self-governments in 2022 [4]

Based on Figs. 1 and 2, it is evident to what extent the local self-governments of Serbia fulfill their legally required obligations regarding noise monitoring. The darker-shaded areas represent local government units that have submitted data to the Environmental Protection

Agency. In contrast, the lighter-shaded areas represent local self-government units that have submitted declarations stating that no noise measurements were conducted within their territories. The primary reason cited for not adhering to the legal requirements is the lack of financial resources in their budgets. The state of the environment reports from 2015 to 2022 include only two maps marking the territories where monitoring was conducted. Therefore, from 2015 to 2020, only the number of local self-governments and agglomerations that provided data is known. These data are presented in Tab. 1. Additionally, the number of measurement points in agglomerations is graphically represented in Fig. 3.

Table 1 Number of measurement points in agglomerations [3-10]

Year	2015	2016	2017	2018	2019	2020	2021	2022
Agglomerations	86	/	68	36	69	50	56	63
Local self-governments	242	195	181	131	269	156	393	457

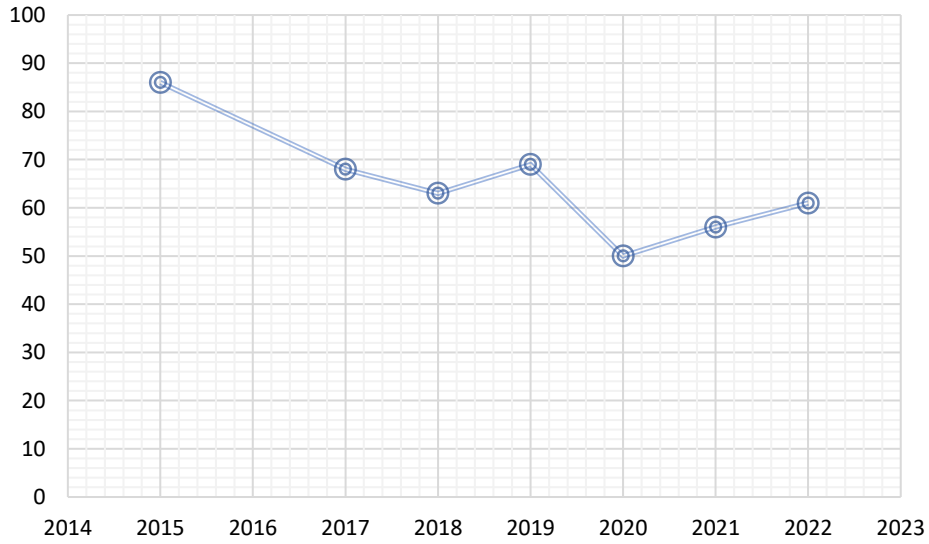

Fig. 3 Number of noise level measurement points in agglomerations [3-10]

Agglomerations, as parts of a territory with over 100,000 inhabitants and a population density that classifies them as urbanized areas, include Belgrade, Niš, Novi Sad, Kragujevac, and Subotica. According to the 2020 Report on the State of the Environment, only four agglomerations submitted reports on noise measurement, but it is not specified which agglomeration failed to fulfill its legal obligation under Article 9, Paragraph 4 [2], regarding financing and implementing environmental noise monitoring within its territory.

The tabular data indicate that the highest number of measurements in agglomerations were conducted in 2015. For 2016, aggregated data for the number of local self-governments and agglomerations were published. The trend of the number of noise level measurements in local self-governments is shown in Fig. 4.

Table 2 Number of submitted reports by local self-governments [3-10]

Year	2015	2016	2017	2018	2019	2020	2021	2022
Number	20	14	14	12	24	16	42	46

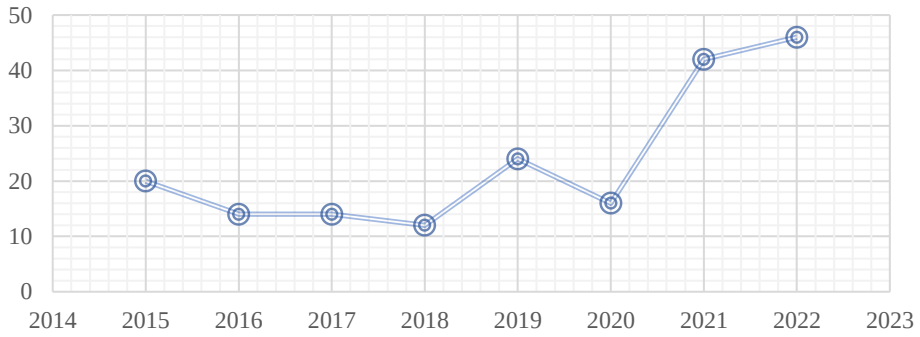

Fig. 4 Number of local self-governments that conducted noise monitoring [3-8]

Figure 5 presents data on the number of measurement points in local self-government units. Figure 6 shows a comparative overview of the number of local self-governments that conducted noise monitoring and the number of measurement points within the implemented monitoring system.

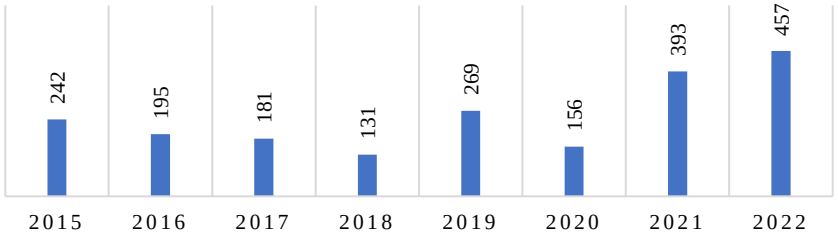

Fig. 5 Number of noise monitoring measurement points in local self-governments [3-10]

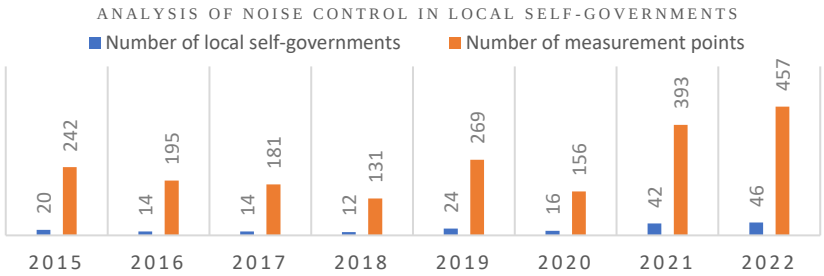

Fig. 6 Comparative overview of the number of local self-governments and the number of noise monitoring measurement points [3-10]

Based on the data from Tab. 2, it is evident that the highest number of noise level measurement data from local self-governments were submitted in 2022.

Figures 3 and 4 indicate a decreasing trend in the number of noise monitoring points in agglomerations and an increasing trend in the number of local self-governments conducting noise monitoring. Approximately 100 local governments [3, 4] are unable to implement noise monitoring.

The graph in Fig. 5 clearly indicates an upward trend in the number of measurement points in local self-governments. It is also noticeable that the fewest measurements were conducted in 2018 (131), with only 12 local self-governments submitting measurement data.

The graph in Figure 6 clearly shows an increase in the number of measurements in 2021 and 2022. Compared to the period from 2016 to 2018, the number of measurement points and local self-governments has increased by approximately threefold.

2. Analysis of Noise Indicator Values

A systematic approach to analyzing the number of measurement points and the number of local self-governments submitting noise monitoring data requires that the analysis be conducted under approximately the same conditions for the examined period.

Creating an indicator of the number of local self-governments per one hundred measurement points is considered a reliable solution. The proposed indicator is the ratio of the number of local self-governments submitting data to the number of measurement points, multiplied by a correction factor of 100. This method allows for the establishment of a foundation for evaluating the noise level monitoring process for the period from 2015 to 2022 or any other specified period. The indicator values are presented in Tab. 3.

Table 3 Number of noise monitoring measurement points per 100 local self-governments [3-10]

Year	Number of local self-governments	Number of measurements	Number of measurement points per 100 local self-governments
2015	20	242	8.26
2016	14	195	7.18
2017	14	181	7.73
2018	12	131	9.16
2019	24	269	8.92
2020	16	156	10.26
2021	42	393	10.69
2022	46	457	10.07

The analysis of the indicator values for the number of measurement points per 100 local self-governments reveals a slight upward trend in the number of measurement points. This trend is particularly noticeable during the period from 2020 to 2022, where, on average, ten measurements were conducted per local self-government. Figure 7 provides clearer calculation results.

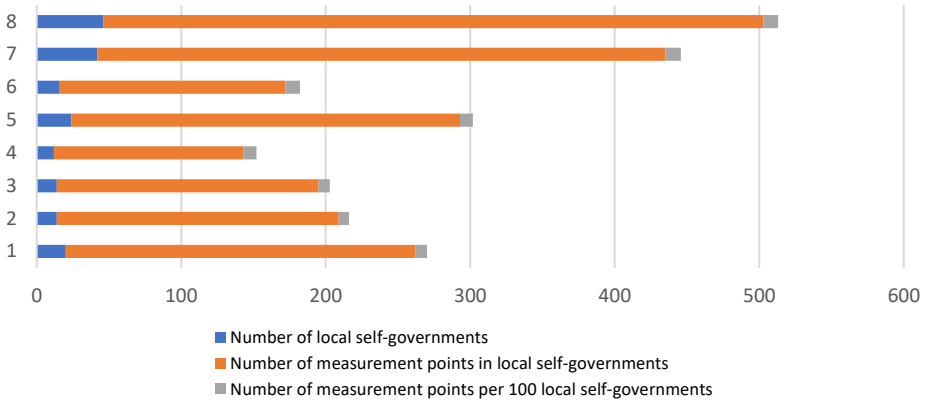

Fig. 7 Analysis of noise control indicators in local self-governments [3-10]

The analysis of the graph shown in Fig. 7 reveals significant progress at the end of the eight-year period, as the results of noise level monitoring in local self-governments are continuously published in the reports on the state of the environment.

The National List of Environmental Indicators defines the description and methodology for calculating the overall noise indicator and the night noise indicator, as well as the method and deadlines for submitting the necessary data.

The reports on the state of the environment present the noise indicators for overall disturbance (L_{den}) and the sleep disturbance indicator during the night (L_{night}) from 10 PM to 6 AM for local self-governments and agglomerations (Tabs. 4-7).

Table 4 Percentage of overall noise level measurement (L_{den}) results for local self-governments, by ranges [3-10]

Year	40-45	46-50	51-55	56-60	61-65	66-70	70-74	> 75
2015	1	10	10	13	30	54	8	1
2016	/	7	7	9	26	39	12	/
2017	/	/	11	13	23	29	14	6
2018	1	6	17	12	33	23	9	/
2019	4	8	15	40	33	27	6	/
2020	3	10	10	14	30	29	4	/

Table 5 Percentage of overall noise level measurement (L_{den}) results for agglomerations, by ranges [3-10]

Year	46-50	51-55	56-60	61-65	66-70	70-74	> 75
2015	/	6	10	14	42	21	7
2016	/	4	10	21	34	18	7
2017	/	4	10	21	34	18	7
2018	5	8	11	27	32	17	/
2019	/	9	19	33	30	9	/
2020	/	8	11	27	32	17	/

Table 6 Percentage of night noise level measurement (L_{night}) results for local self-governments, by ranges [3-10]

Year	<40	40-45	46-50	51-55	56-60	61-65	66-70	70-74
2015	4	11	17	25	26	14	2	/
2016	2	10	12	24	37	13	2	/
2017	3	16	12	19	31	16	2	/
2018	2	18	10	27	28	15		/
2019	4	13	13	25	26	17	2	/
2020	9	12	16	22	23	18	1	/

Table 7 Percentage of night noise level measurement (L_{night}) results for agglomerations, by ranges [3-10]

Year	<40	40-45	46-50	51-55	56-60	61-65	66-70	70-74
2015	2	7	11	14	36	24	5	/
2016	2	10	12	24	37	13	2	/
2017	7	7	9	16	38	19	3	/
2018		16	8	30	24	21		/
2019	1	14	13	21	21	27	3	/
2020	4	10	18	22	24	20	2	/

The analysis of the measurement results presented in Tabs. 5-8 shows that the highest percentage of measurements falls within the range of 66 - 70 dB for the overall noise level and 56 - 60 dB for night noise levels except for 2015 (66 - 70 dB). Figure 8 shows the results for overall noise measurements.

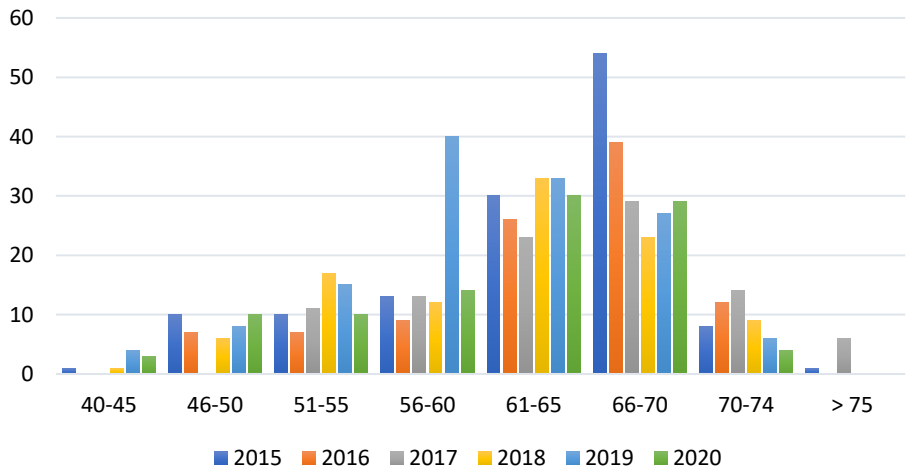

Fig. 8 Comparison of percentages of overall noise level measurement results for local self-governments, by ranges [3-10]

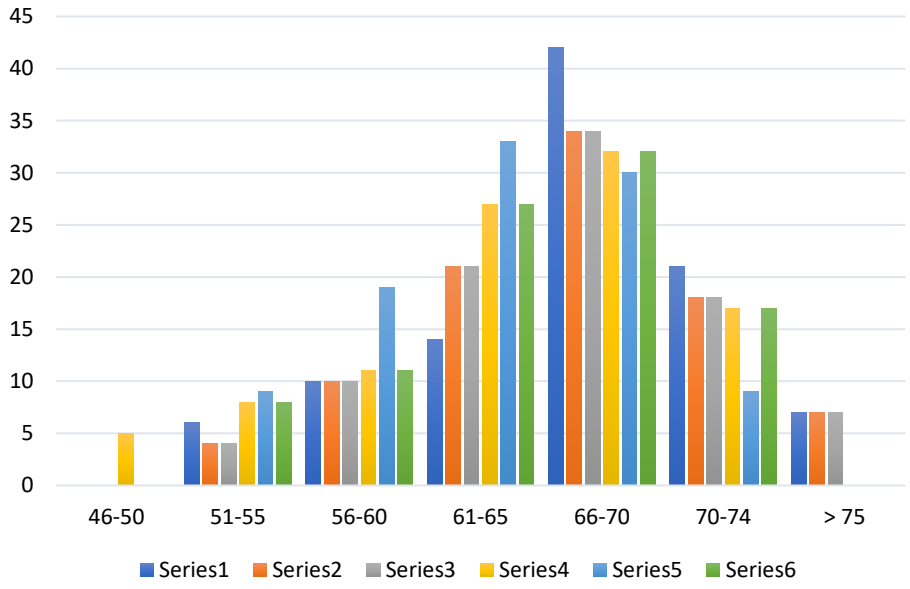

Fig. 9 Comparison of percentages of overall noise level measurement results for agglomerations, by ranges [3-10]

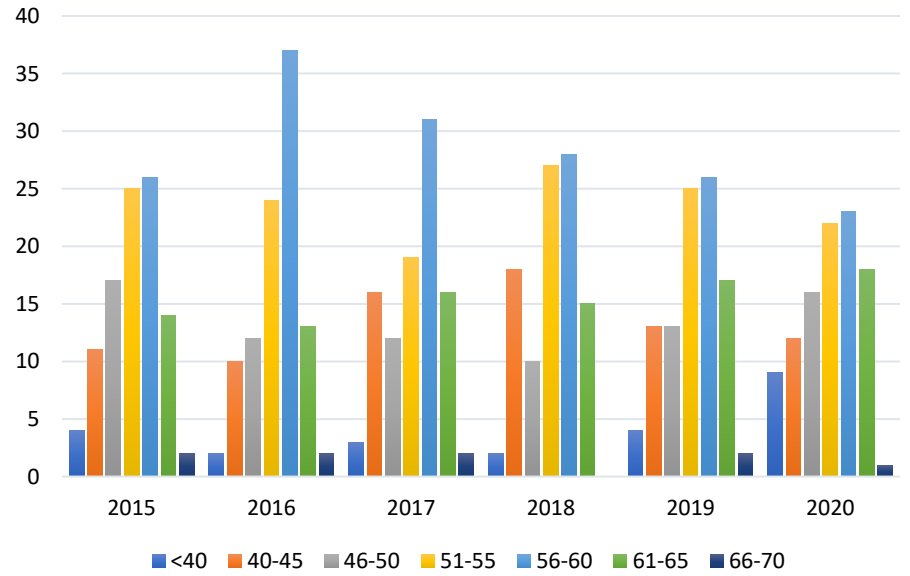

Fig. 10 Comparison of percentages of night noise level measurement results for local self-governments, by ranges [3-10]

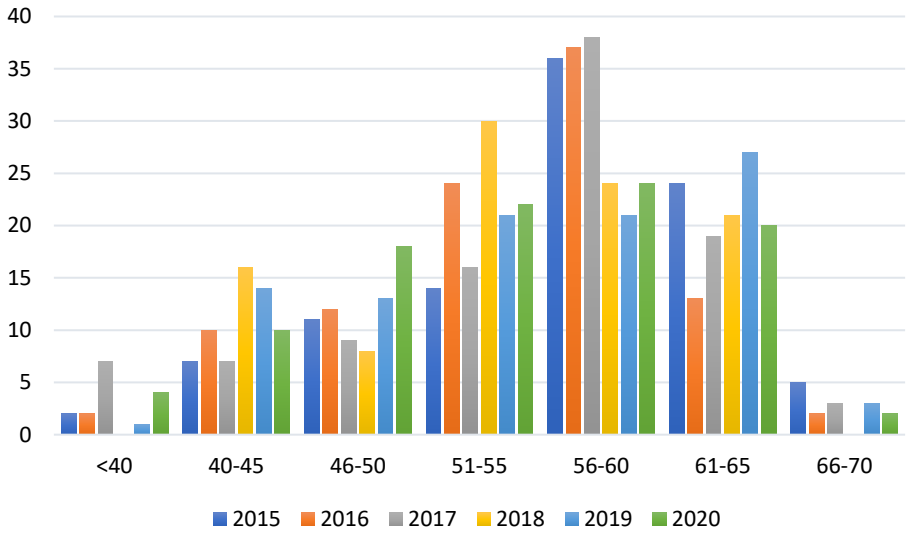

Fig. 11 Comparison of percentages of night noise level measurement results for agglomerations, by ranges [3-10]

From the graphs shown in Figs. 8 and 9, it is evident that the highest percentage of overall noise level values falls within the 66 - 70 dB range. The issue of exceeding limit values is more pronounced in agglomerations, where a significant percentage of results also fall within the 70 - 74 dB range, with some values exceeding 75 dB. The most severe issue was recorded in 2015, both for the overall noise indicator in local self-governments and agglomerations. The reports on the state of the environment for 2021 and 2022 indicate that the highest percentage of total noise indicators for local self-governments and agglomerations is within the 60 - 64 dB range, although the reports do not provide a detailed breakdown of noise level results by ranges.

Similarly, the graphs in Figs. 10 and 11 show that the highest percentage of night noise level indicator values falls within the 56 - 60 dB range, with this trend continuing in the 2021 and 2022 reports. Again, the issue of exceeding limit values is more pronounced in agglomerations, with a significant percentage of results falling within the 61 - 65 dB range, and some values even exceeding 70 dB.

3. Conclusion

The analysis of the state of the environment, particularly concerning noise level as an indicator of state, leads to a conclusion that a systematic approach to addressing noise control issues is needed. A prominent issue is the non-compliance with legal procedures in local self-government units, which lack sufficient financial resources to implement effective noise monitoring. In such cases, it is necessary to reevaluate the number of measurement points, as the analysis showed that the average number of measurements conducted is similar across local self-governments and agglomerations.

To ensure the accessibility of measurement results to the broader public, there is a need to continue presenting data in the same detailed manner as was done until 2020. Reports from 2021 and 2022 provide a more favorable view of the environmental situation but do so by offering only final conclusions without the specific data that would reveal the percentage of results in the 70 - 74 dB and over 75 dB ranges for overall noise indicators, as well as results in the 66 - 70 dB range for night noise indicators. Since noise level limits depend on the intended use of a specific space, it is crucial to include the locations of measurement points to realistically assess excessive noise levels in rest and recreation areas, hospital zones, rehabilitation centers, school zones, or residential areas.

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