

Noise mapping as a tool for controlling industrial noise pollution

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The purpose of this work is to identify the contribution of noise from external sources to the noise pollution generated by a factory, by comparing sound pressure levels measured in its surroundings and those calculated by noise mapping. A metal-mechanical manufacturing plant was chosen and sound pressure levels were measured at discrete points along two rings around it, called receivers. The noise measurement data from the first ring were entered into the Sound Plan software to determine, through iteration, the factory's main noise sources. The software then used this information to calculate noise maps and sound pressure levels at the receiver's positions in the second ring. Finally, the contribution of noise from external sources to the overall noise generated by the factory was determined by comparing the noise measured in the second ring with the simulated data. The placement of partial barriers along some critically *noisy walls* was found to be effective in controlling nighttime noise, ensuring that the sound level limit for this type of neighborhood, which is established by technical standards for environmental noise as $L_{eq} = 60$ dB (A), is not reached.

Keywords: Noise mapping, Noise pollution, Noise control, Industrial noise, Noise sources

Introduction

The global growth in urbanization presents a common factor, i.e., the aggravation of environmental pollution through gas emissions, water pollution and noise pollution. The noise that reaches urban populations is generated by various sources, whose nature may be simple or complex, comprising noise generated by factories (e.g., from the metal-mechanical and construction sectors), transportation systems (roads, railroads, aircraft), by neighbors, and by a wide variety of leisure activities such as cultural and sports events, etc.¹⁻⁷. Many sectors of society are affected by noise. In response to urban and industrial noise pollution, numerous studies have focused on environments destined for activities that involve a high degree of cognitive and intellectual activity, such as educational and working environments [e.g.⁸⁻¹⁸]. In recent years, noise and urban planning have been studied extensively based on noise mapping¹⁹⁻²⁵.

The objective of this work is to use computational noise mapping to evaluate the industrial noise generated by an auto parts manufacturing plant in its surroundings, identify the main sources of noise and

calculate how much the noise levels in the external environment are reduced by noise barriers.

Materials and Methods

The Factory

The plant in question is located in the industrial city of Caxias do Sul, in the south of Brazil in the state of Rio Grande do Sul. This factory manufactures auto parts for the Brazilian automotive industry.

Experimental Procedure

Equivalent continuous sound pressure levels L_{Aeq} were measured during periods of full production, with a temporary change in vehicle traffic on streets adjacent to the factory, in order to capture the noise originating exclusively from the factory. The points of measurement, called receivers, were arranged along two rings around the factory. The first ring was located in the perimeter surrounding the external walls of the factory buildings, at a distance of 1.5 m from the walls and 1.20 m above the ground, according to the guidelines of the Brazilian standard NBR 10151 for noise assessment in communities²⁶. The second ring was located along the external perimeter close to the fence surrounding the plant's grounds. The number of measured points varied

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according to the dimensions of the perimeter of each of the plant's buildings, maintaining a distance of up to 10 m between the points. The sound levels were captured by 143 receivers. The inner (first) ring contained 47 receivers. The outer (second) ring, along the fence surrounding the plant's grounds, contained 96 receivers. The measurements taken *in situ* at each of the 143 receivers lasted for 3 minutes²⁶.

Caxias do Sul Municipal Law 233/2004 establishes limits of noise immission levels, L_{eq} , for external environments in this municipality. During daytime (07:00 to 19:00 h), 60 dB(A) for residential areas and 70 dB(A) for industrial areas. During nighttime (19:00 to 07:00 h), 55 dB(A) for residential areas and 60 dB(A) for industrial areas.

Computational Methodology

The noise measured around the perimeter of the plant's grounds may include noise from other sources such as factories in the vicinity, vehicle traffic, etc. If the second ring is located at a suitable distance from the plant's noise sources, there is a greater possibility of determining the influence of external noise sources. It is desirable for the influence of such external sources to be known during the measurements in order to consider their influence when determining the factory's noise levels.

The noise measures recorded by the receivers in the two rings were entered into a CAD 3D program

using a virtual factory on scale as background, with the existing ground elevations and neighboring buildings. This map was then exported to Sound PLAN software²⁷, where data on noise emission and propagation conditions, ground characteristics and natural barriers were included. Factories contain numerous noise sources, and these sources are approximated as point sources. Each receiver of the inner ring is located at the same height and associated with a point source of emission. Fig. 1 depicts the point sources as red asterisks around the factory.

Because the sound pressure levels of the sources were unknown, a certain value was attributed arbitrarily to a particular source, which was calibrated by the sound pressure levels of the inner receivers closest to it. As a first approximation, each point source was assigned the same sound level measured by the receiver located in front of it. This calibration was revised successively with the adjacent sources until the simulated immission values at the receivers in the first ring approximated the measured values, within an allowable tolerance of up to 1 dB (A).

Results and Discussion

Based on the noise levels measured in the external environment, we aimed to determine if the levels generated by the factory would be within the legal limits of noise immission, as stipulated by the noise

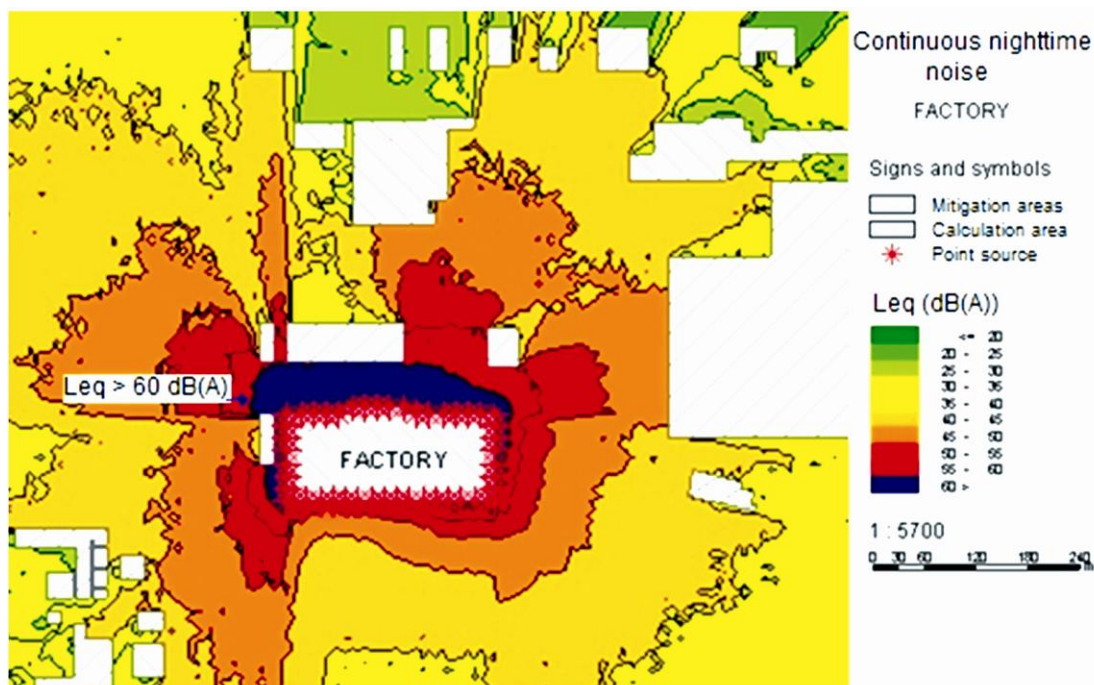


Fig. 1—Simulated propagation of nighttime noise produced by the factory

regulations of the municipality of Caxias do Sul. Based on the results, it is possible to adopt several measures to control noise emissions. From the equivalent noise levels, L_{eq} measured by the receivers in the inner and outer rings during day and night shifts, we observe that most of the noise levels in the outer ring were lower than in the inner ring. After that, it is possible to compare the measured and calculated L_{eq} values captured by the receivers in the inner ring of the factory. The calculated values are similar to the measured ones, confirming the validity of the methodology adopted to obtain the computational results using Sound PLAN software.

The partial error of noise levels for the inner ring is obtained by difference of the computational value with reference to the experimental value for each receiver in the first ring, indicating that the closer to zero the error the better the calibration of the adopted model. The maximum error of L_{eq} was equal to 0.6 dB (A) at daytime in two receivers and equal to 0.7 dB (A) at nighttime in two different receivers, while the others were lower than 1 dB (A), which suffices to calibrate the model. After calibrating the simulated values for the first ring of receivers, the simulated values of the L_{eq} corresponding to the second ring of receivers were obtained and compared with the measured ones. The experimental values were higher than the computational ones, indicating the existence of noise sources outside the factory.

The difference between measured and computational values of sound levels for the outer ring indicates the influence of noise sources outside the factory. Note that the difference is greater in the daytime than at night, which is consistent with the greater number of external activities taking place during the day. The average difference between measured and computational values for the outer ring, attributed to the influence of external noise sources, is 5.4 dB (A) at daytime and 4.9 dB (A) at nighttime. The number of receivers in the outer ring whose experimental immission values exceeded permissible limits were 3 (3.1% of 96 receivers) at daytime and 17 (17.7%) at nighttime. The computational results showed fewer receivers in this condition, no receiver at daytime and only 4 receivers (4.2%) at nighttime, indicating that the plant's noise sources contributed less to the noise pollution than the external sources.

A computational graphical analysis allows for the visual identification of the noise propagation field and its impact in the surroundings of the

evaluated sources. Two parallel boundary lines delimit the factory's area of influence. The internal line is dubbed the *calculation line* and the external one the *mitigation line*. Note that a sufficiently large mitigation area is required. The computational levels of daytime noise did not exceed the immission limit of 70 dB (A) at the outer ring of the factory. Hence, the factory meets the legal limits of external noise emissions levels. Four computational points in the outer ring, corresponding to nighttime noise, exceeded the noise immission limits. Fig. 1 highlights, in dark blue, the areas of the sound propagation field whose immission levels exceeded 60 dB (A). These areas are associated with pressing, cutting and welding operations.

Computational evaluation of noise control in the factory

Some of the computational noise immission values exceeded the nighttime limit of 60 dB (A). Therefore, we decided to measure the sound levels of the internal sources represented by the plant's existing machinery in order to adopt some noise control measures individually or by sector. To characterize some of the machines in the plant as noise sources, experimental measurements were taken on the four sides of the machines while in operation, and these measures were entered as point sources into the SoundPLAN software.

Two different options for noise control were adopted. The first consisted of placing individual sound barriers around machines inside the plant. The second option involved the construction of barriers close to the inner ring of the factory. The nighttime sound pressure levels were calculated after the placement of individual virtual barriers around the noisiest machines, which provided noise attenuation values of up to 10 dB(A). Some areas exceeded the emission limit of 60 dB (A), but only to a minor degree between the inner and outer rings of the factory, when compared with the results obtained without barriers.

Fig. 2 shows the nighttime noise levels after placing virtual acoustic barriers in parts of the plant's inner ring, indicated by light blue lines, which provided attenuation values of up to 10 dB(A). The boundary enclosed by light green lines denotes the inner ring of the factory. A few areas, indicated in dark blue in this figure, exceeded the immission limit of 60 dB (A), but only to a minor degree between the inner and outer rings of the factory, when compared with the results obtained with individual barriers.

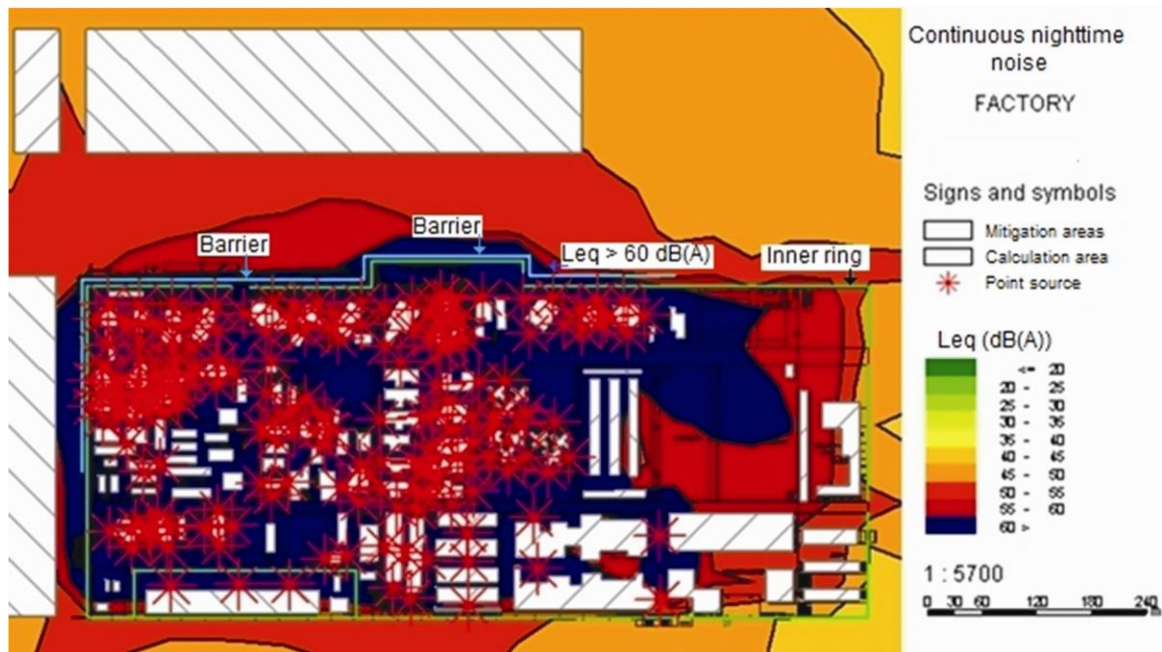


Fig. 2—Control of nighttime noise levels using partial barriers in the inner ring

The results indicate that the number of individual barriers did not suffice to attenuate the noise propagated to the external environment. Since the factory contains many sources of noise, a larger number of machines must be enclosed with barriers to achieve a noise attenuating effect. Controlling noise by placing barriers close to the inner ring of the factory is effective for mitigating nighttime noise. The sound emission levels exceeding 60 dB(A), produced in the areas shown in dark blue, did not reach the neighborhood or the adjacent administration and services buildings of the factory, as indicated in Fig. 2.

Conclusions

Our computational results indicate that the placement of individual barriers around some of the noisier machines did not suffice to limit the noise propagating to the external environment. Since the main objective is to control noise propagating to the external environment, the partial placement of barriers along some critically *noisy walls* is more effective to control nighttime noise, preventing the immission limit of 60 dB(A) from reaching the neighborhood and adjacent buildings in the factory. The use of this methodology allows one to predict noise distribution patterns in the proximities of manufacturing plants, aiming to devise measures to control and reduce noise propagation and thereby satisfy current

Brazilian environmental noise laws. The use of computational tools to analyze noise is suitable for cases in which it is important to be aware of the environmental impact produced by a factory in a given region. The proposed methodology for predicting noise pollution prior to the construction, expansion or modification of manufacturing units is useful, enabling one to meet current noise regulations.

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