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RECENT APPROACHES TO ENVIRONMENTAL NOISE MONITORING AND ESTIMATION OF ITS INFLUENCE TO THE HEALTH OF INHABITANTS

Andrei V. Vassiliev

Department of Mechanics and Environmental Protection, Togliatti State University
Togliatti, 445667, Belorusskaya Str., 14, Russia
NIL9@tltsu.ru

Abstract

Environmental noise impact may cause serious negative problems for inhabitants. Problems and approaches of noise monitoring of urban territories are discussed. Environmental noise monitoring includes not only noise measurement, analysis, and mapping, but also estimation of noise influence to the health of inhabitants. Noise measurement results of the living territory of Samara region and of Togliatti city, Russia, are considered as an example of noise monitoring approach practical realization. Dynamic noise maps of living territory of Togliatti city were created. Estimation of noise influence to the population of Togliatti city has been done. Results allow the author to make a conclusion about the existing of the real problem of noise safety of the city.

1. INTRODUCTION

For the time being acoustical pollution in modern cities is rapidly increased. Disturbing acoustical impact is appreciated by half of Earth population [1]. Transport and industrial sources are making the most significant noise levels in the city environment. Damaging influence of intensive noise to the human's health is not restricted only by impact to ears. It is known, that noise is affecting to the human's central and vegetative nervous systems, influencing to the human's psychological condition etc. The most serious problems are caused by low frequency acoustic affection. That is why it is necessary to estimate and monitor acoustical pollution. The paper refers to the experience and approaches to noise monitoring of urban territories on the example of noise monitoring of Togliatti city, Russia.

2. RUSSIAN SANITARY NORMS AND STANDARDS OF NOISE CONTROL

There are legal, normative and technical documents, determining the procedure of investigation of acoustic pollution of environment and noise affection to the urban living territories. There are international and national standards of noise assessment. In Russia noise levels in living area are evaluated according to hygiene requirements, stated by valid sanitary norms (Sanitary Norms 2.2.4/2.1.8.562-96 [7] Russian State Standards [4,5] and Building

Norms and Rules. Normative parameters for unstable noise are equivalent sound levels L_{Aecv} and maximal sound levels $L_{A\max}$, dBA. There are two periods of evaluation: day (7.00-23.00) and night (23.00-7.00). If noise level is measured inside of building, the permitted value of L_{Aecv} is no more than 40 dBA (day) and 30 dBA (night), the permitted value of $L_{A\max}$ is no more than 55 dBA (day) and 45 dBA (night).

The most serious problems of noise pollution in cities are caused by transport noise affection. Evaluation of transport noise in Russia is carried out according to methodic recommended by Russian State Standard 23337-78* [5]. Results of measurements in every point must be presented as measurements registration forms including date, time and place of measurements, measuring points numbers and digital data of readings of noise levels in measured point. Noise of transport flows is unstable, oscillating in time. For this kind of noise there are some main requirements to carrying out the measurements:

- Time of noise evaluation T in dwelling houses, public buildings and in living territory should be accepted in the day-time - continuously during 8 hours, at night - continuously during 0,5 hour (in the most noisy periods of day).
- Measurement of unstable noise should be carried out at the periods of time of noise evaluation T, which include all typical variations of noise regime in evaluated point. Duration of every measurement of unsteady noise T_m in every point should be at least 30 minutes.
- Reading of sound levels of interrupting noise, which are remaining stable in the intervals with duration less than 0,5 minute, and also of oscillating and impulse noise should be carried out with intervals from 5 to 6 seconds. In every point during the period of noise T_m should be conducted 360 readings of sound levels etc.

3. ANALYSIS OF NOISE SOURCES AND ACOUSTIC SITUATION IN TOGLIATTI CITY. ESTIMATION OF NOISE INFLUENCE TO THE POPULATION OF TOGLIATTI CITY

Let us investigate the main sources of noise impact of Togliatti city. As a typical industrial city Togliatti has as a number of large industrial enterprises as considerable automobile transport park, making significant acoustic impact to abutting dwelling territory. The problem is intensified by the fact that some industrial enterprises and highways are closely adjoining to city's dwelling area. As result significant part of city's population is affected by increased noise level [8, 11, 12].

Automobile transport is the main external noise source affecting to Togliatti city dwelling area. Specific city peculiarity is large automobile transport park, the most part of which consist of cars. This cause intensive transport flows at city's streets, which are generating significant noise impact. A considerable number of the city highways are situated close to the living areas and transport (especially of the Central and Komsomolsky districts). As result are increased noise levels for some dwelling houses.

Noise of moving automobile is induced by the noise from the engine and its systems, automobile aggregates, oscillating body, tires, noise of auxiliary equipment etc. Taking to account continuous growth of the city's automobile park, presently the problem of transport noise impact is coming urgent. It should be noted that for Togliatti city comparatively homogeneous composition of transport flows is typical - rail city transport is absent, impact of aircraft noise is excluded.

Table 1. Equivalent and Maximal Noise Level Values in North Industrial Unit Zone Taking to Account Correction Levels.

N p/p	**MEASUREMENT POINTS DISPLACEMENT**	**DATE OF MEASUREMENT**	Time	Summary Index	Measured equivalent sound levels, L_{Aecv}, dBA	Measured max. sound levels, L_{Amax}, dBA
1	Larina Street (Crossing with Mira Street)	October 04 2005	9:00	1284890	71	83
2	Larina Street (200 m from the Mira Street)	October 04 2005	9:58	661889	68	75
3	Larina Street (400 m from the Mira Street)	October 04 2005	11:10	737777	69	78
4	Larina Street 170	October 04 2005	12:26	717589	69	82
5	Larina Street 153	October 06 2005	12:03	854390	69	77
6	Larina Street 147	October 06 2005	13:15	1174229	71	82
7	Larina Street 143	October 06 2005	14:31	724889	69	78
8	Larina Street 139a	October 06 2005	15:44	654240	68	76
9	Komsomolskaya Street 175	October 07 2005	13:00	506079	67	75
10	Komsomolskaya Street 170	October 07 2005	14:08	531689	67	73
11	Komsomolskaya Street 163	October 07 2005	15:35	549900	67	75
12	Novozavodskaya Street 49	October 10 2005	9:58	1120020	70	96
13	Novozavodskaya Street 55	October 10 2005	11:05	611856	68	75
14	Novozavodskaya Street (Vogla Cement Plant Administration)	October 10 2005	12:16	841220	69	78
15	Novozavodskaya Street (crossing with 50 years of October Street)	October 11 2005	11:17	739429	69	74
16	Novozavodskaya Street (Trolley deport)	October 11 2005	12:27	885000	69	78
17	Novozavodskaya Street	October 04 2005	13:40	808377	69	78
18	Industrialnaya Street 5	October 13 2005	8:56	636103	68	76
19	Industrialnaya Street 16	October 13 2005	10:15	438528	66	74

In years of 2001-2007 collaborators of R&D laboratory "Vibroacoustics, Ecology and Life Protection" of Togliatti State University investigated external noise sources affection to living area of Togliatti city. Since transport is main noise source for Togliatti city, as object of study living territory of the Avtozavodsky, Central and Komsomolsky districts of Togliatti city was selected near to the city streets with intensive transport movement. In total over 150 points have been investigated. Measurements of noise levels in places of living territory of Togliatti city adjoining to noise dangerous zones have been conducted in strict correspondence with above mentioned requirements. Near to the Central and Komsomolsky districts of Togliatti city it is situated a number of industrial enterprises united to so called "North Industrial Unit". Noise estimation and monitoring of North Industrial Unit enterprises for further determination of sanitary zone have been also carried out. Concrete points for measurements carrying out were determined in co-ordination with the Committee of Ecology and Natural Resources and of Department of Architecture of Togliatti city. Measurements have conducted in daytime in weekdays mainly in rush hours and during the lunch-time; and in night time (since 23.00 till 6.00). Results of measurements in every point have been presented as measurements registration forms, which including date, time and place of measurements carrying out, measuring points numbers and digital data of readings of noise levels in measured point [8, 11].

The most significant excess of standard equivalent noise levels have been observed for the following points. Komsomolsky district, night time: point K-07, Matrosova Str., 60, the value of exceeding of normative requirements of equivalent noise level is 8 dBA, maximal noise level - 6 dBA; point K-12, Yaroslavskaya Str., 11: the value of exceeding of normative requirements of equivalent noise level is 5 dBA, maximal level - 8 dBA; day time: point K-10, Chaykina Str., 67, the value of exceeding of normative requirements of maximal noise level is 9 dBA; point K-13, Yaroslavskaya Str., 61, the value of exceeding of normative requirements of maximal noise level is 9 dBA. Central district, night time: point C-18, Lenina Str., 98, the value of exceeding of normative requirements of equivalent noise level is 10 dBA, maximal noise level - 5 dBA; point C-23, Mira Str., 60, the value of exceeding of normative requirements of equivalent noise level is 12 dBA, maximal noise level - 12 dBA; day time: point C-24, Mira Str., 114, the value of exceeding of normative requirements of equivalent noise level is 4 dBA, maximal noise level - 3 dBA. Avtozavodsky district, night time: point A-32, Dzerzhinskogo Str., the value of exceeding of normative requirements of equivalent noise level is 8 dBA, maximal noise level - 3 dBA; day time: point A-04, Topolinaya Str., 21, the value of exceeding of normative requirements of maximal noise level - 19 dBA.

The results of measurements of sound levels in some points of North Industrial Unit zones are shown in Table 1. We may see that in all measuring points there are some exceeding values compared with Sanitary Norms requirements (65 dB). The most significant values of equivalent and maximal noise level are in the points 1, 4, 6.

Analysis of measurement results of external noise levels in living territory of Togliatti city shows, that there are noise dangerous zones of dwelling territory. Population of Togliatti city is approx. 800 thousands people, and at least 100 thousands are living in areas with increased noise levels. The most serious problem of noise influence is for the dwelling territories of Central district adjoining to transport highways. Values in a number of measured points are extremely close to maximally admitted normative requirements. Thus, it is possible to speak about the existing of real problem of noise safety of Togliatti city provision. It is necessary to carry out further investigations of noise levels in all districts of Togliatti city.

4. MODELLING OF NOISE PROPAGATION AND NOISE MAPPING

Modelling of noise propagation in the open space is difficult task [1, 3, 9]. Concerning transport noise evaluation it is better to model not noise of separate cars, but transport flow noise. Formalization and modeling of transport flows it is convenient to do by using of influence diagrams. Such diagrams are usually describing some formalized presentation of modeled categories (objects, processes, properties etc.) in a form of multitude of graphical symbols (assemblies, vertexes) and relations between it. In Russia the types of influence diagrams are the most popular to use in a form of flow graphs, trees of events and functional nets. Flow graphs are including the variety of vertexes and a set of regulated and of unregulated couples, using for visual presentation of modeling process. Trees – non orientated graph, not having cycles, finite and coherent. During last time semantic or functional nets are rapidly developing, which are present graphs, but with additional information in it assemblies and rib. For mathematical description of street-road nets of city methods of graph theory have been taken. Information about city street-road net geometry may be taken from the automobile road schemes, road atlases, drawings etc. For noise maps creation it is necessary to convert graph information to analytical. The following steps have been done:

1. Mathematical apparatus of description have been analyzed and mathematical model of street-road transport nets have been worked out.
2. By using of developed mathematical model street-road transport nets have been created. Transport nets are consisting of the roads with intensive load (marked in the program by black bold strip) and a net of local roads.
3. Algorithms of coding and of information restoring about street-road graph structure was created. Software has been developed to investigate noise situation in Togliatti city streets and roads. Graf networks of the transport mains of Central district are shown in figure 1.

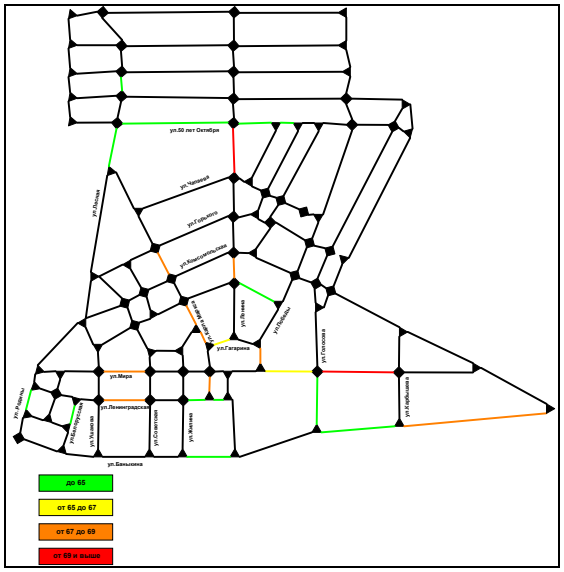

Figure 1. Graphical presentation of transport networks of Central district

Figure 2. Noise map of Central district of Togliatti city

Rapid development of computing technique allows automation of the process of noise maps creation. Modern computers with high velocity proceeding huge volume of information as static, as graphical. As result, a lot of companies are suggesting different types of city noise mapping. Widely Geographic Information Systems (GIS) are used to provide accurate visual

information about noise in city. It should be noted that existing noise mapping tool only showing the acoustical situation only in some defined period. Peculiarity of transport noise mapping is the fact that only transport noise is considered and such sources as industrial noise, internal noise of living areas are not taking to consideration. From the other hand, transport noise map is necessary to include all transport noise sources: automobile transport flows, aircraft noise, railway noise etc. In Togliatti city there is only one main transport noise source: automobile transport. Collaborators of R&D Laboratory "Vibroacoustics, Ecology and Life Protection" have developed their own program provision for city noise maps drawing. Topographic method was used. Noise maps of Togliatti city have been developed. Noise map of the Central district is shown in figure 2. Is very important that noise mapping software is to allow to carry out the storage of database on noise levels. This allows to carry out more efficient evaluation of transport noise in compare with traditional methods. Software "Sound City Test" (version 3) have been developed allowing to save in database the results of transport noise measurements for the all period of measurements [10, 11]. It is possible to add the data and to show on the map all the results of measurements and their dynamics. The window "Control Points" (figure 3) is logically subdivided into two parts: in the top – "Input and editing of points", in the bottom – " Input and editing of variations in points". All the points are presented in special form with network. Such kind of software allows to store all the measured data and to make a conclusion about the dynamics of noise time variations in nearest and far prospect. The method of presentation of results may be different: video-dB, graphs, tables etc. We named our software as "Dynamic noise mapping". Figure 4 is showing the measuring results in the form of diagram.

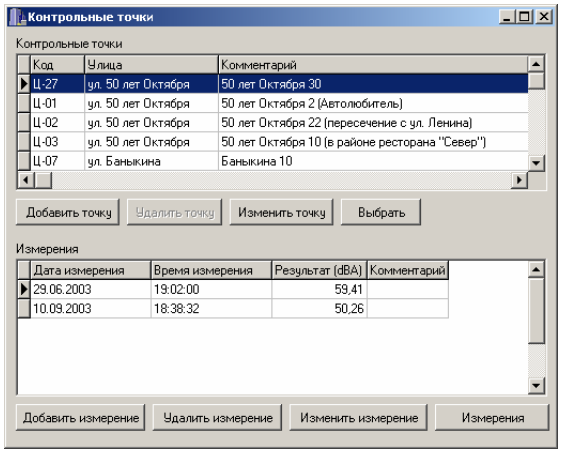

Figure 3. The window "Control Points"

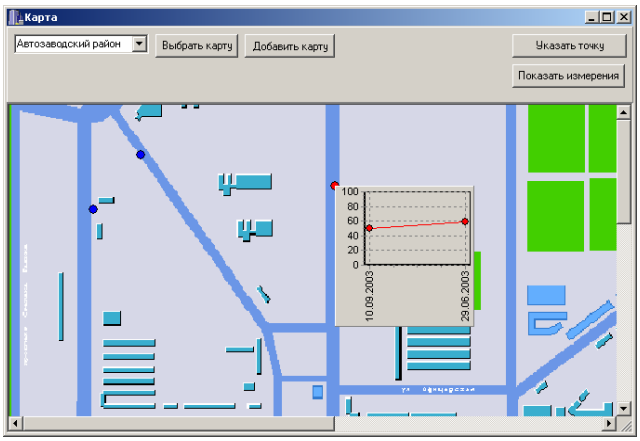

Figure 4. Display of measuring results in the form of diagram

Using software «Sound City Test» [9, 11] dynamic noise maps of the living territory of Samara region and of Togliatti city have been created. Visual dB method was used to show the fact of exceeding of sanitary norms in the points of measurements. Orange colour was used for the points with equivalent noise level in the range from 65 to 70 dBA, red colour – points with equivalent sound levels over 70 dBA etc.

5. CALULATION OF SOUND PROPAGATION FROM THE NORTH INDUSTRIAL UNIT ZONE TO THE LIVING DISTRICTS

Let us to calculate propagation of sound from the North Industrial Unit zone enterprises to the living areas of Central district of Togliatti city. It should be noted that sound level in the point of observation in the open area depends on the source characteristics (sound spectrum,

characteristics of sound direction), from the direction of the point of observation relatively to the source, Earth surface, influence of weather conditions etc. During calculations let us assume the following admissions:

1. We have inconstant noise estimated by L_{ecv}.
2. Under superposition of the several sound waves p_i the mean square of summary sound pressure is determined by equation $p_{сум}^2 = \sum p_i^2$ (no coherence, energetic summation). We may neglect by values $2p_i p_j$ (the effects of interference) if we have broad band noise.
3. Sound sources are considered as pointed (the sizes of the sources are small comparatively to the distance from the point of observation).
4. The point of observation is located in the far sound field of source.

Sound pressure level (dB) of the point source on the distance r (m) in homogeneous medium without the absorption is equal to:

$$L(r) = L_p + 10\lg\Phi - 20\lg r - 10\lg\Omega \qquad (1)$$

where L_p - source sound power level (or sound level), dB (dBA);

Φ - factor of source directivity for the point of observation;

$\Omega = 4\pi$ - full space angle, in which the sound is radiated, $10\lg 4\pi = 11$.

Several authors [1] have showed that sound level from the equation (1) is decreased on 6 dB during doubling of distance r from the source ($20\lg 2 = 6$) due to the geometrical widening of the field in which the sound energy is propagating. The distance r will be considered as equal approx. 5 m.

Results of calculations of sound level variation from the points with maximal values of sound and at close distance from the living areas of the Central district of Togliatti city are showing that the most significant exceeding of the existing norms is in the living zones situated near from the points of Komsomolskaya and Novozavodskaya Streets of the North Industrial Unit zone.

6. CONCLUSIONS

Analysis of recent measurement results of external noise levels in living territory of Togliatti city shows, that noise level is increased approximately in 1 dBA per year. Especially urgent problem of noise reduction in night time: measurements data shows, that for all measuring points the normative requirements were exceeded. Values in a number of measured points in day time are exceeding the norms or extremely close to maximally admitted normative requirements. Thus, it is possible to speak about the existing of real problem of noise safety of Togliatti city provision. Different methods of noise evaluation and mapping have been investigated and described. The results of graphical presentation of transport networks and of topographical transport noise mapping have been presented. Dynamic noise mapping method has been proposed. Results of calculations showing that the most significant exceeding of the existing norms is in the living zones situated near from the points of Komsomolskaya and Novozavodskaya Streets of the North Industrial Unit zone.

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REFERENCES

[1] N.I. Ivanov, A.S. Nikiforov, "*Foundations of Vibroacoustics"*: Testbook. SPB.: "Polytechnika", 2000. – P.: 482.

[2] Luzzi S., Falchi S., "*Mapping and Reducing Noise Pollution in Hospitals*", Proc. of the First International Scientific-Technical Conference "Ecology and Life Protection of Industrial-Transport Complexes" ELPIT-2003, September 11-14 2003, Togliatti, Russia, pp. 49-52.

[3] Luzzi S., Vassiliev A.V., "*A Comparison of Noise Mapping Methods in Italian and Russian Experiences*", Proc. of International Scientific Conference "Forum Acusticum-2005", Budapest, Hungary, August 29 – September 2 2005, pp.1051-1056.

[4] Russian State Standard 12.1.003-83* "SSBT. Noise. General Requirements of Safety".

[5] Russian State Standard 23337-78* "Noise. Methods of Noise Measurement in Urban Territory and in Dwelling Houses and in Public Buildings". Moscow, "Standards" Edition, 1982.

[6] Sanitary Norms CH-2.2.4/2.1.8.562-96 "Noise in Working Places, in Dwelling Houses, Public Buildings and in Urban Territory. Moscow, Ministry of Health of Russia, 1997.

[7] Vassiliev A.V., "*Noise Reduction of Industrial-Transport Complexes: the Ways and the Prospects*", Proc. of the First International Scientific-Technical Conference "Ecology and Life Protection of Industrial-Transport Complexes" ELPIT-2003, September 11-14 2003, Togliatti, Russia, pp. 22-29.

[8] Vassiliev A.V., Utkin N.D., Pereshivailov L.A., "*Transport Noise Affection to the Housing Estates*", Proc. of the 8th International Congress on Noise as a Public Health Problem, Rotterdam, The Netherlands, 29 June – 3 July 2003, pp. 258-259.

[9] Vassiliev A.V., "*Monitoring of Physical Fields of Urban Territories: Modern Approaches, Problems, Prospects*", The Special Issue "ELPIT-2005" of Scientific Edition "Proceedings of Samara Scientific Center of Russian Academy of Sciences", Samara, 2005, volume 1, pp. 111-118.

[10] Vassiliev A.V., "*Software Development for Transport Noise Propagation and Mapping*", Proc. of the 31 Congress of Italian Acoustical Association, Venezia, Italy, May 5-7 2004, pp. 297-303.

[11] Vassiliev A.V., Shevchenko D.P. "*Transport Noise Mapping of Togliatti City*". Proc. of the 11th International Congress on Sound and Vibration, 5-8 July 2004, Saint-Petersburg, Russia. Edited by "Polytechnika", ISBN 5-7325-0816-3, pp. 1283-1290.

[12] Vassiliev A.V. "*Analysis of Noise Characteristic of Living Area of Togliatti City*", Proc. of Monthly Scientific-Technical Journal "Ecology and Industry of Russia", N4, April 2005, pp. 20-24.