MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

Influence of regional climatic factors on acoustic calculations and on the choice of noise reduction measures

Taratorin Andrey[1]
National Research University "MPEI"
111250, Russia, Moscow, Krasnokazarmennaya str., 14

Tupov Vladimir[2]
National Research University "MPEI"
111250, Russia, Moscow, Krasnokazarmennaya str., 14

ABSTRACT

Considered the influence of regional climatic factors on noise attenuation on basis of calculation and analysis of data for 122 cities in Europe. It is shown that for the same noise source sound levels during the year can vary significantly. For different regions of Europe and octave band center frequencies, the change in noise attenuation during the year reaches several dozens of decibels. Analysis of the data for the octave band center frequency 1000 Hz plotted on the map of Europe shows that the largest change in attenuation due to atmospheric absorption during the year occurs on the North of Europe. As the octave band center frequency increases from 1 to 8 kHz, the maximum values shift westward toward Central Europe. But at the same time, for all octave band center frequencies, the minimum values of changes during the year will be observed in the West and North-West of Europe: on the territory of Portugal, Spain, Great Britain and Ireland. For example, for an octave band center frequency 8 kHz, noise attenuation varies from 27-55 dB/km in Western Europe to 86 dB/km in Eastern Europe during the year.

Keywords: noise reduction, climatic factors, energy efficiency
I-INCE Classification of Subject Number: 24

1. INTRODUCTION

Most of the population of large cities lives under influence of excessive noise levels [1-6]. Different countries have different sanitary legislation in spite of this the fact remains that many people in cities live in conditions of acoustic discomfort. At the same time, the same sources of noise with the same characteristics in different climatic conditions lead to different levels of sound pressure at the calculation points. Influence of climatic factors and the ground surface on the required noise abatement was shown in [7]. Effect of regional climatic factors of reducing noise level was shown to territory of the Russian Federation in [8]. This article analysis of the influence of climatic factors on sound pressure levels at calculation points was performed for central and west Europe

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[1] TaratorinAA@mpei.ru
[2] TupovVB@mpei.ru

(for an area with latitude values from 35.2 to 69.0 degrees and longitude from -9.1 to 36.0 degrees). The analysis was performed for 122 cities in west and central Europe.

While sound wave is being propagating in open space, its attenuation is determined by environment sound absorption. Under normal conditions, absorption is carried out by atmospheric air. Such a sound attenuation mechanism is caused by a physical phenomenon called acoustic relaxation. The propagation of sound wave occurs due to the formation of elastic waves of mechanical vibrations in the air. Particles (molecules and atoms) of the environment are taken out of balance by sound wave and tend to return to their initial equilibrium state. Such a mechanism of sound energy dissipation is called acoustic relaxation. The article further discusses the effect of acoustic relaxation on the values of sound pressure levels while performing engineering calculations for different climatic regions.

2. CONSIDERATION OF REGIONAL CLIMATIC FACTORS IN ACOUSTIC CALCULATIONS

Calculation of the attenuation of noise propagation outdoors is carried out according to ISO 9613 (Part 1 and Part 2) [9,10].

The first part is devoted to calculation of the absorption of sound by the atmosphere and in the second part general method of calculation is stated.

In these standards it is assumed that the magnitude of the sound power level of noise sources is known, and the sound pressure levels at the calculated points are a definable quantity. In general, to determine sound pressure levels is used the Equation:

$$L_f = L_w + D_c - A \qquad (1)$$

where f is the symbol for octave-band frequency, L_w is the octave-band sound power level, in decibels, produced by the point sound source relative to a reference sound power of 1 picowatt (1 pW); D_c is the directivity correction, in decibels, that describes the extent by which the equivalent continuous sound pressure level from the point sound source deviates in a specified direction from the level of an omnidirectional point sound source producing sound power level L_w, D_c equals the directivity index D_l of the point sound source plus an index that accounts for sound propagation into solid angles less than 4π steradians; for an omnidirectional point sound source radiating into free space, D_c = 0 dB. A is the octave band center frequency attenuation, in decibels, that occurs during propagation from the point sound source to the receiver.

The value of attenuation A can be calculated according to the following expression:

$$A = A_{div} + A_{atm} + A_{gr} + A_{bar} + A_{misc} \qquad (2)$$

where A_{div} is the attenuation due to the geometrical divergence (due to the energy divergence upon emission into free space); A_{atm} is the attenuation due to atmospheric absorption; A_{gr} is the attenuation due to the ground effect; A_{bar} is the attenuation due to a barrier; A_{misc} is the attenuation due to miscellaneous other effects.

Analysis of Equation 1 and Equation 2 shows that regional climatic factors affect only on the attenuation component A_{atm}, which is defined according to [8] as:

$$A_{atm} = \alpha \cdot d / 1000 \qquad (3)$$

where α is the atmospheric attenuation coefficient, in decibels per kilometer (dB/km), for each octave-band at the midband frequency. This coefficient depends on temperature, humidity, and barometric pressure. d is the distance from the noise source to the receiver point, m. Changing of barometric pressure causes a change in attenuation A_{atm} amounting to approximately 0.1 dB, therefore the influence of this factor can be neglected.

In the calculation of atmospheric attenuation coefficient α, the variables are the sound frequency, air temperature and the concentration of water vapor. The attenuation of sound due to the absorption in the atmosphere is a function of oxygen and nitrogen relaxation frequencies. The acoustic relaxation is a process restoration of thermodynamic equilibrium of the air molecules that caused by changing pressure and temperature in the course of sound wave transmission. The intensity of acoustic relaxation and sound absorption processes depends on the thermodynamic parameters of atmospheric air determined by a temperature and humidity.

The maximum change of the atmospheric attenuation coefficient is determined by the values of average monthly temperature and humidity for each city as:

$$\Delta\alpha = \alpha_{max} - \alpha_{min} \quad (4)$$

where α_{max} and α_{min} are the maximum and minimum values of the atmospheric attenuation coefficient during the year for a city for each octave band center frequency.

Incorrect determination of sound attenuation due to atmospheric absorption leads to errors in the calculation and errors in the design of measures to reduce noise. On the one hand, this can lead to the choice of insufficient measures to reduce noise, on the other – to overspending on measures to reduce noise. Therefore, when choosing measures to reduce noise, consideration of regional climatic factors, especially for high frequencies, is mandatory.

3. ANALYSIS OF CHANGES IN THE ATMOSPHERIC ATTENUATION COEFFICIENT

According to calculation results, an array of data was obtained containing the average values of the atmospheric attenuation coefficient for octave band center frequencies: 31.5; 63; 125; 250; 500; 1000; 2000; 4000; 8000 Hz for every 12 months of the year. A total of 13,176 values were analysed.

An analysis of the data obtained shows that for frequencies of 500 Hz and below, the values of sound absorption coefficients in the atmosphere are comparable with the calculated error and measurement error. Practically at calculation points for frequencies below 500 Hz, it is impossible to fix the influence of climatic factors, and in these cases such influence can be ignored when choosing and developing noise-suppressing measures. The maximum and minimum changes of sound absorption coefficients in the atmosphere during the year for octave-band frequencies of 500-8000 Hz are shown in Table 1.

Table 1. Maximum and minimum changes of atmospheric attenuation coefficient for the territory of Europe

***f*, Hz**	**$\Delta\alpha_{max}$, (dB/km) / city**	**$\Delta\alpha_{min}$, (dB/km) / city**
500	1,7 / Pòdgorica	0,7 / Porto
1000	5,3 / Levi	0,7 / Aberdeen
2000	17,9 / Levi	0,5 / Porto
4000	37,4 / Vitebsk	4,7 / Belt Valletta
8000	86 / Veliko Tarnovo	27 / Sevilla

Figures 1-4 show the difference between the maximum and minimum value of the atmospheric attenuation coefficient during the year, calculated by the formula (4) for different frequencies in territory of Europe.

In Figure 1 for the octave-band with frequency of 8000 Hz it can be seen that the largest difference between α_{max} and α_{min} is in the south-eastern part of Europe, as well as in northern Europe. Moving to the west, the isoline values decrease, and the lowest values are reached in the west in Portugal and Spain. The change of Δα for the territory of Europe is 27-86 dB/km.

Figure 2 allows to conclude that for the octave band center frequency of 4000 Hz, the highest Δα values are reached in the eastern part of Europe on the territory of Belarus, and the smallest – in the western and southern parts of Europe. The change of Δα is 4.7-37.4 dB/km.

Calculated data for the octave band center frequency of 2000 Hz presented in Figure 3 and indicate that the greatest change in sound pressure levels during the year is reached in northern Europe, and the smallest is in the west – in Portugal and Spain. The change of Δα is 0.5-17.9 dB/km.

Figure 4 shows data for octave band center frequency of 1000 Hz. As can be seen, the largest change in Δα remains in the northern part of Europe in Finland, and the smallest shift to the north-western part of the UK. The change of Δα is 0.7-5.3 dB/km.

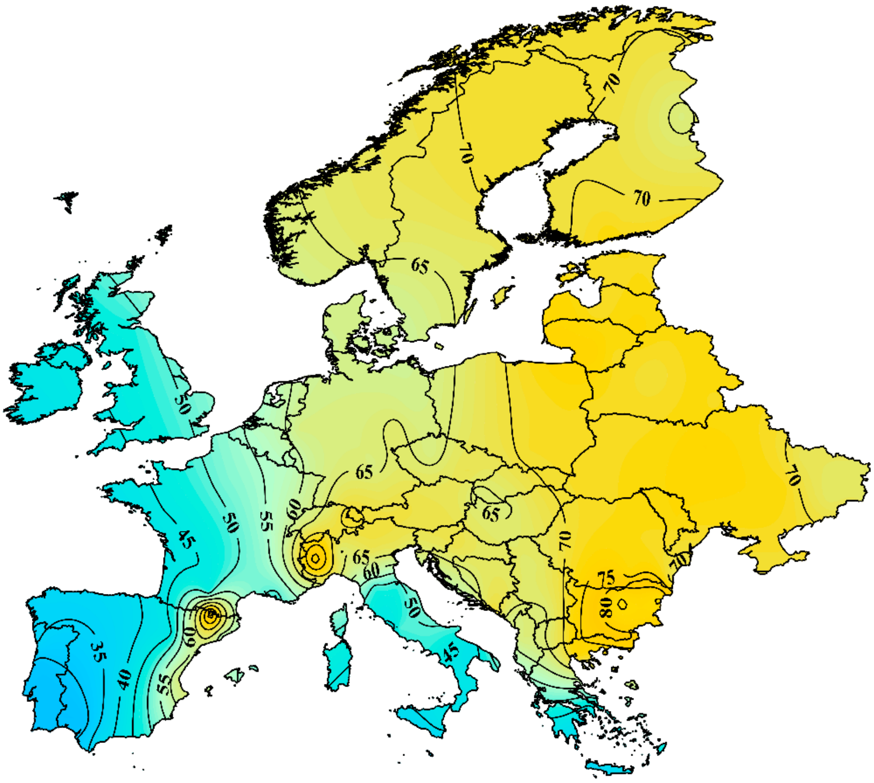

Fig. 1. Isolines of the difference between the maximum and minimum value of atmospheric attenuation coefficient (dB/km) during the year in Europe for 8000 Hz

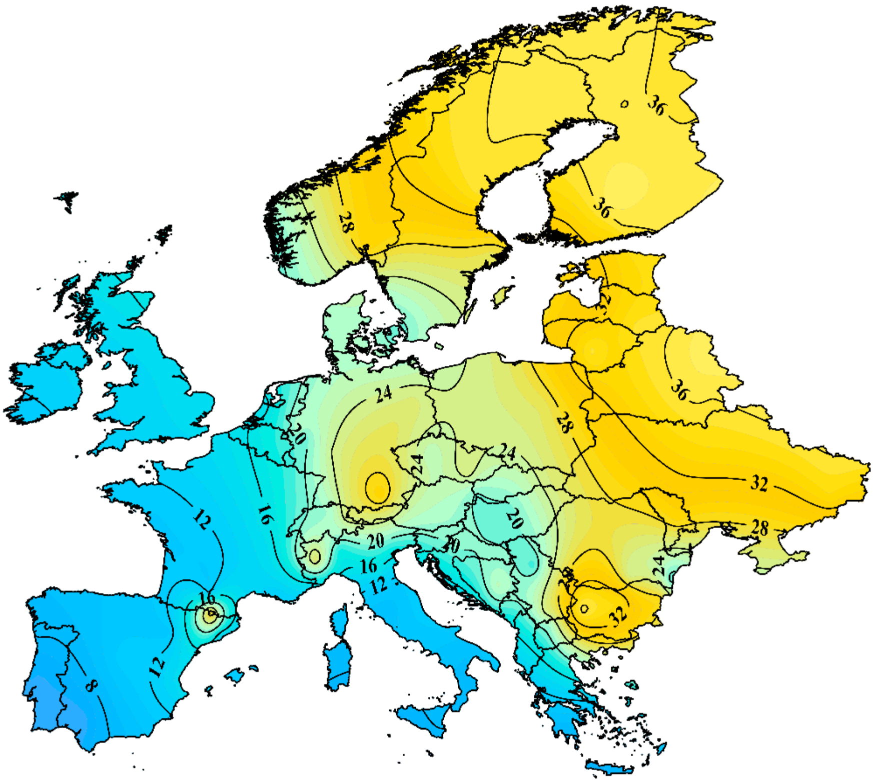

Fig. 2. Isolines of the difference between the maximum and minimum value of atmospheric attenuation coefficient (dB/km) during the year in Europe for 4000 Hz

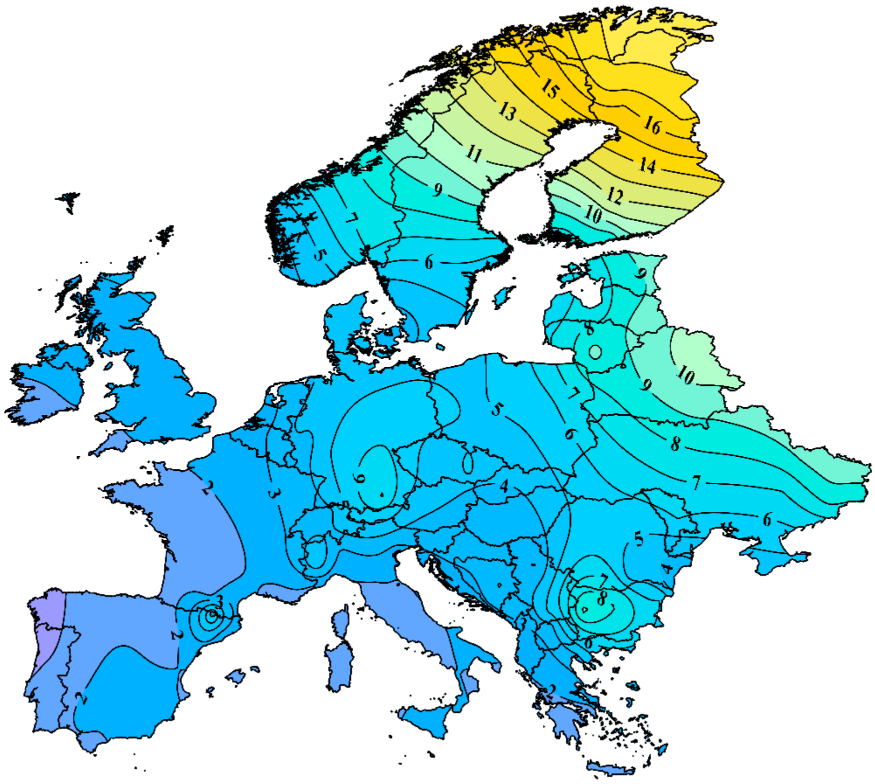

Fig. 3. Isolines of the difference between the maximum and minimum value of atmospheric attenuation coefficient (dB/km) during the year in Europe for 2000 Hz

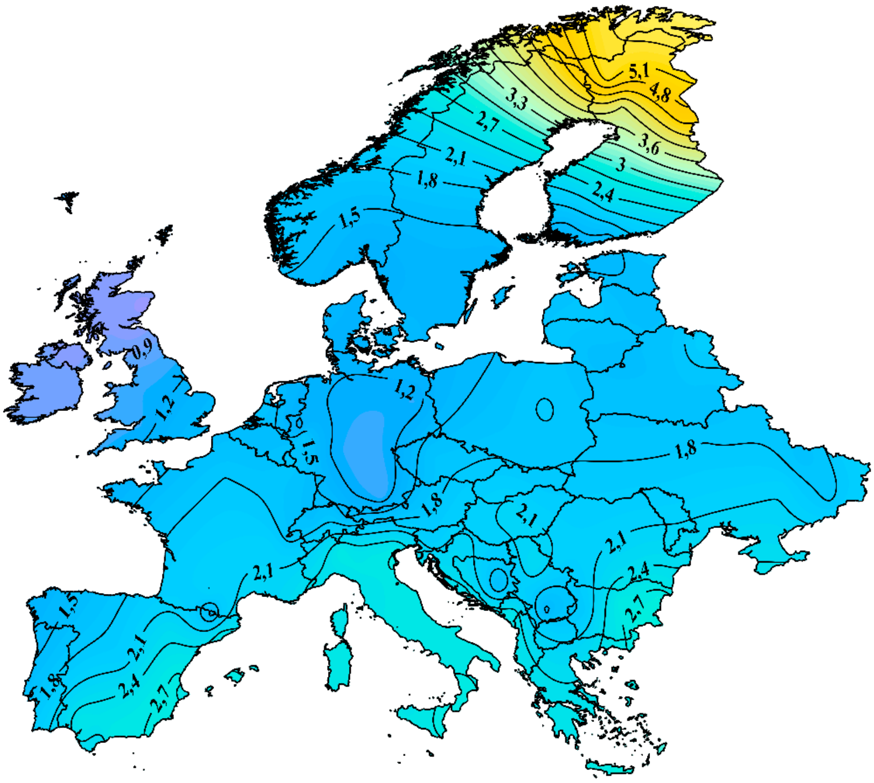

Fig. 4. Isolines of the difference between the maximum and minimum value of atmospheric attenuation coefficient (dB/km) during the year in Europe for 1000 Hz

4. CONCLUSIONS

The calculations allow mapping changes in sound pressure levels in Europe for octave band center frequencies of 31.5-8000 Hz throughout the year. For octave band center frequencies not exceeding 500 Hz, this change is comparable to the accuracy of calculations and measurements. For octave band center frequencies above 1000 Hz, the influence of climatic factors must be taken into account. Also, this influence is non-uniform for the territory of Europe. T he greatest change is achieved in the northern part of Europe. As the frequency increases, the maximum of changes spreads to the southern and western part of Europe. When performing acoustic calculations and choosing noise protection measures, it is necessary to take into account the change in sound pressure levels during the year due to the influence of climatic factors.

5. ACKNOWLEDGEMENTS

The work was supported by Russia Federation President’s research grant for young scientists and postgraduate students, no. SP-3372.2018.1.

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