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DEVELOPMENT OF A METHODOLOGY FOR MONITORING ACOUSTIC NOISE USING MOBILE PHONES FOR ORDINARY CITIZENS

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Abstract

In the context of the «4th industrial revolution» that is taking shape, people with certain knowledge, experience and ecological culture are more actively involved in individual and collective decision-making to overcome various environmental problems. One of these environmental problems is the acoustic noise of the environment. Today, many citizens are wondering: what is the level of acoustic noise pollution in the place where I live, work, study or stay and whether it meets the standards. Is this sound level harmful to my health? To answer these questions, many international and national standards and other regulatory documents have been developed. However, these documents are complex, require the use of expensive equipment, i.e. inaccessible to ordinary citizens. On the other hand, the computational, communication and sensory capabilities of modern mobile phones allow them to measure noise performance in order to conduct noise monitoring. To do this, citizens need simple and clear methods, methodologies, instructions for assessing the noise situation in a certain area and creating noise maps using these measurements. The article attempts to develop a simplified methodology for conducting noise monitoring for citizens using their mobile phones. Also, for clarity of the process, monitoring experiments were carried out with mobile phones and professional sound level meters, in order to assess the harmful effects of traffic noise (B. Vahabzade Avenue) on an educational institution (Baku State University – BSU) and research activities (Institute Information Technology-IIT).

In preparing the article, general scientific methods and methodologies were used, such as analysis and synthesis, comparison, generalization, and a systematic approach.

Citizens can use the survey results to identify areas of noise discomfort using their mobile phones.

Keywords: noise pollution, harmful effects, traffic noise, monitoring using a mobile phone.

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1. Introduction

It is known that at present environmental problems, such as global warming, a sharp decline in biological diversity, erosion of fertile soils, desertification and others, concern all mankind. Intensive human activity is also characterized by processes of environmental pollution. Like radioactive and electromagnetic radiation, waste, etc., acoustic noise is also one of the physical factors that pollute the environment [1].

According to a number of international and regional organizations, such as the World Health Organization (WHO), the European Environment Agency (EEA), the US National Institute for Occupational Safety and Health, NIOSH) noise pollution is the second most important factor after air pollution due to the harmful effects on human health [2–4].

Medical studies have shown that people staying in an excessively noisy environment for a certain period of time can directly lead to the development of a number of serious diseases or create a favorable environment for the occurrence of any pathologies [4, 5]. According to the WHO Regional Office for Europe, 16000 deaths and 72000 hospitalizations are recorded annually in the countries of the European Union (EU) due to noise. Also, in 1 million people, noise is identified as the main cause of other diseases. Currently, due to strong noise, 500 million people in the world are diagnosed with hearing impairment [2].

It should be noted that 80 % of the population of the EU countries are in zones of uncomfortable noise. According to WHO, over the past decade, the noise level in the world's big cities has increased by 40 %, and this trend has a positive trend. For example, 70 % of the territory of such a metropolis as Moscow is subject to noise pollution [6]. Our primary studies prove that the noise level in a significant part of the territory of Baku exceeds the permissible norms [7]. Most countries in the world pay special attention to conducting research on noise problems, assessing the noise situation in the territories through noise monitoring and measures to protect the population from noise. For example, the annual costs of the EU for noise protection measures range from 1 to 2 % of GDP (about 50 billion euros) [3]. Therefore, the study and assessment of environmental noise, and the implementation of appropriate measures to protect human health from excessive noise are relevant and important for each individual in society. The article deals with the issues of conducting acoustic noise monitoring by citizens using mobile phones.

2. Materials and methods

The concepts of sound and noise are associated with auditory sensations and human perception. Sound is created by mechanical vibrations of an elastic medium, which, propagating in a gas, liquid or solid medium, affect the human hearing organs. In this process, only vibrations in the frequency range 16 Hs–20 kHs, which produce a pressure higher than the hearing threshold (the weakest audible sound level), are perceived as sound. In theoretical and practical studies, acoustic noise is usually perceived as «undesirable and harmful noise of anthropogenic origin» [4, 7, 8].

According to, the main noise sources are divided into two groups: mobile and stationary state standard 53187–2008 [9]. Moving noise sources are road, rail, air and water vehicles. Stationary noise sources include engineering equipment of industrial and branch production, household appliances, etc. The ranges of levels created by noise sources are different and can also vary widely during the measurement period. It should be noted that normal speech generates a sound pressure level of 40–45 dB, motor vehicles – 50–100 dB. A level of 120 dB creates pain in the ear, and 200 dB is considered fatal. Therefore, in order to prevent the harmful effects of noise, which manifests itself in hearing impairment up to its loss, it is necessary to determine the permissible noise level as the cause of such pathological conditions, called «noise diseases», and develop a set of measures to eliminate them [8, 10]. Therefore, taking into account the nature of sound sources, regulatory documents have been developed – standards, sanitary and hygienic norms and rules that determine the nominal and permissible noise levels for human activities, places of residence or stay. It should be noted that the EU Directive 2002/49/EP/EC [11] was adopted as international standards for noise management, the WHO ROE guideline for night noise [2].

Control and assessment of environmental noise pollution is carried out through noise monitoring and is one of the types of environmental monitoring. Noise monitoring, first of all, provides a basis for continuous assessment of the environmental conditions of the human environment, determination of appropriate measures in case of violation of target indicators. An assessment based on the data obtained as a result of measurements and calculations during the monitoring process, as well as the compiled operational noise maps, make it possible to identify areas of uncomfortable noise and take appropriate organizational, technical and construction measures to protect the population from the harmful effects of noise in these areas [12]. Other purposes of monitoring may be the detection of hidden or implicit sources of noise, the determination of the technical parameters of the noise performance of engineering equipment, the preparation of noise forecasts for territories, etc. Note that the daytime noise map should reflect the impact of noise on people's labor activity, and the night map should reflect the impact of noise on people's sleep.

Various aspects of the environmental noise monitoring process have been extensively studied in the technical literature. For example, in [13], signals from sound sensors distributed over the monitoring area (along one street in Valencia) are collected in a processing center via a WSN (Wireless Sensor Networks) network on the Internet of Things (IoT) platform. Formulas other than Directive 2002/49 are proposed for the calculation of various noise figures. In [14] a comparative analysis of network protocols and routing protocols of the wireless data transmission system of ad-doc sensors used in noise monitoring systems is presented, and recommendations are given for their use. In [15], methods for eliminating and mitigating the effects of natural sources of background noise (wind, tree noise, bird sounds, etc.) are investigated in order to improve the accuracy of measurements in noise monitoring systems. In [16], the influence of the sampling rate and the digit length of the quantization codes of converters (in sound level meters), which digitize the analog signals of noise sensors, on the measurement accuracy is studied.

There are also studies of mobile phone monitoring of voluntary citizen groups based on the Mobile Crowdsensing (MCS) platform and citizen science methods. For example, in [17], a group from the University of Melbourne (Australia) created a monitoring network to assess the impact of traffic noise on residents living in the same multi-storey building. Noise levels are measured by sound sensors installed at different heights of the building and by residents' and drivers' mobile phones. The measurements are transferred to the monitoring center, where they are processed by standard monitoring methods. In [18–25], noise monitoring is carried out on a citizen science platform: groups of volunteers take measurements using mobile phones and transfer them to a processing center. The same work is carried out by specialists in parallel with the use of professional sound level meters. Measurement results are processed by standard monitoring methods.

3. Results and discussion

Acoustic noise monitoring, as a rule, is carried out according to regulatory documents state standard 53187–2008 [26] in the CIS countries and ISO 1996–2:2007 [11, 27] in the EU, respectively. According to these documents, at the initial stage of monitoring, measurements and calculations are made according to the selected sound level indicators. The result of this process is the calculation of annual estimated sound levels L_{RA}^{den} based on the annual daytime estimated level L_{RA}^{d} between 07:00–19:00, the annual evening estimated level L_{RA}^{e} between 19:00–23:00, and the annual night-time estimated level L_{RA}^{n} between 23:00–07:00 (in both standards, the symbols *d, e, n* are used from the English words *d*-day, *e*-evening and *n*-night, respectively, *den*-from their combinations).

The final is calculated L_{RA}^{den} based on the average estimated values L_{RA}^{d}, L_{RA}^{e} and L_{RA}^{n} for one week of each season. And these estimated weekly levels are calculated according to their average daily, evening and night estimated levels. The daily parameters, in turn, are calculated from the sound pressure levels (SPL) Lp for the above time intervals. For monitoring purposes, the equivalent and maximum noise levels (in some special cases, other indicators) are taken as noise indicators, taking into account the correction type «A» and other influencing factors.

It should be noted that, regardless of the required accuracy of the results, the practical implementation of monitoring is associated with significant difficulties. This is primarily due to the large volume of measurements and calculations that require significant human and time resources. For example, to compile one map with the main noise sources for a city with a population of 300000 people, namely, a daily noise map reflecting integrated noise pollution with equivalent noise levels L_{Aeq} about 1 million measurements and calculations are required [28]. However, by admissible approximations and a significant simplification of monitoring processes, it is possible to save many times labor costs, time and achieve satisfactory results. Note that at each step of the proposed algorithm, both simplified operations for ordinary citizens and generalized requirements of the standards are indicated.

Thus, taking into account the similarity and features of international and regional (in the CIS) standards, it is proposed to carry out the monitoring process according to the following generalized algorithm:

1. Measurements should cover the entire territory, provided that the distance between the measuring points (microphones) should be no more than 50 m from each other, carried out every 5 minutes during the day with fixing the coordinates of the measurement points. In the simplified version, it is sufficient to take measurements at two or three points, in the morning, evening and night intervals, with type «*A*» correction («*A*» scale is set by default). Depending on the purpose

of monitoring, measurements are made in 1/2 octave bands of the frequency spectrum or 1/3 bands of frequencies, if a more accurate spectral analysis of sounds is required (in a simplified version, 1/2 octave bands are enough).

2. Based on the indicators, L_{RA}^{d}, L_{RA}^{e}, L_{RA}^{n} the actual daily estimated sound level is calculated:

a) according to the CIS standard ISO 1996–2:2007:

$$L_{RA}^{den}=10\lg\left[\frac{16-e}{24}10^{L_{RA}^{d}/10}+\frac{e}{24}10^{(L_{RA}^{e}+K_e)/10}+\frac{8}{24}10^{(L_{RA}^{n}+K_n)/10}\right], \tag{1}$$

where K_e, K_n are corrections for evening and night time intervals according to state standard 53187–2008:5 in the evening, 10 for the night period, dBA; *e* is the duration of the night time interval;

b) according to the EU Directive [11]:

$$L_{den}=10\lg\frac{1}{24}\left(12*10^{\frac{Lday}{10}}+4*10^{\frac{Levening+5}{10}}+8*10^{\frac{Lnight+10}{10}}\right). \tag{2}$$

3. According to the standard, by averaging the values of the levels, L_{RA}^{d}, L_{RA}^{e} and L_{RA}^{n} the noise index is calculated for the reference time intervals (weekly, monthly, etc.):

$$\overline{L}_{RA}^{k}=10\lg\left\{\frac{1}{N}\sum_{i=1}^{N}10^{L_{RAi}^{k}/10}\right\},(k=d,e,n), \tag{3}$$

where L_{RAi}^{k} is the level of the reference interval calculated for day i, dBA; N is the number of days in the reference interval, for example, for a week $N=7$.

4. In some cases, for example, near sources that generate noise of high intensity and with a certain frequency (in buildings near the airport, around presses, riveting machines, construction sites, etc.) it may be more appropriate to determine the maximum noise level. This will allow a more objective assessment of the harmful effects of noise. In this case, the algorithm procedures remain the same, and L_{RA}^{den} (for daily intervals or support intervals) is calculated by the maximum $L_{A\max}^{d}$, $L_{A\max}^{e}$, $L_{A\max}^{n}$ levels:

$$L_{RA\max}^{k}=\max_{j}\left\{L_{A\max j}^{k}+K_j\right\}, k=d,e,n, \tag{4}$$

where $L_{A\max j}^{k}$ is the maximum sound level calculated when j noise source operates in k reference time interval, dBA.

5. The results of noise monitoring obtained by measurements and calculations are processed. First of all, this includes the elimination of repeated measurements, the rejection of measurements with a difference of less than 3 dB at one point, data clustering by the same noise levels (with a difference of 5 dB), taking into account the measurement coordinates, etc.

6. Based on the average annual values of noise indicators, operational noise maps of the territory are compiled. According to the requirements of the standards, annual day and night maps are mandatory, while others are compiled for the purposes of special monitoring. Group data with the same noise level are connected by isolines, taking into account the coordinates on the physical map of the area. The difference between areas is enhanced by visualization methods. In a simplified version, this is not necessary if the measurements were carried out at one or more close points.

7. The reasons for the occurrence of uncomfortable noise areas (zones) on maps (in a simplified version at measurement points) are analyzed, reports are developed for the relevant authorities and action plans for noise protection and proposals for their application are drawn up.

Comparative studies (1) and (2) show that there are some differences between these formulas both in terms of terminology, sound level indicators and limit values chosen for monitoring purposes, and in the mathematical formulas used to calculate these indicators. First of all, let's compare these formulas according to accuracy criteria. Then let's evaluate the impact of road noise (street noise) on various types of labor activity at two sites.

First experiment. Comparison of calculation formulas according to the criterion of accuracy. For calculations, the measurement data of traffic noise on the street (B. Vahabzade Avenue) between the Institute of Information Technologies (IIT) and Baku State University (BSU) were used. The measurement point is the extreme border of the carriageway (**Fig. 1**).

Fig. 1. Photo of the monitoring area (BSU on the left, IIT on the right)

To do this, in the morning, in the evening and at night, in sufficient quantities, measurements were taken and the arithmetic mean values were calculated for each period of time. In both experiments, let's take the equivalent daily noise level as the noise indicator L_{RA}^{den}. The measurements were carried out using the «Sound Level Meter» function of the Xiaomi smartphone Redmi Note 8 with the Android operating system.

To start measuring, it is first necessary to download and activate one of the Sound Meter apps (e.g, Sound Meter, SPL Meter, Splend Apps, Db Meter, etc.) from an app database, such as the Google Play Store (or simply called Play Market is the former name of Android Market). The smartphone will measure the ambient sound at a certain frequency (for example, once per second), calculate the arithmetic average of the measurements during the session and correct them according to type «*A*». The result, as an equivalent sound level L_{Aeq}, measured in dBA, is displayed on the screen in the form of text, graphs or tables. To improve the measurement accuracy, it is recommended to run several sessions for as long as possible (for example, 10–20 minutes) in the standard daytime, evening and night periods. It is recommended that the measurements cover the driving time of light and heavy vehicles at high speeds (the noise level is, among other things, directly proportional to the speed and weight of the vehicles). There is no need to use other features of the «Sound Level Meter» programs for the purposes of the experiment. Those interested can get detailed information about other program options on the Internet. In the calculations for the evening and night periods, the same correction values for noise levels are used: 5 dBA for the evening and 10 dBA for the night. However, the duration of the time intervals for the day and night periods are different. If in (2) these durations are constants, then in (1) they are variables, and, according to state standard 53187-2008, depend on the geographical location, climatic conditions, etc., and the determination of their values is within the competence of the relevant executive authority. In Azerbaijan, this is the Ministry of Ecology and Natural Resources. To show the differences in the results, in (1) let's take the following time periods: 14-hour daytime and 2-hour evening intervals, respectively. The experimental data are presented in **Table 1**. As follows from the **Table 1** difference between (1) and (2) to some extent affects the calculation results. However, for practical purposes, the insignificant difference between the results, due to the daily component, does not exceed the allowable limit.

In order to estimate the error of the results of measurements using a telephone, measurements were also made in parallel with a professional sound level meter, such as a reference meter of accuracy class 1 «Ecophysics-110A». A CAL200 instrument (accuracy class 1) was used as an acoustic calibrator. Experiments have shown that the computational error of experiments conducted by mobile phones does not exceed 5–7 %, which, with a parametric assessment of sound signals, can be considered acceptable for monitoring purposes [29–31].

Table 1
Computational experiment data

Measured parameters	L_{RA}^{d} / L_{day}	L_{RA}^{e} / L_{eve}	L_{RA}^{n} / L_{nig}
Arithmetic mean values of measured parameters, dBA	80	55.6	45.4
Time intervals of measurement periods			
Formulas	Diurnal	Evening	Night
According to the formula «(1)»	14	2	8
According to the formula «(2)»	12	4	8
Calculated daily levels			
L_{RA}^{den}, dBA		77.67	
L_{den}, dBA		77.01	

Second experiment. Assessing the impact of traffic noise on workplaces. Using experimental data, it is possible to calculate the impact of car noise on workplaces at both facilities, taking into account the presence of green spaces – noise barriers on the path of noise propagation. The noisy IIT object is workplaces in a one-story building located in front of its main building «*A*». **Fig. 2** shows the layout of the experimental objects.

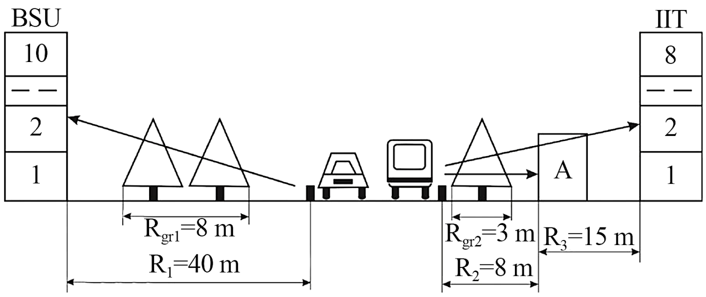

Fig. 2. Scheme of arrangement of experimental objects

For the calculation, let's use the formula from the methodological manual [32]:

$$L = L_p + 10\lg\Phi - 10\lg\left(2\pi R^2\right) - \beta_\alpha R - \beta_{\alpha\, gree} R_{gree} \sqrt[3]{f} \; / \; 8, \qquad (5)$$

where L – value of the sound level parameter at the calculated point; Lp – average noise level of the source (from **Table 1**: $Lp \approx 78$ dBA); Φ – noise directivity factor (Φ = 1, if the noise is evenly distributed in all directions); R – distance from the noise source to the calculation point, m; β_α – sound absorption coefficient in air, under normal weather conditions $\beta_\alpha = 0.0052$ dBA/m; $\beta_{\alpha\, gree}$ – sound level reduction per 1 m of forest belt width, $\beta_{\alpha\, green} = 0.08$ dBA/m; R_{gree} – forest belt width, m; f – measurement frequency (in the experiment let's take the standard frequency of 1/2 octave, $f = 1000$ Hs.

Calculation results:

1. For BSU:

$$L_{\text{BSU}} = 78 + 10\lg 1 - 10\lg\left(6.28 * 40^2\right) - 0.0052 * 40 - 0.08 * 8 * \sqrt[3]{1000} \; / \; 8 = 37.0 \text{ dBA}.$$

2. For IIT:

$$L_{\text{IIT}} = 78 + 10\lg 1 - 10\lg\left(6.28 * 8^2\right) - 0.0052 * 8 - 0.08 * 3 * \sqrt[3]{1000} / 8 = 51.36 \text{ dBA}.$$

It follows that at the calculated point the noise level, according to SN 2.2.4/2.1.8.562-96, for IIT has a relatively high value (51.3 > 50 dBA), for BSU within the normal range (37.0 < 40 dBA) (**Table 2**). An experiment was also carried out in order to compare the results obtained by formula (3) with the results of measurements carried out by telephone. To do this, at different times, numerous measurement sessions were carried out from the 2nd floor of the BSU building and inside building «*A*» (with the windows of both buildings open). It was found that the results of calculations coincide with the results of measurements with an allowable error: L_{BSU} = 36.5 dBA; L_{IIT} = 53.0 dBA. And the noise level in the main building of the institute is much lower than the norm (≈41 dBA) due to the role of building «*A*» in preventing the propagation of sound vibrations and its remoteness from the sound source.

The IIT administration was informed about the results of the ongoing experiments and the need to take certain measures to reduce excessive noise levels (for example, reducing the speed of transport, prohibiting the movement of trucks, etc.).

The authors plan to conduct research on the following topics related to acoustic noise problems:

a) improvement of the methodology proposed in the article;

b) development of a method for analyzing noise by its spectral composition and assessing it in more hazardous to health ranges using a mobile phone (for example, infrasonic frequencies);

c) development of a simple method for compiling noise maps of the territories of some critical objects (for example, our institutes, etc.), etc.

Table 2
Permissible sound levels for scientific activities and educational institutions according to SN 2.2.4/2.1.8.562–96

Types of labor activity, worker. place	**Sound pressure levels, dB, in octave bands with geometric mean frequencies, Hs**									**Level sound, L_A, and $L_{A.eq}$, dBA**	**Max. sound levels L_{Amaax}, dBA**
	31.5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**		
1. Creative activity, work with increased requirements, scientific activity, design, etc.	86	71	61	54	49	45	42	40	38	50	60
2. Classrooms, classrooms, teachers' rooms, ... auditoriums of schools and other educational institutions, etc.	79	63	52	45	39	35	32	30	38	40	55

4. Conclusions

According to the results of the research, it is noted that at present acoustic noise pollution has become a global environmental problem. Therefore, it is very important for the health of each person to be able to assess the level of acoustic noise pollution in the place of its stay (at home, at work, in an educational institution, etc.). Therefore, the article examines the issues of assessing the level of noise pollution using the capabilities of modern mobile phones. For this purpose, a simple and generalized methodology, of noise monitoring for ordinary citizens is proposed. Two widely used formulas are also proposed for calculating the daily equivalent noise level using this methodology, which is the main monitoring indicator. Computational experiments have been carried out, which show that if to use the measurements obtained using applications for modern mobile phones and calculate using both formulas, let's get approximately the same results. Also, in order to determine the measurement error over the phone, experiments were carried out in parallel with a professional sound level meter and the results were compared.

To illustrate the use of the proposed methodology, an experiment was conducted to assess the impact of traffic noise on the educational institution and research institute where the authors work. The results of the monitoring were checked for compliance with the requirements of the regulatory documents used in the CIS. It turned out that in the first case, the noise exposure is 37.0 dBA (the norm is 40 dBA), which is within the normal range, in the second case it is 51.36 dBA, that is, above the permissible limit (the norm is 50 dBA). Due to the screening role of building «*A*» and the remoteness, the noise level in the main building of the institute is below the norm (41 dBA). An experiment was also carried out in order to compare the results obtained by the analytical formula (3) with the results of measurements carried out by telephone. Some possible measures are indicated to reduce the harmful effects of noise on the staff of the institute.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

Data will be made available on reasonable request.

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References

[1] Agaev, B. S., Mehtiev, Sh. A., Aliev, T. S. (2018). On the harmful effects of medical electronic equipment and their waste on human health and the environment. Information society, 6, 30–38.

[2] Night noise guidelines for Europe. World Health Organization. Available at: https://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf

[3] ILO code of practice: Protection of workers against noise and vibration in the working environment. Available at: https://www.ilo.org/global/publications/ilo-bookstore/order-online/books/WCMS_PUBL_9221017095_EN/lang--en/index.htm

[4] Occupational Noise Exposure - Criteria for a Recommended Standard (2014). CreateSpace Independent Publishing Platform.

[5] Jonsson, A. (1978). Noise as a possible risk factor for raised blood pressure in man. Journal of Sound and Vibration, 59 (1), 119–121. doi: https://doi.org/10.1016/0022-460x(78)90487-x

[6] The concept of reducing noise and vibration levels in the city of Moscow: Appendix 1 (2007). Decree of the Government of Moscow, 896.

[7] Alekberov, R. G., Agayev, B. S. (2020). Acoustic noise pollution: problems and solutions. Informasiya cəmiyyəti problemlər, 1, 26–37. doi: https://doi.org/10.25045/jpis.v11.i1.02

[8] Rychtáriková, M., Vermeir, G. (2013). Soundscape categorization on the basis of objective acoustical parameters. Applied Acoustics, 74 (2), 240–247. doi: https://doi.org/10.1016/j.apacoust.2011.01.004

[9] Aumond, P., Lavandier, C., Ribeiro, C., Boix, E. G., Kambona, K., D'Hondt, E., Delaitre, P. (2017). A study of the accuracy of mobile technology for measuring urban noise pollution in large scale participatory sensing campaigns. Applied Acoustics, 117, 219–226. doi: https://doi.org/10.1016/j.apacoust.2016.07.011

[10] Zinkin, V. N. (2014). Modern aspects of control and monitoring of infrasound as a harmful production factor in transport and industrial facilities. Actual problems of transport medicine, 4 (2 (38-II)), 10–25.

[11] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise - Declaration by the Commission in the Conciliation Committee on the Directive relating to the assessment and management of environmental noise. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32002L0049&qid=1680252000448

[12] SNiP 23-03-2003. Protected from noise.

[13] Segura-Garcia, J., Felici-Castell, S., Perez-Solano, J. J., Cobos, M., Navarro, J. M. (2015). Low-Cost Alternatives for Urban Noise Nuisance Monitoring Using Wireless Sensor Networks. IEEE Sensors Journal, 15 (2), 836–844. doi: https://doi.org/10.1109/jsen.2014.2356342

[14] Clausen, T., Dearlove, C., Jacquet, P., Herberg, U. (2014). The Optimized Link State Routing Protocol Version 2. doi: https://doi.org/10.17487/rfc7181
[15] Maijala, P., Shuyang, Z., Heittola, T., Virtanen, T. (2018). Environmental noise monitoring using source classification in sensors. Applied Acoustics, 129, 258–267. doi: https://doi.org/10.1016/j.apacoust.2017.08.006
[16] Santini, S., Vitaletti, A. Wireless Sensor Networks for Environmental Noise Monitoring. Available at: http://www.vs.inf.ethz.ch/publ/papers/santinis07_noise.pdf
[17] Gubbi, J., Marusic, S., Rao, A. S., Yee Wei Law, Palaniswami, M. (2013). A pilot study of urban noise monitoring architecture using wireless sensor networks. 2013 International Conference on Advances in Computing, Communications and Informatics (ICACCI). doi: https://doi.org/10.1109/icacci.2013.6637321
[18] Santini, S., Ostermaier, B., Adelmann, R. (2009). On the use of sensor nodes and mobile phones for the assessment of noise pollution levels in urban environments. 2009 Sixth International Conference on Networked Sensing Systems (INSS). doi: https://doi.org/10.1109/inss.2009.5409957
[19] Maisonneuve, N., Stevens, M., Niessen, M. E., Hanappe, P., Steels, L. (2009). Citizen noise pollution monitoring. 10th Annual International Conference on Digital Government Research, 96–103. Available at: https://www.researchgate.net/publication/221584801_Citizen_Noise_Pollution_Monitoring
[20] Grubeša, S., Petošić, A., Suhanek, M., Đurek, I. (2018). Mobile crowdsensing accuracy for noise mapping in smart cities. Automatika, 59 (3-4), 286–293. doi: https://doi.org/10.1080/00051144.2018.1534927
[21] Kanjo, E. (2009). NoiseSPY: A Real-Time Mobile Phone Platform for Urban Noise Monitoring and Mapping. Mobile Networks and Applications, 15 (4), 562–574. doi: https://doi.org/10.1007/s11036-009-0217-y
[22] Maisonneuve, N., Stevens, M., Niessen, M. E., Steels, L. (2009). NoiseTube: Measuring and mapping noise pollution with mobile phones. Environmental Science and Engineering, 215–228. doi: https://doi.org/10.1007/978-3-540-88351-7_16
[23] Maisonneuve, N., Stevens, M., Ochab, B. (2010). Participatory noise pollution monitoring using mobile phones. Information Polity, 15 (1,2), 51–71. doi: https://doi.org/10.3233/ip-2010-0200
[24] Antonić, A., Marjanović, M., Pripužić, K., Podnar Žarko, I. (2016). A mobile crowd sensing ecosystem enabled by CUPUS: Cloud-based publish/subscribe middleware for the Internet of Things. Future Generation Computer Systems, 56, 607–622. doi: https://doi.org/10.1016/j.future.2015.08.005
[25] Yusifov, F. F. (2020). Evaluation of public services based on the satisfaction of citizens. Information society, 4, 38–51.
[26] SN2.2.4/2.1.8.562-96. Noise at workplaces, in the premises of residential, public buildings and in residential areas.
[27] Sultanova, A. B., Abdullayeva, M. Y. (2021). Neural Networks - Based Ecological Forecasting. 14th International Conference on Theory and Application of Fuzzy Systems and Soft Computing – ICAFS-2020, 738–743. doi: https://doi.org/10.1007/978-3-030-64058-3_92
[28] Koshurnikov, D., Maksimova, E. (2018). Review of foreign and domestic practices of noise mapping in dense urban areas. Bulletin of the PNRPU. Applied Ecology. Urban Development, 3, 27–43. doi: https://doi.org/10.15593/2409-5125/2018.03.03
[29] Agaev, B. S., Pashaev, F. Kh. (2013). Speech quality assessment method in corporate VoIP. Speech quality assessment method in corporate VoIP networks. Information Technologies, 8, 34–40.
[30] Rutenko, A. N., Fershalov, M. Yu., Ushchipovskii, V. G. (2020). Acoustic Noise Generated on a Shallow-Water Shelf by Vessels with Electric Motors. Acoustical Physics, 66 (5), 517–527. doi: https://doi.org/10.1134/s1063771020050127
[31] Sorokin, V. N., Leonov, A. S. (2021). Phase Analysis of the Activity of a Voice Source. Acoustical Physics, 67 (2), 193–209. doi: https://doi.org/10.1134/s106377102102007x
[32] Elikin, A. B., Masleva, O. V. (2014). Acoustic dirty. Instruction manuals for the implementation of practical work in the discipline «Ecology». Nizhny Novgorod.

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