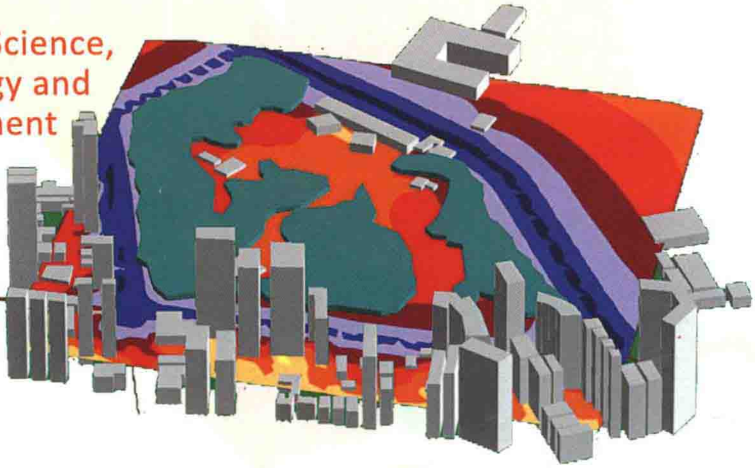
Noise Pollution in Urban and Industrial Environments

Measurements and Noise Mapping

Pollution Science, Technology and Abatement



Paulo Henrique Trombetta Zannin
Editor

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POLLUTION SCIENCE, TECHNOLOGY AND ABATEMENT

NOISE POLLUTION IN URBAN AND INDUSTRIAL ENVIRONMENTS

MEASUREMENTS AND NOISE MAPPING

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EDITOR

nova publishers
New York

Library of Congress Cataloging-in-Publication Data

Names: Zannin, Paulo Henrique Trombetta, editor.
Title: Noise pollution in urban and industrial environments : measurements and noise mapping / editors, Paulo Henrique Trombetta Zannin (Department of Mechanical Engineering, Federal University of Paranba, Brazil).
Description: Hauppauge, New York : Nova Science Publishers, Inc., [2016] | Series: Pollution science, technology and abatement | Includes bibliographical references and index.
Identifiers: LCCN 2016018364 (print) | LCCN 2016031763 (ebook) | ISBN 9781634852692 (hardcover) | ISBN 9781634852944 (Ebook) | ISBN 9781634852944 ()
Subjects: LCSH: Noise pollution. | Urban pollution. | Industrial noise. | Noise--Measurement.
Classification: LCC TD892 .N657 2016 (print) | LCC TD892 (ebook) | DDC 620.2/3--dc23
LC record available at https://lccn.loc.gov/2016018364

Published by Nova Science Publishers, Inc. † New York

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This book is dedicated in loving memory to my parents Belony and Altayr,
and to my wife Carolina, my twins Beatriz and Vitor,
and my aunt and uncle Arlete and Clávio.

PREFACE

Urban and industrial noise pollution is present in virtually every country in the world. Noise pollution studies are therefore needed to find solutions to improve the quality of life in cities.

The analyses described in the 18 chapters of this book are based on field measurements of sound pressure levels and computer calculations of noise maps. Noise mapping is a highly effective technique to visualize the problem of noise in large urban centers and noise generated by manufacturing plants. This technique facilitates the search for answers to the problem of noise pollution and is helpful for comparing solutions, enabling one to select the most effective and economically feasible solution. Several case studies are described throughout the book. These are examples of real cases, which were used to assess the quality of urban and industrial environments. Based on measurements, noise maps are calculated to show the current situation of noise pollution. Subsequent analyses based on noise mapping simulations indicate the urban and industrial noise abatement measures recommended for the cases in question.

The first chapter discusses the environmental noise assessment standards of the International Organization for Standardization, ISO. In addition to ISO standards 1) ISO 1996-1 – "Basic quantities and assessment procedure," and 2) ISO 1996-2 – "Acquisition of data pertinent to land use," national and local standards are also presented and discussed. This chapter reviews noise map calculations and design, as well as the model for calculating road traffic noise contained in the ISO 9613-2 standard.

Chapter 2 describes mathematical models based on statistical analyses to calculate nighttime and daytime highway traffic noise. Unlike the daytime model, the nighttime model is presented with class intervals.

A methodology for the assessment of environmental noise generated by heavy traffic on an urban stretch of a highway is discussed in Chapter 3. The noise pollution assessment was based on extensive field measurements of equivalent sound pressure levels and the subsequent calculation of noise maps. The noise maps were calculated based on heavy vehicle counts, road conditions, and average speed of vehicle traffic. The noise levels recorded on this road exceed the levels recommended by current legislation and indicate that taking only one control measure does not suffice to counteract noise efficiently. Instead, a plan involving various measures taken jointly is needed to effectively mitigate the problem.

Urban noise has often been cited as an environmental impact that affects society negatively, which is why it has been analyzed with greater care in reports submitted to government environmental agencies. Chapter 4 offers a detailed explanation of how to characterize noise in a community, thus assisting in decision-making for urban planning, environmental control and environmental licensing. To this end, noise characterization is performed quantitatively and qualitatively, the former by means of noise monitoring and modeling, and the latter by means of sound perception interviews, soundwalks and hearing tests.

Chapter 5 describes noise in urban areas surrounding power substations. The noise levels that reach houses and buildings situated around the substations is then quantified based on noise maps.

Urban parks are considered important locales for physical activity. It is therefore essential that park settings be attractive and of good quality, since they can contribute to improve the quality of life of urban populations through the practice of physical exercise. Chapter 6 describes the quality of environmental sound in public parks. Based on environmental noise measurements and noise mapping, an investigation was made to determine if the fitness and leisure equipment (sports courts, equipment for push-ups, sit-ups and leg stretching, walking simulators and playground) inside parks are located in areas exposed to environmental noise from the immediate surroundings (thoroughfares with heavy vehicle traffic). It was found that the L_{Aeq} levels in the areas closest to the outer perimeters of the parks are higher than in the more distant areas. Thus, primarily due to the urban shape of the surroundings, environmental noise was found to have a negative effect on urban park environments. This effect could be mitigated by building thoroughfares with heavy traffic further away from parks, considering the urban context of the park, and/or by placing fitness and leisure equipment at a greater distance from the park's outer perimeters, thereby promoting greater acoustic comfort.

Chapter 7 describes a study of sound pressure levels and frequency spectrum measured in the surroundings of the Polytechnic Center of the Federal University of Paraná (Campus III), located in Curitiba, Brazil. The findings indicate that the measured sound pressure levels exceed not only the limits specified by Brazil's environmental standards but also those established by the municipality of Curitiba for educational environments. The analysis of the noise frequency spectrum around the Polytechnic Center campus reveals a wide range of frequencies varying from 50 Hz up to, in some cases, 10000 Hz, 12500 Hz, 16000 Hz and 20000 Hz. This finding is one that causes concern, because a combination of high sound levels and high frequencies can interfere in the cognitive process of students and teachers, impairing the teaching and learning process.

An investigation of noise levels on dedicated bus lanes in the integrated bus rapid transit system (BRTS) of the city of Curitiba is described in Chapter 8. Equivalent sound pressure levels (L_{eq}) along the traffic lanes were measured and also predicted through computer simulations based on noise map calculations.

Chapter 9 highlights the concerns about noise levels in the modern world, which have worsened as a result of urbanization and industrialization. These factors have impaired the sound quality in urban areas due to the multiplicity of noise sources. This chapter describes the problem of noise pollution in São Paulo, one of the world's largest cities. One of the districts in the municipality of São Paulo, comprising an area of approximately 8 km^2, was selected for a noise assessment based on noise maps, and an evaluation of the effects of noise on the health of the population based on a household survey about noise-related annoyance and sleep disturbance. An analysis of the noise maps revealed high sound pressure levels caused by urban traffic, ranging, in some cases, from 80 to 85 dB(A). The percentage of people suffering from a high rate of sleep disorders (Ln indicator – % HSD) and people highly annoyed (Lden indicator - %HA) due to noise was considerably greater than that recommended by the World Health Organization. The problem of noise pollution should be considered a priority in environmental planning, in order to improve urban soundscapes and education on environmental health so as to increase people's well-being and quality of life.

Chapter 10 presents an assessment of noise levels on the Federal University of Paraná Jardim Botânico Campus II, based on sound measurements and calculated noise levels using noise mapping. This campus is surrounded by streets with intense vehicle traffic, which contributes to cause the noise levels to exceed the legal limits established for educational areas.

Buildings with multiple floors are exposed to external noise levels that vary according to the height of each floor above ground. These levels must be known in order to design the proper sound insulation for each floor. Chapter 11 proposes a methodology aided by three-dimensional acoustic mapping to design the sound insulation of building facades. The technique consists basically of three stages: creation of an acoustic map of the region and the buildings of interest, determination of the sound insulation requirements of each floor, and dimensioning of their exterior facade elements. The method is applied to a building of 152 meters with 44 floors, which is taken as an example. The results indicate that the floors of the building are exposed to four different ranges of sound pressure levels, and thus have different sound insulation requirements. Using this method, different types of windows are selected to meet the requirements of each floor, taking into account safety aspects in the dimensioning, without wasting resources.

Chapter 12 describes a study on noise pollution in downtown Campo Grande, the state capital of Mato Grosso do Sul, Brazil, which has a population of approximately 200,000. Two types of noise maps are created, one characterizing the "general situation" to identify the entire range of sound levels, and the other defining the "characteristics of the areas" to illustrate the sound levels that fall below or above the established limits. This dual strategy is very useful for the identification of acoustically polluted streets and areas. Lastly, several noise mitigation measures are suggested, and three new simulated scenarios are presented. However, despite the implementation of low-noise road surfaces for the existing streets and the elimination of heavy vehicles, which reduce the sound levels by 0-5 dB(A) at the facades of buildings along the streets, these noise mitigation measures do not suffice to fully solve the existing problem of noise pollution. It is therefore advisable to implement additional measures to effectively reduce urban noise in cases such as this one.

A rail traffic noise assessment in an urban setting is described in Chapter 13. Measurements were taken of noise levels generated by trains passing through residential neighborhoods with and without blowing their horns. Noise maps were also calculated showing noise pollution generated by the train traffic. The measurements indicated that the noise levels generated by the passage of the train with its horn blowing are extremely high. The noise generated by the train horn affects 750,000 of the 1.8 million inhabitants of the city under study. Therefore, urgent measures are needed to control and reduce these noise levels. In fact, we would do well to keep in mind the words of Fields and Walker (1982): "*Noise is rated as the most serious environmental nuisance caused by railways.*"

Chapter 14 analyzes the impact of environmental noise generated by a paper mill on its surroundings, based on equivalent noise level measurements and noise mapping. Noise maps are used to simulate noise control solutions at the noise sources. After simulating the effect of the adoption of noise control measures, new simulations of the noise levels reaching the town adjacent to the paper mill confirm the efficacy of the proposed noise control measures. Noise maps are helpful in investment planning because they allow for budgetary control, i.e., prioritization of the most critical actions that will actually be effective in controlling industrial noise that impacts surrounding communities.

Chapter 15 discusses a methodology for determining the contribution of environmental noise to the noise pollution generated by a factory, by comparing experimental measurements of environmental sound pressure levels against noise maps showing the propagation of industrial noise. An auto parts plant was chosen for a case study, and experimental measurements of sound pressure levels were taken at discrete points, called receivers, located along two rings around the plant. The noise measurements taken along the inner ring were entered into a software program in order to iteratively quantify the plant's most important noise sources. The program then generated noise propagation maps and simulated sound pressure levels at the receiver positions along the outer ring. These simulated sound pressure levels were then compared with the experimental noise measurements taken at the outer ring to ascertain the contribution of environmental noise sources to the noise emissions of the factory. The placement of partial barriers along some critically noisy walls was found to be effective in controlling the nighttime impact noise, preventing noise immission levels exceeding 60 dB(C) from reaching the neighborhoods surrounding the plant.

Any intervention in an urban environment that leads to variations in a determinant parameter or variable of the noise emission process should be assessed predictively and proactively in the medium and long term, in view of its possible effects on the environment where it is implemented. Hence, scientific tools must be developed to measure the impact of noise pollution in urban areas. Chapter 16 presents a prediction matrix for the assessment of traffic-related noise pollution. This matrix, which was created based on noise prediction maps, allows for the qualification and quantification of the global impact of environmental noise resulting from the implementation of a road construction project and its operation.

Chapter 17 describes the reactions to aircraft noise of people living in the proximities of a medium sized airport located in a densely populated urban area, based on a questionnaire distributed to people living or working near this airport to determine how they are affected by aircraft noise and environmental noise in general. The maximum equivalent sound pressure level, L_{Max}, generated during aircraft takeoffs exceeds 100 dB(A). Sound maps of the airport and its surroundings were calculated to evaluate the impact of environmental noise generated by the daily air traffic flow. One of the main complaints of the questionnaire's respondents was sleep disruption between 6 and 8 am, which is the period corresponding to the highest flow of airplane takeoffs and landings.

In addition to the substantial amount of research that has focused on human well-being, the impact of noise on wildlife has gained considerable scientific attention in recent years. Nevertheless, studies in South American countries are still scanty. To address this lack, chapter 18 of this book analyzes the possible disruption of the acoustic communication in birds caused by urban noise. The chapter begins with an overview of what is known on the subject, followed by acoustical data of both urban noise and birdsong measured in a city in southern Brazilian. The idea is to offer the reader a general introduction to the theme, as well as a preliminary assessment of how problematic these impacts can be nationwide. In addition, given that this research field is still incipient in Brazil, new investigations may lead to very different avenues of interest, of both theoretical and applied focus.

The topics presented and discussed in this book, considering the proper distance and relativity specific to each country, can help to solve and/or shed light on local problems that involve urban and industrial noise pollution.

This book should be of interest for use in theory and practice. We believe that numerous professionals, even those not specialized in noise control, will find it useful. The target audience of this book includes undergraduate and graduate students, as well as professionals working in the areas of environmental management of cities, of factories, in architecture, urban design, in environmental, mechanical and civil engineering, urban planning, health care professionals, etc.

The Editor gratefully acknowledges the German Government, through the German Academic Exchange Service – DAAD (Deutscher Akademischer Austauschdienst) and the Brazilian Government, through the National Council for Scientific and Technological Development – CNPq, for their financial support, which enabled the purchase of the sound level meters and software used in the studies described in this book. Special thanks go to CNPq, whose Grants Nos. 302738/2010-0 and 303786/2014-0 financed the translation of this book from Portuguese to English.

Last but not least, the Editor and all the other authors of this book express their sincere thanks to Ms. Beatrice Allain for her excellent work and dedication in translating all the chapters from Portuguese into English.

Full Professor Dr.-Ing. Paulo Henrique Trombetta Zannin
Curitiba
February 21, 2016

CONTENTS

In: Noise Pollution in Urban and Industrial Environments
Editor: Paulo Henrique Trombetta Zannin
ISBN: 978-1-63485-269-2

Chapter 1

ENVIRONMENTAL NOISE ASSESSMENT STANDARDS AND REGULATIONS

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ABSTRACT

This chapter discusses the standards for environmental noise assessment of the International Organization for Standardization, ISO. In addition to the standards: 1) ISO 1996-1 – Basic quantities and assessment procedure, and 2) ISO 1996-2 – Acquisition of data pertinent to land use, national and local standards are also presented and discussed. This chapter reviews noise map calculations and design, as well as the model for calculating road traffic noise contained in the ISO 9613-2 standard.

1. ENVIRONMENTAL NOISE

The ISO 1996-1 standard – Description, measurement and assessment of environmental noise, Part 1: Basic quantities and assessment procedure – defines the basic items to be used to describe noise in community environments and describes basic assessment procedures. It also specifies methods to assess exposure to several types of environmental noise.

The ISO 1996-1 standard provides adjustments for the assessment of noise levels from different sources, since the community's response to noise from different sources that produce the same sound pressure level may vary. The ISO 1996-1 standard describes settings

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for sounds that have different characteristics, and also indicates settings for nighttime, weekends and holidays. These settings can be added to measurements or predictions of the equivalent continuous sound pressure level. Table 1, adapted from ISO 1996-1, describes the recommended settings.

2. Measuring and Mapping Noise

The purpose of the ISO 1996-2 standard – Description and measurement of environmental noise, Part 2: Acquisition of data pertinent to land use – is to provide data acquisition methods that describe environmental noise.

The ISO 1996-2 specifies that for data acquisition, the geographical description of the area to be assessed must be considered; the major sources must be characterized; the situation of the receiver, such as location, occupation, use and characterization of the immediate surroundings, must be described; and weather conditions must be noted.

If there is tonal noise, the ISO 1996-2 standard recommends that: 1) If audible and noticeable when measured in the 1/3 octave band, add 5 to 6 dB; 2) If inaudible and perceptible only when measured in a narrow band, add 2 to 3 dB.

To adjust impulse noise, ISO 1996-2 recommends the following: 1) In the case of strong impulse noises such as explosions, add 11.7 dB to the measured environmental noise (L_{Aeq}); and 2) For normal impulse noises, add 3 dB to the measured environmental noise (L_{Aeq}).

Table 1. Sound pressure level recommended by the ISO 1996-1 standard

Characterization of the sound source	Specification of the sound source	Level adjustment according to the specification of the sound source[dB]
Noise source	Road traffic Aircraft Railway Industry	0 3 to 6 -3 to -6 0
Characteristics of the Noise source	Normal Impulse Noise Strongly Impulse Noise Tonal Noise	5 12 3 to 6
Time of day	Evening Nighttime Weekends Daytime (7:00h to 22:00h)	5 10 5

According to the ISO 1996-2 standard: 1) The average sound level can be determined from measurements, calculations, or both; 2) As for the measurement technique to be used, e.g., instrumentation, the number of microphone positions and the duration of the measurement depend on the type of source and receiver; 3) The instruments should preferably be of type 1 or at least type 2; 4) Measurements should be taken at the height of the receiver and at a distance of 1 to 2 meters from the façade; 5) The time interval should be chosen so that it covers all the variations of noise emission and transmission; and 6) The measurement