General Government and Health and Human Services Committee Meeting Agenda

April 14, 2026

6:00 p.m.

Hybrid In-Person and Virtual Meeting

304 E. Grand River Ave., Board Chambers, Howell, Michigan

Zoom Virtual Meeting ID: 399-700-0062 / Password: LCBOC

https://us02web.zoom.us/j/3997000062

Commissioners

Roger Deaton - Chairman, Wes Nakagiri - Vice Chairman, Frank Sample, Melvin Paunovich

A quorum of the Board of Commissioners may be in attendance at this meeting.

Pages

1. **Call Meeting to Order**
2. **Pledge of Allegiance to the Flag**
3. **Roll Call**
4. **Approval of Agenda**
5. **Call to the Public**

   Act 388 of 1976 offer; Act 267 of 1976
6. **Approval of Minutes**

   6.1 **Meeting Minutes dated: March 9, 2026** — 3
7. **Reports**

   7.1 **Health Advisory Committee** — 5

   Holly Austin, Health Advisory Committee Member

   7.2 **Health Department Accreditation**

   Matt Bolang, Health Officer
8. **Resolutions for Consideration**

   8.1 **Emergency Medical Services** — Amy Chapman — 219

   Resolution Authorizing an Agreement with Emergency Vehicles Plus to Provide a New Ambulance

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	Resolution Authorizing an Agreement with Bound Tree Medical to Provide Medical Supplies		

9. Adjournment

General Government and
Health and Human Services Committee
Meeting Minutes

March 9, 2026, 6:00 p.m.
Hybrid In-Person and Virtual Meeting
304 E. Grand River Ave., Board Chambers, Howell, Michigan
Zoom Virtual Meeting ID: 399-700-0062 / Password: LCBOC
https://us02web.zoom.us/j/3997000062

Members Present: Roger Deaton - Chairman, Wes Nakagiri - Vice-Chairman, Frank Sample, Melvin Paunovich

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1. Call Meeting to Order

The meeting was called to order by Committee Chair, Roger Deaton, at 6:00 p.m.

2. Pledge of Allegiance to the Flag

All rose for the Pledge of Allegiance to the Flag of the United States of America.

3. Roll Call

Roll call by the recording secretary indicated the presence of a quorum.

4. Approval of Agenda

Motion to approve the agenda as presented.

It was moved by F. Sample
Seconded by W. Nakagiri

Yes (4): R. Deaton, W. Nakagiri, F. Sample, and M. Paunovich; No (0): None; Absent (0): None.

Motion Carried (4-0-0)

5. Call to the Public: Act 388 of 1976 offer; Act 267 of 1976

The following individuals addressed the committee: Steve Williams - Marion Township.

6. Approval of Minutes

6.1 Meeting Minutes dated: February 9, 2026

Motion to approve the minutes as presented.

It was moved by W. Nakagiri
Seconded by F. Sample

Yes (4): R. Deaton, W. Nakagiri, F. Sample, and M. Paunovich; No (0): None; Absent (0): None.

Motion Carried (4-0-0)

7. Reports

None.

UNAPPROVED

8. Resolutions for Consideration

8.1 Board of Commissioners

Resolution from the Livingston County Board of Commissioners Recognizing and Celebrating the 250th Anniversary of the United States of America

Motion to recommend the resolution to the Board of Commissioners.

It was moved by: F. Sample
Seconded by: W. Nakagiri

Yes (4): R. Deaton, W. Nakagiri, F. Sample, and M. Paunovich; No (0): None; Absent (0): None.

Motion Carried (4-0-0)

8.2 County Clerk

Resolution Revising Vital Records, Expedited, and Marriage Waiver Fees

Motion to recommend the resolution to the Board of Commissioners.

It was moved by: W. Nakagiri
Seconded by: M. Paunovich

Yes (4): R. Deaton, W. Nakagiri, F. Sample, and M. Paunovich; No (0): None; Absent (0): None.

Motion Carried (4-0-0)

8.3 Emergency Medical Services

Resolution Approving the Emergency Medical Services Reorganization

Motion to recommend the resolution to the Board of Commissioners.

It was moved by: F. Sample
Seconded by: W. Nakagiri

Yes (4): R. Deaton, W. Nakagiri, F. Sample, and M. Paunovich; No (0): None; Absent (0): None.

Motion Carried (4-0-0)

9. Adjournment

Motion to adjourn the meeting at 6:08 p.m.

It was moved by F. Sample
Seconded by W. Nakagiri

Yes (4): R. Deaton, W. Nakagiri, F. Sample, and M. Paunovich; No (0): None; Absent (0): None.

Motion Carried (4-0-0)

Natalie Hunt, Recording Secretary

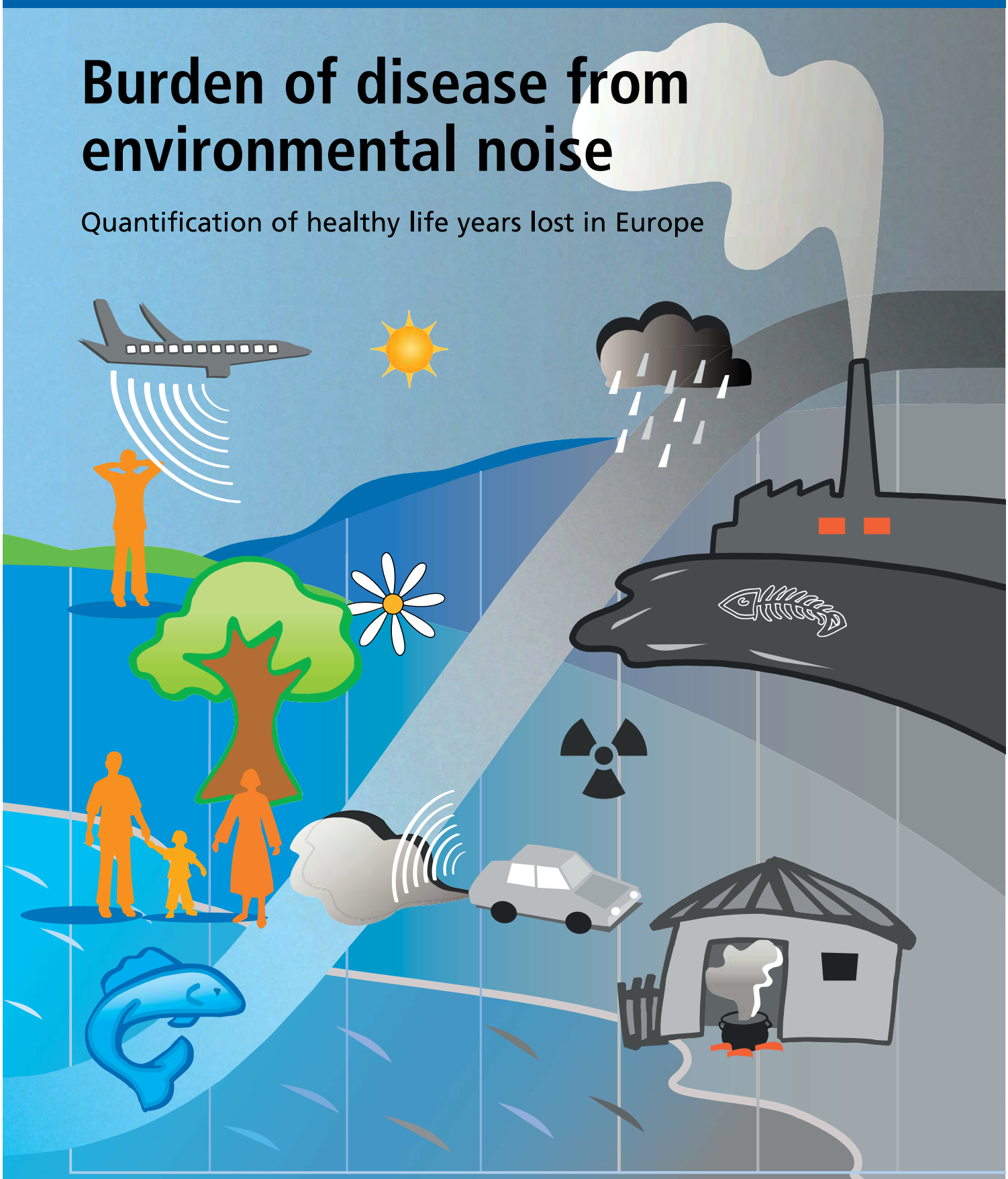
UNAPPROVED

World Health Organization
REGIONAL OFFICE FOR Europe

JRC
EUROPEAN COMMISSION

Burden of disease from environmental noise

Quantification of healthy life years lost in Europe



Burden of disease from environmental noise

Quantification of healthy life years lost in Europe





The WHO European Centre for Environment and Health, Bonn Office, WHO Regional Office for Europe coordinated the development of this publication.

KEYWORDS

NOISE – ADVERSE EFFECTS

ENVIRONMENTAL EXPOSURE

ENVIRONMENTAL HEALTH

RISK ASSESSMENT

PUBLIC HEALTH

HEALTH STATUS

EUROPE

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Edited by Frank Theakston, layout by Dagmar Bengs

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ABSTRACT

The health impacts of environmental noise are a growing concern among both the general public and policy-makers in Europe. This publication was prepared by experts in working groups convened by the WHO Regional Office for Europe to provide technical support to policy-makers and their advisers in the quantitative risk assessment of environmental noise, using evidence and data available in Europe. The chapters contain the summary of synthesized reviews of evidence on the relationship between environmental noise and specific health effects, including cardiovascular disease, cognitive impairment, sleep disturbance and tinnitus. A chapter on annoyance is also included. For each outcome, the environmental burden of disease methodology, based on exposure–response relationship, exposure distribution, background prevalence of disease and disability weights of the outcome, is applied to calculate the burden of disease in terms of disability-adjusted life-years (DALYs). With conservative assumptions applied to the calculation methods, it is estimated that DALYs lost from environmental noise are 61 000 years for ischaemic heart disease, 45 000 years for cognitive impairment of children, 903 000 years for sleep disturbance, 22 000 years for tinnitus and 587 000 years for annoyance in the European Union Member States and other western European countries. These results indicate that at least one million healthy life years are lost every year from traffic-related noise in the western part of Europe. Sleep disturbance and annoyance, mostly related to road traffic noise, comprise the main burden of environmental noise. Owing to a lack of exposure data in south-east Europe and the newly independent states, it was not possible to estimate the disease burden in the whole of the WHO European Region. The procedure of estimating burdens related to environmental noise exposure presented here can be used by international, national and local authorities as long as the assumptions, limitations and uncertainties reported in this publication are carefully taken into account.

LIST OF ACRONYMS AND ABBREVIATIONS

ADL	Activity of daily life
AF	Attributable fraction
AR	Attributable risk
CI	Confidence interval
CLAMES	Classification and Measurement System of Functional Health
DALY	Disability-adjusted life year
DEN	Day-evening-night equivalent level
DW	Disability weight
EBD	Environmental burden of disease
EEA	European Environment Agency
EEG	Electroencephalogram
EMG	Electromyogram
END	Environmental noise directive (2002/49/EC)
EOG	Electrooculogram
ETC LUSI	European Topic Centre on Land Use and Spatial Information
EU	European Union
EUR-A	WHO epidemiological subregion in Europe: Andorra, Austria, Belgium, Croatia, Cyprus, the Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, the Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland and the United Kingdom
GBD	Global burden of disease
HA	Highly annoyed people
HSD	Highly sleep disturbed people
ICD-9	International Statistical Classification of Diseases and Related Health Problems, ninth revision
ICD-10	International Statistical Classification of Diseases and Related Health Problems, tenth revision
$L_{Aeq,th}$ or $L_{eq,th}$	A-weighted equivalent sound pressure level over t hours
L_{den}	Day-evening-night equivalent sound level
L_{dn}	Day-night equivalent sound level
L_{night}	Night equivalent sound level
NIHL	Noise-induced hearing loss
NOISE	Noise Observation and Information Service for Europe
NYHA	New York Heart Association
OR	Odds ratio
OSAS	Obstructive sleep apnea syndrome
PAR	Population attributable risk
PSG	Polysomnography
REM	Rapid eye movement
SWS	Slow wave sleep
WHO	World Health Organization
YLD	Years lost due to disability
YLL	Years of life lost

FOREWORD

Public health experts agree that environmental risks constitute 25% of the burden of disease. Widespread exposure to environmental noise from road, rail, airports and industrial sites contributes to this burden. One in three individuals is annoyed during the daytime and one in five has disturbed sleep at night because of traffic noise. Epidemiological evidence indicates that those chronically exposed to high levels of environmental noise have an increased risk of cardiovascular diseases such as myocardial infarction. Thus, noise pollution is considered not only an environmental nuisance but also a threat to public health.

In 1999, WHO summarized the scientific evidence on the harmful impacts of noise on health and made recommendations on guideline values to protect public health in its *Guidelines for community noise*. The European Union (EU) enacted a directive on the management of environmental noise in 2002 and, accordingly, most EU Member States have produced strategic noise maps and action plans on environmental noise. The WHO European Centre for Environment and Health, Bonn Office, with the financial support of the European Commission, developed *Night noise guidelines for Europe* and provided expertise and scientific advice to policy-makers for future legislation in the area of night noise control and surveillance. Furthermore, a series of projects addressing the health burden of noise was implemented by the WHO Regional Office for Europe in 2005–2009.

At the Fifth Ministerial Conference on Environment and Health, in Parma, Italy in March 2010, the Member States urged WHO to develop suitable guidelines on environmental noise policy. This publication, developed by WHO with the support of the Joint Research Centre of the European Commission, responds to that request by assisting policy-makers in quantifying the health impacts of environmental noise. The evidence-base on burden of disease presented here will inform the new European health policy, Health 2020, which is being prepared by the WHO Regional Office for Europe for endorsement by the Member States in 2012.

The review of the scientific evidence supporting exposure–response relationships and case studies in calculating burden of disease was performed by a working group composed of outstanding scientists. The contents of this publication have been peer reviewed. The Regional Office is thankful to those who contributed to its development and presentation of this document and believe that this work will facilitate the implementation of the Parma Declaration and contribute to improving the health of the citizens of Europe.

Dr Guénaël R. M. Rodier
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EXECUTIVE SUMMARY

Introduction

Urbanization, economic growth and motorized transport are some of the driving forces for environmental noise exposure and health effects. Environmental noise is defined as noise emitted from all sources except industrial workplaces. The EU Directive on the management of environmental noise (END) adds industrial sites as sources of environmental noise.

To estimate the environmental burden of disease (EBD) due to environmental noise, a quantitative risk assessment approach has to be used. Risk assessment refers to the identification of hazards, the assessment of population exposure and the determination of appropriate exposure–response relationships. The EBD is expressed as disability-adjusted life years (DALYs). DALYs are the sum of the potential years of life lost due to premature death and the equivalent years of "healthy" life lost by virtue of being in states of poor health or disability.

WHO estimated the global burden of disease (GBD) in the second half of the 1990s. The environmental burden of disease due to environmental factors such as lead, outdoor and indoor air pollution and water and sanitation was first published in 2002. The WHO European Centre for Environment and Health, Bonn Office, convened meetings of a working group to estimate the EBD due to exposure to environmental noise. The conclusions and recommendations of these meetings were synthesized to develop this guidance publication on risk assessment of environmental noise using evidence and data available in Europe.

The target audience for this publication is primarily policy-makers, their technical advisers and staff from supporting agencies, and other stakeholders who need to estimate the effects of environmental noise. It brings together evidence-based information on health effects of environmental noise and provides exemplary guidance on how to quantify these effects. In summary, the aims of the publication are to provide:

- guidance on the procedure for the health risk assessment of environmental noise;
- reviews of evidence on the relationship between environmental noise and health effects;
- exemplary estimates of the burden of the health impacts of environmental noise; and
- a discussion of the uncertainties and limitations of the EBD procedure.

The health end-points of environmental noise considered by the working group for the EBD estimation included cardiovascular disease, cognitive impairment, sleep disturbance, tinnitus and annoyance. Although annoyance was not addressed as a health outcome of the GBD project, it was selected for the EBD estimation in consideration of WHO's broad definition of health.

Exposure assessment

Assessment of exposure to noise requires consideration of many factors, including:

- the measured or calculated/predicted exposure, described in terms of an appropriate noise metric; and
- the distribution of the exposure of the population to noise.

Population noise exposure in this publication is based on the noise mapping mandated by the END, using the annual average metrics of L_{den} (day-evening-night equivalent level) and L_{night} (night equivalent level) proposed in the Directive.

$$L_{den} = 10 \cdot \lg \frac{1}{24} \left(12 \cdot 10^{\frac{L_{day}}{10}} + 4 \cdot 10^{\frac{L_{evening}+5}{10}} + 8 \cdot 10^{\frac{L_{night}+10}{10}} \right)$$

with $L_{day} = L_{eq,12h}$, $L_{evening} = L_{eq,4h}$

and $L_{night} = L_{eq,8h}$

with $L_{Aeq,th}$ the A-weighted equivalent sound pressure level over t hours outside at the most exposed facade.

Methods of environmental burden of disease assessment

The burden of disease is expressed in DALYs in the general population through the equation

$$DALY = YLL + YLD$$

In this equation, YLL is the number of "years of life lost" calculated by

$$YLL = \sum_i (N_i^m \cdot L_i^m + N_i^f \cdot L_i^f)$$

where $N_i^m (N_i^f)$ is the number of deaths of males (females) in age group i multiplied by the standard life expectancy $L_i^m (L_i^f)$ of males (females) at the age at which death occurs. YLD is the number of "years lived with disability" estimated by the equation

$$YLD = I \cdot DW \cdot D$$

where I is the number of incident cases multiplied by a disability weight (DW) and an average duration D of disability in years. DW is associated with each health condition and lies on a scale between 0 (indicating the health condition is equivalent to full health) and 1 (indicating the health condition is equivalent to death).

The EBD of each end-point was estimated using the following information and data:

- the distribution of environmental noise exposure within the population;
- the exposure–response relationships for the particular health end-point;
- the population-attributable fraction due to environmental noise exposure;
- a population-based estimate of the incidence or prevalence of the health end-point from surveys or routinely reported statistics; and
- the value of DW for each health end-point.

Cardiovascular diseases

The evidence from epidemiological studies on the association between exposure to road traffic and aircraft noise and hypertension and ischaemic heart disease has increased during recent years. Road traffic noise has been shown to increase the risk of ischaemic heart disease, including myocardial infarction. Both road traffic noise and aircraft noise increase the risk of high blood pressure. Very few studies exist regarding the cardiovascular effects of exposure to rail traffic noise.

Exposure–response relationships

Numerical meta-analyses were carried out assessing exposure–response relationships between community noise and cardiovascular risk. A polynomial function was fitted through the data points from the analytic studies within the noise range from 55 to 80 dB(A):

$$OR = 1.63 - 6.13 \cdot 10^{-4} \cdot L^2_{day,16h} + 7.36 \cdot 10^{-6} \cdot L^3_{day,16h}$$

Estimated burden in western Europe

Based on the exposure data from the noise maps of EU Member States, it is estimated that the burden of disease from environmental noise is approximately 61 000 years for ischaemic heart disease in high-income European countries.

Cognitive impairment in children

The case definition of noise-related cognitive impairment is: The Reduction in cognitive ability in school-age children that occurs while the noise exposure persists and will persist for some time after the cessation of the noise exposure. The extent to which noise impairs cognition, particularly in children, has been studied with both experimental and epidemiological studies.

Hypothetical exposure–response relationship

Based on available evidence, a hypothetical exposure–response relationship between noise level (L_{dn}) and risk of cognitive impairment was formulated: all of the noise-exposed children were cognitively affected at a level as high as 95 dB(A) L_{dn}, and no children were affected at a relatively low level, such as 50 dB(A) L_{dn}. A linear relationship in the range of these two limits was assumed as a basis for a conservative approximation of YLD.

Estimated burden in western Europe

If one extrapolates the exposure distribution and population structure of Sweden to western European countries, the estimated DALYs for the EUR-A countries are 45 000 years for children aged 7–19 years.

Sleep disturbance

Sleep disturbance can be measured electro-physiologically or by self-reporting in epidemiological studies using survey questionnaires. In epidemiological studies, "self-reported sleep disturbance" is the most easily measurable outcome indicator, because electro-physiological measurements are costly and difficult to carry out on large samples and may themselves influence sleep.

Exposure–response relationship

The percentage of "highly sleep disturbed" persons (*HSD*) as a function L_{night} was calculated with the equation:

$$HSD[\%] = 20.8 - 1.05 \cdot L_{night} + 0.01486 \cdot L^2_{night}$$

Estimated burden in western Europe

Conservative estimates applied to the calculation using exposure data from noise maps give a total of 903 000 DALYs lost from noise-induced sleep disturbance for the EU population living in towns of > 50 000 inhabitants.

Tinnitus

Tinnitus is defined as the sensation of sound in the absence of an external sound source. Tinnitus caused by excessive noise exposure has long been described; 50% to 90% of patients with chronic noise trauma report tinnitus. In some people, tinnitus can cause sleep disturbance, cognitive effects, anxiety, psychological distress, depression, communication problems, frustration, irritability, tension, inability to work, reduced efficiency and restricted participation in social life.

Exposure–response relationship

For tinnitus due to environmental noise, exposure to social/leisure noise such as personal music players, gun shooting events, music concerts, sporting events and events using firecrackers is most relevant for western Europe and North American countries. Population-based studies associating exposure to leisure noise with the risk of tinnitus are rare. From studies on people with tinnitus, a mean prevalence was calculated of those with slight, moderate and severe tinnitus.

Estimated burden in western Europe

Applying the mean prevalence data to the EUR-A population of 344 131 386 people aged 15 years and over in 2001, the prevalence of slight, moderate and severe tinnitus was estimated. DW of 0.01 was chosen for slight tinnitus and 0.11 for moderate and severe tinnitus. An educated guess of 0.03 was made for the population-attributable fraction of tinnitus caused by environmental noise exposure. DALYs for noise-induced tinnitus were estimated to be 22 000 years for the EUR-A adult population.

Annoyance

WHO defines health as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. Therefore, a high level of annoyance caused by environmental noise should be considered as one of the environmental health burdens. Standardized questionnaires are used to assess noise-induced annoyance at the population level. The percentage of highly annoyed is the most widely used prevalence indicator for annoyance in a population.

Exposure–response relationship

The percentage of "highly annoyed" persons (HA) due to road traffic noise was calculated with the equation:

$$HA[\%] = 0.5118 \cdot (L_{den} - 42) - 1.436 \cdot 10^{-2} \cdot (L_{den} - 42)^2 + 9.868 \cdot 10^{-4} \cdot (L_{den} - 42)^3$$

Estimated burden in western Europe

Conservative estimates applied to the calculation using exposure data from noise maps give a total of 587 000 DALYs lost from noise-induced annoyance for the EU population living in towns of > 50 000 inhabitants.

Conclusions

There is sufficient evidence from large-scale epidemiological studies linking the population's exposure to environmental noise with adverse health effects. Therefore, environmental noise should be considered not only as a cause of nuisance but also a concern for public health and environmental health.

This publication was produced by the working group convened by the Regional Office to provide policy-makers and their advisers in national and local authorities with exemplary practices of using WHO methods of quantifying the burden of disease for selected health end-points. Because of the uncertainties in exposure assessment, exposure–response relationships and health statistics, conservative assumptions were made as far as possible.

It is estimated that DALYs lost from environmental noise in the western European countries are 61 000 years for ischaemic heart disease, 45 000 years for cognitive impairment of children, 903 000 years for sleep disturbance, 22 000 years for tinnitus and 587 000 years for annoyance. If all of these are considered together, the range of burden would be 1.0–1.6 million DALYs.[1] This means that at least 1 million healthy life years are lost every year from traffic-related noise in the western European countries, including the EU Member States. Sleep disturbance and annoyance related to road traffic noise constitute most of the burden of environmental noise in western Europe. Owing to a lack of exposure data in south-east Europe and the newly independent states, it was not possible to estimate the disease burden in the whole of the WHO European Region.

The procedure of estimating the burden of selected health end-points related to environmental noise exposure presented here can be used by international, national and local authorities as long as the assumptions, limitations and uncertainties reported in this publication are carefully taken into account. This publication also provides an updated review of evidence for the future development of suitable guidelines on noise by WHO, as its urged by Member States in the Parma Declaration adopted at the Fifth Ministerial Conference on Environment and Health in 2010.

1 The extent to which years lost from different effects are additive across different outcomes is unclear. The different health outcomes might have synergistic rather than antagonistic effects when the combined effects occur in a person. Therefore, it would be a prudent approach to add the DALYs of different outcomes without considering synergistic effects.

1. INTRODUCTION

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Noise is a major environmental issue, particularly in urban areas, affecting a large number of people. To date, most assessments of the problem of environmental noise have been based on the annoyance it causes to humans, or the extent to which it disturbs various human activities. Assessment of health outcomes potentially related to noise exposure has so far been limited *(1)*.

According to preliminary results from the Environmental Burden of Disease (EBD) in Europe project in six European countries *(2)* reported at the WHO Ministerial Conference held in Parma in March 2010 *(3)*, traffic noise was ranked second among the selected environmental stressors evaluated in terms of their public health impact in six European countries. Further, the trend is that noise exposure is increasing in Europe compared to other stressors (e.g. exposures to second hand smoke, dioxins and benzene), which are declining.

In its *Guidelines for community noise (4)*, the WHO defined environmental noise as "noise emitted from all sources except for noise at the industrial workplace". European Union (EU) Directive 2002/49/EC on the management of environmental noise *(5)* defines environmental noise as "unwanted or harmful outdoor sound created by human activities, including noise from road, rail, airports and from industrial sites". The terms community, residential or domestic noise have also been applied to environmental noise, although these terms are not necessarily used consistently. This publication examines health risk assessment for these sources of environmental noise.

In recent years, evidence has accumulated regarding the health effects of environmental noise. For example, well-designed, powerful epidemiological studies have found cardiovascular diseases to be consistently associated with exposure to environmental noise. In order to inform policy and to develop management strategies and action plans for noise control, national and local governments need to understand and consider this new evidence on the health impacts of environmental noise. For this purpose, there should be a risk assessment to evaluate the extent of the potential health effects.

The process of risk assessment of environmental noise requires knowing:

- the nature of the health effects of noise;
- the levels of exposure at which health effects begin to occur and how the extent of the effect changes with increasing noise levels; and
- the number of people exposed to these hazardous levels of noise.

Quantitative risk assessments based on EBD methodology have been developed and used by WHO to help the Member States quantify several environment-related

health problems *(6)*. The EBD is usually expressed as the number of deaths and the metric disability-adjusted life year (DALY), which combines the concepts of (*a*) potential years of life lost due to premature death and (*b*) equivalent years of "healthy" life lost by virtue of being in a state of poor health or disability. An estimate for burden of disease due to noise exposure has been made in Germany and other European countries as well as by nongovernmental organizations.

In recent years, the Bonn Office of the WHO European Centre for Environment and Health has organized several meetings of experts to examine the current state of knowledge and to further develop approaches for quantifying the effect of noise on health. The outcomes of these meetings are summarized in this publication.

Aims of this publication

The target audience for this publication is primarily policy-makers and their technical advisers who need to evaluate the issue of environmental noise in their jurisdictions. Publication brings together information on the evidence base on the health effects of environmental noise and provides guidance on how to quantify these effects. It aims to provide:

- synthesized reviews of evidence on the relationship between environmental noise and health effects in order to inform policy-makers and the public about the health impacts of exposure to noise;

- exemplary estimates of the health impacts of environmental noise based on exposure–response relationships, exposure distribution, population-attributable fraction, background prevalence of disease and disability weights; and

- guidance on the process of health risk assessment of environmental noise consistent with the EBD methodology of WHO.

This publication has been prepared with a European focus in terms of policy, available data and legislation. Nevertheless, as long as the assumptions, limitations and uncertainties described in the various chapters are carefully taken into account, the processes of risk assessment illustrated here can also be applied outside Europe.

Risk assessment

The objective of risk assessment is to support decision-making by assessing risks of adverse effects on human health and the environment from chemicals, physical factors and other environmental stresses. There are several different frameworks available to guide risk assessment. The one used in this publication is the framework outlined in the WHO guideline publication *Evaluation and use of epidemiological evidence for health risk assessment (7)*. Other frameworks are used by other organizations *(8,9)*.

The WHO model splits health risk assessment into two activities: health hazard characterization and health impact assessment *(7)*. The results of risk assessment can be fed into risk management, including regulatory options. This publication focuses on health impact assessment aspect of risk assessment; the management of risk from environmental noise is not discussed here.

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The process of risk assessment involves the synthesis and interpretation of the evidence from the available data, often across scientific disciplines. There are several limitations, challenges and uncertainties at each step. These include the availability and consistency of the evidence, chance and bias affecting the validity of studies, and the transparency, reproducibility and comprehensiveness of reviews.

Hazard identification (identification of effects of noise)

After reviewing the available scientific evidence supporting causal association, the following outcomes were selected for inclusion:

- cardiovascular disease
- cognitive impairment
- sleep disturbance
- tinnitus
- annoyance.

While a chapter on hearing impairment due to environmental noise would have been useful, it was found that the data available on the prevalence of leisure noise and the relationship between environmental noise and hearing impairment were not adequate for burden of disease calculations.

On the other hand, it was thought to be important to include a chapter on the effect of environmental noise on annoyance. Although annoyance cannot be classified as a "health effect", it does affect the well-being of many people and therefore may be considered to fall within the WHO definition of health as being "a state of complete physical, mental and social well-being". More importantly, however, it is the effect of noise that most lay people are aware of and concerned about. It was believed that many jurisdictions would be interested in estimating the effects of noise on this outcome.

Exposure assessment

There are many different sources of environmental noise to which people are exposed including, for example:

- transport (road traffic, rail traffic, air traffic);
- construction and industry;
- community sources (neighbours, radio, television, bars and restaurants); and
- social and leisure sources (portable music players, fireworks, toys, rock concerts, firearms, snowmobiles, etc.).

Noise from all sources may be relevant to the assessment of risk, and hence it may be appropriate to assess the exposure of the population of interest to all of these sources. In practice, it is almost impossible to consider exposure to all sources in the risk assessment, because some exposures are difficult to estimate at the population level (for example, leisure noise through attending music concerts or listening to personal music devices). By contrast, considerable work has been done on assessing the exposure of populations to noise sources such as air traffic and road traffic.

Assessment of exposure to noise requires consideration of many factors, including:

- measured exposure or calculated/predicted exposure
- choice of noise indicator
- population distribution
- time-activity patterns of the exposed population
- combined exposures to multiple sources of noise.

The exposure of the population of interest to the noise source can be obtained by measurement or by using models that calculate noise exposure based on information about the source and on information about sound propagation conditions from source to receiver. Such calculation models can also be used to predict levels of noise exposure for some time in the future based on estimated changes in noise sources. Best-practice methods should be adopted for measurement or for calculation in the assessment of exposure, with a full understanding of the assumptions, limitations and potential errors associated with any approach to measurement or estimation. For example, a common approach to assessing the exposure of people to transport noise is to use, as a proxy, the exposure of the most exposed side of the dwelling in which they live. This may not always be a good approximation, however, because the rooms in which people spend most time may not be on the most exposed side of the dwelling.

Noise exposure mapping is a commonly adopted step in the process of estimating the noise exposure of a population. EU Directive 2002/49/EC on the management of environmental noise *(5)* mandated all EU Member States to produce strategic noise maps based on harmonized indicators by 2008 (see Box 1.1).

Box 1.1. EU Directive 2002/49/EC on the management of environmental noise

Noise has high priority on lists of environmental issues in Europe and noise reduction has increasingly become a focus for EU legislation and management. From the 1970s, successive directives have laid down specific noise emission limits for most road vehicles and for many types of outdoor equipment. Despite this increasingly stringent control of emissions, however, and despite the considerable effort and progress made in controlling noise from industry, there has been little improvement in the levels of noise exposure of people across Europe. The European Commission's 1996 Green Paper on future noise policy *(11)* marked the start of an extended "knowledge based" approach to the problem of noise, with a special emphasis on assessing and then managing the exposure of the population to environmental noise.

The European Commission developed a new framework for noise policy based on shared responsibility between the EU and national and local governments. It included a comprehensive set of measures to improve the accuracy and standardization of data to help improve the coherency of different actions:

- the creation of a Noise Expert Network *(12)*, whose mission is to assist the Commission in the development of its noise policy;

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- EU Directive 2002/49/EC on the management of environmental noise *(5)*; and

- the follow-up and further development of existing EU legislation relating to sources of noise such as motor vehicles, aircraft and railway rolling stock, and the provision of financial support to noise-related studies and research projects.

The European Parliament and Council adopted Directive 2002/49/EC of 25 June 2002, whose main aim is to provide a common basis for tackling noise problems across the EU. The underlying principles of the Directive are similar to those for other environment policy directives:

- monitoring the environmental problem by requiring competent authorities in Member States to produce strategic noise maps for major roads, railways, civil airports and urban agglomerations, based on harmonized noise indicators;

- informing and consulting the public about noise exposure, its effects and the measures considered to address noise, in line with the principles of the Aarhus Convention *(13)*;

- addressing local noise issues by requiring competent authorities to draw up action plans to reduce noise where necessary and maintain environmental noise quality where it is good (the Directive does not set any limit value nor does it prescribe the measures to be used in the action plans, which remain at the discretion of the competent authorities); and

- developing a long-term EU strategy, including objectives to reduce the number of people affected by noise and providing a framework for developing existing EU policy on noise reduction from sources.

Detailed information is available on the authorities responsible for implementing the Directive in Member States and on the agglomerations, major roads, railways and airports to be covered by the noise maps and action plans.

Exposure assessment requires specification of the noise metric that is to be utilized. There is a wide variety of noise indicators and extensive discussion of these can be found in the WHO *Guidelines for community noise (4)*. This includes such matters as the type of physical scale and the period of the day over which exposure is to be integrated: for example, "night", "evening" or "day".

The EU has adopted harmonized noise metrics across all of its Member States, suggesting L_{den} (day-evening-night equivalent level) as an appropriate metric to assess annoyance and L_{night} (night equivalent level) as a metric to assess sleep disturbance *(5)*. While noise limits are set individually by each EU Member State, these suggested metrics are to be used for strategic mapping of exposure in all countries. They are common across all transport sources and other sources of environmental noise. Definitions of these metrics in Directive 2002/49/EC are paraphrased in Box 1.2 below. Strategic noise maps using these harmonized noise metrics are to be used throughout Europe to assess the number of people exposed to different levels of noise. This information on population exposure can be used in the risk assessment process for environmental noise. Directive 2002/49/EC also allows the use of supplementary noise metrics (other than L_{den} and L_{night}) to monitor or control special noise situations.

A key consideration is that risk assessment cannot be carried out (using an exposure-specific approach) unless both the exposure assessment and the exposure–response relationship utilize the matching noise indicators. This becomes an issue when there is evidence that the best relationship between a particular health effect and exposure may be based on one indicator, yet data on exposure are only available based on another. While the work required by Directive 2002/49/EC will increase the availability of exposure assessments using the harmonized noise indicators, available exposure–response relationships may be reported using other indicators. These matters are discussed within each of the chapters on the various health outcomes. Exposure–response relationships reported may utilize different noise indicators because the meta-analyses in which these relationships were derived relied on studies using other noise indicators, or because there is evidence that the relationship between a particular health outcome and noise exposure is better described using a different noise indicator.

The quality of exposure data is critical to the accuracy of risk assessment. Some of the difficulties in measuring noise and preparing noise maps are outlined in a good practice guide *(14)*. They include: coverage of all relevant sources; inaccuracies in the process of linking people to noise levels and thus obtaining exposure distributions; and accounting for the presence of a quiet side or special sound insulation of a house, in particular for effects related to sleeping.

Box 1.2. Harmonized noise indicators in EU Directive 2002/49/EC

The day-evening-night level L_{den} in decibels is defined by:

$$L_{den} = 10 \cdot \lg \frac{1}{24} \cdot \left(12 \cdot 10^{\frac{L_{day}}{10}} + 4 \cdot 10^{\frac{L_{evening}+5}{10}} + 8 \cdot 10^{\frac{L_{night}+10}{10}} \right)$$

- L_{day}, $L_{evening}$ and L_{night} are the A-weighted 12, 4, 8 hours average sound levels, respectively, as defined in ISO 1996-2:1987 *(15)*.
- The day is 12 hours, the evening 4 hours and the night 8 hours. Member States may shorten the evening period by 1 or 2 hours and lengthen the day and/or the night period accordingly (same for all the sources).
- The start of the day (and consequently the start of the evening and the start of the night) shall be chosen by the Member State (same for all sources); the default values are 07:00–19:00, 19:00–23:00 and 23:00–07:00 local time.
- The incident sound is considered, which means that no account is taken of the sound that is reflected at the facade of the dwelling under consideration.

The nighttime noise indicator L_{night} is the A-weighted long-term average sound level.

- The night is 8 hours as defined above.

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Supplementary noise indicators. In some cases, in addition to L_{den} and L_{night}, and where appropriate L_{day} and $L_{evening}$, it may be advantageous to use special noise indicators and related limit values. Some examples (consult Directive 2002/49/EC for full advice) are:

- a very low average number of noise events in one or more of the periods (for example, less than one noise event an hour); a noise event could be defined as a noise that lasts less than five minutes, such as the noise from a passing train or aircraft;
- strong low-frequency content of the noise; and
- L_{Amax} or SEL (sound exposure level) for night period protection in the case of noise peaks.

Environmental burden of disease assessment

A detailed introduction to the calculation of EBD is available elsewhere *(16,17)*. In this section, we describe the main methods used to calculate EBD that are applied in the following chapters on each health outcome of environmental noise, and discuss some of the strengths and weaknesses of each approach.

In general, the number of deaths and cases of each of the outcomes is estimated in the initial process of EBD calculation. The burden of disease is expressed in deaths and DALYs. The DALY combines in one measure the time lived with disability (YLD) and the time lost due to premature mortality (YLL) in the general population:

$$DALY = YLL + YLD$$

The YLD is the number of incident cases (I) multiplied by a disability weight (DW) and an average duration of disability in years (L):

$$YLD = I \cdot DW \cdot L$$

The YLL essentially corresponds to the number of deaths (N) multiplied by the standard life expectancy at the age at which death occurs (L):

$$YLL = N \cdot L$$

These simple formulae can be further adjusted by discounting for the timing of the health effect (now or in the future) and by the relative value of a year of life lived at different ages using different assumptions (age weighting).

The approach to estimating total disease burden can be summarized in the following steps: (*a*) estimating the exposure distribution in a population; (*b*) selecting one or more appropriate relative risk estimates from the literature, generally from a recent meta-analysis; and (*c*) estimating the population-attributable fraction with the formula for population-attributable fraction. This is referred to in this volume as the exposure-based approach. In certain instances, the number of cases is also directly estimated on the basis of the exposure (outcome-based approach).

Exposure-based approach

This approach uses the distribution of noise exposure within the study population to estimate the fraction of disease in the population that is attributable to noise. This is then applied to the disease estimates. This approach requires the measurement or calculation of:

- the distribution of the exposure to environmental noise within the population (prevalence of noise exposure);
- the exposure–response relationship for the particular outcome;
- a population-based estimate of the incidence or prevalence of the outcome from surveys or routinely reported statistics; and
- a value of DW for each health outcome.

Prevalence of noise exposure

Estimates are required of the distribution of the exposure in the population of interest using the chosen noise metric.

Exposure–response relationship

Exposure–response relationships are usually obtained from epidemiological studies. The validity of any exposure–response relationship depends on the quality of the studies used to derive it, the choice of studies used and the modelling process used to pool the results. It is therefore very important that the process to derive the exposure–response relationships is well defined. In some cases, very well-designed studies can provide this information. In other cases, it is necessary to undertake a meta-analysis to combine a number of different studies. According to the WHO guidelines *(4)*, the process of meta-analysis should include, as a minimum:

- a systematic review of the available epidemiological information on exposure–response relationships;
- an inventory of studies that provide quantitative information on exposure or that allow linkage to such information;
- additional selection of studies according to clear inclusion criteria; and
- a meta-analysis of published results or pooling of original data.

The exposure–response relationship may be reported as a regression formula or as a relative risk measure for a given change in noise (or comparing noise-exposed to noise-unexposed). Important issues to consider in the meta-analysis are:

- the quality of studies that have been used in the meta-analysis and the selection criteria used;
- the completeness of the search for studies;
- the quality of the assessment of noise exposure;
- the temporality of the noise exposure (for example, nighttime noise exposure is relevant for sleep disturbance, while daytime noise exposure is important for annoyance and cognitive impairment); and
- the relevance of the published studies to the population for which the risk assessment is being carried out.

In addition, it may be necessary to extrapolate relationships beyond the range of exposure observed in the available epidemiological studies. The arguments for the validity of such an extrapolation must be stated.

Incidence (or prevalence) of outcome

The definition of health outcome in the exposure–response relationship should be consistently used when the incidence data are collected. Some outcomes are easily obtained from national health statistics. For example, deaths from cardiovascular disease in a population per year are routinely collected in most developed countries.

For other outcomes, such routine data may not be available and in these cases prevalence or incidence of outcomes may need to be determined by surveys of the population. The accuracy of the estimates of these outcomes depends on the questions used for each individual survey. Standardized and validated questionnaires are recommended. For example, asking people how often they take medication to overcome sleeping difficulties may differ according to the availability of medication and the definition of sleeping difficulties implicit in the question. The timing of the outcome is important, either reflecting lifetime prevalence ("Have you ever had ...?"), point prevalence ("Do you currently have ...?") or incidence ("Since the last survey have you developed new ...?"). Depending on the condition, severity may be important as different severities of the outcome may have different DWs (e.g. mild, moderate or severe hearing loss).

Attributable fraction

The attributable fraction is the proportion of disease in the population that is estimated to be caused by noise. The accuracy of the fraction of the outcome attributable to environmental noise may also be difficult to specify. If the distribution of exposure and the exposure–response relationship are known, the population-attributable risk percentage can be estimated for a population (see above). The following formulae can be used to calculate the attributable risk percentage (AR%), the population-attributable risk percentage (PAR%), and the population-attributable risk (PAR) for each noise category *(16)*:

$AR\% = (RR-1) / RR \cdot 100\ [\%]$

$PAR\% = P_e/100 \cdot (RR-1) / (P_e/100 \cdot (RR-1) + 1) \cdot 100\ [\%]$

$PAR = PAR\% / 100 \cdot N_d$

RR = relative risk (odds ratios are estimates of the relative risk)

P_e = percentage of the population exposed [%]

N_d = number of subjects with disease (disease occurrence).

A more generalized formula for the calculation of the population-attributable fraction (PAF) that better accounts for multiple comparisons for large relative risks may also be used:

$PAF = \{\Sigma(P_i \cdot RR_i) - 1\} / \Sigma (P_i \cdot RR_i)\}$

P_i = proportion of the population in exposure category i

RR_i = relative risk at exposure category i compared to reference level

$\Sigma P_i = 1$

$PAR = PAF \cdot N_d$

Disability weight

DWs allow non-fatal health states and deaths to be measured under a common unit *(15)*. DWs quantify time lived in various health states to be valued and quantified on a scale that takes account of societal preferences. DWs that are commonly used for calculating DALYs are measured on a scale of 0–1, where 1 represents death and 0 represents ideal health.

The values of DWs for various disease states have been the subject of considerable discussion and work. They are generally derived from expert panels. This work has been documented extensively *(17)* and will not be summarized further here. WHO has a reasonably comprehensive list of DWs *(17)* and these are recommended for use. If there is no appropriate DW, then an expert committee may be asked to find an appropriate DW by analogy with other known DWs.

Advantages and disadvantages of this method

The methods described above are the most common approach used in health risk assessments because the methodology has been established and accepted in comparative risk analysis of WHO's EBD projects *(16)*. They provide standardized estimates of the health risk due to noise that may be understood by workers in the field. However, as described above, these methods require detailed data on noise exposure, the outcome and the exposure–response relationship. Such data are not always easy to obtain and often have significant limitations. For example, the exposure–response relationships may be based on extrapolation from a small number of studies with few subjects and perhaps even a measure of noise exposure that is not available on a population basis. This means that the estimates usually suffer from a considerable degree of uncertainty. This uncertainty is very difficult to quantify, although it is sometimes possible to provide low and high limits using sensitivity analyses *(17)*.

Outcome-based approach

For some noise-related outcomes, such as sleep disturbance and tinnitus, it is possible to estimate the burden directly through national or international surveys. This approach requires:

- an estimate of the prevalence of the outcome attributable to environmental noise; and
- a value of DW corresponding to this outcome.

The choice of questions in the survey needs to be carefully considered so as to be able to differentiate various severities of outcome and be compatible with the DWs. When the data on outcomes are not specific to environmental noise, attributable fractions should be applied to the data. When information on population exposure and/or the exposure–response relationship is not known, expert opinion may be

sought on what proportion of cases of an outcome is due to environmental noise. This approach was used for the chapter for tinnitus in this report, because exposure data on leisure noise and exposure–response relationships are not available for tinnitus.

The number of cases can then be multiplied by the DW to obtain the DALYs. When using this method, the attribution of the cause of the outcome tends to be more subjective than in exposure-based approaches.

Process of developing this publication

There is currently little information at the international level on the health impact of environmental noise in the WHO European Region. The WHO Regional Office for Europe has carried out an assessment study to provide methodological guidance for estimating the burden of disease related to environmental noise by calculating preliminary estimates of DALYs for the European Region.

The noise EBD project was started in 2005. An expert working group was convened in Stuttgart in June 2005 to review the health effects of noise and the selection of noise-related health outcomes for EBD estimation. Cardiovascular disorders, cognitive impairment, sleep disturbance, hearing loss, tinnitus and annoyance were selected as outcomes to be considered.

A second meeting was held in Bern in December 2005 to review the initial estimates of the burden of disease from environmental noise. Experts provided background documents and made presentations reviewing the detailed methods and preliminary results of EBD assessment for the selected noise-related outcomes. For each topic, a state-of-the-art review was made regarding the exposure data, exposure–response relationships, outcome data, DW and DALY calculation. WHO staff provided the topic-specific experts with methodological guidance based on previous global burden of disease experience. The meeting identified methodological constraints and informational gaps in quantification of DALYs due to environmental noise.

The methods and preliminary estimates were further elaborated in Berlin in April 2006 and in Bonn in December 2006. It was noted that calculation of DALYs is not possible for more than a few countries owing to the limited availability of data in most European countries. Because of this difficulty, the working group had to focus on providing methodological guidance on risk assessment rather than on estimating the EBD of environmental noise. Because EU Directive 2002/49/EC provides exposure data in many countries, it was also decided that the exposure metrics should use the Directive indicators as much as possible. With these aims in mind, a meeting of experts was convened in Bonn in May 2008.

Subsequent to the Bonn meeting, the authors of this chapter edited the final document. All chapters have been peer-reviewed, both within the working group and externally. At the final compilation of the chapters on health outcomes, the chapter on hearing loss was excluded because of a lack of epidemiological data pointed out by the reviewers. All other chapters were revised by the authors, taking into account the comments of the reviewers.

In 2010, exposure data on urban areas of > 250 000 inhabitants in the EU Member States became available through the EEA with the enforcement of EU Directive 2002/49/EC *(18)*. Accordingly, the WHO secretariat decided to include the EBD calculations for the EU population using the available data. In every step of the calculation that involved uncertainties, the working group made conservative assumptions in filling the information gap in order to avoid any possibility of overestimation.

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REFERENCES

1. de Hollander AE et al. An aggregate public health indicator to represent the impact of multiple environmental exposures. *Epidemiology,* 1999, 10:606–617.
2. EBoDE, 2010 [web site] (http://en.opasnet.org/w/Ebode, accessed 10 November 2010).
3. *Health and environment in Europe: progress assessment.* Copenhagen, WHO Regional Office for Europe, 2010) (http://www.euro.who.int/document/E93556.pdf, accessed 6 April 2010).
4. *Guidelines for community noise.* Geneva, World Health Organization, 1999 (http://www.who.int/docstore/peh/noise/guidelines2.html, accessed 21 July 2010).
5. 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. *Official Journal of the European Communities*, 2002, L 189:12–25.
6. Quantifying environmental health impacts [web site]. Geneva, World Health Organization, 2010 (http://www.who.int/quantifying_ehimpacts/en/, accessed 21 July 2010).
7. *Evaluation and use of epidemiological evidence for environmental health risk assessment. Guideline document.* Copenhagen, WHO Regional Office for Europe, 2000 (http://www.euro.who.int/document/e68940.pdf, accessed 21 July 2010).
8. *Framework for environmental health risk management.* Washington, DC, Presidential/Congressional Commission on Risk Assessment and Risk Management, 1997 (http://www.riskworld.com/nreports/1997/risk-rpt/pdf/EPAJAN.PDF, accessed 21 July 2010).
9. *Health Canada decision-making framework for identifying, assessing, and managing health risks.* Ottawa, Health Canada, 2000 (http://www.hc-sc.gc.ca/ahc-asc/alt_formats/hpfb-dgpsa/pdf/pubs/risk-risques-eng.pdf, accessed 21 July 2010).
10. *IPCS risk assessment terminology.* Geneva, World Health Organization, 2004 (http://www.inchem.org/documents/harmproj/harmproj/harmproj1.pdf, accessed 21 July 2010).
11. *Future noise policy: European Commission Green Paper.* Brussels, European Commission, 1996 (http://europa.eu/documents/comm/green_papers/com96_540/summary_en.htm#c1, accessed 21 July 2010).
12. The EU Noise Expert Network [web site]. Brussels, European Commission, 2010 (http://ec.europa.eu/environment/noise/expert.htm, accessed 21 July 2010).
13. *Convention on access to information, public participation in decision-making and access to justice in environmental matters.* Geneva, United Nations Economic Commission for Europe, 1998.
14. *Good practice guide for strategic noise mapping and the production of associated data on noise exposure, version 2.* Brussels, European Commission Working Group Assessment of Exposure to Noise, 2006 (http://ec.europa.eu/environment/noise/pdf/wg_aen.pdf, accessed 21 July 2010).
15. *Description and measurement of environmental noise. Part 2. Guide to the acquisition of data pertinent to land use.* Geneva, International Organization for Standardization, 1991 (ISO 1996-2:1987).
16. Prüss-Üstün A et al. *Introduction and methods: assessing the environmental burden of disease at national and local levels.* Geneva, World Health Organization, 2003.
17. Mathers CD et al. *Global burden of disease in 2002: data sources, methods and results.* Geneva, World Health Organization, 2003 (Global Programme on Evidence for Health Policy Discussion Paper No. 54).
18. Noise Observation and Information Service for Europe (NOISE) [web site]. Copenhagen, European Environment Agency, 2009 (http://noise.eionet.europa.eu/index.html, accessed 15 February 2011).

2. ENVIRONMENTAL NOISE AND CARDIOVASCULAR DISEASE

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This chapter examines the burden of cardiovascular diseases related to environmental noise. It is a common experience that noise is unpleasant and affects the quality of life. It disturbs and interferes with activities of the individual, including concentration, communication, relaxation and sleep *(1,2)*. Besides the psychosocial effects of community noise, there is concern about the impact of noise on public health, particularly regarding cardiovascular outcomes *(3–5)*.

According to the WHO Global Burden of Disease 2000 study, ischaemic heart disease is the leading cause of death in developed and developing countries (22.8% and 9.4% of total deaths, respectively *(6,7)*. Worldwide, 12.6% of deaths are caused by ischaemic heart disease, 9.6% by cerebrovascular disease and 1.6% by hypertensive heart disease *(8)*. High blood pressure and high levels of blood lipids, including cholesterol and triglycerides, are major (biological or endogenous) risk factors for ischaemic heart disease. Endogenous risk factors can be affected by exogenous risk factors (e. g. nutrition, environmental factors). Worldwide, 13.5% of deaths are attributable to high blood pressure (hypertension) and 6.9% to high (total) cholesterol levels. 1.4% of deaths are attributed to urban air pollution according to the WHO Global Burden of Disease 2000 study *(6,8)*.

The auditory system is continuously analysing acoustic information, which is filtered and interpreted by different cortical and sub-cortical brain structures. Arousal of the autonomic nervous system and the endocrine system is associated with repeated temporal changes in biological responses. In the long run, chronic noise stress may affect the homeostasis of the organism due to dysregulation, incomplete adaptation and/or the physiological costs of the adaptation *(9–17)*. Noise is considered a nonspecific stressor that may cause adverse health effects in the long run. Epidemiological studies suggest a higher risk of cardiovascular diseases, including high blood pressure and myocardial infarction, in people chronically exposed to high levels of road or air traffic noise. This chapter collates the available evidence regarding risk estimation for the burden of cardiovascular disease attributable to environmental noise in European regions.

Definition of outcome

Cardiovascular disease includes ischaemic heart disease, hypertension (high blood pressure) and stroke. There is no evidence available on the relationship between noise and stroke, so it will not be considered further here.

Ischaemic heart diseases (ICD 10 codes I20–I25) include angina (I20), acute myocardial infarction (I21), subsequent myocardial infarctions and complications of infarctions (I22 and I23), other acute forms of ischaemic heart disease (I24) and chronic ischaemic heart disease (I25). Essential hypertension is classified as I10 with further codes for hypertensive heart failure (I11), hypertensive renal disease (I12) and hypertensive heart and renal disease (I13).

Summary of evidence linking noise and cardiovascular disease

Epidemiological studies on the relationship between transportation noise (particularly road traffic and aircraft noise) and cardiovascular effects have been carried out on adults and on children, focusing on mean blood pressure, hypertension and ischaemic heart diseases as cardiovascular end-points. The evidence, in general, of a positive association has increased during recent years *(18–20)*. While there is evidence that road traffic noise increases the risk of ischaemic heart disease, including myocardial infarction, there is less evidence for such an association with aircraft noise because of a lack of studies. However, there is increasing evidence that both road traffic noise and aircraft noise increase the risk of hypertension. Very few studies on the cardiovascular effects of other environmental noise sources, including rail traffic, are known. Numerical meta-analyses were carried out assessing exposure–response relationships in quantitative terms *(21,22)* and the issue has been addressed in various WHO projects. The exposure–response curves presented here refer to the data collected for these projects, to illustrate the processes of a quantitative risk assessment.

Biological model of causation

Non-auditory health effects of noise have been studied in humans and animals for several decades, using laboratory and empirical methods. Biological reaction models have been derived, based on the general stress concept *(17,23–30)*. Noise is a nonspecific stressor that arouses the autonomous nervous system and the endocrine system *(9,11–14,31,32)* (C. Maschke & K. Hecht, unpublished data, 2005). A neuro-endocrinological definition of stress is that it is a state that threatens homeostatic or adaptable systems in the body *(16,33,34)*. Increased allostatic load is associated with various diseases, including ischaemic heart disease *(35)*. The epidemiological reasoning is based on three facts. First, experimental studies in the laboratory have been carried out for a long time and revealed an increased vegetative and endocrine reactivity during periods of exposure *(1,36–70)*. However, the question regarding long-term effects of chronic noise exposure cannot be answered from short-term experiments. Second, animal studies have shown manifest disorders in species exposed to high levels of noise for a long time *(71–83)*. However, effects in humans and animals cannot be directly compared, particularly because two pathways may be relevant – the direct effect due to nervous innervation and the indirect effect due to the cognitive perception of the sound; the latter is certainly different in humans. Furthermore, noise levels in animal studies were higher than in ambient situations. Third, occupational studies have shown health disorders in workers chronically exposed to noise for many years *(20,84–98)*. However, noise levels were higher than in the ambient environment. Epidemiological research has therefore been carried out with respect to community noise levels to test the hypothesis and to quantify the risk.

Among other non-auditory health end-points, short-term changes in circulation, including blood pressure, heart rate, cardiac output and vasoconstriction, as well as stress hormones (epinephrine, norepinephrine and corticosteroids), have been studied in experimental settings for many years *(32,99)*. Classical biological risk factors have been shown to be elevated in subjects that were exposed to high levels of noise *(44,54,79,100–111)*.

From this, the hypothesis emerged that persistent noise stress increases the risk of cardiovascular disorders, including hypertension and ischaemic heart disease. According to the noise/stress reaction model, the arousal of the endocrine and autonomic nervous system affects classical biological risk factors (e.g. blood pressure, blood lipids, glucose regulation, blood flow, haemostatic factors and cardiac output). Chronic metabolic changes or dysfunction due to noise increase the risk of manifest diseases, including hypertension, arteriosclerosis and myocardial infarction.

Exposure–response relationship

For a quantitative risk assessment and the derivation of guidelines for public health noise policy, a common exposure–response curve is required. The risk estimates obtained from different noise studies can be summarized using the statistical approach of meta-analysis.

Definition of exposure

Energy-based indicators of exposure (L_{eq}) are adequate and sufficient for assessing the relationship between long-term exposure to community noise and chronic diseases such as cardiovascular disorders. While single event noise indicators can be useful predictors (as additional information) for assessing the effects of acute noise (e. g. sleep disturbance) *(112)*, integrated noise indicators (e.g. a year's average noise level) are suitable predictors in epidemiological studies for assessing the long-term effects of chronic noise exposure. Such indicators should measure noise during certain periods of the day. Examples include $L_{day,16h}$ (day-noise indicator 7:00 to 23:00), $L_{day,12h}$ + $L_{evening,4h}$ (day-noise indicator 7:00 to 19:00 and evening-noise indicator 19:00 to 23:00) and $L_{night,8h}$ (night-noise indicator 23:00 to 7:00). $L_{day,16h}$ is a useful indicator for estimating health impacts according to the method proposed here. When information on noise for the various periods of the day, i.e. day/evening/night, is available, weighted and non-weighted indicators can easily be calculated for use in health studies and related quantitative risk assessment. This includes the indicators L_{den} (weighted day-evening-night noise indicator) and L_{night} according to Directive 2002/49/EC *(113)*, which are considered in noise mapping.

If only one figure is anticipated to describe the noise situation, a single noise indicator may be a useful factor to be considered in noise studies (e.g. L_{24h}, L_{dn} or L_{den}). However, since night noise is assessed separately according to Directive 2002/49/EC, it does not appear reasonable when daytime noise and nighttime noise exposures are then combined in a weighted 24-hour indicator. With respect to health effects, it would make much more sense to clearly distinguish between real day and night indicators. An optimal noise study would try to distinguish between the exposure of the living room during the day (L_{day}) and the exposure of the bedroom during the night (L_{night}). Further, the concept of L_{den} is annoyance-based. From a cardiovascular point of view, there is no rationale known for weighing factors such as +5 dB(A) or +10 dB(A) for the evening and night periods of the day. It would be a better approach to consider day and night exposures separately with respect to its effects, particularly for noise sources other than road traffic noise (where the day and night noise levels are usually highly correlated). Studies should also try to distinguish between the exposure of the living room (during daytime) and the exposure of the bedroom (during nighttime). However, such information is often not available.

When comparing study results for the meta-analyses, problems arise from the fact that different noise indicators (including even more complex national noise indices) have been used in different studies. However, conversion formulas are available for approximation. For example, with respect to road traffic noise the following empirical formula can be used for conversions between $L_{day,16h}$ and L_{den} *(114)*:

$$L_{den} \approx L_{day,16h} - 2 \cdot \ln((L_{day,16h} - L_{night,8h})/22.4))$$

However, this conversion can, per se, not be applied to other noise sources such as aircraft noise and railway noise. Nevertheless, as long as particular studies referring to Directive 2002/49/EC indicators L_{den} and L_{night} are largely missing, exposure–response relationships (regression coefficients) based on other noise indicators could approximately be considered for assessing the relative increase in risk with increasing noise level.

For the meta-analyses, noise exposure was divided into 5-dB(A) categories for the daytime outdoor average A-weighted sound pressure level ($L_{day,16h}$). This was considered in most studies. Information on nighttime exposure ($L_{night,8h}$) was seldom available. Newer studies used non-weighted or weighted averages of the 24-hour exposure (L_{eq}, L_{dn}, L_{den}) *(113)*. Some aircraft noise studies used national calculation methods (e.g. Dutch Kosten Units). Some of the studies considered subjective ratings of the noise, including noise annoyance, as indicators of noise exposure. Sound levels were converted on the basis of best-guess approximations to $L_{day,16h}$ for comparison and pooling.

In urban settings, average nighttime noise levels for road traffic tend to be approximately 7–10 dB(A) lower than average daytime levels and are relatively independent of the traffic volume of the street (except motorways) *(115–117)*. Measurements showed that L_{den} was approx. 1–3 dB(A) higher than $L_{day,16h}$ where the difference between $L_{day,16h}$ and $L_{night,8h}$ ranged from 10 to 5 dB(A) *(114)*.

In the conversion formula given above, if the difference between day and night sound levels is of the order of 7–8 dB(A), then this accounts for approximately 2 dB(A) higher L_{den} values compared to $L_{day,16h}$. This is commonly found for road traffic noise in urban streets with the 24-hour noise levels tending to be only slightly lower than daytime levels *(118)*. A conversion factor of 2 dB(A) was also suggested based on Norwegian data (T. Gjestland, personal communication, 2006). Another study found the difference range $L_{den} - L_{dn}$ to be between 0 and 1.5 dB, depending on whether the noise level L_{Aeq} dropped in the evening *(119)*.

To summarize, because the differences between L_{den} and L_{dn} are usually small, in epidemiological studies in which the relative effects of road traffic noise are studied, sound emission during the daytime can be taken as an approximate relative measure of the overall sound emission, including at night. This is further justified by the fact that existing noise regulations usually accept a 10-dB(A) difference between the day and the night. However, this approximation can only be made with respect to road traffic noise. For train and aircraft noise, no such approximation can be made. Approximate formulae for the conversion of different noise indicators are also given in the *Good practice guide for strategic noise mapping (120)*.

Meta-analysis – road traffic noise and myocardial infarction

To determine the most up-to-date and accurate exposure–response relationship between community noise and myocardial infarction, a meta-analysis was carried out *(21,121)*. By 2005, a total of 61 epidemiological studies had been recognized as having either objectively or subjectively assessed the relationship between transportation noise and myocardial infarction. Nearly all of the studies referred to road traffic noise or (commercial) aircraft noise, and a few to military aircraft noise. Most of the studies were of the cross-sectional type (descriptive studies) but observational studies such as case-control and cohort studies (analytical studies) were also available. The study subjects were children and adults. Confounding factors were not always adequately considered in some older studies. Not many studies provided information on exposure–response relationships, because only two exposure categories were considered.

All epidemiological noise studies were evaluated with respect to their feasibility for inclusion in a meta-analysis. The following criteria for the inclusion in the analysis/synthesis process were applied: (*a*) peer-reviewed in the international literature; (*b*) reasonable control of possible confounding (stratification, model adjustment, matching); (*c*) objective assessment of exposure (sound level); (*d*) objective assessment of outcome (clinical assessment); (*e*) type of study (analytical or descriptive); and (*f*) multi-level exposure–response assessment (not only dichotomous exposure categories).

Based on the above criteria, five analytical (prospective case-control and cohort) and two descriptive (cross-sectional) studies were suitable for derivation of a common exposure–response curve for the association between road traffic noise and the risk of myocardial infarction. Two separate meta-analyses were undertaken by considering the analytical studies and descriptive studies separately. The analytical studies comprised those that were carried out in Caerphilly and Speedwell with a pooled analysis of 6 years follow-up data *(122,123)* and the three Berlin studies *(124,125)*. The descriptive studies comprised the cross-sectional analyses that were carried out on the studies in Caerphilly and Speedwell *(126)*. All studies referred to the road traffic noise level during the day ($L_{day,16h}$) and the incidence (analytical studies) or prevalence (descriptive studies) of myocardial infarction as the outcome. The study subjects were men. In all analytical studies the orientation of rooms (moderator of the exposure) was considered for the exposure assessment (at least one bedroom or living room facing the street or not). In all descriptive studies the traffic noise level referred to the nearest facades that were facing the street and did not consider the orientation of rooms/windows (source of exposure misclassification). The individual effect estimates of each study were adjusted for the covariates given in these studies. This means that different sets of covariates were considered in each study. Nevertheless, this pragmatic approach accounts best for possible confounding in each study and provides the most reliable effect estimates derived from each study.

The common set of covariates considered in the descriptive studies were age, sex (males only) social class, body mass index, smoking, family history of ischaemic heart disease, physical activity during leisure time and prevalence of pre-existing diseases. The common set of covariates considered in the analytical studies were

age, sex (males only), social class, school education, employment status, shift work, smoking and body mass index. Some of the analytical studies also considered physical activity during leisure time, family history of ischaemic heart disease or myocardial infarction, prevalence of pre-existing diseases, work noise and marital status. In one study, the effect estimates were further adjusted for hypertension and diabetes mellitus. This may be a conservative approach owing to over-controlling, because these biological (risk) factors may be mediators along the pathway from exposure (noise stress) to disease.

The odds ratios calculated for the different 5-dB(A) noise categories ($L_{day,16h}$) within a single study were then pooled between studies for each noise category. Since higher exposure categories usually consist of smaller numbers of subjects than the lower categories, regression coefficients across the whole range of noise levels within a study tend to be largely influenced by the lower categories. This may lead to an underestimation of the risk in higher noise categories. The multi-level approach pooled the effect estimates of single studies within each noise category, thus giving more weight to the higher noise categories and accounting for possible non-linear associations.

The results from the two meta-analyses (descriptive studies and analytical studies) are shown in Table 2.1 *(121)*. For each meta-analysis we include the odds ratios (OR) and 95% confidence intervals (CI) for the original studies (with the weights used in the pooled analysis), the pooled OR and CI and the Laird Q-test of heterogeneity between studies. If the *P*-value from the Q-test is < 0.05, the studies are too heterogeneous and should not be combined.

The pooled estimates and CIs are shown graphically in Fig. 2.1 (descriptive studies) and Fig. 2.2 (analytical studies). The descriptive (cross-sectional) studies (Fig. 2.1) cover the sound level range of $L_{day,16h}$ from > 50 to 70 dB(A), while the cohort and case-control studies (Fig. 2.2) cover the range from ≤ 60 to 80 dB(A). The two curves together can serve as a basis for estimating the exposure–response relationship. From Fig. 2.1, it can be seen that below 60 dB(A) for $L_{day,16h}$ no noticeable increase in myocardial infarction risk is to be detected. For noise levels greater than 60 dB(A), the myocardial infarction risk increases (Fig. 2.1 and 2.2).

A polynomial function was fitted through the data points from the analytical studies (Fig. 2.2), to generate a continuous exposure–response curve that can be applied to categorized noise data and also to continuous noise data. The data points were weighted by the number of subjects (N-weighting) *(21,121)*. Mean category values of the decibel-axis are considered for the calculation. For the reference category "≤ 60 dB(A)", a value of 55 dB(A) was used because this category also includes a large number of noise levels below 55 dB(A). Using alternative values for this reference category (e.g. 52.5 or 57.5) had only a very marginal effect on the coefficients and the fit statistics. According to the empirical German noise assessment model (*Lärmbelastungsmodell*), daytime noise levels tend to be equally distributed across the categories > 45–50, > 50–55 and > 55–60 (127). In urban settings, background levels during the day do not often fall below 50 dB(A).

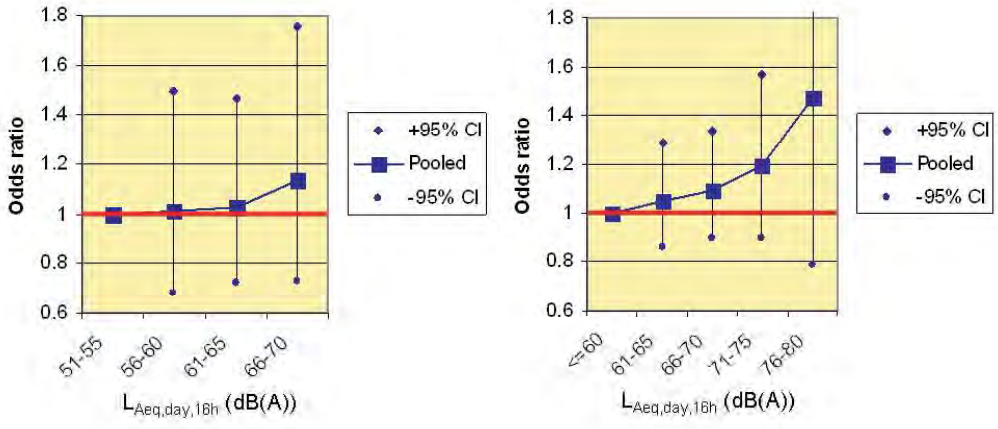
Table 2.1. Odds ratios and 95% confidence intervals from descriptive and analytical studies on the relationship between road traffic noise level and the incidence/prevalence of myocardial infarction

Descriptive studies	Road traffic noise level, $L_{day,16h}$ (dB(A))					N
	51–55	56–60	61–65	66–70		
Caerphilly	1.00	1.00 (0.58–1.71) [13.29]	0.90 (0.56–1.44) [17.23]	1.22 (0.63–2.35) [8.98]		2512
Speedwell	1.00	1.02 (0.57–1.83) [11.19]	1.22 (0.70–2.12) [12.62]	1.07 (0.59–1.94) [10.94]		2348
Pooled	1.00	1.01 (0.68–1.50)	1.02 (0.72–1.47)	1.14 (0.73–1.76)		
Q-test		*P* = 0.96	*P* = 0.41	*P* = 0.77		
Analytical studies	**< 60**	**61–65**	**66–70**	**71–75**	**76–80**	**N**
Caerphilly & Speedwell	1.00	0.65 (0.27–1.57) [4.95]	1.18 (0.74–1.89) [17.48]	—	—	3950
Berlin I	1.00	1.48 (0.57–3.85) [4.21]	1.19 (0.49–2.87) [4.94]	1.25 (0.41–3.81) [3.09]	1.76 (0.11–28.5) [0.50]	243
Berlin II	1.00	1.16 (0.82–1.65) [31.43]	0.94 (0.62–1.42) [22.76]	1.07 (0.68–1.68) [18.92]	1.46 (0.77–2.78) [9.27]	4035
Berlin III	1.00	1.01 (0.77–1.32) [54.42]	1.13 (0.86–1.49) [50.87]	1.27 (0.88–1.84) [28.24]	—	4115
Pooled	1.00	1.05 (0.86–1.29)	1.09 (0.90–1.34)	1.19 (0.90–1.57)	1.47 (0.79–2.76)	
Q-test		*P* = 0.57	*P* = 0.87	*P* = 0.84	*P* = 0.90	

Source: Babisch 2006 (121).

Note: Numbers are odds ratios; 95% confidence intervals are given in round brackets; weights are given in square brackets; N = sample size; Pooled = pooled estimates from meta-analysis of the studies shown; P = probability of the Q-test for heterogeneity.

Fig. 2.1 & 2.2. Pooled effect estimates (meta-analysis) of the association between road traffic noise and the prevalence (Fig. 2.1, left) and incidence (Fig. 2.2, right) of myocardial infarction (odds ratio +/- 95% confidence interval)



Source: Babisch (21).

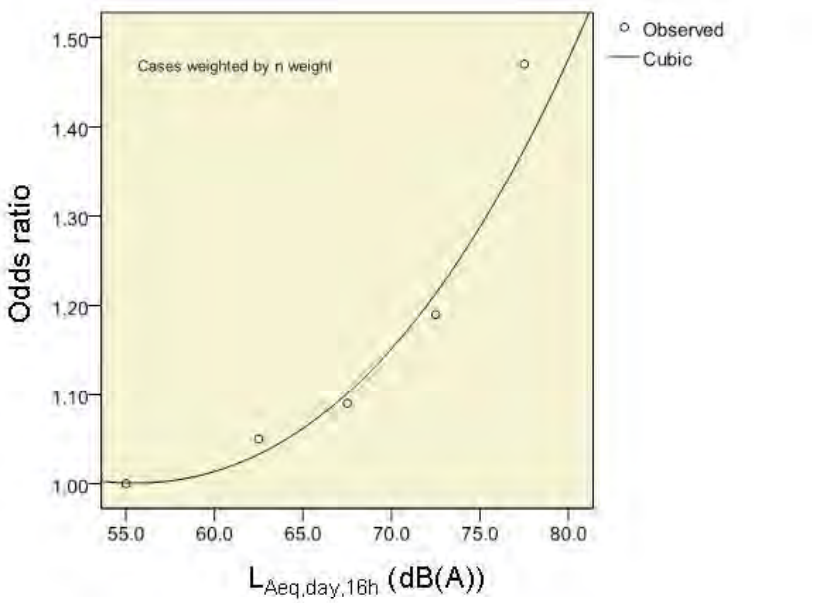
The result is shown graphically in Fig. 2.3 and mathematically below. This polynomial function explains 96% of the variance (R^2) in the meta-analytical results. Because of the data used to derive this function, the exposure–response function refers to road traffic noise and to the daytime noise indicator $L_{day,16h}$. It is defined for noise levels ranging from 55 to approximately 80 dB(A):

$$OR = 1.63 - 0.000613 \cdot (L_{day,16h})^2 + 0.00000736 \cdot (L_{day,16h})^3$$

The analytical studies were chosen for the risk curve because of their generally accepted higher credibility with respect to causal inference. However, when both descriptive and analytical studies were considered together for one polynomial fit, the results were almost identical. This exposure–effect curve will regularly be updated with respect to information from new studies. For practical application, the odds ratios for different noise levels are given in Appendix 1 to this chapter.

Alternatively, a fixed-effect meta-analysis of a linear trend was carried out *(21)*. It revealed an OR of 1.17 (95% CI 0.87–1.57, $P = 0.301$, $P(Q) = 0.943$).

Fig. 2.3. Polynomial fit of the exposure-response relationship for road traffic noise and the incidence of myocardial infarction



Source: Babisch (21).

Meta-analysis: road traffic noise and hypertension

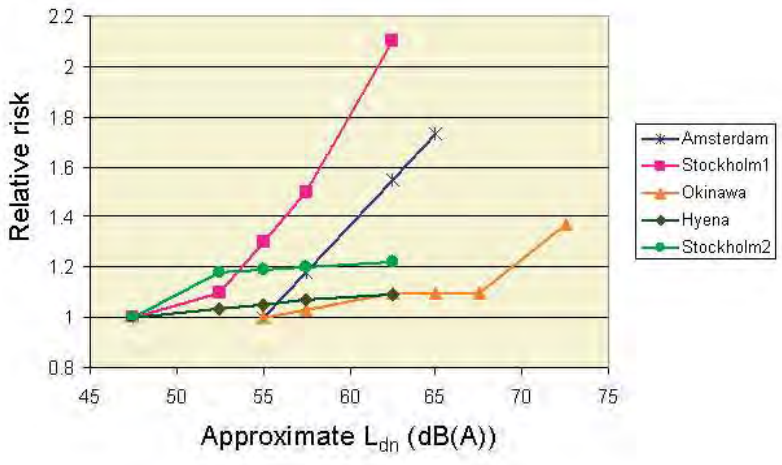
Regarding hypertension, a pooled estimate of the relative risk of 0.95 (95% CI 0.84–1.08) per 5-dB(A) increase in noise level during the day ($L_{day,16h}$ < 55–80 dB(A)) was calculated for the association between road traffic noise and hypertension based on a meta-analysis published in 2002 *(20)*. This estimate was recently updated based on new study results, and a pooled estimate of 1.12 (95% CI 0.97–1.30) was reported *(22)*. Significant results were found in two recently published studies, showing increases in the risk of hypertension of 1.05 (95% CI 1.00–1.10) per 5-

dB(A) increase in noise level (L_{24h} = 45–75 dB(A)) *(128)* and 1.38 (95% CI 1.06–1.80) per 5-dB(A) increase in the 24-hour noise level ($L_{24h} \approx$ 40–70 dB(A)) *(129)*, respectively. In a study looking at the combined effects of road traffic noise and air pollution on the prevalence of hypertension, the odds ratios for noise did not wane after adjustment for air pollution *(130)*.

Meta-analysis: aircraft noise and hypertension

The results of five studies on the relationship between aircraft noise and high blood pressure are shown in Fig. 2.4 *(128,131–135)*. The study subjects were men and women. A noise-level-related data pooling (categorical approach) was difficult to perform owing to the fact that different (national) exposure indices were used. Furthermore, different definitions of hypertension were applied. Individual odds ratios and confidence intervals were taken from summary reports and the original publications for this purpose to calculate regression coefficients of individual studies and odds ratios with respect to the weighted day/night noise indicator L_{dn}, which is supposed to be very similar to L_{den}. When the coefficients of a linear trend from the five studies were taken together ("regression approach"), the pooled estimate of the relative risk was 1.13 (95% CI 1.00–1.28) per 10 dB(A) for aircraft noise levels ranging between approximately 47 and 67 dB(A) *(136)*. The statistical test for heterogeneity of the studies was significant (P(Q) = 0.002). However, fixed and random effect estimates were the same. Owing to the results of new studies, this pooled effect estimate was smaller than that obtained from an earlier meta-analysis where the estimate of the relative risk was 1.59 (95% CI 1.30–1.93) per 10-dB(A) increase in the noise level *(20)*.

Fig. 2.4. Association between aircraft noise and the prevalence or incidence of high blood pressure



Source: Babisch & Van Kamp (136).

Disability weight

Different values of DW are used in the WHO comparative risk assessment reports by the different categories of epidemiological subregion that were defined based on geographical location and the level of infant and adult mortality (7).

The DW for acute myocardial infarction in the WHO EUR-A epidemiological subregion[2] is 0.405 *(7)*. However, disability weights of 0.108 and 0.186 are given for angina pectoris and congestive heart failure. No DW is given for ischaemic heart disease as a group. Hypertensive heart disease for the EUR-A epidemiological subregion is 0.201 but no DW is given for hypertension alone. In the literature, however, disability weights of 0.350 and 0.352 are reported for ischaemic heart disease as a group and for hypertension, and one year was considered for the duration of ischaemic heart disease and hypertension *(137)*.

EBD calculations

Two examples are given for calculating EBD from noise for cardiovascular disease. First, the exposure-specific approach is used to estimate the DALYs from myocardial infarction due to road traffic noise in Germany. Second, different noise exposure prevalence data are used to estimate the attributable fraction of myocardial infarction due to noise in Berlin.

Exposure-based approach for road traffic noise and myocardial infarction in Germany

An example is given for Germany regarding road traffic noise and myocardial infarction. These EDB calculations use an exposure-based approach. The country-specific population-attributable fraction (impact fraction) and the attributable cases can be calculated based on the distribution of the population in different exposure categories and the respective relative incidence of disease. This approach requires:

- a population-based estimate of the prevalence of the outcome in Germany obtained from surveys or national statistics;
- an estimate of the attributable fraction of the outcome caused by environmental noise, calculated from German estimates of exposure prevalence and Fig. 2.3; and
- a value of DW for each case of the outcome caused by environmental noise.

Prevalence of noise exposure

According to the older German noise exposure model (*Lärmbelastungsmodell*), it was estimated (reference year 1999) that approximately 16% of the German population were exposed to road traffic noise levels (taken at the facades of their houses) exceeding 65 dB(A) during the day ($L_{day,16h}$), that some 15% were exposed to 60–65 dB(A) and that approximately 69% were exposed to levels below 60 dB(A) *(138)*. The noise distribution is shown in Table 2.2. During the night, noise levels tend to be 7–10 dB(A) lower.

Attributable fraction calculation

By applying the polynomial equation of the exposure–response function (Fig. 2.3) to the noise exposure distribution of the German population, it is possible to calculate an attributable fraction (AF) for each exposure group, that is, the proportion of cases of myocardial infarction due to noise exposure.

2 The WHO EUR-A epidemiological subregion comprises Andorra, Austria, Belgium, Croatia, Cyprus, the Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, the Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

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The risk ratios attributed to the exposure categories are taken from Fig. 2.2. Using the formula of the population-attributable fraction (PAF) provides the following results:

$$PAF = \frac{(1.031 \cdot 0.153 + 1.099 \cdot 0.090 + 1.211 \cdot 0.051 + 1.372 \cdot 0.015 + 1 \cdot 0.691) - 1}{1.031 \cdot 0.153 + 1.099 \cdot 0.090 + 1.211 \cdot 0.051 + 1.372 \cdot 0.015 + 1 \cdot 0.691} = 0.0291$$

The resulting attributable fraction of myocardial infarction due to road traffic noise for the German population in the year 1999 is therefore 2.9%.

Table 2.2. Example: attributable fraction for myocardial infarction due to road traffic noise, estimated from the noise exposure pattern in Germany

Road traffic noise 1999, $L_{day,16h}$ (dB(A))	Percentage exposed	Relative risk	Attributable fraction
< 60	69.1	1.000	0.00
60–64	15.3	1.031	3.03
65–69	9.0	1.099	9.03
70–74	5.1	1.211	17.44
> 75	1.5	1.372	27.13

Cases of and deaths from myocardial infarction due to noise

According to the national health statistics, 849 557 cases of ischaemic heart diseases (ICD 9, No. 410–414), including 133 115 cases of acute myocardial infarction (ICD 9, No. 410), were diagnosed in 1999 *(139)*. The number of deaths due to myocardial infarction in Germany in 1999 was 76 961. So as not to double count cases when DALYs are calculated, the number of deaths was subtracted from the number of cases, leaving 56 154 new cases that did not result in death.

To calculate the cases due to traffic noise, the number of cases of myocardial infarction is multiplied by the attributable risk. Since there is no reason to believe that cases resulting in death should differ from those that do not with respect to noise exposure, the same attributable risk is applied to both groups of myocardial infarction cases.

The number of cases of non-fatal myocardial infarction (56 154) multiplied by 2.9% results in approximately 1629 new cases per year of non-fatal myocardial infarction in Germany attributable to traffic noise.

In addition, a proportion of deaths from myocardial infarction may also be attributable to traffic noise. Each of these deaths includes future YLL. Life expectancy at each age in 2002–2004 was used *(139)*. For each age group, the number of deaths due to myocardial infarction was multiplied by the life expectancy at that age separately for males and females. The total YLL for each sex was multiplied by 2.9% to give the YLL attributable to noise. This results in approximately 29 488 YLL.

Calculation of DALYs

To gain a rough estimate of the DALYs lost due to noise-related myocardial infarction for one year, the formulae in the previous chapter can be used:

DALY = YLL + YLD

where YLD = I · DW · L and YLL = number of deaths · average loss of life per death due to myocardial infarction.

Assuming one year of disability for each non-fatal case of myocardial infarction, the total DALYs are equal to:

29 488 + (1 629 · 0.405 · 1) = 30 147

This does not include ongoing morbidity after the first year.

Exposure-based approach for road traffic noise and myocardial infarction in Berlin

Another example, referring to the city of Berlin, is based on recent noise exposure data (L_{den} and L_{night}) derived from the strategic noise maps according to Directive 2002/49/EC *(113,140)*. The noise distribution is shown in Table 2.3 and it can be seen that the prevalences of exposure are lower than those in Table 2.2. Since Berlin is a metropolitan city where the noise exposure is likely to be higher than in smaller communities and rural areas, the data suggest that the traffic noise exposure in Germany, in general, is lower than estimated by the old *Lärmbelästigungsmodell (138)*. However, one has to consider that only the primary road network was assessed. On the other hand, traffic volumes of more than about 12 000 vehicles during the day (6:00–22:00) – corresponding to approximately L_{Aeq} = 65 dB(A) – are not very likely for the secondary road network. Applying the formula given above, the attributable fraction for Berlin is 0.0107, meaning that approximately 1.1% of all myocardial infarctions would be attributable to the road traffic noise in Berlin.

Table 2.3. Estimated road traffic noise exposure for the city of Berlin

Average sound pressure level, L_{den} (dB(A))	Number of citizens exposed [a]	Percentage exposed [b]	Relative risk of myocardial infarction [c]
Approx. < 55	2 683 449	80.53	1.000
> 55–59	220 200	6.61	1.000
60–64	155 000	4.65	1.015
65–69	140 200	4.21	1.067
70–74	112 600	3.38	1.161
> 75	20 800	0.62	1.302

[a] Numbers refer to the primary road network of Berlin.

[b] Total population of Berlin: 3 332 249 (2005).

[c] Odds ratios are derived from the polynomial risk equation for $L_{day,16h} = L_{den}$ - 2 dB(A).

Estimation of ischaemic heart disease burden from road traffic noise in the EU Member States

There is no international database on noise exposure of the European population covering the whole European Region. However, the Noise Observation and Information Service for Europe (NOISE) maintained by the European Environment Agency (EEA) and the European Topic Centre on Land Use and Spatial Information (ETC LUSI) on behalf of the European Commission provide noise exposure data that can be used for calculating disease burden in the western European countries. It contains data related to strategic noise maps delivered in accordance with EU Directive 2002/49/EC relating to the assessment and management of environmental noise (*141*). As for road traffic noise, the dataset covers the exposure distribution in approximately 20% of the total EU population as of January 2010. Bearing in mind that there are uncertainties and assumptions involved in using the exposure data based on strategic noise maps by the Member States (see below), we can use this official data to estimate burden of disease in the EU Member States.[3]

Table 2.4 summarizes the distribution of the population exposed to road traffic noise in agglomerations with more than 250 000 inhabitants, and relative risks and attributable fractions for respective exposure categories. The risk ratios attributed to different L_{den} categories are taken from Appendix 1 of this chapter. Applying the formula given above, the attributable fraction is 0.018, meaning that approximately 1.8% of all myocardial infarctions would be attributable to road traffic noise in these western European countries.

Table 2.4. Road traffic noise exposure for the European countries reporting noise maps

Road traffic noise within agglomeration L_{den} (dB(A))	Percentage exposed [a]	Relative risk [b]	Attributable fraction
< 55	50	1.000	0.00
55–59	17	1.000	0.00
60–64	19	1.015	1.48
65–69	9	1.067	6.29
70–74	4	1.161	13.87

Source: Noise Observation and Information Service for Europe *(141)*.

[a] The population size is 110 million living in agglomerations with > 250 000 inhabitants.

[b] The risk ratios attributed to different L_{den} categories are taken from Appendix 1 of this chapter.

3 Austria, Bulgaria, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

In 2008, WHO published an updated report on global burden of disease *(142)*. In this report, the DALYs for disease cluster categories were reported by different subregions based on income levels. High-income European countries[4] correspond to the EUR-A subregion with very low child and adult mortalities in the previous reports. DALYs of cardiovascular diseases are reported in the categories of rheumatic heart disease, hypertensive heart disease, ischaemic heart disease, cerebrovascular disease and inflammatory heart diseases. The total burden of ischaemic heart disease is 16 826 000 DALYs out of 883 million people in the WHO European Region, of which 3 376 000 DALYs are out of 407 million people in the high-income European countries. As DALYs for myocardial infarction were not published, we applied the above attributable fraction to the category of ischaemic heart disease. In other words, for the sake of DALY calculation, we assumed that road traffic noise has the similar impact on all ischaemic heart disease as on myocardial infarction. In high-income European countries, DALYs attributable to transport noise were estimated to be 60 768 years (1.8% of 3 376 000 DALYs) *(142)*.

Uncertainties, limitations and challenges

Biological plausibility of association

The biological plausibility of the hypothesis of noise effects is well-documented (see previous section summarizing the evidence). Acute noise effects have been studied extensively over the past 50 years, and a general noise reaction model was well-established before research moved from the laboratory to test hypotheses with respect to the long-term effects of noise in epidemiological studies.

The auditory system is continuously analysing acoustic information, which is filtered and interpreted by different cortical and sub-cortical brain structures causing acute responses of the autonomic nervous and the endocrine system, even during sleep. Long-term noise stress can adversely affect biological risk factors due to chronic dysregulation. Considering this pathway, noise must be viewed as an environmental risk factor. In epidemiological noise studies, higher risk estimates were found when length of exposure was considered (years in residence). The same accounts for room orientation and window opening habits (higher risks when rooms were facing the street with windows open). This is in accordance with the noise hypothesis and the effects of chronic noise stress (exposure effect).

Generalization of myocardial infarction to other ischaemic heart diseases

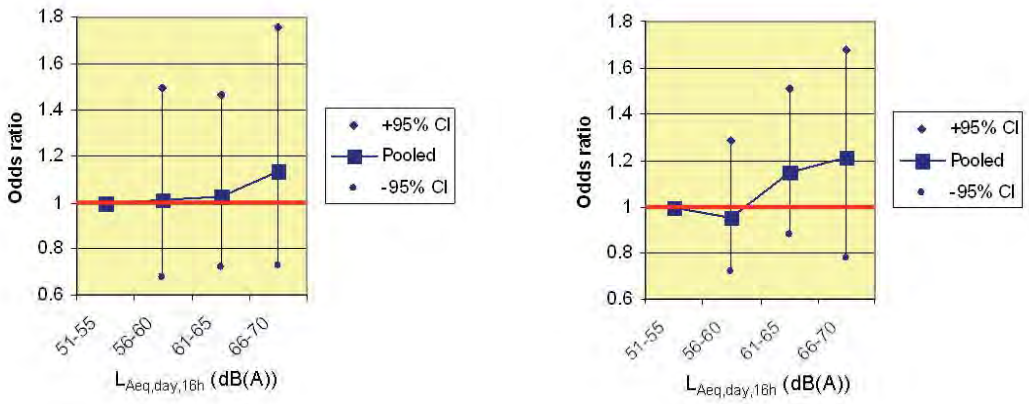
Myocardial infarction was considered for the meta-analysis because it was the outcome most commonly assessed in the studies that met the inclusion criteria for the review. The noise impact on myocardial infarction may have been easier to detect by epidemiological studies, because misclassification in the diagnosis of myocardial infarction is less likely than for all ischaemic heart diseases. Ischaemic heart disease comprises: acute myocardial infarction, other acute and sub-acute forms of ischaemic heart disease, old myocardial infarction, ischaemic signs in the electrocardiogram, angina pectoris, coronary atherosclerosis and chronic ischaemic heart disease.

4 High-income European countries are: Andorra, Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, the Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

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Because there is no exclusive causal mechanism postulated specifically for myocardial infarction, it has been suggested that the impact fraction of traffic noise could be applied to all types of ischaemic heart disease. Therefore, the exposure–response curve for myocardial infarction could be generalized to all ischaemic heart diseases for the calculation of DALYs. This is supported by Fig. 2.5 and Fig. 2.6, which shows the association between road traffic noise level during the day ($L_{day,16h}$) and the prevalence of myocardial infarction and ischaemic heart diseases based on two studies, where all detailed information was assessed within each study *(126)*. It can be seen that the associations with the noise level look quite similar. The point estimate of pooled effect estimates for noise levels higher than 60 dB(A) are slightly higher for (all) ischaemic heart diseases than for myocardial infarction.

Fig. 2.5 & 2.6. Exposure-response curve for road traffic noise and the prevalence of myocardial infarction (Fig. 2.5, left) and all ischaemic heart diseases (Fig. 2.6, right)



Source of the data: Babisch et al. 1993 *(126)*

Specificity of hypertension as an outcome

Pooling of data is difficult when different criteria and assessment methods for the disease end-points were used in different studies. For example, with respect to hypertension, some aircraft noise studies refer to the former WHO criterion of a measured blood pressure of 160/100 mmHg, while others refer to the current WHO criterion of 140/90 mmHg. Perhaps more importantly, different determinants of high blood pressure were used, including self-reported doctor-diagnosed hypertension, anti-hypertensive drug medication, actual blood pressure measurements, or combinations of the three. The heterogeneity of the studies may be less of a problem with respect to the slope of the pooled exposure–response curve. However, decisions must be made regarding the onset (threshold) of the increase in risk. For the calculation of the attributable fraction, estimates of different scenarios can be made.

Generalization of evidence to both sexes

The exposure–response curve derived from male study subjects was generalized to women. The subjects in the noise studies were mostly men, owing to considerations of statistical power in the study design. Cardiovascular diseases are more frequent in middle-aged males *(143)*. For reasons of homogeneity, the relatively small number of females was excluded from the calculation of the pooled effect estimates.

The available results of noise studies do not allow for a distinction between the sexes. There is some indication that males may be more affected by road traffic noise *(125,128,144,145)* but contradictory results have also been found *(129)*. Studies on the association between environmental noise and high blood pressure showed no consistent pattern with respect to higher relative risks in either men or women *(18)*. In studies where females were considered, the hormonal/menopausal status was not assessed, which could act as a confounder (falsely showing differences between the sexes) *(146)*.

In laboratory studies, the focus was primarily on "before-after" effects of noise exposure in the same test subjects rather than on gender differences. In occupational noise studies, gender was often considered as a confounding factor but not as a potentially effect-modifying factor in the statistical analyses. Male blue collar workers were predominantly found in high-noise workplaces. Studies on the association between environmental noise and high blood pressure showed no consistent pattern with respect to higher relative risks in either men or women *(121)*.

Although there are differences in the absolute risk between males and females, it seems reasonable to assume that, in relative terms, females may be just as affected by noise stress as males. Nevertheless, in future noise studies, potential gender differences should be addressed.

Issues of statistical significance

The confidence intervals of the effect estimates shown in Fig. 2.1 and 2.2 for the association between traffic noise and myocardial infarction include relative risks of 1.0. The purpose of the meta-analysis was to derive a "best guess" pooled relationship for the calculation of population-attributable risks. Individual studies showed significant ($P < 0.05$) or borderline significant ($P < 0.10$) results when the highest exposure categories were combined and/or subsets of subjects with long years in residence were considered *(124,125)*. When the meta-analysis is carried out for subsamples of subjects that had lived for at least 10 or 15 years in their dwellings, larger effect estimates were also obtained in the meta-analysis *(21)*. For example, when the upper two noise categories of the exposure–response curve are combined, the pooled effect estimate is OR = 1.25 ($P = 0.068$) in the total sample, and OR = 1.44 ($P = 0.020$) in the sub-sample, the latter being statistically significant. Regarding linear trend, the odds ratio in the sub-sample of subjects with many years of residence was 1.44 per 10-dB(A) increase in the noise level (CI 0.97–2.12, $P = 0.067$), which was borderline significant. However, for the calculation of population-attributable risk percentages, the weaker effect estimates were considered to apply to the entire study populations, because information about modifiers of exposure such as length of residence or window/room orientation will not be available for general populations. Depending on the results of new studies, the current risk curves must be regularly updated.

Lack of exposure data

The lack of accurate exposure data is a major hindrance in estimating actual burden of disease. How can exposure data from countries and subregions be obtained? EU Member States have just started to systematically assess the environmental noise due

to road, rail and air traffic and commercial/industrial activities in their communities according to EU Directive 2002/49/EC *(113)*. The noise mapping data for Directive 2002/49/EC can be used as shown above. It should be noted that the application of the exposure data for the urban population to the total population in the EU may lead to overestimation of burden. To avoid this possibility, we extrapolated only to agglomerations with > 50 000 inhabitants (57% of the EU population). The accuracy and representativeness of exposure data will improve when the second round of noise mapping produce data from agglomerations with 100 000–250 000 inhabitants in 2012. Exposure data will be still sparse from the WHO EUR-B[5] and EUR-C[6] epidemiological subregions. Extrapolation of exposure data from EUR-A to the EUR-B and EUR-C epidemiological subregions might be problematic because the level of noise exposure of the population might be quite different between these subregions.

Road traffic is a key environmental noise source. However, results from epidemiological studies with respect to the association of other environmental noise sources (such as air traffic noise, railways or even leisure noise) with myocardial infarction are rarely available. For the time being, the exposure–response curve derived for road traffic noise could be used, considering that at the same average noise level, aircraft noise tends to be more annoying and conventional railway noise less annoying than road traffic noise *(119,147)*. Furthermore, exposure misclassification diluting the true effects is less of a problem with respect to aircraft noise because all sides of the house are equally exposed. (*Note*. According to Directive 2002/49/EC, noise levels refer to the most exposed side of a dwelling.) The characteristics of road traffic noise and its effects can be quite different from rail and aircraft noise, which is an additional source of uncertainty when applying road noise curves to other noise sources and vice versa.

Confounding with air pollution

Air pollutants have also been shown to be associated with cardiovascular end-points *(148–155)*. In real life, individuals exposed to road noise are also likely to be exposed to air pollution arising from road traffic. It is not yet clear whether the impact of noise on ischaemic heart disease is independent, additive or synergistic to the impact of outdoor air pollution. Air pollution studies have not controlled for noise and vice versa. Air pollution epidemiology carried out in the last century focused primarily on respiratory illness, which was not an issue in noise research. However, cardiopulmonary mortality was also identified as a key outcome of acute and chronic exposure to air pollutants.

Most information on hospital admissions due to acute changes (increases) in levels of air pollutants come from time-series studies *(150)*. Studies on short-term exposure to elevated concentrations of fine particulate matter are associated with acute changes in cardiopulmonary health. However, since traffic volume does not show

5 The WHO EUR-B epidemiological subregion comprises Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Georgia, Kyrgyzstan, Montenegro, Poland, Romania, Serbia, Slovakia, Tajikistan, the former Yugoslav Republic of Macedonia, Turkey, Turkmenistan and Uzbekistan.

6 The WHO EUR-C epidemiological subregion comprises Belarus, Estonia, Hungary, Kazakhstan, Larvia, 6 Lithuania, the Republic of Moldova, the Russian Federation and Ukraine.

considerable day-to-day variations, the changes in air pollution in these studies are due to other factors that affect the concentration of air pollutants, mainly changes in weather conditions. Noise levels in urban environments, on the other hand, are primarily determined by the relatively constant traffic volume per day, and much less by weather conditions when the distance of houses from the street is short (urban noise). In this respect, confounding between noise and air pollution is not likely with respect to short-term effects in time-series studies.

The health effects of noise in general refer to long-term chronic noise stress. Confounding can be an issue in long-term effects observed by cross-sectional, case-control and cohort studies. Epidemiological studies have shown strong associations of mortality and life expectancy with long-term exposure to fine particulate matter and sulfates *(156)*. However, the study designs of cohort studies on the association between air pollutants and cardiopulmonary mortality differ considerably from those of noise exposure. In air pollution studies, the spatial exposure is often considered on an ecological basis. Subjects from different metropolitan areas with different mean (background) concentrations of air pollutants have been compared with respect to disease occurrence. No distinction is usually made between busy streets and side streets *(148,149,152,157)*. In noise studies, the exposure in front of a study participant's house was assessed on an individual level with respect to nearby sound sources, along with individual confounding factors. Differences of 1:100 (20 dB(A)) in terms of sound intensity are common for people living in different streets or even only a few yards away from one another, because shielding is highly effective for noise. The sound level can diminish from the front to the back of a house by 30 dB(A) or more (sound intensity 1:1000). To some extent, one could say that major air pollution studies refer to macro-scale exposures while noise studies refer to micro-scale exposures.

Further, cardiovascular effects of noise (hypertension) were also found for noise sources where air pollutants are less likely to be co-varying factors, e.g. occupational noise *(20)* and aircraft noise *(121)*. It was shown that the relative contribution of airport operations to the emission levels of nitrogen oxides, carbon monoxide, sulfur dioxide, volatile organic compounds and black smoke was small compared to the background concentrations in the vicinity of an airport *(158)*. In spite of this obvious co-exposure, there was a lack of interaction between the scientific community dealing with the health impacts of noise and that dealing with air pollution. However, this has changed in recent years and studies on their combined effects are currently under way *(130,159,160)*. Some studies have used the distance to major roads as a surrogate for exposure to air pollutants. However, noise would be as good an explanation for the observed effects *(161–165)*.

Method of calculating the exposure–response relationship

Different approaches have been used to calculate pooled effect estimates and exposure–response relationships. These include the "regression approach" and the "categorical approach". In the regression approach, the slopes (regression coefficients) across all noise categories of each noise study are pooled to assess a common regression coefficient. In the categorical approach, the relative risks found for the same

noise category in each noise study are pooled and considered for the calculation of an exposure–response curve. The regression approach has the advantage that regression coefficients can be pooled regardless of actual noise levels; only the slope (regression coefficient) of the exposure–response relationship is taken into account. The categorical approach is noise-level oriented. Possible thresholds of effects can be determined, and it is less likely to obscure possible non-linear associations, but it requires comparable exposure indicators of the studies considered in the meta-analysis. Often both, trend and categorical contrast analyses are carried out simultaneously (128).

Conclusions

The noise indicators used for noise mapping in the EU can – in principle – be used for a quantitative risk assessment regarding cardiovascular risk if exposure–response relationships are known. Only two end-points – hypertension and ischaemic heart disease – should be considered at this stage. If necessary, different exposure–response curves could be used for different exposures. Some studies showed that associations between noise level and cardiovascular outcomes were stronger with respect to noise exposure at night *(128,166,167)*. In this respect, it can be useful to consider different exposure–response relationships for day and night noise, particularly if the exposed side of the house is considered for exposure assessment. For practical reasons, attempts should be made to reduce the set of necessary exposure–response curves to a minimum. The noise indicator L_{den} may be useful for assessing and predicting annoyance in the population. However, non-weighted day and night noise indicators may be more appropriate for health-effect-related research and risk quantification. It is a matter for future research to determine how the integrated noise indicator L_{den} performs in noise studies, particularly with respect to noise sources (railways, aircraft) other than road traffic where the differences between day and night noise are less uniform and depend on location and other circumstances (e. g. night noise regulations).

We adopted conservative assumptions whenever necessary. One exception was to extrapolate the exposure data from urban population to the whole population of the EU. This was necessary because of a lack of exposure data for the rural population as of 2010. Considering the advanced level of urbanization in western Europe and the bias toward the null in the estimation of relative risks due to random misclassification of exposure, the overall impact of overestimation due to extrapolation might be minimal. Nevertheless, it is desirable to use exposure data for the whole population when it is available.

We have to learn to live with uncertainties *(168,169)*. Nevertheless, "no exposure data" does not mean "no exposure" and "no scientific evidence" does not mean "no effect" *(170)*. Using the precautionary principle, decisions can be made based on best available data *(171,172)*. Future epidemiological noise research will need to focus on vulnerable groups, effect modifiers, sensitive hours of the day, coping mechanisms, differences between noise sources, possible confounding with air pollution, differences between objective (noise level) and subjective (noise perception) exposure, and multiple exposures (home, work and leisure environments).

REFERENCES

1. Berglund B, Lindvall T, Schwela DH, eds. *Guidelines for community noise*. Geneva, World Health Organization, 1999 (http://whqlibdoc.who.int/hq/1999/a68672.pdf, accessed 22 July 2010).
2. Schwela DH. The World Health Organization guidelines for environmental health. *Noise/News International*, 2000, 8:9–22.
3. Suter AH. Noise sources and effects – a new look. *Sound & Vibration*, 1992, 25:18–38.
4. Passchier-Vermeer W, Passchier WF. Noise exposure and public health. *Environmental Health Perspectives*, 2000, 108(Suppl. 1):123–131.
5. Stansfeld S, Haines M, Brown B. Noise and health in the urban environment. *Reviews on Environmental Health*, 2000, 15:43–82.
6. *The world health report 2002 – reducing risks, promoting healthy life*. Geneva, World Health Organization, 2002.
7. Mathers CD et al. *Global burden of disease in 2002: data sources, methods and results*. Geneva, World Health Organization, 2003 (Global Programme on Evidence for Health Policy Discussion Paper No. 54) (http://www.who.int/healthinfo/paper54.pdf, accessed 28 August 2006).
8. Lopez AD et al., eds. *Global burden of disease and risk factors.* Washington, DC and New York, The World Bank and Oxford University Press, 2006 (http://www.dcp2.org/pubs/GBD, accessed 22 July 2010).
9. Maschke C, Rupp T, Hecht K. The influence of stressors on biochemical reactions – a review of present scientific findings with noise. *International Journal of Hygiene and Environmental Health*, 2000, 203:45–53.
10. Maschke C. Excretion of cortisol under nocturnal noise and differences due to analytic techniques. *Noise & Health*, 2002, 5(17):47–52.
11. Maschke C, Hecht K. Stress and noise – the psychological/physiological perspective and current limitations. In: Luxon L, Prasher D, eds. *Noise and its effects*. Chichester, John Wiley & Sons, 2007.
12. Spreng M. Central nervous system activation by noise. *Noise & Health*, 2000, 2(7):49–57.
13. Spreng M. Possible health effects of noise induced cortisol increase. *Noise & Health*, 2000, 2(7):59–63.
14. Spreng M. Noise induced nocturnal cortisol secretion and tolerable overhead flights. *Noise & Health*, 2004, 6(22):35–47.
15. Rylander R. Annoyance and stress. *Journal of Aviation and Environmental Research*, 2002, 7(Suppl.):4–6.
16. McEwen BS. Stress, adaption, and disease. Allostasis and allostatic load. *Annals of the New York Academy of Sciences*, 1998, 840:33–44.
17. Sapolsky RM, McEwen BS. Induced modulation of endocrine history: a partial review. *Stress*, 1997, 2:1–12.
18. Babisch W. Transportation noise and cardiovascular risk: updated review and synthesis of epidemiological studies indicate that the evidence has increased. *Noise & Health*, 2006, 8:1–29.
19. Babisch W. Traffic noise and cardiovascular disease: epidemiological review and synthesis. *Noise & Health*, 2000, 2(8):9–32.
20. van Kempen EEMM. et al. The association between noise exposure and blood pressure and ischaemic heart disease: a meta-analysis. *Environmental Health Perspectives*, 2002, 110:307–317.
21. Babisch W. Road traffic noise and cardiovascular risk. *Noise & Health*, 2008, 10(38):27–33.

22. van Kempen EEMM. *Transportation noise exposure and children's health and cognition* [thesis]. Utrecht, University of Utrecht, 2008.
23. Henry JP, Stephens PM. *Stress, health, and the social environment, a sociobiologic approach to medicine*. New York, Springer-Verlag, 1977.
24. Ising H et al. Health effects of traffic noise. *International Archives of Occupational and Environmental Health*, 1980, 47:179–190.
25. Lercher P. Environmental noise and health: an integrated research perspective. *Environment International*, 1996, 22:117–128.
26. Babisch W. The noise/stress concept, risk assessment and research needs. *Noise & Health*, 2002, 4(16):1–11.
27. Sapolsky RM, Krey LC, McEwan BS. The neuroendocrinology of stress and aging: the glucocorticoid cascade hypothesis. *Endocrine Reviews*, 1986, 7:284–306.
28. Sapolsky RM. Effects of stress and glucocorticoids on hippocampal neuronal survival. In: Brown MR, Koob GF, Rivier C, eds. *Stress. Neurobiology and Neuroendocrinology*. New York, Marcel Dekker, 1990:293–322.
29. McEwen BS. Protective and damaging effects of stress mediators. *New England Journal of Medicine*, 1998, 338:171–179.
30. McEwen BS. et al. Characterization of brain adrenal steroid receptors and their involvement in the stress response. In: Brown MR, Koob GF, Rivier C, eds. *Stress. Neurobiology and neuroendocrinology*. New York, Marcel Dekker, 1990:275–292.
31. Wüst S. et al. Genetic factors, perceived chronic stress, and the free cortisol response to awakening. *Psychoneuroendocrinology*, 2000, 25:707–720.
32. Babisch W. Stress hormones in the research on cardiovascular effects of noise. *Noise & Health*, 2003, 5(18):1–11.
33. Kirschbaum C, Hellhammer DH. Noise and stress – salivary cortisol as a non-invasive measure of allostatic load. *Noise & Health*, 1999, 4:57–65.
34. Born J, Fehm HL. The neuroendocrine recovery function of sleep. *Noise & Health*, 2000, 7:25–37.
35. Sabbah W et al. Effects of allostatic load on the social gradient in ischaemic heart disease and periodontal disease: evidence from the Third National Health and Nutrition Examination Survey. *Journal of Epidemiology and Community Health*, 2008, 62:415–420.
36. Vera MN, Vila J, Godoy JF. Cardiovascular effects of traffic noise: the role of negative self-statements. *Psychological Medicine*, 1994, 24:817–827.
37. Raggam RB et al. Personal noise ranking of road traffic: subjective estimation versus physiological parameters under laboratory conditions. *International Journal of Hygiene and Environmental Health*, 2007, 210:97–105.
38. Lusk SL et al. Acute effects of noise on blood pressure and heart rate. *Archives of Environmental Health*, 2004, 59:392–399.
39. Maschke C et al. Stress hormone changes in persons exposed to simulated night noise. *Noise & Health*, 2002, 5(17):35–45.
40. Muzet A. Environmental noise, sleep and health. *Sleep Medicine Reviews*, 2007, 11:135–142.
41. Levi L. A new stress tolerance test with simultaneous study of physiological and psychological variables. *Acta Endocrinologica*, 1961, 37:38–44.
42. Levi L. Sympatho-adrenomedullary responses to emotional stimuli: methodologic, physiologic and pathologic considerations. In: Bajusz E, ed. *An introduction to clinical neuroendocrinology*. Basel, S. Karger, 1967.
43. Arguelles AE, Ibeas D, Ottone JP. Pituitary-adrenal stimulation by sound of different frequencies. *Journal of Clinical Epidemiology and Metabolism*, 1962, 22:846–851.

44. Arguelles AE et al. Endocrine and metabolic effects of noise in normal, hypertensive and psychotic subjects. In: Welch BL, Welch AS, eds. *Physiological effects of noise*. New York, Plenum Press, 1970.
45. Glass D, Singer JE, Friedman LN. Psychic cost of adaption to an environmental stressor. *Journal of Personality and Social Psychology*, 1969, 12:200–210.
46. Anticaglia JR, Cohen A. Extra-auditory effects of noise as a health hazard. *American Industrial Hygiene Association Journal*, 1970, 31:277–281.
47. Welch BL, Welch AS, eds. *Physiological effects of noise*. New York, Plenum Press, 1970.
48. Kryter KD. *The effects of noise on man*. New York, Academic Press, 1970.
49. Kryter KD. Non-auditory effects of environmental noise. *American Journal of Public Health*, 1972, 62:389–398.
50. Kryter K, Poza F. Effects of noise on some autonomic system activities. *Journal of the Acoustical Society of America*, 1980, 67:2036–2044.
51. Miyazaki M. Effect of undesirable sound (noise) on cerebral circulation. *Japanese Circulation Journal*, 1971, 35:931–936.
52. Semczuk B, Górny H. Studies on the effect of noise on cardiorespiratory efficiency. *Polish Medical Journal*, 1971, 10(3):594–598.
53. Favino A et al. Radioimmunoassay measurements of serum cortisol, thyroxine, growth hormone and luteinizing hormone with simultaneous electroencephalographic changes during continuous noise in man. *Journal of Nuclear Biology and Medicine*, 1973, 17:119–122.
54. Verdun di Cantogno L et al. Urban traffic noise cardiocirculatory activity and coronary risk factors. *Acta Oto-laryngologica*, 1976, Suppl. 339:55–63.
55. Griefahn B, Muzet A. Noise-induced sleep disturbances and their effects on health. *Journal of Sound and Vibration*, 1978, 59:99–106.
56. Mosskov JI, Ettema JH. Extra-auditory effects in short-term exposure to aircraft and traffic noise. *International Archives of Occupational and Environmental Health*, 1977, 40:165–173.
57. Mosskov JI, Ettema JH. Extra-auditory effects in short-term exposure to noise from a textile factory. *International Archives of Occupational and Environmental Health*, 1977 40:174–176.
58. Mosskov JI, Ettema JH. Extra-auditory effects in long-term exposure to aircraft and traffic noise. *International Archives of Occupational and Environmental Health*, 1977, 40:177–184.
59. Andrén L et al. Noise as a contributory factor in the development of elevated arterial pressure. *Acta Medica Scandinavica*, 1980, 207:493–498.
60. Andrén L. Cardiovascular effects of noise. *Acta Medica Scandinavica*, 1982 Suppl. 657:7–41.
61. Andrén L et al. Effect of noise on blood pressure and "stress" hormones. *Clinical Science*, 1982, 62:137–141.
62. Andrén L et al. Circulatory effects of noise. *Acta Medica Scandinavica*, 1983, 213:31–35.
63. Bach V et al. Cardiovascular responses and electroencephalogram disturbances to intermittent noises: effects of nocturnal heat and daytime exposure. *European Journal of Applied Physiology*, 1991, 63:330–337.
64. Carter N et al. Cardiovascular and autonomic response to environmental noise during sleep in night shift workers. *Sleep*, 2002, 25:457–464.
65. Chen CJ et al. Measurement of noise evoked blood pressure by means of averaging method: relation between blood pressure rise and SPL. *Journal of Sound and Vibration*, 1991, 151:383–394.
66. Parrot J et al. Cardiovascular effects of impulse noise, road traffic noise, and intermittent pink noise at LAeq = 75 dB, as a function of sex, age, and level of anxiety: a comparative study. I. Heart rate data. *International Archives of Occupational and Environmental Health*, 1992, 63:477–484.

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67. Slob A, Wink A, Radder JJ. The effect of acute noise exposure on the excretion of corticosteroids, adrenalin and noradrenalin in man. *Internationales Archiv für Arbeitsmedizin*, 1973, 31:225–235.
68. Chang T-Y et al. Effects of occupational noise exposure on 24-hour ambulatory vascular properties in male workers. *Environmental Health Perspectives*, 2007, 115:1660–1664.
69. Chang T-Y et al. Effects of occupational noise exposure on blood pressure. *Journal of Occupational and Environmental Medicine*, 2003, 45:1289–1296.
70. Fogari R et al. Transient but not sustained blood pressure increments by occupational noise. An ambulatory blood pressure measurement study. *Journal of Hypertension*, 2001, 19:1021–1027.
71. Ising H, Nawroth H, Günther T. Accelerated aging of rats by Mg deficiency and noise stress. *Magnesium-Bulletin*, 1981, 3(2):142–146.
72. Flynn AJ, Dengerink HA, Wright JW. Blood pressure in resting, anesthetized and noise-exposed guinea pigs. *Hearing Research*, 1988, 34:201–206.
73. Engeland WC, Miller P, Gann DS. Pituitary-adrenal and adrenomedullary responses to noise in awake dogs. *American Journal of Physiology*, 1990, 285(Suppl. 2)(82):R672–R677.
74. Armario A, Castellanos JM, Balasch J. Chronic noise stress and insulin secretion in male rats. *Physiology & Behavior*, 1984, 34:359–361.
75. Maass B, Jacobi E, Esser G. Platelet adhesiveness during exposure to noise. *German Medicine*, 1973, 3:111–113.
76. Michaud DS et al. Differential impact of audiogenic stressors on Lewis and Fischer rats: behavioral, neurochemical, and endocrine variations. *Neuropsychopharmacology*, 2003, 28:1068–1081.
77. Peterson EA. Noise raises blood pressure without impairing auditory sensitivity. *Science*, 1981, 211:1450–1452.
78. Altura BM et al. Noise-induced hypertension and magnesium in rats : relationship to microcirculation and calcium. *Journal of Applied Physiology*, 1992, 72:194–202.
79. Algers B, Ekesbo I, Strömberg S. The impact of continuous noise on animal health. *Acta Veterinaria Scandinavica*, 1978, 67(Suppl.):1–26.
80. Ising H et al. Increase of collagen in the rat heart induced by noise. *Environment International*, 1979, 2:95–105.
81. Morizono T et al. Hyperlipidemia and noise in the chinchilla. *Acta Oto-laryngologica*, 1985, 99:516–524.
82. Günther T et al. Magnesium intake and blood pressure of spontaneously hypertensive rats. *Magnesium-Bulletin*, 1984, 6(3):120–126.
83. Andriukin AA. The influence of sound stimulation on the development of hypertension. *Cor et Vasa*, 1961, 3:285–293.
84. Deyanov C et al. Study on the level of blood pressure and prevalence of arterial hypertension depending on the duration of occupational exposure to industrial noise. *Central European Journal of Occupational and Environmental Medicine*, 1995, 1(2):109–116.
85. Stansfeld SA, Matheson MP. Noise pollution: non-auditory effects on health. *British Medical Bulletin*, 2003, 68:243–257.
86. Concha-Barrientos M, Campbell-Lendrum D, Steenland K. *Occupational noise. Assessing the burden of disease from work-related hearing impairment at national and local levels*. Geneva, World Health Organization, 2004 (Environmental Burden of Disease Series, No. 9).
87. Babisch W. Epidemiological studies of the cardiovascular effects of occupational noise – a critical appraisal. *Noise & Health*, 1998, 1(1):24–39.

88. McNamee R et al. Occupational noise exposure and ischaemic heart disease mortality. *Occupational and Environmental Medicine*, 2006, 63:813–819.
89. Davies HW et al. Occupational exposure to noise and mortality from acute myocardial infarction. *Epidemiology*, 2005, 16:25–32.
90. Zhao Y et al. A dose response relation for noise induced hypertension. *British Journal of Industrial Medicine*, 1991, 48:179–184.
91. van Dijk FJH. Epidemiological research on non-auditory effects of occupational noise exposure. *Environment International*, 1990, 16:405–409.
92. Lang T, Fouriaud C, Jacquinet-Salord M-C. Length of occupational noise exposure and blood pressure. *International Archives of Occupational and Environmental Health*, 1992, 63:369–372.
93. Melamed S, Kristal-Boneh E, Froom P. Industrial noise exposure and risk factors for cardiovascular disease: findings from the CORDIS study. *Noise & Health*, 1999, 1(4):49–56.
94. Melamed S, Fried Y, Froom P. The joint effect of noise exposure and job complexity on distress and injury risk among men and women: The Cardiovascular Occupational Risk Factors Determination in Israel Study. *Journal of Occupational and Environmental Medicine*, 2004, 46:1023–1032.
95. Powazka E et al. A cross-sectional study of occupational noise exposure and blood pressure in steelworkers. *Noise & Health*, 2002, 5(17):15–22.
96. Sbihi H, Davies H, Demers PA. Hypertensive disease in sawmill workers chronically exposed to high noise levels. *Occupational and Environmental Medicine*, 2008, 65:643–646.
97. Talbott EO et al. Evidence for a dose–response relationship between occupational noise and blood pressure. *Archives of Environmental Health*, 1999, 54:71–78.
98. Virkkunen H, Kauppinen T, Tenkanen L. Long-term effect of occupational noise on the risk of coronary heart disease. *Scandinavian Journal of Work, Environment & Health*, 2005, 31:291–299.
99. Berglund B, Lindvall T, eds. *Community noise*. Stockholm, Center for Sensory Research, 1995.
100. Manninen O, Aro S. Urinary catecholamines, blood pressure, serum cholesterol and blood glucose response to industrial noise exposure. *Arhiv za Higijenu Rada i Toksikologiju*, 1979, 30:713–718.
101. Dugué B, Leppänen E, Gräsbeck R. Preanalytical factors and standardized specimen collection: the effects of industrial noise. *Stress Medicine*, 1994, 10:185–189.
102. Marth E et al. Fluglärm: Veränderung biochemischer Parameter. *Zentralblatt für Bakteriologie, Parasitenkunde, Infektionskrankheiten und Hygiene*, 1988, 185:498–508.
103. Rai RM et al. Biochemical effects of chronic exposure to noise in man. *International Archives of Occupational and Environmental Health*, 1981, 48:331–337.
104. Schulte W, Otten H. Ergebnisse einer Tiefffluglärmstudie in der Bundesrepublik Deutschland: Extraaurale Langzeitwirkungen. In: Ising H, Kruppa B, eds. *Lärm und Krankheit – Noise and Disease. Proceedings of the International Symposium, Berlin, 1991*. Stuttgart, Gustav Fischer Verlag, 1993:322–338.
105. Yoshida T et al. Effects of road traffic noise on inhabitants of Tokyo. *Journal of Sound and Vibration*, 1997, 205:517–522.
106. Knipschild P, Sallé H. Road traffic noise and cardiovascular disease. *International Archives of Occupational and Environmental Health*, 1979, 44:55–59.
107. von Eiff AW et al. Verkehrslärm und Hypertonie-Risiko. 2. Mitteilung: Hypothalamus-Theorie der essentiellen Hypertonie. *Münchener medizinische Wochenschrift*, 1981, 123:420–424.
108. Goto K, Kaneko T. Distribution of blood pressure data from people living near an airport. *Journal of Sound and Vibration*, 2002, 250:145–149.

109. von Eiff AW et al. Der medizinische Untersuchungsteil. In: Deutsche Forschungsgemeinschaft, ed. *Fluglarmwirkungen – Eine interdisziplinare Untersuchung uber die Auswirkungen des Fluglarms auf den Menschen*. Boppard, Harald Boldt Verlag, 1974:349–424.
110. Babisch W et al. Traffic noise, work noise and cardiovascular risk factors: The Caerphilly and Speedwell Collaborative Heart Disease Studies. *Environment International*, 1990, 16: 425–435.
111. Lercher P, Kofler W. Adaptive behavior to road traffic noise blood pressure and cholesterol. In: Vallet M, ed. *Noise and Man'93. Proceedings of the 6th International Congress on Noise as a Public Health Problem, Nice, 1993*. Arcueil Cedex, Institut National de Recherche sur les Transports et leur Sécurité, 1993:465–468.
112. Griefahn B, Marks A, Robens S. Noise emitted from road, rail and air traffic and their effects on sleep. *Journal of Sound and Vibration*, 2006, 295:129–140.
113. 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. *Official Journal of the European Communities*, 2002, L 189:12–25.
114. Bite M, Bite PZ. Zusammenhang zwischen den Straßenverkehrslärmindizes $L_{Aeq(06-22)}$ und $L_{Aeq(22-06)}$ sowie L_{den}. *Zeitschrift für Lärmbekämpfung*, 2004, 51:27–28.
115. Evans GW et al. Community noise exposure and stress in children. *Journal of the Acoustical Society of America*, 2001, 109:1023–1027.
116. Ullrich S. Lärmbelastung durch den Straßenverkehr. *Zeitschrift für Lärmbekämpfung*, 1998, 45:22–26.
117. Utley WA. Descriptors for ambient noise. In: *InterNoise 85. Proceedings of the International Conference on Noise Control Engineering in Munich, 1985*. Bremerhaven, Verlag für neue Wissenschaft GmbH, 1985:1069–1073.
118. Rylander R et al. Dose–response relationships for traffic noise and annoyance. *Archives of Environmental Health*, 1986, 41:7–10.
119. Miedema HME, Oudshoorn CGM. Annoyance from transportation noise: relationships with exposure metrics DNL and DENL and their confidence intervals. *Environmental Health Perspectives*, 2001, 109:409–416.
120. *Good practice guide for strategic noise mapping and the production of associated data on noise exposure, version 2*. Brussels, European Commission Working Group Assessment of Exposure to Noise, 2006 (http://ec.europa.eu/environment/noise/pdf/wg_aen.pdf, accessed 21 July 2010).
121. Babisch W. *Transportation noise and cardiovascular risk. Review and synthesis of epidemiological studies: dose–effect curve and risk estimation*. Dessau, Umweltbundesamt, 2006 (WaBoLu-Hefte 01/06) (http://www.umweltbundesamt.de/uba-info-medien/mysql_medien.php?anfrage=Kennummer&Suchwort=2997, accessed April 2006).
122. Babisch W et al. Traffic noise and cardiovascular risk: The Caerphilly and Speedwell studies, third phase – 10 years follow-up. *Archives of Environmental Health*, 1999, 54:210–216.
123. Babisch W, Ising H, Gallacher JEJ. Health status as a potential effect modifier of the relation between noise annoyance and incidence of ischaemic heart disease. *Occupational and Environmental Medicine*, 2003, 60:739–745.
124. Babisch W et al. The incidence of myocardial infarction and its relation to road traffic noise – the Berlin case-control studies. *Environment International*, 1994, 20:469–474.
125. Babisch W et al. Traffic noise and risk of myocardial infarction. *Epidemiology*, 2005, 16:33–40.
126. Babisch W et al. Traffic noise and cardiovascular risk: the Caerphilly and Speedwell studies, second phase. Risk estimation, prevalence, and incidence of ischaemic heart disease. *Archives of Environmental Health*, 1993, 48:406–413.
127. Umweltbundesamt. *Daten zur Umwelt. Der Zustand der Umwelt in Deutschland 2000*. Berlin, Erich Schmidt Verlag GmbH, 2001:321–332.

128. Jarup L et al. Hypertension and exposure to noise near airports – the HYENA study. *Environmental Health Perspectives*, 2008, 116:329–333.
129. Bluhm GL et al. Road traffic noise and hypertension. *Occupational and Environmental Medicine*, 2007, 64:122–126.
130. de Kluizenaar Y et al. Hypertension and road traffic noise exposure. *Journal of Occupational and Environmental Medicine*, 2007, 49:484–492.
131. Knipschild P. Medical effects of aircraft noise: community cardiovascular survey. *International Archives of Occupational and Environmental Health*, 1977, 40:185–190.
132. Rosenlund M et al. Increased prevalence of hypertension in a population exposed to aircraft noise. *Occupational and Environmental Medicine*, 2001, 58:769–773.
133. Matsui T et al. The Okinawa study: effects of chronic aircraft noise on blood pressure and some other physiological indices. *Journal of Sound and Vibration*, 2004, 277:469–470.
134. Matsui T et al. Association between blood pressure and aircraft noise exposure around Kadena airfield in Okinawa. In: Boone R, ed. *Internoise 2001. Proceedings of the 2001 International Congress and Exhibition on Noise Control Engineering, The Hague, 2001*, Vol. 3. Maastricht, Nederlands Akoestisch Genootschap, 2001:1577–1582.
135. Eriksson C et al. Aircraft noise and incidence of hypertension. *Epidemiology*, 2007, 18:716–721.
136. Babisch W, van Kamp I. Exposure–response relationship of the association between aircraft noise and the risk of hypertension. *Noise & Health*, 2009, 11(44):161–168.
137. Stassen KR, Collier P, Torfs R. Environmental burden of disease due to transportation noise in Flanders (Belgium). *Transportation Research Part D*, 2008, 13:355-358
138. Umweltbundesamt. *Data on the environment. The state of the environment in Germany*, 2005 ed. Dessau, Federal Environmental Agency, 2005:85–90.
139. Gesundheitsdaten online. Gesundheitsberichterstattung des Bundes [online database]. Berlin, Statistisches Bundesamt and Robert Koch-Institut, 2005 (http://www.gbe–bund.de, accessed 20 June 2005).
140. Umweltatlas Berlin [online database]. Senatsverwaltung für Stadtentwicklung, 2007 (http://www.stadtentwicklung.berlin.de/umwelt/umweltatlas/dinh_07.htm, accessed April 2008).
141. Noise Observation and Information Service for Europe (NOISE) [web site]. Copenhagen, European Environment Agency 2009 (http://noise.eionet.europa.eu/index.html, accessed 31 July 2010).)
142. *Global burden of disease: 2004 update*. Geneva, World Health Organization, 2008 (http://www.who.int/healthinfo/global_burden_disease/GBD_report_2004update_full.pdf, accessed 3 February 2011).
143. Yusuf S et al. Global burden of cardiovascular diseases. Part I: general considerations, the epidemiologic transition, risk factors, and impact of urbanization. *Circulation*, 2001, 104:2746–2753.
144. Herbold M, Hense H-W, Keil U. Effects of road traffic noise on prevalence of hypertension in men: results of the Lübeck blood pressure study. *Sozial- und Präventivmedizin*, 1989, 34:19–23.
145. Belojevic G, Saric-Tanaskovic M. Prevalence of arterial hypertension and myocardial infarction in relation to subjective ratings of traffic noise exposure. *Noise & Health*, 2002, 4(16):33–37.
146. Farley TMM et al. Combined oral contraceptives, smoking, and cardiovascular risk. *Journal of Epidemiology & Community Health*, 1998, 52:775–785.
147. Miedema HME, Vos H. Exposure–response relationships for transportation noise. *Journal of the Acoustical Society of America*, 1998, 104:3432–3445.

148. Pope CA III et al. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *JAMA*, 2002, 287:1132–1141.
149. Pope CA III et al. Cardiovascular mortality and long-term exposure to particulate air pollution. *Circulation*, 2004:71–77.
150. Anderson HR et al. *Meta-analysis of time-series studies and panel studies of particulate matter (PM) and ozone (O_3). Report of a WHO task group*. Copenhagen, WHO Regional Office for Europe, 2004.
151. Rabl A. Analysis of air pollution mortality in terms of life expectancy changes: relation between time series, intervention and cohort studies. *Environmental Health*, 2006, 5:1–19.
152. Dockery DW et al. An association between air pollution and mortality in six U. S. cities. *New England Journal of Medicine*, 1993, 329:1753–1759.
153. Dockery, D.W., Epidemiologic evidence of cardiovascular effects of particulate air pollution. *Environmental Health Perspectives*, 2001, 109(Suppl. 4):483–486.
154. Brunekreef B, Holgate ST. Air pollution and health. *Lancet*, 2002, 360:1233–1242.
155. Brook RD et al. Air pollution and cardiovascular disease. *Circulation*, 2004, 109:2655–2671.
156. Schwela D, Kephaloupoulos S, Prasher D. Confounding or aggravating factors in noise-induced health effects: air pollutants and other stressors. *Noise & Health*, 2005, 7(28):41–50.
157. Naess O et al. Relation between concentration of air pollution and cause-specific mortality: four-year exposures to nitrogen dioxide and particulate matter pollutants in 470 neighborhoods in Oslo, Norway. *American Journal of Epidemiology*, 2006, 165:435–443.
158. Public health impact of large airports. Report by a committee of the Health Council of the Netherlands. The Hague, Health Council of the Netherlands, 1999 (Publication No. 1999/14E).
159. Jarup L et al. Hypertension and exposure to noise near airports (HYENA): study design and noise exposure assessment. *Noise & Health*, 2006, 8:58–59.
160. Heimann D et al. *Air pollution, traffic noise and related health effects in the Alpine space – a guide for authorities and consulters. ALPNAP comprehensive report*. Trento, Università degli Studi di Trento, 2007.
161. Gehring U et al. Long-term exposure to ambient air pollution and cardiopulmonary mortality in women. *Epidemiology*, 2006, 17:545–551.
162. Hoek G et al. Association between mortality and indicators of traffic-related air pollution in the Netherlands: a cohort study. *Lancet*, 2002, 360:1203–1209.
163. Hoffmann B et al. Residence close to high traffic and prevalence of coronary heart disease. *European Heart Journal*, 2006, 27:2696–2702.
164. Hoffmann B et al. Residential exposure to traffic is associated with coronary atherosclerosis. *Circulation*, 2007, 116:489–496.
165. Tonne C et al. A case-control analysis of exposure to traffic and acute myocardial infarction. *Environmental Health Perspectives*, 2007, 115:53–57.
166. Maschke C. Epidemiological research on stress caused by traffic noise and its effects on high blood pressure and psychic disturbances. In: de Jong R et al., eds. *ICBEN 2003. Proceedings of the 8th International Congress on Noise as a Public Health Problem, Rotterdam, 2003*. Schiedam, Foundation ICBEN, 2003:93–95.
167. Greiser E, Greiser C, Janhsen K. Night-time aircraft noise increases prevalence of prescriptions of anthypertensive and cardiovascular drugs irrespective of social class – the Cologne–Bonn Airport study. *Journal of Public Health*, 2007, 15:1613–2238.
168. Rose G. Editorial: epidemiology and environmental risks. *Sozial- und Präventivmedizin*, 1992, 37:41–44.
169. Scheuplein RJ. Uncertainty and the "flavors" of risk. *EPA Journal*, 1993, Jan–Mar:16–17.

170. Morrell S, Taylor R, Lyle D. A review of health effects of aircraft noise. *Australian and New Zealand Journal of Public Health*, 1997, 21:221–236.
171. *Evaluation and use of epidemiological evidence for environmental health risk assessment. Guideline document*. Copenhagen, WHO Regional Office for Europe, 2000 (http://www.euro.who.int/document/e68940.pdf, accessed 21 July 2010).
172. Horton R. The *new* new public health of risk and radical engagement. *Lancet*, 1998, 352:251–252.

Appendix 1. Exposure-response curve (polynomial fit) of the association between road traffic noise and incidence of myocardial infarction

$$OR = 1.629657 - 0.000613 \cdot (L_{day,16h})^2 + 0.000007357 \cdot (L_{day,16h})^3$$

$L_{day,16h}$	L_{den}*	OR
55	57	1
55.5	57.5	1
56	58	1
56.5	58.5	1
57	59	1
57.5	59.5	1.002
58	60	1.003
58.5	60.5	1.005
59	61	1.007
59.5	61.5	1.009
60	62	1.012
60.5	62.5	1.015
61	63	1.019
61.5	63.5	1.022
62	64	1.027
62.5	64.5	1.031
63	65	1.036
63.5	65.5	1.042
64	66	1.047
64.5	66.5	1.054
65	67	1.06
65.5	67.5	1.067
66	68	1.074
66.5	68.5	1.082
67	69	1.091
67.5	69.5	1.099
68	70	1.108
68.5	70.5	1.118
69	71	1.128
69.5	71.5	1.138
70	72	1.149
70.5	72.5	1.161
71	73	1.173
71.5	73.5	1.185
72	74	1.198
72.5	74.5	1.211
73	75	1.225
73.5	75.5	1.239
74	76	1.254
74.5	76.5	1.269
75	77	1.285
75.5	77.5	1.302
76	78	1.318
76.5	78.5	1.336
77	79	1.354
77.5	79.5	1.372
78	80	1.391
78.5	80.5	1.411
79	81	1.431
79.5	81.5	1.452
80	82	1.473

*Approximation: $L_{den} = L_{Aeq,16h} + 2$ dB

3. ENVIRONMENTAL NOISE AND COGNITIVE IMPAIRMENT IN CHILDREN

Staffan Hygge
Rokho Kim

It has been suspected for many years that children's learning and memory are negatively affected by noise. Over 20 studies have shown negative effects of noise on reading and memory in children *(1,2)*: epidemiological studies report effects of chronic noise exposure and experimental studies report acute noise exposure. Tasks affected are those involving central processing and language, such as reading comprehension, memory and attention *(3–6)*. Exposure during critical periods of learning at school could potentially impair development and have a lifelong effect on educational attainment.

Evidence from recent well-controlled epidemiological studies with representative samples of children has also made it possible to start to quantify the magnitude of noise-induced impairment on children's cognition and identify the relative contribution of different sources of noise. Children may be exposed to noise for many of their childhood years and the consequences of long-term noise exposure on reading comprehension and further cognitive development remain unknown. Such quantifications, albeit initially crude, will in the long run help to estimate and quantify how much cognitive development individual children could be expected to lose because of noise, and the economic impact of this for learning in schools. In turn, such estimates will be also of value for making projections on the societal level, including political decision about any sociodemographic redistribution of noise exposure. On the other hand, exposure–response curves can also be used for social engineering decisions about how much of an improvement, and for whom, can be expected from a reduction in noise levels.

This chapter attempts to contribute to this general goal by placing the negative effects of noise on children's cognition into the risk assessment context.

Definition of outcome

Cognitive impairment is not an outcome of a clinical diagnosis; it is therefore not possible to derive a conventional exposure–risk relationship suitable for calculating burden of disease. Lopez et al. *(7)* defined cognitive impairment as "delayed psychomotor development and impaired performance in language skills, motor skills, and coordination equivalent to a 5- to 10-point deficit in IQ". Contemporaneous cognitive deficit is defined as "reduction in cognitive ability in school-age children, which occurs only while infection persists".

These definitions are not helpful and not readily applicable to the studies reported on noise and cognition in children. None of the studies has explicitly employed IQ as an end-point and the confining of any reduction in cognitive ability to the duration of the noise exposure is too restrictive. Therefore, our case definition of noise related cognitive impairment is:

> Reduction in cognitive ability in school-age children that occurs while the noise exposure persists and will persist for some time after the cessation of the noise exposure.

A notable characteristic of this definition is that the cognitive impairment is assumed to show itself during the noise exposure as well as some time after the exposure has stopped.

Summary of evidence linking noise and cognitive impairment in children

The extent to which noise impairs cognition, particularly in children, has been studied with both experimental and epidemiological designs. The epidemiological studies report effects of chronic noise exposure and the experimental studies of acute noise exposure. The studies relevant to children's cognition are not many and do not always meet strict methodological criteria. Nevertheless, there are three recent studies that meet basic methodological quality criteria and are also comparable with each other in terms of the cognitive functions measured.

One of the most compelling studies in this field is the naturally occurring longitudinal quasi-experiment reported by Evans and colleagues, examining the effect of the relocation of Munich airport on children's (9–10 years, N = 326) health and cognition *(8–10)*. In 1992, the old Munich airport closed and was relocated. Prior to relocation, high noise exposure was associated with deficits in long-term memory and reading comprehension. Two years after the closure of the airport, these deficits disappeared, indicating that effects of noise on cognition may be reversible if exposure ceases. Most convincing was the finding that deficits in the very same memory and reading comprehension tasks developed over a two-year follow-up in children who became newly exposed to noise near the new airport.

The recent large-scale RANCH study, which compared the effect of road traffic and aircraft noise on children's (9–10 years, N = 2844) cognitive performance in the Netherlands, Spain and the United Kingdom, found a linear exposure–effect relationship between long-term exposure to aircraft noise and impaired reading comprehension and recognition memory, after taking a range of socioeconomic and confounding factors into account *(11)*. No associations were observed between long-term road traffic noise exposure and cognition, with the exception of episodic memory, which surprisingly showed better performance in high road traffic noise areas. Neither aircraft noise nor road traffic noise affected attention or working memory.

A study of ambient noise exposure (predominantly road and rail sources) of fourth-grade children living in the Tyrol mountain region compared three cognitive measures for schoolchildren (mean age 9–7 years, N = 123) exposed to 46 or 62 dB(A) L_{dn}. The two sociodemographically homogeneous samples differed only in their noise exposure range (M = 46.1 L_{dn} vs M = 62 L_{dn}). Long-term noise exposure was significantly related to both intentional and incidental memory. The improvement in cognitive performance in the quieter group was estimated at 0.5% (recall prose and recognition) to 1% (free recall) per dB. The authors note that the magnitude of the effects shown was smaller than those uncovered in earlier airport noise studies.

Both the RANCH and Tyrol studies indicate that aircraft noise may be worse for cognition than road traffic noise. For aircraft noise, exposure evidence from the Munich study seems to indicate that L_{Aeq} = 60 may be a dividing line, but the RANCH study results suggest more of a linear association between aircraft noise exposure and impairment of reading comprehension. For ambient road and rail noise, the Tyrol study suggests that effects occur around L_{dn} = 60.

Other field studies of children have had some methodological limitations, which make them less relevant as evidence. For example, the testing of cognitive capacities took

place in noisy conditions for the noise-exposed and in quieter conditions for the children in the control groups. Testing in silent conditions would have been preferred, in order to compare the noise effect on memory and learning between exposure and control groups *(12–16)*. Also, for some studies, the sociodemographic variables and different reading curricula between the schools were not fully adjusted or controlled for.

Experimental studies of the impact of acute noise exposure on reading and memorizing new material are generally not as vulnerable to selection biases as epidemiological studies. Memory tests are made in silence of material that was read in noise. Participants are randomized to exposure and control groups, and children are sampled from sociodemographically comparable schools. To a certain extent, there is comparability between the memory and reading tests employed in the experimental studies and the field studies (the Munich and RANCH studies), even though the field studies concern chronic noise exposure and the second set acute noise exposure.

Exposure–response relationship

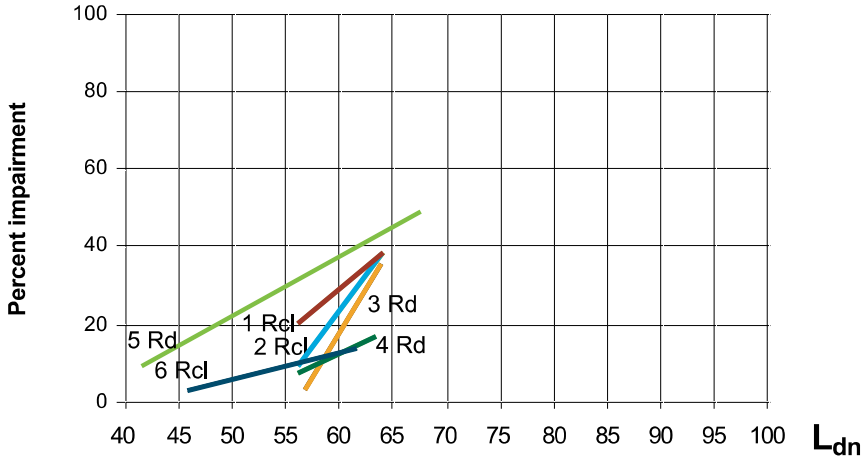
Only the Tyrol study *(17)* has used the noise indicator L_{dn}. The Munich study used $L_{eq,24h}$ and the RANCH study predominantly used $L_{eq,16h}$. The L_{dn} and L_{eq} metrics are not directly equivalent: L_{dn} is always equal to or larger than L_{eq}, with the following differences between L_{dn} and L_{eq} (T. Gjestland, personal communication, 2006):

- evenly distributed traffic flow, + 6.4 dB
- evenly distributed 07:00–22:00, no night traffic, + 1.9 dB
- 10% of traffic during 22:00–07:00, + 2.9 dB.

Although it is not clear which noise metric is the most adequate, L_{dn} may be more appropriate for the measurement of noise effects on cognition for some specific noise sources. For example, for aircraft noise exposure, the RANCH study found that both school $L_{eq,16h}$ and home $L_{eq,8h}$ (so a comparison of daytime noise exposure at school and nighttime noise exposure at home) had a similar detrimental effect on reading comprehension scores. These findings suggest that a measure such as L_{dn}, which combines daytime and nighttime exposure, would be appropriate for examining the effects of aircraft noise on cognition. However, this issue may be more complicated for other noise sources. For cognition, the fact that children spend the daytime at school and the nighttime at home needs to be taken into consideration. Aircraft noise exposure at school and home were highly correlated in the RANCH study, which could account for the similar effect on cognition for the daytime and nighttime measures. Road traffic noise at home and school were less highly correlated, suggesting that exposure measures that cover the 24-hour period may be less reliable in detecting cognitive effects and could be associated with error.

Fig. 3.1 shows the exposure–response curves from the different epidemiological studies. This can be summarized in quantitative terms: for the field studies in Fig. 3.1, memory recall and reading have average slopes of around 2% per L_{dn}, as calculated by the mean of the slopes of the six lines. Thus, for recall and reading, it is expected that a reduction of the chronic noise level by 5 L_{dn} would result in improved performance by 10%. As noted above, the only available road traffic noise study *(17)* had a less steep slope. The fact that we do not have much data from road traffic noise exposure set a limit to the generality of our conclusion, but the results of studies on aircraft noise, albeit few, are nevertheless consistent.

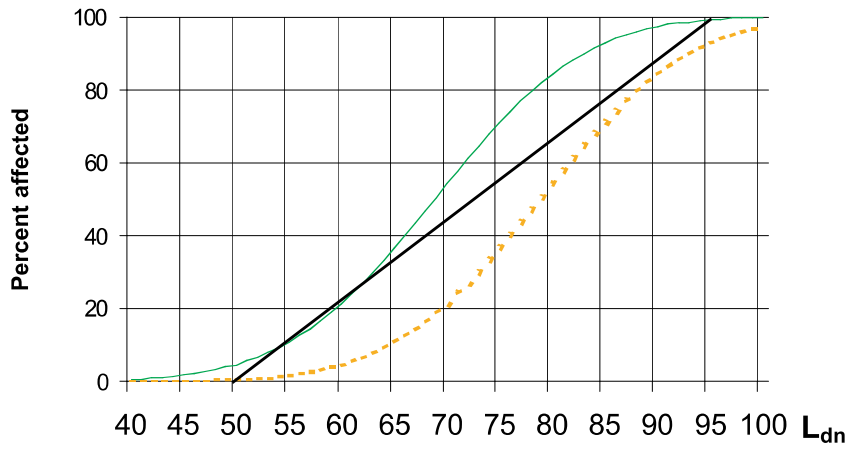
Fig. 3.1. Exposure-response curves from different epidemiological studies



Notes. Rd = reading; Rcl = memory, recall
1 = recall, children, old airport *(10)*.
2 = recall, children, new airport *(10)*.
3 = reading, children, old airport *(10)*.
4 = reading, children, new airport *(10)*.
5 = reading, children *(11)*.
6 = free recall, children *(17)*.

To obtain the exposure–response relationship, we need to use the information above to determine an approximate curve. Assuming that 100% of those exposed to noise are cognitively affected at the very high noise levels, e.g. 95 L_{dn}, and that none are affected at a safely low level, e.g. 50 L_{dn}, a straight line (linear accumulation) connecting these two points, as in Fig. 3.2, can be used a basis for approximations. This straight line is an underestimation of the real effect, since for theoretical reasons based on an (assumed) underlying normal distribution, the true curve should have the same sigmoidal function form as the two curves in Fig. 3.2. Within the noise exposure bracket 55–65 L_{dn}, the straight line and the solid line sigmoidal distribution agree on approximately 20% impairment. In the bracket 65–75 L_{dn}, the number should be in the range of 45–50% and above 75 L_{dn} in the range of 70–85%.

Fig. 3.2. Hypothetical exposure-risk curves and estimated percentage of affected people



Disability weight

Lopez et al. *(7)* suggested DWs for different cognitive impairments ranging from 0.468 (e.g. Japanese encephalitis) or 0.024 (e.g. as a result of iron deficiency anaemia). Contemporaneous cognitive deficit was given a DW of 0.006. Thus, this is a very conservative choice to go with the definition of contemporaneous cognitive deficit and a DW of 0.006 in estimates of the noise-related impairment of children's cognition.

There would be no mortality due to cognitive impairment, so estimation of YLD per year will be sufficient to estimate the total DALYs.

EBD calculations

Two examples are given. First, the exposure-specific approach is used to calculate the burden of disease from cognitive impairment due to noise in children aged 7–19 years in Sweden. And second, the values estimated in the first example are extrapolated to all of the WHO EUR-A epidemiological subregion *(7)*.

Note that the calculations rest on the assumption that the noise effects are there only when people are exposed. There is no assumption made that the inflicted noise-induced disability lasts longer than the noise exposure. It would not be unreasonable to set a case also for lasting cognitive effects of noise after the cessation of exposure, but that has explicitly not been done here.

Exposure-specific approach to environmental noise and cognitive impairment in Swedish children

For the first example, the exposure-specific approach is used to calculate the burden of cognitive impairment due to environmental noise in children aged 7–19 in Sweden. This approach requires:

- the distribution of the prevalence of exposure to environmental noise within the population from EU data;
- the exposure–response relationship between noise and the outcome from Table 3.1; and
- a value of DW for each case of the outcome caused by environmental noise.

Prevalence of noise exposure

There are no relevant figures for how many children are exposed to different noise levels. What are available are estimates of the percentage of people exposed to noise at different levels in the EU. For instance, Roovers et al. *(18)* stated that around 68% are exposed to L_{dn} levels < 55, 19% to 55–65, 11% to 65–75 and 2% to > 75. This is shown in Table 3.1, although statistics for the specific countries within geographical regions such as the EU may vary *(19)*.

The noise exposure distribution shown in Table 3.1 is for adults, but there is no reason to believe that the exposure distribution for children is very different. If there is a difference in noise exposure levels, children are more likely than adults to be exposed to noise.

To calculate the number of children exposed to the noise levels that meet the criterion of cognitive impairment, the age distribution in the population must be consid-

ered. In Sweden, 23.9% of the population are aged under 20 years and 16.53% were in the age range of the mandatory school system in 2004. In 2004, there were 1 489 437 school-aged children in Sweden. It can be noted that the proportion of the population up to 19 years (23.95%) fits closely with the 24.2% for the EU in 1998 *(19)*.

Table 3.1. Percentage of the population exposed to various levels of noise (L_{dn}) and calculated number of exposed children aged 7–19 years

Noise level (L_{dn})	Population exposed	Number of children exposed
< 55	68%	1 012 817
55–65	19%	282 993
65–75	11%	163 838
> 75	2%	29 789
Total	100%	1 489 437

Source: Roovers et al. *(18)*.

Number of cases of and YLD from cognitive impairment caused by environmental noise

Combining the number of children exposed (Table 3.1) with the likelihood of cognitive impairment if exposed (Fig. 3.2), the number of children with noise-induced cognitive impairment can be calculated. To estimate YLD due to the cognitive impairment, this number is multiplied by the DW of 0.006 (Table 3.2).

Table 3.2. Estimated number of children aged 7–19 years in Sweden with noise-induced cognitive impairment and DALYs per year due to noise-induced cognitive impairment (NICI)

Age group and noise exposure level	No. of children aged 7–19 exposed	Percentage of children who will develop NICI	No. of children with NICI	DALYs lost for NICI
7–19 years, < 55 L_{dn}	1 012 817	0	0	0.0
7–19 years, 55–65 L_{dn}	282 993	20	56 599	339.6
7–19 years, 65–75 L_{dn}	163 838	50	81 919	491.5
7–19 years, > 75 L_{dn}	29 789	75	22 342	134.1
Total	1 489 437		160 859	965.2

According to our estimates, there are 160 859 Swedish children aged 7–19 (point prevalence) who could be cognitively impaired to the extent of DW 0.006. This can also be considered equivalent to 160 859 years lived with this disability in 2004. This amounts to 965 YLD for noise-induced cognitive impairment in Swedish children aged 7–19 years. This estimate is based on the conservative assumption that noise effects on cognitive impairment and childhood learning are temporary.

Exposure-specific approach for environmental noise and cognitive impairment in children in the EUR-A epidemiological subregion

The noise exposure figures in Table 3.1 were taken to be representative for Europe, and the distribution of children aged 7–19 years of age in Sweden is close to that reported for Europe as a whole. Therefore, the number of DALYs per million children aged 7–19 in the EUR-A countries can be calculated (Table 3.3). The absolute DALY for the EUR-A countries, with an estimated total population of 420 503 million, is therefore 45 036.

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Table 3.3. Estimated DALYs per year per million children aged 7–19 in the EUR-A epidemiological subregion

Age group and noise exposure level	Percentage of population exposed to noise level	Percentage of population who will develop cognitive impairment	Number impaired per million	DALYs lost per million
7–19 years, < 55 L_{dn}	11.24	0	0	0.0
7–19 years, 55–65 L_{dn}	3.14	20	6 281	37.7
7–19 years, 65–75 L_{dn}	1.82	50	9 090	54.5
7–19 years, > 75 L_{dn}	0.33	75	2 475	14.9
All other age groups	83.47	0	0	0.0
Total	100.00		17 846	107.1

Uncertainties, limitations and challenges

Source of noise

The slopes reported in Fig. 3.1 are for aircraft noise only. In contrast to the Munich study, which focused on aircraft noise, the RANCH study also included road traffic noise. But for road traffic noise, there was no indication of a significant impairment of children's cognition. As an explanation, the authors pointed out that aircraft noise, because of its intensity, the location of the source, and its variability and unpredictability, is likely to have a greater effect on children's reading than road traffic noise, which might be of a more constant intensity. Thus, it is conceivable that aircraft noise is more damaging than road traffic noise for children's cognition. This may also be true when the L_{dn} level is controlled for, which has been reported for children's memory in an experimental acute noise study *(20)*.

Even though there may be a degree of difference between aircraft and road traffic noise, acting on the safety principle would suggest treating them as equally damaging to children's cognition and to assume that there is approximately the same response effect regardless of noise source. This may, however, tend to overestimate the effects of road traffic noise.

Design of epidemiological studies

It should be noted that the RANCH study was a cross-sectional study in contrast to the prospective, longitudinal Munich study. This may make the Munich study more powerful in picking up unconfounded cause–effect relationships between noise exposure and outcomes.

Possibility of long-term cognitive impairment from chronic noise exposure

The DALYs calculated in Table 3.2 have not taken into account any lasting or long-standing impairment of cognitive functioning that could occur as a result of long-term noise exposure. Our calculations are restricted to the period in children's life when they attend primary school, assuming that the impacts of noise are negligible on the cognitive function of adults. This assumption is very conservative, however, because it is more likely that children who have passed through the mandatory school system in a noisy environment would live with a long-term consequence of

cognitive impairment. They are also more likely to live in a noisy environment even after the schooling period, which is more likely for children who go to school in areas exposed to aircraft noise. It would be realistic to assume that the impaired cognitive function will carry over to the years after the schooling period. If future studies provide an estimation of the severity and the duration of such chronic effect of noise on cognitive function, the calculation of DALYs should be updated.

Assumption of the duration of the impact

There is some evidence from the Munich study *(10)* that after the cessation of exposure to aircraft noise, children (age 9–11 years) recover within 18 months to the cognitive performance levels of their year-mates who were not exposed to much aircraft noise. Thus, it is possible that, at least for young children, chronic noise effects are reversible and that the DWs will diminish with increasing age. However, we assumed in our calculation that the effects are temporary and recovery is quicker, yielding YLD values that are conservative.

Assumption of the exposure–risk relationship

As pointed out above, with reference to the linear and sigmoidal accumulation of effects in Fig. 3.2, we have most likely not overestimated the fractions of children affected in the noise exposure ranges 65–75 L_{dn} (50%) and > 75 L_{dn} (75%). Further, we might have underestimated the average DW (0.006) for those affected by the higher level of noise. These two conservative assumptions may have led to a significant underestimation of the real DALYs in the EUR-A epidemiological subregion given in Table 3.3. For example, if DW doubles and quadruples to 0.012 and 0.0024 in the exposure brackets 65–75 L_{dn} and > 75 L_{dn}, respectively, the DALYs will be much greater than shown in Table 3.3.

Policy considerations

An alternative to viewing the noise-induced cognitive impairment of children from a burden-of-disease perspective is to analyse the impairment in terms of wasted learning units. The learning units could be given a monetary value in wasted teaching hours in schools – wasted for the teachers, the pupils and society. Therefore, the societal impact will probably be larger than the impact reflected by DALYs, which solely estimate the impact on specific cognitive impairment. A calculation of wasted learning units instead of DALYs is probably a more complicated task, with many more uncertain parameters. For the time being, DALYs from noise-induced impairment of cognition in children, together with DALYs from other environmental risks, may provide evidence for prioritizing policy options, such as lowering recommended noise levels in control guidelines for schools and learning.

Conclusions

Reliable evidence indicates the adverse effects of chronic noise exposure on children's cognition. There is no generally accepted criterion for quantification of the degree of cognitive impairment into a DW. However, it is possible to make a conservative estimate of loss in DALYs using the methods presented in this chapter. It is important to consider the assumptions, uncertainties and limitations in the methods when interpreting the estimated values of EBD.

REFERENCES

1. Evans GW, Hygge S. Noise and cognitive performance in children and adults. In: Luxon LM, Prasher D, eds. *Noise and its effects*. Chichester, John Wiley, 2007:549–566.
2. Evans GW, Lepore SJ. Nonauditory effects of noise on children. *Children's Environments,* 1993, 10:31–51.
3. Haines MM et al. Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children. *Psychological Medicine,* 2001, 31:265–277.
4. Haines MM et al. West London schools study: Aircraft noise at school and child performance and health. *Psychological Medicine,* 2001, 31:1385–1396.
5. Evans GW, Maxwell L. Chronic noise exposure and reading deficits; the mediating effects of language acquisition. *Environment and Behavior,* 1997, 29:638–656.
6. Cohen S, Glass DC, Singer JE. Apartment noise, auditory discrimination, and reading ability in children. *Journal of Experimental Social Psychology,* 1973, 9:407–422.
7. Lopez AD et al. *Global burden of disease and risk factors.* Washington, DC & New York, The World Bank & Oxford University Press, 2006.
8. Evans GW, Hygge S, Bullinger M. Chronic noise and psychological stress. *Psychological Science,* 1995, 6:333–338.
9. Evans GW, Bullinger M, Hygge S. Chronic noise exposure and physiological response: a prospective study of children living under environmental stress. *Psychological Science,* 1998, 9:75–77.
10. Hygge S, Evans GW, Bullinger M. A prospective study of some effects of aircraft noise on cognitive performance in school children. *Psychological Science,* 2002, 13:469–474.
11. Stansfeld SA et al. Aircraft and road traffic noise and children's cognition and health: a cross-sectional study. *Lancet,* 2005, 365:1942–1949.
12. Bronzaft A. The effect of a noise abatement program on reading ability. *Journal of Environmental Psychology,* 1981, 1:215–222.
13. Bronzaft AL, McCarthy DP. The effect of elevated train noise on reading ability. *Environment and Behavior,* 1975, 7:517–527.
14. Green K, Pasternack B, Shore R. Effects of aircraft noise on reading ability of school age children. *Archives of Environmental Health,* 1982, 37:24–31.
15. Haines MM et al. Multi-level modeling of aircraft noise on performance tests in schools around Heathrow London airport. *International Journal of Epidemiology and Community Health,* 2002, 56:139–144.
16. Lukas J, Du Pree R, Swing J. *Report of a study on the effects of freeway noise on academic achievement of elementary school children and a recommendation for a criterion level for school noise abatement programs.* Sacramento, CA, California Department of Health, 1981.
17. Lercher P, Evans GW, Meis M. Ambient noise and cognitive processes among primary schoolchildren. *Environment and Behavior,* 2003, 35:725–735.
18. Roovers C, van Blokland G, Psychas K. Road traffic noise mapping on a European scale. In: Cassereau D, ed. *Proceedings InterNoise 2000, Nice, France, 2000,* Vol. 6:3587–3590.
19. Van den Hazel P, Zuurbier M, eds. *PINCHE project: final report WP1, exposure assessment.* Arnhem, Public Health Services Gelderland Midden, 2005 (http://www.pinche.hvdgm.nl/Pinche_website/resource/pdf/documents/final/PINCHE_WP1_final_181105.pdf, accessed 28 July 2010).
20. Hygge S. Classroom experiments on the effects of different noise sources and sound levels on long-term recall and recognition in children. *Applied Cognitive Psychology,* 2003, 17:895–914.

4. ENVIRONMENTAL NOISE AND SLEEP DISTURBANCE

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Sleep disturbance is one of the most common complaints raised by noise-exposed populations, and it can have a major impact on health and quality of life. Studies have shown that noise affects sleep in terms of immediate effects (e.g. arousal responses, sleep stage changes, awakenings, body movements, total wake time, autonomic responses), after-effects (e.g. sleepiness, daytime performance, cognitive function deterioration) and long-term effects (e.g. self-reported chronic sleep disturbance).

Sufficient undisturbed sleep is necessary to maintain performance during the day as well as for general good health *(1)*. The human organism recognizes, evaluates and reacts to environmental sounds even while asleep *(2)*. These reactions are part of an integral activation process of the organism and express themselves as, for example, changes in sleep structure or increases in heart rate. Although they are natural (and even necessary) reactions to noise, it is assumed that a substantial increase in the number of such effects constitutes a health issue. Environmental noise may reduce the restorative power of sleep by means of repeatedly occurring activations (so-called sleep fragmentation). Acute and chronic sleep restriction or fragmentation has been shown to affect, among other things, waking psychomotor performance *(3)*, memory consolidation *(4)*, creativity *(5)*, risk-taking behaviour *(6)*, signal detection performance *(7)* and risks of accidents *(8,9)*.

There is an ample number of laboratory and field studies that provide sufficient evidence to conclude that traffic noise causally and relevantly disturbs sleep and, depending on noise levels, may impair behaviour and well-being during the subsequent period awake *(10–22)*. Although clinical sleep disorders (e.g. obstructive sleep apnoea, which is a sleep disorder characterized by pauses in breathing during sleep) have been shown to be associated with increased risks for cardiovascular disease, little is known about the long-term effects of noise-disturbed sleep on health. However, recent epidemiological studies do suggest that nocturnal exposure to traffic noise increases the risk of cardiovascular disease *(23–25)*.

In this chapter, available exposure–response relationships for various sleep disturbance indicators are discussed. Subsequently, a method for estimating the burden of self-reported sleep disturbance due to noise is proposed and illustrated.

Definition of outcome

Sleep disturbances can be measured electrophysiologically, using so-called polysomnography (PSG), or with self-reporting in epidemiological studies using survey questionnaires. PSG, i.e. the simultaneous recording of the electroencephalogram (EEG), the electrooculogram (EOG), the electromyogram (EMG)

and other physiological variables, remains the gold standard for measuring and evaluating sleep. According to specific conventions *(26,27)*, the night is usually divided into 30-second epochs. Depending on EEG frequency and amplitude, specific patterns in the EEG, muscle tone in the EMG and the occurrence of slow or rapid eye movements in the EOG, different stages of sleep are assigned to each epoch. Wake, superficial sleep stages S1 and S2, deep sleep stages S3 and S4, and REM (rapid eye movement) sleep are differentiated. Current knowledge assumes that sleep stages differ in their function and in their relevance for sleep recuperation, where continuous periods of deep sleep and REM sleep seem to be especially important for sleep recuperation *(4)*. Shorter activations in the EEG and EMG, so-called arousals, can also be detected with polysomnography *(26,28)*. These arousals are usually accompanied by activations of the autonomic nervous system (e.g. increases in heart rate and blood pressure) and they may contribute to sleep fragmentation *(29,30)*. Further, motility (i.e. body movement during sleep) has been found to be a relatively easy to use and sensitive measure for sleep disturbance, and has been shown to be a predictor of effects such as awakening and self-reported sleep quality *(22)*. Depending on their frequency, acute noise effects on sleep (arousals, awakenings, body movements) cause a general elevation of the organism's arousal level that consequently leads to a redistribution of time spent in the different sleep stages, with an increase of the amounts of wake and stage S1 and a decrease of slow wave sleep (SWS) and REM sleep *(16,31–33)*.

In epidemiological studies, "self-reported sleep disturbance" is the most easily measurable outcome indicator, because physiological measurements are costly and difficult to carry out on large samples and may themselves influence sleep. However, since during most of the night the sleeper is not aware of himself or his surroundings, the process of falling asleep and longer wake periods during the night contribute disproportionately to subjective estimates of sleep quality and quantity, which may therefore differ substantially from objective measures *(34)*. Nevertheless, self-reported sleep disturbance may have validity in its own right by reflecting the impact on sleep as perceived by the subject over a longer period of time.

In surveys asking about sleep disturbance, responses can be graded on a scale from 0 to 100. On this scale, similar to definitions of noise annoyance, cut-off values were chosen of 50 and 72 to determine the percentage of people sleep-disturbed and highly sleep-disturbed by transportation noise, respectively *(35)*. In the case study included in this chapter, high sleep disturbance is used as the sleep disturbance indicator. Using a lower cut-off value (i.e. sleep-disturbed) would give higher prevalence but would be associated with a lower DW, resulting in either a higher or a lower estimate of the burden caused by sleep disturbance due to noise. An important reason for using high sleep disturbance is that this is closer to the case definition used in studies associating a DW to sleep disturbance based on the comparison to other health states (see below).

Noise exposure

Appropriate exposure indicator

In the position paper on dose–effect relationships for nighttime noise *(36)*, as well as in the EU's Directive 2002/49/EC *(37)*, L_{night} was proposed as the nighttime noise indicator for sleep disturbances (see Chapter 1). L_{night} is defined as the "A-weighted long-term average sound level as defined in ISO 1996-2: 1987", determined over all night periods of a typical year. Noise events in the period between 23:00 and 7:00 contribute to the calculation of L_{night}. In WHO's *Night noise guidelines for Europe (38)*, several $L_{night,outside}$ exposure categories are linked with sufficient scientific evidence to health and sleep disturbance outcomes, and can accordingly be used to assess the degree of sleep disturbance associated with transportation noise (see Table 4.1). Additionally, it is possible to derive exposure–response relationships between L_{night} and instantaneous reactions to noise (such as the number of additionally induced EEG awakenings or behaviourally confirmed awakenings) to assess the expected degree of sleep fragmentation. However, L_{night} is an equivalent continuous sound pressure level summarizing complex time patterns of exposure into a single value. This necessarily leads to information loss: noise scenarios, which differ in number, acoustical properties and placement of noise events, may calculate to the same L_{night} but differ substantially in their effects on sleep. In contrast to daytime traffic, where high traffic densities may lead to more or less constant and continuous noise levels, low traffic densities during the night often go along with intermittent exposure to single noise events. Hence, traffic-noise-induced alterations in sleep structure depend crucially on the number of noise events, the acoustical properties (such as maximum sound pressure levels) of single noise events, the placement of noise events within the night, and noise-free intervals between noise events *(11,19,39)*. Indeed, the *Night noise guidelines for Europe (38)* still support the validity of the recommendation of the WHO *Guidelines for community noise (40)* that, in order to prevent sleep disturbances, one should consider the equivalent sound pressure level and the number and level of sound events. Also, Directive 2002/49/EC *(37)* states that it may be advantageous to use maximum sound pressure level L_{Amax} or sound exposure levels as supplementary noise indicators for night period protection. However, predicting after-effects such as self-reported sleep disturbance or long-term health effects may require information on the long-term average sound level.

Exposure data for estimating the burden of sleep disturbance due to noise

Since road traffic noise accounts for the larger proportion of people exposed in most European countries (based on data from France, the Netherlands, Switzerland and the United Kingdom), road traffic noise exposure data are chosen here to estimate the burden of disease. As an example, exposure data from the Netherlands are used (Table 4.2). The exposure assessment was based on most exposed facade at dwellings, not on individuals. The total population was 15.864 million in the Netherlands in 2000. Assuming that household size does not differ between the noise exposure categories, these data may be extrapolated to the whole population. It should be noted that, because of the method of calculation used (25-metre grid), the higher levels tend to be underestimated.

Table 4.1. Ranges for the relationship between nocturnal noise exposure and health effects in the population

$L_{night,outside}$	Health effects observed in the population
< 30 dB(A)	Although individual sensitivities and circumstances differ, it appears that up to this level no substantial biological effects are observed.
30 – 40 dB(A)	A number of effects are observed to increase: body movements, awakenings, self-reported sleep disturbance and arousals. The intensity of the effect depends on the nature of the source and the number of events. Vulnerable groups (for example, children and chronically ill and elderly people) are more susceptible. However, even in the worst cases, the effects seem modest.
40 – 55 dB(A)	Adverse health effects are observed among the exposed population. Many people have to adapt their lives to cope with the noise at night. Vulnerable groups are more severely affected.
> 55 dB(A)	The situation is considered increasingly dangerous for public health. Adverse health effects occur frequently, and a sizable proportion of the population is highly annoyed and sleep-disturbed. There is evidence that the risk of cardiovascular disease increases.

Source: Night noise guidelines for Europe (38).
Note. The guidelines assume an average attenuation of 21 dB(A) between inside and outside noise levels.

Table 4.2. Percentage of dwellings per environmental noise class in the Netherlands, 2000

L_{night} levels dB(A)- source	<39	40–44	45–49	50–54	>54
Motorways	70.2	16.2	9.1	3.1	1.4
Regional roads	93.8	3.4	1.6	0.8	0.3
City roads	57.9	17.7	15.2	8.0	1.3
All roads	21.9	37.3	25.9	11.9	3.0
Railways	76.6	12.4	6.3	2.7	1.9
Amsterdam Airport	98.1	1.4	0.5	0.0	0.0
All types of traffic	18.6	24.7	31.3	18.6	6.8

Source: Unpublished data from the Netherlands National Institute for Public Health and the Environment (RIVM), method described in Dassen AGM, Jabben J, Janssen PMH. [*Development of the environmental model for population annoyance and risk analysis. Partial validation and risk analysis.*] (abstract in English). Bilthoven, RIVM, 2001 (RIVM report 2001 725401001/2001).

Exposure–response relationship

Exposure–response relationships from experimental and field studies

Experimental and field studies have shown clear exposure–response relationships between single noise events and instantaneous arousals, EEG awakenings, behavioural awakenings or motility *(12,14,19,22,38,42–44)*. Exposure–response relationships between L_{night} or similar integrated measures and instantaneous sleep disturbance are rare *(45,46)*. This may in part be attributed to the fact that L_{night} as a whole-night indicator can only be directly related to whole-night sleep parameters. In principle, exposure–response relationships on the single event level can be used to

predict the expected degree of sleep fragmentation depending on L_{night}, given the fact that the number and loudness of noise events are positively correlated with L_{night}. However, the variance in the number of noise-induced awakenings, and therefore the imprecision of the prediction, increases with increasing L_{night}, as many different exposure patterns can lead to the same L_{night} in the higher exposure categories. Therefore, it may be advantageous for assessing sleep disturbance to gather information on the number of noise events contributing to L_{night} additional to L_{night}.

Although instantaneous effects such as arousals, EEG awakenings, behavioural awakenings and elevated motility all reflect relevant aspects of the complex concept of sleep disturbance, it is not clear how they could be used to assess the burden of disease. Their occurrence is not pathological per se, as these reactions are also a physiological part of sleep in the absence of noise-induced sleep disturbance. They only reach pathological significance once a certain physiological frequency is exceeded, i.e. once sleep fragmentation reaches a relevant degree. However, inter-individual variability in the sensitivity to noise exposure is high, and it is not clear to what extent the exposure–response relationships that were derived from field study subject samples with limited representativeness can be extrapolated to the population. Furthermore, although new research is under way, at the moment relationships are almost exclusively available for aircraft noise, whereas an assessment of the burden of sleep disturbance due to noise requires an assessment of the risk of other main sources as well.

Exposure–response relationships from epidemiological studies

Miedema et al. *(47)* presented synthesis curves for self-reported sleep disturbance from aircraft, road traffic and railway noise. These curves were based on the pooled data from 15 original data sets (more than 12 000 individual observations) obtained from 12 field studies (*a*) where L_{night} was included in the dataset or there was the possibility to calculate/estimate this metric on the basis of information regarding the included sites; and (*b*) where questions regarding waking up or being disturbed by transportation noise during the night were answered. Studies using questions that included disturbance of rest were excluded because resting is different from sleeping and does not necessarily take place during the night only. A more extensive analysis was recently completed *(35)*. It was based partly on the same data but included pooled data from 28 original data sets obtained from 24 field studies (23 000 participants) carried out since 1970. This analysis yielded very similar curves and included 95% confidence intervals that took into account the variation between individuals and studies.. However, no polynomial approximations were published for these curves, and therefore the functions from Miedema et al. *(47)* were used for the present purpose. The percentage of "highly sleep-disturbed" persons (%HSD) as a function of noise exposure indicated by L_{night} was found to be as follows.

Aircraft: $\%\ HSD = 18.147 - 0.956\ (L_{night}) + 0.01482(L_{night})^2$

Road traffic: $\%\ HSD = 20.8 - 1.05\ (L_{night}) + 0.01486(L_{night})^2$

Railways: $\%\ HSD = 11.3 - 0.55\ (L_{night}) + 0.00759\ (L_{night})^2$

The curves are based on data in the L_{night} (outside, maximally exposed facade) range 45–65 dB(A). Low exposure levels (L_{night} < 45 dB(A)) were excluded from the analyses because the assessment of those noise levels was relatively inaccurate and other sources may be more important in situations with these low levels. High exposure levels (L_{night} > 65 dB(A)) were also excluded, because in the areas of very high ex-

posure levels there may also have been self-selection of persons with low sensitivity to noise. Therefore, the extrapolation of the presented functions is expected to give a better indication of sleep disturbance at low and very high levels than using the data at these levels. The polynomial functions are close approximations of the curves in this range and their extrapolations to lower exposure (40–45 dB(A)) and higher exposure (65–70 dB(A)).

Although cumulative effects of simultaneous exposure to noise from different types of traffic should ideally be taken into account, knowledge on the effects of simultaneous exposure to different noise sources is limited *(48)*. A pragmatic way would be to calculate a single L_{night} value for all modes of transportation and base the risk assessment on this combined exposure measure, or preferably to use the methodology established earlier for determining the relationship between exposure to multiple noise sources and annoyance *(49)*.

Disability weight

The WHO DW for primary insomnia is 0.100 and is defined *(50)* as:

> *… difficulty falling asleep, remaining asleep, or receiving restorative sleep for a period [of] no less than one month. This disturbance in sleep must cause significant distress or impairment in social, occupational, or other important functions and does not appear exclusively during the course of another mental or medical disorder or during the use of alcohol, medication, or other substances.*

This definition of primary insomnia excludes the sleep disturbances that appear during the use of "other substances" or outside factors such as light or noise. When sleep is permanently disturbed by environmental factors and becomes a sleep disorder, it is classified in the International Classification of Sleep Disorders *(51)* as "environmental sleep disorder". Environmental sleep disorder (of which noise-induced sleep disturbance is an example) is a sleep disturbance due to a disturbing environmental factor that causes a complaint of either insomnia or daytime fatigue and somnolence *(38)*. While noise-induced sleep disturbance is not to be considered as a case of primary insomnia, the "burden of disease" of primary insomnia and noise-induced environmental sleep disorder may be similar. Van Kempen, cited in Knol & Staatsen *(41)*, reported a mean DW of 0.100 for severe sleep disturbance due to noise, based on a pilot study among 13 medical experts working according to a protocol by Stouthard *(52)*. De Hollander *(58)* expanded the study to 35 environmental physicians, epidemiologists and public health professionals and also found a mean DW of 0.10 (median DW: 0.08; standard deviation: 0.10; range: 0–0.45) using the same protocol. Although an earlier study published by de Hollander et al. *(53)* used a DW of only 0.010 for the same condition, no DW was available at that time so the weight of the least severe category of the first GBD study by Murray et al. *(59)* was used.

Müller-Wenk *(54)* found a mean DW of 0.055 (median DW: 0.04; range: 0.02–0.31) for those highly sleep-disturbed by nighttime road noise, based on a survey of 42 Swiss physicians who were asked to interpolate this type of sleep disturbance into a list of health states with existing DWs. In 2005, Knoblauch &

Müller-Wenk *(55)* interviewed a sample of 14 general practitioners recently admitting patients with obstructive sleep apnoea syndrome (OSAS) to the sleep clinic in St Gallen in Switzerland. They were asked to compare the relative mean severity of the health state of contacted persons with OSAS, with primary insomnia or with sleep disturbance due to increased exposure to road noise in the bedroom. This case definition of sleep disturbance is comparable to that of "highly sleep disturbed" on which the exposure–response relationship was based. Based on their own professional experience, 9 of the 14 respondents considered noise-related sleep disturbance to be less serious on average than primary insomnia, and 11 of the 14 considered noise-related sleep disturbance to be less serious on average than OSAS; the mean judgement of the 14 respondents was that noise-related sleep disturbance has a mean severity of 0.9 times the severity of primary insomnia (range: 0–2.1), which resulted in a DW of 0.09 (CI 0.06–0.12). As in the previous studies, the distribution was rather skewed; the median severity ratio was 0.63, which corresponds to a DW of 0.063.

Following the *Night noise guidelines for Europe (38)*, 0.07 was chosen as the DW of noise-related sleep disturbance in the calculation of DALYs. This value takes into account both the medians and the means of the DW observed in the above studies. Given the rather skewed distributions of the reported DWs, the median of the study with the lowest DW *(54)* was chosen as a low estimate, whereas the highest observed mean value *(41,58)* was chosen as a high estimate, yielding the uncertainty interval (0.04–0.10). The uncertainty in the exposure–response relationship was not factored in for this analysis.

EBD calculations

This section provides methodological guidance to two approaches to calculating the burden of sleep disturbance related to environmental noise. The first method is the exposure-based approach using the exposure–response relationship and exposure data. The second method is the direct estimation of the burden using a population survey.

Exposure-based assessment

The exposure-based approach estimates the prevalence of high sleep disturbance (reporting 72 or higher on a 100-point scale) due to noise by combining the exposure data with the exposure–response relationships for high sleep disturbance. One year of nighttime exposure to road traffic noise is proposed as the duration causing high sleep disturbance, since people with a bedroom exposed to a road with a high level of night traffic are subject to more or less stationary noise levels at night. Therefore, it can be assumed that their sleep disturbance exists all year round.

DALYs for sleep disturbance were calculated using the road traffic noise exposure distribution in L_{night} as assessed in the Netherlands in 2000 (see Table 4.2), the total population of the Netherlands in 2000 (15 864 000), the exposure–response relationships presented above for sleep disturbance due to road traffic noise (using the expected percentage of highly sleep-disturbed people at the midpoint of the category as a function of L_{night} in the range 45–65 dB(A)) and the DWs (see Table 4.3). This calculation suggests that there are about 24 669 DALYs lost in the Netherlands due to road traffic noise-induced sleep disturbance. Taking 0.04 and 0.10 as the extremes of the range for the weights, the credible range for the DALYs is from 14 096

to 35 242. This is a very conservative estimate, derived only for the exposure–response and exposure data for road traffic noise and not including the impacts of aircraft and railway noise. However, although the impact at a given exposure level is expected to be higher for aircraft noise (but slightly lower for railway noise) *(35)*, far fewer people are exposed to aircraft (and railway) noise than to road traffic noise.

Table 4.3. Exposure-based approach to estimating DALYs for highly sleep-disturbed people due to environmental noise, using exposure data from the Netherlands

Exposure category L_{night} (dB(A))	Percentage of population exposed	Percentage of people highly sleep-disturbed	Number of cases in the Netherlands	DALYs		
				DW = 0.04	DW = 0.07	DW = 0.10
45 – 49	25.9	4.3	176 677	7 068	12 367	17 668
50 – 54	11.9	6.4	121 009	4 840	8 471	12 101
>54	3.0	11.5	54 730	2 188	3 831	5 473
Total				14 096	24 669	35 242

Source: Unpublished data from the Netherlands National Institute for Public Health and the Environment (RIVM), method described in Dassen AGM, Jabben J, Janssen PMH. [*Development of the environmental model for population annoyance and risk analysis. Partial validation and risk analysis.*] (abstract in English). Bilthoven, RIVM, 2001 (RIVM report 2001 725401001/2001).

Burden of sleep disturbance from road traffic noise in western Europe

As mentioned in Chapter 2, the Noise Observation and Information Service for Europe (NOISE) provides noise exposure data that can be used for calculating disease burden in western European countries. Following the same method used in Chapter 2, the percentage of people highly sleep-disturbed can be calculating using the mid–level values of the exposure categories in the NOISE dataset. Because the NOISE dataset does not provide data on the categories of < 45 dB(A) and 45–49 dB(A), the percentages for these two categories were calculated conservatively by assuming the same percentages between the two categories of 45–49 dB(A) and 50–54 dB(A). The mid-level value of the category was used in the application of exposure–response functions specific to the noise sources. Because the L_{night} was the annual average of exposure level by definition, the duration of effects was also considered to be one year.

Tables 4.4, 4.5 and 4.6 summarize the distribution of population exposed to road, rail and air traffic noise, respectively, during the night in agglomerations with more than 250 000 inhabitants, and exposure-based DALY calculation using the exposure–response function presented above. Owing to a lack of exposure data covering the rural population, it was not possible to estimate DALYs for the whole EU population including rural areas without extrapolation. Assuming that the observed exposure distributions using the strategic noise maps may apply to approximately 285 million people living in cities or agglomerations with more than 50 000 inhabitants (57% of the total EU population), we can cautiously infer that the DALYs are approximately 903 000 years for urban population in the EU assuming DW = 0.07 (Table 4.7). Taking 0.04 and 0.10 as the extremes of the range for DWs, the credible range for the DALYs is 0.52–1.29 million. It should be noted that the burden in rural areas or small town with less than 50 000 inhabitants is not included here, and that we did not count the burden in the exposure range below 45 dB(A).

Table 4.4. DALYs for highly sleep-disturbed people due to road traffic noise in the EU

Exposure category L_{night} (dB(A))	Percentage of population exposed [a]	Percentage of people highly sleep-disturbed [b]	Number of cases per million [b]	DALYs lost in the urban population [c]		
				DW = 0.04	DW = 0.07	DW = 0.10
< 45	44 [d]	NA	NA	NA	NA	NA
45–49	20 [d]	4.5	8 906	101 526	177 670	253 814
50–54	20	6.6	13 266	151 230	264 652	378 074
55–59	10	9.6	9 556	108 937	190 640	272 342
60–64	5	13.2	6 611	75 365	131 888	188 412
65–69	1	17.6	1 763	20 099	35 174	50 248
Total	100		40 102	457 156	800 023	1 142 890

[a] The source of exposure data is the Noise Observation and Information Service for Europe (NOISE) as of June 2010.
[b] The percentage and number of cases were calculated with the polynomial equation, using the mid-level values of exposure categories.
[c] DALYs were calculated for the 285 million persons living in agglomerations with > 50 000 inhabitants.
[d] Noise maps do not provide data for the categories of < 45 dB(A) and 45–49 dB(A) for L_{night}. Therefore, the percentages of population in these categories were interpolated using a very conservative assumption: the percentage for the 45–49 dB(A) is the same as that for 50–54 dB(A).

Table 4.5. DALYs for highly sleep-disturbed people due to rail traffic noise in the EU

Exposure category L_{night} (dB(A))	Percentage of population exposed [a]	Percentage of people highly sleep-disturbed [b]	Number of cases per million [b]	DALYs lost in the urban population [c]		
				DW = 0.04	DW = 0.07	DW = 0.10
< 45	93 [d]	NA	NA	NA	NA	NA
45–49	3 [d]	2.3	690	7 866	13 765	19 664
50–54	3	3.3	1 003	11 440	20 019	28 599
55–59	1	4.8	477	5 437	9 515	13 593
60–64	0	6.6	0	0	0	0
65–69	0	8.8	0	0	0	0
Total	100		2 170	24 743	43 300	61 857

[a] The source of exposure data is the Noise Observation and Information Service for Europe (NOISE) as of June 2010.
[b] The percentage and number of cases were calculated with the polynomial equation, using the mid-level values of exposure categories.
[c] DALYs were calculated for the 285 million persons living in agglomerations with > 50 000 inhabitants.
[d] Noise maps do not provide data for the categories of < 45 dB(A) and 45–49 dB(A) for L_{night}. Therefore, the percentages of population in these categories were interpolated using a very conservative assumption: the percentage for the 45–49 dB(A) is the same as that for 50–54 dB(A).

Table 4.6. DALYs for highly sleep-disturbed people due to air traffic noise in the EU

Exposure category L_{night} (dB(A))	Percentage of population exposed[a]	Percentage of people highly sleep-disturbed[b]	Number of cases per million[b]	DALYs lost in the urban population[c]		
				DW = 0.04	DW = 0.07	DW = 0.10
<45	96[d]	NA	NA	NA	NA	NA
45–49	2[d]	6.2	1 235	14 078	24 637	35 195
50–54	2	8.8	1 761	20 075	35 130	50 186
55–59	0	12.2	0	0	0	0
60–64	0	16.3	0	0	0	0
65–69	0	21.1	0	0	0	0
Total	100		2 996	34 153	59 767	85 382

[a] The source of exposure data is the Noise Observation and Information Service for Europe (NOISE) as of June 2010.
[b] The percentage and number of cases were calculated with the polynomial equation, using the mid-level values of exposure categories.
[c] DALYs were calculated for the 285 million persons living in agglomerations with > 50 000 inhabitants.
[d] Noise maps do not provide data for the categories of < 45 dB(A) and 45–49 dB(A) for L_{night}. Therefore, the percentages of population in these categories were interpolated using a very conservative assumption: the percentage for the 45–49 dB(A) is the same as that for 50–54 dB(A).

Table 4.7. DALYs for highly sleep-disturbed people due to all traffic noise in the EU

Source of traffic noise	DALYs[a]		
	DW = 0.04	DW = 0.07	DW = 0.10
Road	457 156	800 023	1 142 890
Rail	24 743	43 300	61 857
Air	34 153	59 767	85 382

[a] For the 285 million population living in agglomerations with > 50 000 inhabitants.

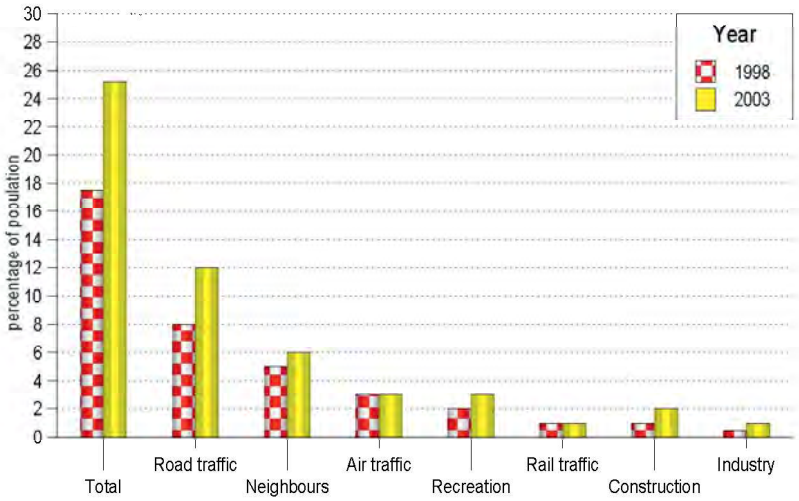
Outcome-based assessment

The burden of highly disturbed sleep due to nighttime noise in terms of DALYs may also be directly estimated on the basis of survey data in the population concerned. Survey data from the Netherlands were used as an example in this section. Fig. 4.1 shows the relative contributions to overall sleep disturbance caused by noise from different sources in the Netherlands. These data were derived from surveys in 1998 and 2003 *(56)* in which 4000 and 2000 people, respectively, all of whom were randomly selected, were asked: "To what extent is your sleep disturbed by noise from (source mentioned) ...?" on a scale from 0 to 10 (pertains to noise perceived in the last 12 months). People recording the three highest points on the scale were considered "highly disturbed" according to an international convention that is close to the case definition used in the pooled analysis to define the exposure–response relationship *(46)*. About 12% of the general population reported being highly disturbed by road traffic noise during sleep in the Netherlands in 2003. The totals are calculated from the number of people reporting serious sleep disturbance from one or more sources. About 25% of the general population reported being highly disturbed by any source of noise during sleep in the previous 12 months. This approach allows

cases from multiple sources to be counted more directly. Since this study is based on a survey conducted in the Netherlands, it is not representative of other Member States in the EU.

Considering that the Netherlands had a population of 16 225 000 in 2003, approximately 1 947 000 and 4 056 250 people were highly disturbed during sleep by road traffic noise and any source of noise, respectively. The corresponding DALYs calculated with a DW of 0.07 are 136 290 years and 283 937 years for road traffic noise and any source of noise, respectively (Table 4.8). The uncertainty in the survey estimates was not factored in for this analysis.

Fig. 4.1. Percentages of the population claiming to be highly disturbed by noise during sleep from two surveys in the Netherlands



Source: van den Berg et al. *(36)*.

Table 4.8. The estimated DALYs lost due to sleep disturbance using prevalence data from the Netherlands

Noise source	Percentage of population highly sleep disturbed	Population of the Netherlands	Number of cases in the Netherlands	DALYs		
				DW = 0.04	DW = 0.07	DW = 0.10
Road traffic	12	16 225 000	1 947 000	77 880	136 290	194 700
One or more sources	25	16 225 000	4 056 250	162 104	283 937	405 625

Uncertainties, limitations and challenges

Comparing two approaches

The DALYs based on the second method are significantly greater than those based on the exposure-based estimates. One of the reasons for the difference may be that the exposure–response relationship is not given for values below 45 dB(A) and above 65 dB(A), where the uncertainties of the relationship are greater. By not counting the people in the exposure range below 45 dB(A), the prevalence of sleep disturbance is underestimated. In addition, the percentage of sleep disturbed above the level of 65 dB(A) may be underestimated, also resulting in an underestimation of the burden of sleep disturbance induced by road traffic noise. This could partly be solved by extrapolating the exposure–response relationship for the range between 40 and 70 dB(A), should exposure data be available in this range.

Uncertainty with respect to the exposure-response relationship

The amount of variance in sleep disturbance scores explained by the exposure–response relationships is intermediate (road traffic, railways) or at the low end within the range of usual values that are considered meaningful (aircraft), so that they are not suited to predicting individual reactions. However, in most cases the uncertainty regarding individual reactions is not what matters for noise policy. Most policy, including policy based on estimates of the burden of disease due to environmental noise, is made with a view to the overall reaction to exposures in a (reference) population. This means that it is not the uncertainty with respect to the prediction of an individual or group reaction that is important, but that regarding the exact relationship between exposure and response in the (reference) population. The accuracy of the estimation of this relationship is described by the confidence intervals around the curve. If properly established, the confidence interval takes into account the variation between individuals as well as the variation between studies *(57)*, which are much smaller than the wide prediction intervals for individuals. The functions can be useful for evaluating the nighttime noise exposure in a particular area by predicting what the response of the reference population would be in that area.

With regard to aircraft noise, it should be noted that the variance in the responses is large compared to the variance found for rail and road traffic, meaning that the uncertainty is higher. One of the reasons for higher uncertainty may be that the time pattern of noise exposures around different airports varies considerably due to specific nighttime regulations. Also, there are indications of a time trend, whereby the most recent studies show the highest self-reported sleep disturbance, leading to a possible underestimation of the response at a given aircraft noise exposure level by the current curve.

Applications and limitations of the exposure-response relationship

According to the EU position paper on dose–effect relationships for nighttime noise *(36)*, the exposure–response relationships above represent the current best estimates of the influences of nocturnal traffic noise exposure (conceptualized as L_{night}) on self-reported sleep disturbance for road traffic and for rail traffic, when no other factors are taken into account. As mentioned above, the uncertainty may be higher with respect to aircraft noise, and such responses should be considered as indicative only.

A limitation of the exposure–response relationship is that it does not take into account other (exposure) variables that determine, in addition to average nighttime noise levels outdoors at the most exposed facade, the exposure level in the bedroom. Most important may be the difference in exposure between the most exposed facade and the bedroom facade, as well as the difference between the outdoor exposure at the bedroom facade and the indoor exposure in the bedroom. Also, adding noise exposure descriptors other than the nighttime average, such as noise in the early or late parts of the night, descriptors of peak levels or number of events may improve the prediction of self-reported sleep disturbance.

Also, it must be stressed again that the sleeper is not aware of himself or his surroundings during most parts of the night, and hence subjective estimates of noise-induced sleep disturbance may differ substantially from objective measures. Indeed, recent laboratory studies indicate that the impact of traffic noise on sleep structure increases in the order air road rail, thus reversing the order observed for self-reported measures such annoyance and sleep disturbance *(19,48)*. Therefore, although the estimated DALYs may correctly reflect the burden of disease in terms of self-reported sleep disturbance, it is questionable whether the estimates correctly reflect aspects that would reflect consequences of chronically fragmented sleep in terms of impairment of daytime performance or long-term health effects that are not obtainable via self-reporting.

Conclusions

Although self-reported sleep disturbance may not reflect the total impact of nighttime noise on sleep, it is the only effect for which exposure–response relationships on the basis of L_{night} are available for the most important noise sources. Furthermore, while it is hard to weigh self-reported sleep disturbance, it may be even harder to assign a DW to physiological changes indicating a certain degree of sleep fragmentation.

An example using data from 2000 on exposure in the Netherlands indicates a conservative estimate of some 25 000 DALYs lost yearly due to sleep disturbance induced by road traffic noise.

With the increasing effort devoted to noise mapping, more and better data on the levels of exposure to nighttime noise will become available in the EU Member States, so that, by combining them with the relationships, the prevalence of self-reported sleep disturbance can be estimated. Our calculation using the noise maps data showed that DALYs assuming DW = 0.07 were 307 959 years for the EU population living in agglomerations with > 250 000 inhabitants. Cautious extrapolation indicated that DALYs assuming DW = 0.07 might be in the range 0.5–1.0 million years for whole EU population.

We adopted conservative assumptions whenever necessary except for extrapolation of exposure data from larger agglomerations to the population of the agglomerations with > 50 000 inhabitants in the EU Member States. Considering that we did not count cases of high sleep disturbance occurring below 45 dB(A) and milder sleep disturbance at all ranges, we are confident that the above DALY estimation is not an overestimation.

REFERENCES

1. Banks S, Dinges DF. Behavioral and physiological consequences of sleep restriction. *Journal of Clinical Sleep Medicine,* 2007, 3:519–528.
2. Oswald I, Taylor AM, Treisman M. Discriminative responses to stimulation during human sleep. *Brain,* 1960, 83:440–453.
3. van Dongen HP et al. The cumulative cost of additional wakefulness: dose–response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep,* 2003, 26:117–126.
4. Stickgold R. Sleep-dependent memory consolidation. *Nature,* 2005, 437:1272–1278.
5. Wagner U et al. Sleep inspires insight. *Nature,* 2004, 427:352–355.
6. Mckenna BS et al. The effects of one night of sleep deprivation on known-risk and ambiguous-risk decisions. *Journal of Sleep Research,* 2007, 16:245–252.
7. Basner M et al. Effects of night-work, sleep loss, and time-on-task on simulated threat detection performance. *Sleep,* 2008, 31:1251–1259.
8. Barger LK et al. Extended work shifts and the risk of motor vehicle crashes among interns. *New England Journal of Medicine,* 2005, 352:125–134.
9. Scott LD et al. The relationship between nurse work schedules, sleep duration, and drowsy driving. *Sleep,* 2007, 30:1801–1807.
10. Basner M. Nocturnal aircraft noise increases objectively assessed daytime sleepiness. *Somnologie,* 2008, 12:110–117.
11. Basner M et al. *Effects of nocturnal aircraft noise. Vol. 1. Executive summary.* Cologne, Deutsches Zentrum für Luft- und Raumfahrt, 2004.
12. Basner M, Isermann U, Samel A. Aircraft noise effects on sleep: Application of the results of a large polysomnographic field study. *Journal of the Acoustical Society of America,* 2006, 119:2772–2784.
13. Brink M, Wirth K, Schierz C. Effects of early morning aircraft overflights on sleep and implications for policy-making. In: *Proceedings of Euronoise 2006, Tampere, Finland, 30 May – 1 June 2006.*
14. Finegold LS, Elias B. A predictive model of noise induced awakenings from transportation noise sources. In: *Proceedings of the 2002 International Congress and Exposition on Noise Control Engineering, Dearborn, MI, August 19–21, 2002.*
15. Griefahn B et al Autonomic arousals related to traffic noise during sleep. *Sleep,* 2008, 31:569–577.
16. Griefahn B, Marks A, Robens S. Noise emitted from road, rail and air traffic and their effects on sleep. *Journal of Sound and Vibration,* 2006, 295:129–140.
17. Horne JA et al. A field study of sleep disturbance: effects of aircraft noise and other factors on 5,742 nights of actimetrically monitored sleep in a large subject sample. *Sleep,* 1994, 17:146–159.
18. Hume K, Van F, Watson A. *Effects of aircraft noise on sleep: EEG-based measurements.* Manchester, Manchester Metropolitan University, 2003.
19. Marks A, Griefahn B, Basner M. Event-related awakenings caused by nocturnal transportation noise. *Noise Control Engineering Journal,* 2008, 56:52–62.
20. Öhrström E et al. Effects of road traffic noise on sleep: studies on children and adults. *Journal of Environmental Psychology,* 2006, 26:116–126.
21. Ollerhead JB et al. *Report of a field study of aircraft noise and sleep disturbance.* London, Department of Transport, 1992.
22. Passchier-Vermeer W et al. *Sleep disturbance and aircraft noise exposure – exposure effect relationships.* Netherlands, TNO, 2002.

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23. Babisch W. *Transportation noise and cardiovascular risk. Review and synthesis of epidemiological studies. Dose-effect curve and risk estimation.* Berlin, Federal Environmental Agency, 2006.
24. Greiser E, Greiser C, Janhsen K. Night-time aircraft noise increases prevalence of prescriptions of antihypertensive and cardiovascular drugs irrespective of social class – the Cologne-Bonn Airport study. *Journal of Public Health,* 2007, 15:327–337.
25. Jarup L et al. Hypertension and exposure to noise near airports: the HYENA study. *Environmental Health Perspectives,* 2008, 116:329–333.
26. Iber C et al. *The AASM manual for the scoring of sleep and associated events: rules, terminology and technical specifications.* Westchester, IL, American Academy of Sleep Medicine, 2007.
27. Rechtschaffen A et al. *A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects.* Washington, DC, US Government Printing Office, 1968.
28. Bonnet MH et al. The scoring of arousal in sleep: reliability, validity, and alternatives. *Journal of Clinical Sleep Medicine,* 2007, 3:133–145.
29. Basner M et al. An ECG-based algorithm for the automatic identification of autonomic activations associated with cortical arousal. *Sleep,* 2007, 30:1349–1361.
30. Sforza E et al. Heart rate activation during spontaneous arousals from sleep: effect of sleep deprivation. *Clinical Neurophysiology,* 2004, 115:2442–2451.
31. Basner M et al. Aircraft noise: effects on macro- and micro-structure of sleep. *Sleep Medicine,* 2007, 9:382–387.
32. Basner M, Samel A. Effects of nocturnal aircraft noise on sleep structure. *Somnologie,* 2005, 9:84–95.
33. Samel A, Basner M. Extrinsische Schlafstörungen und Lärmwirkungen. Somnologie, 2005, 9:58–67.
34. Silva GE et al. Relationship between reported and measured sleep times: the Sleep Heart Health Study (SHHS). *Journal of Clinical Sleep Medicine,* 2007, 3:622–630.
35. Miedema HME, Vos H. Associations between self-reported sleep disturbance and environmental noise based on reanalyses of pooled data from 24 studies. *Behavioral Sleep Medicine,* 2007, 5:1–20.
36. van den Berg M et al. *Position paper on dose–effect relationships for night time noise.* Brussels, European Commission Working Group on Health and Socio-Economic Aspects, 2003 (http://ec.europa.eu/environment/noise/pdf/positionpaper.pdf, accessed 28 July 2010).
37. 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. *Official Journal of the European Communities,* 2002, L 189:12–25.
38. *Night noise guidelines for Europe.* Copenhagen,WHO Regional Office for Europe, 2009 (http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf, accessed 28 July 2010).
39. Basner M, Siebert U. Markov processes for the prediction of aircraft noise effects on sleep. *Medical Decision Making,* 2010, 30:275–289.
40. Berglund B, Lindvall T, Schwela DH, eds. *Guidelines for community noise.* Geneva, World Health Organization, 1999 (http://whqlibdoc.who.int/hq/1999/a68672.pdf, accessed 22 July 2010).
41. Knol AB, Staatsen BAM. *Trends in the environmental burden of disease in the Netherlands 1980–2020.* Bilthoven, RIVM, 2005 (RIVM report 500029001/2005).
42. *Effects of aviation noise on awakenings from sleep.* Federal Interagency Committee on Aviation Noise (FICAN), 1997.

43. Passchier-Vermeer W. *Night-time noise events and awakening.* Delft, TNO, 2003.
44. *Quantities and procedures for description and measurement of environmental sound – Part 6. Methods for estimation of awakenings associated with outdoor noise events heard in homes.* New York, American National Standards Institute, 2008.
45. Passchier-Vermeer W et al. *Sleep and traffic noise – summary report.* Delft, TNO, 2007.
46. Quehl J, Basner M. Annoyance from nocturnal aircraft noise exposure: laboratory and field-specific dose–response curves. *Journal of Environmental Psychology,* 2006, 26:127–140.
47. Miedema HME, Passchier-Vermeer W, Vos H. *Elements for a position paper on night-time transportation noise and sleep disturbance.* Delft, TNO, 2003 (Inro Report 2002-59).
48. Basner M et al. Single and combined effects of air, road and rail traffic noise on sleep. In: *Proceedings of the 9th International Congress on Noise as a Public Health Problem (ICBEN), 19–25 July 2008, Foxwoods, CT, USA.*
49. Miedema HME. Relationship between exposure to multiple noise sources and noise annoyance. *Journal of the Acoustical Society of America, 2004, 116:949–957.*
50. AllPsych ONLINE. The virtual psychology classroom [online database]. International Society for Mental health Online, 2005 (http://allpsych.com/disorders/sleep/insomnia.html, accessed 29 July 2010).
51. *International Classification of Sleep Disorders,* 2nd ed. Darien, IL, American Academy of Sleep Medicine, 2005.
52. Stouthard M et al. *Disability weights for diseases in the Netherlands.* Department of Public Health, Netherlands, 1997.
53. de Hollander AE et al. An aggregate public health indicator to represent the impact of multiple environmental exposures. *Epidemiology,* 1999, 10:606–617.
54. Müller-Wenk R. *Attribution to road traffic of the impact of noise on health.* Berne, Swiss Agency for the Environment, Forests and Landscape 2002 (Environmental Series No. 339) (http://www.bafu.admin.ch/publikationen/publikation/00490/index.html?lang=en, accessed 28 July 2010).
55. Knoblauch A, Müller-Wenk R. Insomnia and noise-related sleep disturbance. In: *Quantifying burden of disease from environmental noise: second technical meeting report, Bern, Switzerland, 15–16 December 2005.* Copenhagen, WHO Regional Office for Europe, 2005 (http://www.euro.who.int/_data/assets/pdf_file/0005/87638/Noise_EDB_2nd_mtg.pdf, accessed 29 July 2010).
56. van Dongen JEF et al. *Hinder door milieufactoren en de beoordeling van de leefomgeving in Nederland.* Bilthoven, RIVM & Delft, TNO-INRO, 2004.
57. Miedema HME, Oudshoorn CGM. Annoyance from transportation noise: relationship with exposure metrics DNL and DENL and their confidence intervals. *Environmental Health Perspectives,* 2001, 109:409–416.
58. de Hollander AEM. Assessing and evaluating the health impact of environmental exposures: "deaths, DALYs or dollars?" (thesis). Utrecht, University of Utrech, 2004.
59. Murray CJL. Rethinking DALYs. In: Murray CJL, Lopez AD, eds. *The global burden of disease: a comprehensive assessment of mortality and disability from disease, injury, and risk factors in 1990 and projected to 2020.* Cambridge, MA, Harvard University Press, 1996 (Global Burden of Disease and Injury Series, Vol. I).

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5. ENVIRONMENTAL NOISE AND TINNITUS[7, 8]

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Several authors consider tinnitus to be a symptom of the auditory system and not as a disease per se. On the other hand, tinnitus is an entry in the International Classification of Diseases (ICD-9 (388.3) and ICD-10 (H93.1)). Tinnitus is very often found to be present concomitantly with hearing loss. This is also true for noise-induced tinnitus and noise-induced hearing loss (NIHL) *(1,2)*. Nevertheless, tinnitus may be experienced by persons exposed to excessive noise without measurable hearing loss *(3)*. The natural history, the annoyance and disability, the clinical approaches for diagnosis and treatment and the consequences of tinnitus differ significantly from these elements in persons with NIHL. For instance, insomnia reported by tinnitus sufferers is not a consequence of NIHL. Therefore, the authors consider it justified that tinnitus be analysed per se as an independent outcome of environmental noise risk assessment and burden of disease.

Definition of outcome

Tinnitus is the general term for sound perception (for instance, roaring, hissing or ringing) that cannot be attributed to an external sound source. To put it in terms of auditory abilities, tinnitus is the inability to perceive silence *(4)*. Tinnitus defined in such broad terms is rather prevalent. It is widely believed that mild, occasional or acute temporary tinnitus is experienced by nearly everybody in their lifetime at some time or another, the majority resolving spontaneously *(5)*. There is considerable variation in tinnitus expression, its etiology and its effects on patient's lives *(6)*.

Tinnitus may be classified according to its different attributes: duration of a single episode (seconds, minutes; intermittent, continuous), temporal duration (days, months, years) or severity (degree of annoyance, interference with daily living). Dauman & Tyler *(7)* proposed a classification according to five parameters of tinnitus: pathology, severity, duration, site and etiology. Stephens & Hétu *(8)* proposed a clas-

7 This chapter is dedicated to the late Xavier Bonnefoy, who was an essential initiator, leader and motivator during its development. Part of this work was presented at the Internoise2006, 3-6 December 2006, Honolulu, Hawaii, USA.

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sification according to the patient's abilities and quality of life. In fact, there is no unique internationally recognized classification.

Tinnitus can cause in some patients one or several of the following consequences:

- sleep disturbance (difficulty in falling asleep or going back to sleep)
- cognitive effects (difficulty with attention and concentration)
- anxiety
- psychological distress
- depression (case reports of suicide)
- communication and listening problems (hearing problems)
- frustration
- irritability
- tension
- inability to work
- reduced efficiency
- restricted participation in social life.

Tinnitus annoyance and experienced handicap can be measured in clinical or research settings on an individual basis by several valid questionnaires. The severity grading classification (grade I to grade IV) as measured by the Tinnitus Severity Questionnaire developed by Goebel et al. is probably one of the most frequently used tinnitus questionnaires in Germany *(9)*. Other countries use different questionnaires that have good psychometric properties (i.e. good internal consistency and test–retest reliability), such as the Tinnitus Reaction Questionnaire *(10)*, which measures emotional tinnitus-related distress, the Tinnitus Handicap Questionnaire *(11)*, which measures the self-reported severity of tinnitus as a handicap, and the Tinnitus Handicap Inventory *(12)*, which quantifies the impact of tinnitus on everyday life. Psychoacoustical measurements of tinnitus can also be made. Typically, however, these measurements do not predict the psychological distress reported by patients *(13)*.

In population-based survey studies, simple questions about duration and the degree of annoyance caused by tinnitus are usually used, rather than the tools described above to assess the individual status. According to Davis *(6)*, at least two elements should be included into any epidemiological study: tinnitus that lasts for five minutes or more (additionally whether it is present for some or all the time); and an assessment of the impact of tinnitus (for example, severity or annoyance). The general agreement of the authors and contributors to this chapter is to focus, for burden of disease purposes, on the degree of severity of disabling tinnitus rather than on its duration.

The proposed operational case definition of tinnitus is a sound perception (for instance roaring, hissing, ringing, noise in the ears or the like) at the time of the survey or during the past year that cannot be attributed to an external sound source,

and having disabling consequences in terms of constant disturbance of the emotional, cognitive, psychological or physical state of the patient. The term "constant" implies that the person has tinnitus that causes an impact on his or her functional life most of the time in at least one of these spheres.

Summary of evidence linking noise and tinnitus

A very small proportion of tinnitus cases signal the presence of an underlying treatable medical condition, such as a tumour or chronic partial opening of the Eustachian tube, but the majority of cases have no apparent or treatable cause. Tinnitus caused by excessive exposure to noise has long been described *(14–16)*. Fifty to 90% of patients with chronic noise trauma report tinnitus *(17)*.

Between 12% and 50% of persons with noise-induced hearing loss report having tinnitus *(18–21)*. Nevertheless, as stated before, tinnitus may be experienced by persons exposed to excessive noise who do not have measurable hearing loss *(3)*.

There is no single pathophysiological pathway to explain the occurrence of tinnitus. All structures of the auditory system have been suggested as possible sites of generation for tinnitus, from the periphery to the auditory cortex. Many explanatory models have been proposed, based on either anatomical, physiological, clinical or neuropsychological approaches. The underlying mechanisms responsible for transient and chronic tinnitus are most likely also different *(2)*. Despite those limitations in understanding the pathophysiology, however, there is no doubt that acute and chronic noise exposure can cause incapacitating tinnitus *(2,22)*. In noise-induced hearing loss and noise-induced tinnitus, it can be assumed that genesis is based on the same pathophysiological pathway *(23–27)*.

Hearing impairment is not expected to occur at $L_{Aeq,8h}$ levels of 75 dB(A) or below, even for prolonged occupational noise exposure. It is also expected that environmental noise exposure with a $L_{Aeq,24h}$ of 70 dB(A) or below will not cause hearing impairment in the large majority of people, even after a lifetime of exposure *(28)*. Although, to our knowledge, there are no empirical data to propose a no observed adverse effect level (NOAEL) for noise-induced tinnitus, it is reasonable and plausible to use the same protective NOAELs for tinnitus as those for noise-induced hearing loss. Therefore, for this burden of disease calculation, social/leisure noise is the most relevant source of exposure and concern for the EUR-A epidemiological subregion and North American countries, as these sources may typically exceed these thresholds. It is worth noting that traffic noise exceeds 85 dB(A) in some urban settings of developing countries *(29–31)*.

Exposure–response relationship

The exposure of interest in this context is leisure exposure, such as personal music players, gun shooting events, music concerts, sporting events and the use of firecrackers. To develop an exposure–response relationship, it would be necessary to find studies that linked these leisure noise exposures with the relative risk of occurrence of moderate to severe tinnitus. Although there are some studies based on this approach *(32–36)*, few could be identified and these did not cover all exposure settings. It was therefore not possible to develop an exposure–response relationship.

An alternative would be to estimate the relationship between noise and tinnitus derived from the risk curve relating noise exposure to hearing loss. This theoretical approach would be based on the existence of a valid quantitative relationship between noise-induced hearing loss levels and tinnitus risk. Should such a curve exist or be derived from existing data, the ISO 1999:1990 standard could be used to derive the risk of tinnitus per noise exposure level and duration. Although we know that the prevalence of tinnitus increases with the prevalence of noise-induced hearing loss, according to a recent literature review by Tyler *(37)* we are still not aware of any valid quantified relationship per hearing level between tinnitus prevalence and noise-induced hearing loss. Some authors do present data about this relationship, but we are not aware of any valid curves that could be used for burden of disease calculation.

Both these approaches also require population exposure data regarding the prevalence of exposure to leisure noise, which are not readily available at present.

Disability weight

There were no DWs readily available for tinnitus for burden of disease calculations. Three different approaches have been used to estimate DWs.

A first approach was for the authors to propose DWs by analogy with comparable diseases for which WHO already had DWs from the Global Burden of Disease Project. The best comparison proposed by the experts was with chronic pain, as this health problem shares several characteristics with tinnitus, such as: ongoing unwanted internal (centrally located) stimulus; causing or inducing co-morbidity (secondary symptoms) in terms of constant disturbance of the emotional, cognitive, psychological or physical state; not so well-understood pathophysiology; a lack of valid objective clinical findings or confirmatory laboratory tests; and possible response to cognitive therapy. Chronic pelvic pain has a DW of 0.122, whereas low back pain caused by chronic intervertebral disc protrusion has a DW of 0.121 (range 0.103–0.125). Other plausible comparisons are with cases of primary insomnia, which have a DW of 0.100 while a mild depressive episode has a DW of 0.140. As tinnitus may induce in some cases any of these two consequences, an interpolation in those ranges seemed reasonable. Thus, a DW of 0.120 was suggested *(38)*.

As this first approach was not considered to be very robust, a second approach was developed, based on the Canadian Population Health Impact of Disease Project, as an alternative to this first approach *(39)*. The preference scores (conceptually corresponding to one minus DW) were based on rating by health professionals and university experts using the Classification and Measurement System of Functional Health (CLAMES) *(40)* (see Appendix 1). This attempt did not give the expected results owing to unresolved methodological issues, and thus was not pursued.

Finally, an expert panel approach was undertaken. Based on all the available data, former proposals and an expert portrait of functional limitations caused by tinnitus (see Appendix 2), a third approach was proposed by the WHO expert on the Global Burden of Disease Project, Dr Colin D. Mathers, together with the WHO expert responsible for the Environmental Noise Burden of Disease Project, Dr Rokho Kim and the first author. This approach was based on the concept of "affecting ability to lead a normal life" (or affecting quality of life in terms of disabling consequences)

within the definition of disabling tinnitus. Two different DWs for different levels of severity of disabling tinnitus were proposed: 0.01 for mildly (slightly) disabling tinnitus and 0.11 for an aggregate moderate and severely disabling tinnitus. These two severity weights are for limitations in leading a normal life. These provisional proposals, pending a more formal valuation exercise, are based on approximate correspondence to the following conditions in a Dutch DW study that used the same methodology as the Global Burden of Disease Project *(41)*. This study estimated the following DWs for activities of daily living (ADL) limitations in the elderly:

- no to mild ADL limitations in the elderly, 0.01 (range 0.006–0.012)
- moderate to severe ADL limitations in the elderly, 0.11 (range 0.056–0.174).

For comparison, this study gave low back pain an average weight of 0.06, mild to moderate agoraphobia and epilepsy both a weight of 0.11, and mild stable angina (NYHA class 1–2) a weight of 0.08. Some comparable weights used in the GBD 2001 update of the Global Burden of Disease Study include:

- primary insomnia (causing problems with usual activities), 0.10
- dysthymia, 0.14
- moderate iron deficiency (80–109 g/l haemoglobin in women), 0.011.

It is worth mentioning that the DW of 0.11 for moderate to severely disabling tinnitus is very close to the proposed DW of 0.120 that emerged from the first approach. Therefore, DWs of 0.01 for slightly disabling tinnitus and of 0.11 for moderate to severely disabling tinnitus are used for the burden of disease calculations in this chapter.

EBD calculations

Outcome-based approach for leisure-noise-induced tinnitus in the EUR-A epidemiological subregion

The approach chosen for this chapter uses survey-based studies to estimate the prevalence of tinnitus on a population basis. With this approach, it is necessary to estimate the attributable portion of tinnitus caused by environmental noise exposure.

Prevalence of the outcome

A comprehensive review of the literature was made using published documents as identified by PubMed's internet resource through Laval University's Ariane search tool (http://ariane.ulaval.ca/web2/tramp2.exe/log_in?setting_key=french), references cited in selected articles, the authors and contributors of unpublished documents, and experts' opinions. When more than one published article was based on the same study population and design, the later or updated version was used.

The three research strategies retrieved more than 400 studies in English, French, Spanish or German. From that first extraction, 99 were selected as being potentially of interest. A global quality assessment of the studies was done independently by two reviewers, who classified each study as pass or fail based on criteria including external validity, internal validity and data analysis. Disagreements on the inclusion/exclusion of articles were resolved by consensus among the reviewers. Once

studies were selected, a data extraction form was used. This process led to the identification of 23 epidemiological studies of interest that met minimal specified quality criteria and these were presented in a background paper *(38)*.

To select the studies that are to be used for burden of disease calculations, the authors identified those that estimated point prevalence. Also, sampling had to be random and population-based. The authors analysed, when available, the wording of the questions. There is no internationally recognized standard definition of disabling tinnitus. None of the questions used in these studies answered specifically and in a standardized manner all the consequences of chronically disabling tinnitus. The selected studies estimated the prevalence of tinnitus through various concepts such as annoyance, difficulty falling asleep, and tinnitus moderately or very bothersome. Table 5.1 gives a summary of the six selected studies, with specification of the potential disability concept that could be used in each one. All six are cross-sectional descriptive prevalence studies estimating a point or yearly prevalence, based on random samples of the study population.

Table 5.1. Summary of studies selected for burden of disease calculations for tinnitus

Reference (age group in years, country) [sample size]	Question	Selected potential disability concept
Axelsson & Ringdahl *(42)* (20–80, Sweden) [3600]	Do you suffer from tinnitus?	Question 6. Severity of tinnitus (mark the most appropriate alternative) Tinnitus does not bother me particularly Tinnitus bothers me only in quiet surroundings Tinnitus disturbs my sleep […] Tinnitus plagues me all day
Davis *(43)* (17+, England) [48 313]	Nowadays do you get noises in your head or ears?	Tinnitus affecting quality of life
Hannaford et al. *(44)* 2005 (14+, Scotland) [15 788]	(missing exact question) ["Most questions related to current or recent (within the previous twelve months) symptoms … "]	Tinnitus problems "affected their ability to lead a normal life"
Nondahl et al. *(21)* 2002 (48–92, USA) [3737]	In the past year, have you had buzzing, ringing, or noise in your ears?	"Significant tinnitus" if at least moderate tinnitus or tinnitus causing difficulty in falling asleep
Paré & Levasseur *(45)* (15+, Canada) [20 773]	Do you hear ringing, buzzing or whistling noises in your ears or head that last 5 minutes or more at a time?	Do these noises [tinnitus] bother you? (moderately or a lot)
Sindhusake et al. *(18)* (55–99, Australia) [2015]	Have you experienced any prolonged ringing, buzzing or other sounds in your ears or head within the past year, that is, lasting for 5 minutes or longer?	Tinnitus "gets you down"

As the most common complaint from tinnitus sufferers is sleep disturbance, a first proposal by the experts was to use these data for burden of disease purposes. Although this was appealing, these results give only a partial picture of all the possible consequences of tinnitus. Of all the concepts used in the selected studies, those used by Davis *(43)* and by Hannaford *(44)*, as presented in Table 5.1, match more closely the global concept of disabling tinnitus and the similar concepts used for burden of disease calculations for other health problems. Therefore, the results of these two studies were used for burden of disease calculations of tinnitus induced by environmental noise. Despite the fact that the concepts used in these two studies do not correspond exactly to the wording of the operational case definition, the authors consider that these concepts match in an acceptable and reasonable way our definition of disabling tinnitus for calculating DALYs. Studies using similar concepts for disabling tinnitus could eventually be used for burden of disease calculations.

Based on the two selected studies, the authors calculated a weighted prevalence (with weights based on sample size) of tinnitus according to severity level (Table 5.2).

Table 5.2. Weighted population prevalence calculation for disabling tinnitus

Reference	Sample size (age group)	No. of cases of disabling tinnitus		
		Slight	Moderate	Severe
Davis *(43)*	19 023 (17+)	634 (3.3%)	228 (1.2%)	83 (0.4%)
Hannaford et al. *(44)*	15 788 (14+)	564 (3.6%)	189 (1.2%)	59 (0.4%)
Weighted mean prevalence	—	3.4	1.2	0.4

The general trend for the relationship between tinnitus prevalence and age generally shows that tinnitus prevalence increases with age and decreases after 60–70 years of age *(6)*. Hannaford et al. *(44)* do not present the results by age group for disabling tinnitus. Davis *(6)* reports an increasing prevalence with age for disabling tinnitus (see Table 5.3). For burden of disease calculations, the crude prevalence rate was used, as both studies cover almost the same age range (14 years and over or 17 years and over) and were done in two countries that have similar age distributions. For countries with different age distributions than European countries, the prevalence data by age group presented in chapter 9, Tables: section 1 page 901 under "Tinnitus affecting quality of life" of reference 43 can be used.

There are no clinically or statistically significant gender differences for noise-induced tinnitus *(6,38)*. Therefore, the authors suggest not taking gender into account for burden of disease calculations of tinnitus induced by environmental noise.

Prevalent cases in EUR-A countries were calculated based on population data extracted from the European health for all database *(46)* (Table 5.3). There is some evidence that noise-induced tinnitus is present in children *(47)*. To our knowledge, there are no population data on the prevalence of tinnitus in children. As the available prevalence data are based on two population studies of young people aged 14 years and over and 17 years and over, respectively, prevalent cases in EUR-A countries were calculated for age 15 years and over. The year 2001 was used for this example of calculation for comparison with *The world health report 2002 (48)*.

Table 5.3. Population and prevalent cases of disabling tinnitus per severity level for the WHO EUR-A epidemiological subregion, 15 years old and over, 2001

Total population	Population aged 15 years and over	Weighted prevalence per severity level	Prevalent cases of disabling tinnitus by severity level
413 967 744	344 131 386	Slight: 3.4%	11 845 523
		Moderate: 1.2%	4 122 166
		Severe: 0.4%	1 407 670
		Total	17 375 359

Attributable fraction of the outcome

As mentioned above, the prevalence approach involves proposing an attributable fraction of tinnitus specifically caused by environmental noise exposure in order to be able to calculate environmental noise burden of disease. Most studies reviewed, including the two selected ones, report the prevalence of tinnitus in the study population with no direct reference to cause. The few that do address cause do not specifically address environmental noise as a causal factor. There is no particular clinical presentation of tinnitus induced by environmental noise compared to tinnitus from other causes.

For burden of disease purposes, a case of environmental-noise-induced tinnitus is one that corresponds to the exclusive case definition. Cases due to mixed causes such as occupational and environmental noise exposures should be excluded from the attributable fraction. This choice will tend to give a conservative estimate of burden of disease due to tinnitus induced by environmental noise.

Only two data sources were readily available to estimate the population-attributable fraction for environmental noise. One is based on a large study in which 1535 patients attending the Tinnitus Clinic at the Oregon Health & Science University answered a standardized questionnaire. Among the 1406 patients with a valid noise exposure history, 16.2% (228/1406) reported having been exposed to recreational noise without any occupational or military exposures. Of these patients, 199 (14.2%) reported having usually or always at least one of 15 disability items. To the question "Were illness, accident or other special circumstances associated with the onset of your present tinnitus?", 26 (1.8%) reported that the onset of tinnitus was associated with exclusive recreational noise exposure. This last figure should be considered as an absolute minimum for this population, as people often do not relate the onset of their tinnitus with noise exposure unless it began suddenly following a brief, intense exposure (S.E. Griest & W.H. Martin, unpublished data, 2008).

The other available estimation is from Girard & Simard, who produced preliminary results based on a large medical surveillance database of over 88 320 workers' audiometric examinations carried out between 1983 and 1996 (S.A. Girard & M. Simard, unpublished data, 2005). After adjustment for occupational noise exposure level and duration, hearing level and age, the estimated attributable fraction of tinnitus caused exclusively by hobby or leisure noise exposure was 4.6% for this cohort *(38)*.
A third source of information was used. The authors asked 14 audiology experts (clinicians, rehabilitation centre professionals and university professors), one specialized psychologist and two ear, nose and throat medical specialists for their opinion on their estimation of the attributable portion of tinnitus caused exclusively by environmental

noise exposure. The experts first gave an individual estimate of the attributable fraction with figures ranging from 1% to 15%. After discussing this issue during a meeting with a subgroup of the same experts, based on the three available data sources, the consensus was for an estimated attributable fraction of 3% as a conservative but plausible and reasonable figure.

Calculation of DALYs

According to current knowledge and the data presented, the authors consider that there is no premature mortality caused by environmental-noise-induced tinnitus and therefore no YLL. Even though there are some reports of tinnitus sufferers committing suicide *(49)*, these are likely to be already accounted for in calculations of burden of disease attributed to suicide.

Table 5.4 presents the calculations of DALYs for disabling tinnitus, without reference to cause, for the WHO EUR-A epidemiological subregion in 2001.

Table 5.4. DALY calculation for disabling tinnitus per severity level for WHO EUR-A epidemiological subregion, 15 years of age and over, 2001

Severity	Prevalent cases	Disability weight	DALYs
Slight	11 845 523	0.01	118 455
Moderate	4 122 166	0.11	453 438
Severe	1 407 670	0.11	154 844
Total	17 375 359	—	726 737

As a comparison, the burden of non-cause-specific disabling tinnitus in EUR-A countries is higher than that of lower respiratory infections and several other well-recognized health problems (Table 5.5).

Table 5.5. Comparison of burden of disease for disabling tinnitus with some other common health problems, EUR-A epidemiological subregion, 2001

Health problem	DALYs
Unipolar depressive disorders	4 091 000
Hearing loss, adult onset	1 857 000
Diabetes mellitus	1 083 000
Disabling tinnitus	726 000
Lower respiratory infections	614 000
Oral diseases	353 000
Prostate cancer	335 000
Hypertensive heart disease	317 000
HIV/AIDS	208 000
Sexually transmitted diseases, excluding HIV	79 000

Source: World Health Organization *(48)* (except for disabling tinnitus).

DALYs for environmental-noise-induced disabling tinnitus for the WHO EUR-A epidemiological region in 2001 are presented in Table 5.6 by introducing the 3% population-attributable fraction into the calculations.

Table 5.6. Calculation of DALYs for environmental noise induced tinnitus by severity level for the WHO EUR-A epidemiological subregion, 15 years of age and over, 2001

Severity	Prevalent cases	Disability weight	Population-attributable fraction	DALYs
Slight	11 845 523	0.01	0.03	3 554
Moderate	4 122 166	0.11	0.03	13 603
Severe	1 407 670	0.11	0.03	4 645
Total	17 375 359	—	—	21 802

As a comparison, the burden of disease for environmental-noise-induced disabling tinnitus is higher than that for cataracts or hepatitis B in EUR-A countries (Table 5.7).

Table 5.7. Comparisons of burden of disease for environmental-noise-induced disabling tinnitus with some other common health problems, WHO EUR-A epidemiological subregion, 2001

Health problem (from all causes unless mentioned)	DALYs
Mild mental retardation caused by lead[a]	55 000
Hepatitis C[b]	30 000
Upper respiratory infections[b]	26 000
Environmental-noise-induced disabling tinnitus	22 000
Cataracts[b]	19 000
Hepatitis B[b]	18 000
Appendicitis[b]	16 000
Periodontal disease[b]	16 000
Gonorrhoea[b]	15 000

[a] *Source*: Fewtrell L et al. *(50)*.
[b] *Source*: World Health Organization *(48)*.

These calculations are likely to be valid for the WHO EUR-A epidemiological subregion. They are based on valid population prevalence data corresponding reasonably to the case definition and with DWs matching this case definition, using a rather conservative but plausible impact fraction. Although several aspects of the calculation method are based on expert opinion, all the best available data were integrated into a systematic logical reproducible analysis.

Uncertainties, limitations and challenges

Accuracy of estimates of tinnitus prevalence

The approach chosen for this chapter uses survey-based studies to estimate the prevalence of tinnitus on a population basis. Depending on the questions used for each individual survey, the results may represent anything from lifetime to point prevalence of tinnitus, with or without considerations of duration or severity. In a recent review of the literature *(38)*, prevalence of tinnitus varied from 3% to 36%.

Burden of disease calculations being based on an annual occurrence of the event of interest multiplied by duration, the prevalence data used must reflect a yearly prevalence. Therefore, only point prevalence data, or at the most the previous year's data on disabling tinnitus should be considered.

This approach has some limits for calculating global burden of disease: the prevalence of tinnitus may be different from one country to another; and the survey questions vary from one study to another as there is no standardization of questionnaires. Also, cross-sectional studies have some limitations as they cannot assess the evolution of the problem in terms of fluctuations in duration and severity.

Clinical studies reveal that some individual cases of tinnitus do fluctuate over time from more to less disabling and vice versa *(6)*. Nevertheless, it is assumed that, on average, the overall prevalence will remain stable all year round on a population level.

Lack of exposure data

To our knowledge, there are no valid population data available at present on the prevalence of exposure to leisure-time noise sufficient to induce tinnitus.

Calculating burden of disease in countries other than those in Europe

The authors were unable to identify population data on disabling tinnitus outside the Organisation for Economic Co-operation and Development (OECD) countries. As tinnitus is by essence a subjective experience, its natural history may differ in different cultural settings. The authors consider that it may be risky to infer similar prevalences for economically developing countries as those found in the selected studies. For instance, as stated above, traffic noise in some urban settings is above the levels that can produce tinnitus, thus likely adding to the number of noise sources that induce disabling tinnitus and therefore to the attributable fraction of environmental-noise-induced tinnitus. Should national burden of disease calculations for environmental-noise-induced tinnitus be estimated, calculations should adjust for the age distribution of the target population.

Some experts are convinced that the burden of tinnitus is influenced by the cultural situation. For instance, given that moderate tinnitus can impair cognitive functions such as auditory working memory and visual attention span *(51,52)*, the burden may be higher in cultures with frequent highly demanding professional work, where tinnitus may contribute to unacceptable mistakes.

Conclusions

To our knowledge, the global burden of disease for disabling tinnitus or environmental-noise-induced tinnitus has never been estimated before. The epidemiology of functional limitations caused by tinnitus is rather scarce and even more so for environmental-noise-induced tinnitus.

Although the proposed approach is in some aspects based on expert opinion, hopefully it will be useful as a starting place from which to better ascertain the burden of suffering caused by tinnitus. One of the fundamental goals in constructing summary measures of health is to identify the relative magnitude of different health problems, including diseases, injuries and risk factors *(53)*. The estimate of environmental-noise-induced tinnitus presented in this chapter is based on the best available sci-

ence and may err on the conservative side, according to the authors. Therefore, it is our hope that this work will help to better understand and value the importance of diseases such as tinnitus, which are often not very well known or understood outside specific expert circles, and therefore not a very high priority in the political agenda.

REFERENCES

1. Vio MM, Holme RH. Hearing loss and tinnitus: 250 million people and a US$10 billion potential market. *Drug Discovery Today,* 2005, 10:1263–1265.
2. Eggermont JJ. Tinnitus: neurobiological substrates. *Drug Discovery Today,* 2005, 10:1283–1290.
3. Jones JR et al. *Self-reported work-related illness in 1995. Results from a household survey.* Norwich, The Stationery Office, 1998.
4. Leroux T, Lalonde M. Proposal for an enriched classification of abilities relating to the senses and perception – Hearing. *International Classification of Impairments, Disabilities and Handicap (ICIDH) International Network,* 1993, 5(3)/6(1):33–37.
5. MacFadden D. *Tinnitus facts, theories, and treatments. Working Group 89. Committee on Hearing, Bioacoustics, and Biomechanics, National Research Council.* Washington, DC, National Academy Press,1982.
6. Davis A, Refaie EA. Epidemiology of tinnitus. In: Tyler RS, ed. *Tinnitus handbook.* San Diego, CA, Singular Publishing Group, 2000.
7. Dauman R, Tyler RS. Some considerations on the classification of tinnitus. In: Aran JM, Dauman R, eds. *Proceedings of the Fourth International Tinnitus Seminar, Bordeaux, France, 1992:*225–229.
8. Stephens D, Hétu R. Impairment, disability and handicap in audiology: towards a consensus. *Audiology,* 1991, 30:185–200.
9. Zenner HP, de Maddalena H, Zalaman IM. Validity and reliability of three tinnitus self-assessment scales. *Acta Oto-laryngologica,* 2006, 125:1184–1188.
10. Wilson PH et al. Tinnitus Reaction Questionnaire: Psychometric properties of a measure of distress associated with tinnitus. *Journal of Speech and Hearing Research,* 1991, 34:197–201.
11. Kuk FK et al. The psychometric properties of a tinnitus handicap questionnaire. *Ear and Hearing,* 1990, 11:434–442.
12. Newman CW, Jacobson GP, Spitzer JB. Development of the Tinnitus Handicap Inventory. *Archives of Otolaryngology – Head & Neck Surgery,* 1996, 122:143–148.
13. *Møller AR. Hearing: its physiology and pathophysiology.* San Diego, CA, Academic Press, 2000.
14. Holt EE. Boiler-maker's deafness and hearing in a noise. *Transactions of the American Otological Society,* 1882,3:34–44.
15. Sataloff J. Occupational deafness in industrial medicine and surgery. *Journal of Medicine in Industry,* 1952, 21(7).
16. Vernon JA, Moller AR, eds. *Mechanisms of tinnitus.* Needham Heights, MA, Allyn and Bacon, 1995.
17. Spoendlin H. Inner ear pathology and tinnitus. In: Feldmann H, ed. *Proceedings of the Third International Tinnitus Seminar.* Munster, Harsch Verlag Karlsrehe,1987:42–51.
18. Sindhusake D et al. Factors predicting severity of tinnitus: a population-based assessment. *Journal of the American Academy of Audiology,* 2004, 15:269–280.
19. Kähäri K et al. Assessment of hearing and hearing disorders in rock/jazz musicians. *International Journal of Audiology,* 2003, 42:279–288.
20. Palmer KT et al. Occupational exposure to noise and the attributable burden of hearing difficulties in Great Britain. *Occupational and Environmental Medicine,* 2002, 59:634–639.
21. Nondahl DM et al. Prevalence and 5-year incidence of tinnitus among older adults: the epidemiology of hearing loss study. *Journal of the American Academy of Audiology,* 2002, 13:323–331.
22. Plontke SKR et al. The incidence of acoustic trauma due to New Year's firecrackers. *European Archives of Oto-rhino-laryngology,* 2002, 259:247–252.
23. Zenner HP et al. The inner hair cell afferent/efferent synapses revisited: a basis for new therapeutic strategies. *Advances in Oto-rhino-laryngology, 2002, 59:124–130.*

24. Pujol R, Puel JL. Excitotoxicity, synaptic repair, and functional recovery in the mammalian cochlea. A review of recent findings. *Annals of the New York Academy of Sciences,* 1999, 884: 249–252.
25. Puel JL et al. Excitotoxicity and repair of cochlear synapses after noise-trauma induced hearing loss. *Neuroreport,* 1998, 22:2109–2114.
26. Puel JL et al. Synaptic regeneration and functional recovery after excitotoxic injury in the guinea pig cochlea. *Comptes Rendus de l'Académie des Sciences. Série III, Sciences de la Vie,* 1995, 318:67–75.
27. Pujol R et al. Pathophysiology of the glutamatergic synapses in the cochlea. *Acta Oto-laryngologica,* 1993, 113:330–334.
48. *Guidelines for community noise.* Geneva, World Health Organization, 1999 (http://whqlibdoc.who.int/hq/1999/a68672.pdf, accessed 22 July 2010).
29. Joshi SK et al. Environmental noise induced hearing loss in Nepal. *Kathmandu University Medical Journal,* 2003, 1:177–183.
30. Chakraborty MR et al. Noise level in different places of Dhaka Metropolitan City (DMC) and noise-induced hearing loss (NIHL) in Dhaka City dwellers. *Bangladesh Medical Research Council Bulletin, 2005, 31(2):68–74.*
31. Zaidi SH. Noise levels and the sources of noise pollution in Karachi. *Journal of the Pakistan Medical Association,* 1989, 39:62–65.
32. Holgers KM, Pettersson B. Noise exposure and subjective hearing symptoms among school children in Sweden. *Noise & Health,* 2005, 7(27):27–37.
33. Mercier V, Luy D, Hohmann BW. The sound exposure of the audience at a music festival. *Noise & Health,* 2003, 5(19):51–58.
34. Smith PA et al. The prevalence and type of social noise exposure in young adults in England. *Noise & Health,* 2000, 2(6):41–56.
35. Axelsson A, Prasher D. Tinnitus induced by occupational and leisure noise. *Noise & Health,* 2000, 2(8):47–54.
36. Segal S et al. Inner ear damage in children due to noise exposure from toy cap pistols and firecrackers: a retrospective review of 53 cases. *Noise & Health,* 2003, 5(18):13–18.
37. Tyler RS. *Tinnitus treatment. Clinical protocols.* New York, Thieme Medical Publishers, 2006.
38. Deshaies P et al. *Quantification of the burden of disease for tinnitus caused by community noise. Background paper.* Quebec, WHO Collaborating Centre on Environmental and Occupational Health Impact Assessment and Surveillance, 2005 (http://www.chuq.qc.ca/oms/pdf/TinnitusBackgroundPaper2005.pdf accessed 29 July 2010).
39. Population Health Impact of Disease in Canada (PHI) [web site]. Ottawa, Public health Agency of Canada (http://www.phac-aspc.gc.ca/phi-isp/index-eng.php, accessed 30 July 2010)
40. McIntosh CN et al. Eliciting Canadian population preferences for health states using the Classification and Measurement System of Functional Health (CLAMES). Chronic Diseases in Canada, 2007, 28(1–2):29–41.
41. Stouthard MEA et al. *Disability weights for diseases in the Netherlands.* Rotterdam, Department of Public Health, Erasmus University, 1997.
42. Axelsson A, Ringdahl A. Tinnitus – a study of its prevalence and characteristics. *British Journal of Audiology,* 1989, 23:53–62.
43. Davis A. *Hearing in adults. The prevalence and distribution of hearing impairment and reported hearing disability in the MRC Institute of Hearing Research's National Study of Hearing.* Nottingham, MRC Institute of Hearing Research, 1995.
44. Hannaford PC et al. The prevalence of ear, nose and throat problems in the community: results from a national cross-sectional postal survey in Scotland. *Family Practice,* 2005, 22: 227–233.

45. Paré L, Levasseur M. Problèmes auditifs et problèmes visuels. In: *Enquête sociale et de santé 1998,* 2nd ed. Quebec, Institut de la statistique du Québec, 2001.
46. European health for all database (HFA-DB) [online database]. Copenhagen, WHO Regional Office for Europe, 2010 (http://data.euro.who.int/hfadb/, accessed 30 July 2010).
47. Holgers, KM. Tinnitus in 7-year-old children. *European Journal of Pediatrics,* 2003, 162:276–278.
48. *The world health report 2002 – reducing risks, promoting healthy life.* Geneva, World Health Organization, 2002 (http://www.who.int/whr/2002/en/index.html, accessed 30 July 2010).
49. Johnston M, Walker M. Suicide in the elderly. Recognizing the signs. *General Hospital Psychiatry,* 1996, 18:257–260.
50. Fewtrell L, Kaufmann R, Prüss-Üstün A. *Lead: assessing the environmental burden of disease at national and local level.* Geneva, World Health Organization, 2003 (WHO Environmental Burden of Disease Series, No. 2).
51. Hallam RS, McKenna L, Shurlock L. Tinnitus impairs cognitive efficiency. *International Journal of Audiology,* 2004, 43:218–226.
52. Rossiter S, Stevens C, Walker G. (2006) Tinnitus and its effect on working memory and attention. *Journal of Speech, Language, and Hearing Research,* 49:150–160.
53. Murray et al. *Summary measures of population health concepts, ethics, measurement and applications.* Geneva, World Health Organization, 2002.

Appendix 1. Classification and Measurement System of Functional Health (CLAMES)

Core attributes

Pain or discomfort	1. Generally free of pain and discomfort 2. Mild pain or discomfort 3. Moderate pain or discomfort 4. Severe pain or discomfort
Physical functioning	1. Generally no limitations in physical functioning 2. Mild limitations in physical functioning 3. Moderate limitations in physical functioning 4. Severe limitations in physical functioning
Emotional state	1. Happy and interested in life 2. Somewhat happy 3. Somewhat unhappy 4. Very unhappy 5. So unhappy that life is not worth while
Fatigue	1. Generally no feelings of tiredness, no lack of energy 2. Sometimes feel tired, and have little energy 3. Most of the time feel tired, and have little energy 4. Always feel tired, and have no energy
Memory and thinking	1. Able to remember most things, think clearly and solve day-to-day problems 2. Able to remember most things but have some difficulty when trying to think and solve day-to-day problems 3. Somewhat forgetful, but able to think clearly and solve day-to-day problems 4. Somewhat forgetful, and have some difficulty when trying to think or solve day-to-day problems 5. Very forgetful, and have great difficulty when trying to think or solve day-to-day problems
Social relationships	1. No limitations in capacity to sustain social relationships 2. Mild limitations in capacity to sustain social relationships 3. Moderate limitations in capacity to sustain social relationships 4. Severe limitations in capacity to sustain social relationships 5. No capacity or unable to relate to other people socially

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Supplementary attributes

Anxiety	1. Generally not anxious 2. Mild levels of anxiety experienced occasionally 3. Moderate levels of anxiety experienced regularly 4. Severe levels of anxiety experienced most of the time
Speech	1. Able to be understood completely when speaking with strangers or friends 2. Able to be understood partially when speaking with strangers but able to be understood completely when speaking with people who know you well 3. Able to be understood partially when speaking with strangers and people who know you well 4. Unable to be understood when speaking to other people
Hearing	1. Able to hear what is said in a group conversation, without a hearing aid, with at least three other people 2. Able to hear what is said in a conversation with one other person in a quiet room, with or without a hearing aid, but require a hearing aid to hear what is said in a group conversation with at least three other people 3. Able to hear what is said in a conversation with one other person in a quiet room, with or without a hearing aid, but unable to hear what is said in a group conversation with at least three other people 4. Unable to hear what others say, even with a hearing aid
Vision	1. Able to see well enough, with or without glasses or contact lenses, to read ordinary newsprint and recognize a friend on the other side of the street 2. Unable to see well enough, even with glasses or contact lenses, to recognize a friend on the other side of the street but can see well enough to read ordinary newsprint 3. Unable to see well enough, even with glasses or contact lenses, to read ordinary newsprint but can see well enough to recognize a friend on the other side of the street 4. Unable to see well enough, even with glasses or contact lenses, to read ordinary newsprint or to recognize a friend on the other side of the street
Use of hands and fingers	1. No limitations in the use of hands and fingers 2. Limitations in the use of hands and fingers, but do not require special tools or the help of another person 3. Limitations in the use of hands and fingers, independent with special tools and do not require the help of another person 4. Limitations in the use of hands and fingers, and require the help of another person for some tasks 5. Limitations in the use of hands and fingers, and require the help of another person for most tasks

Source: Public Health Agency of Canada (http://www.phac-aspc.gc.ca/phi-isp/state_preference-eng.php#clames).

Appendix 2. CLAMES description of a typical (median or average) case of disabling tinnitus causing some consequences

CLAMES attribute	Experts' description of consequence of tinnitus	Corresponding CLAMES descriptor*	CLAMES score
Pain or discomfort	Moderate physical discomfort as the person hears the sound in a lot of day-to-day circumstances (discomfort refers to an unpleasant sensation that is not pain, such as nausea or itching)	Moderate pain or discomfort	3
Physical functioning	Generally no limitations in physical functioning	Generally no limitations in physical functioning	1
Emotional state	More unhappy or sad than happy during waking hours (more than 50% of the time unhappy), […]	Somewhat unhappy (you are not completely unhappy, but you are more unhappy than happy)	3
Fatigue	[…] with little energy and feeling tired most of the time	Most of the time feel tired, and have little energy (most of your waking hours are spent feeling tired or fatigued)	3
Memory and thinking	No problems with memory or thinking clearly, but will have some difficulty in solving day-to-day problems (tinnitus influence on cognition, on thinking capacity and on attention)	Able to remember most things but have some difficulty when trying to think and solve day-to-day problems	2
Social relation-ships	Induces mild limitations in the capacity to sustain social relationships (will limit the number of people and of groups of people they relate to)	Mild limitations in the capacity to sustain social relationships (you have an inhibited capacity for social relationships: you do not always have the ability to maintain the full range of usual social relationships)	2
Anxiety	Anxiety is a hallmark of tinnitus causing consequences (sequelae): there is a high level of anxiety experienced most of the time; there is a feeling of loss of control and helplessness	Severe levels of anxiety experienced most of the time (you experience excessive uneasiness, worry or fear most of the time)	4
Speech	No effect on speech	Able to be understood completely when speaking with strangers or friends	1

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CLAMES attribute	Experts' description of consequence of tinnitus	Corresponding CLAMES descriptor*	CLAMES score
Hearing	The independent effect of tinnitus on communication is rather difficult to pinpoint, as a majority of tinnitus sufferers do have some hearing impairment (these are two concomitant health problems that may both affect communication capacities); hearing impairment affects particularly communication in a group conversation; Zenner states that the communication problems do not have the same origin for hearing loss and tinnitus; for tinnitus patients with hyperacusis without hearing loss, often hyperacusis is the source of difficulties communicating in groups of 3 or more people; better descriptor for tinnitus is that it causes more of a discomfort or intolerance in situations of group conversations, rather than an impossibility to hear a conversation; nevertheless, the experts consider that, on average, tinnitus does cause some communication problems in groups	Able to hear what is said in a conversation with 1 other person in a quiet room, with or without a hearing aid, but require a hearing aid to hear what is said in a group conversation with at least 3 other people Able to hear what is said in a conversation with 1 other person in a quiet room, with or without a hearing aid, but unable to hear what is said in a group conversation with at least 3 other people	3 (2)
Vision	No effect on vision	Able to see well enough, with or without glasses or contact lenses, to read ordinary newsprint and recognize a friend on the other side of the street	1
Use of hands and fingers		No limitations in the use of hands and fingers	1

6. ENVIRONMENTAL NOISE AND ANNOYANCE

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Noise annoyance is widely accepted as an end-point of environmental noise that can be taken as a basis for evaluating the impact of noise on the exposed population. As a consequence, EU Directive 2002/49/EC *(1)* recommends evaluating environmental noise exposures on the basis of estimated noise annoyance.

As discussed in Chapter 1, WHO defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" *(2)*. This implies that noise-induced annoyance may be considered an adverse effect on health. People annoyed by noise may experience a variety of negative responses, such as anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation or exhaustion *(3–5)*. Furthermore, stress-related psychosocial symptoms such as tiredness, stomach discomfort and stress have been found to be associated with noise exposure as well as noise annoyance *(6,7)*. Some public health experts feel that severe forms of noise-related annoyance should be considered a legitimate environmental issue affecting the well-being and quality of life of the population exposed to environmental noise. The most important issue in the present context is to what extent health (according to the broad definition given above) is reduced by noise and whether a DW that expresses this reduction, when combined with the prevalence of annoyance, leads to a significant burden of "disease". The other possibility would be that noise annoyance does not significantly contribute to disability and, hence, should not be taken into account when considering the noise-induced burden of disease.

In this chapter, a method for estimating the burden of annoyance due to noise is proposed and illustrated, and related issues are discussed. The method was developed by the Netherlands National Institute for Public Health (RIVM) *(8)* and initially applied to the Netherlands. First, a closer look is taken at noise annoyance in the context of burden of disease calculations.

Definition of outcome

Noise annoyance is assessed at the level of populations by means of a questionnaire. Efforts have been made by the International Commission on Biological Effects of Noise and the International Organization for Standardization *(9)* towards the use of standardized questions asking for the degree of annoyance, and introducing an 11-point numerical scale and a 5-point semantic scale. Recoding scales into a 0–100 annoyance response scale, cut-off values of 50 and 72 have been used to determine the percentage of people annoyed and highly annoyed, respectively. For the 5-point scale, however, cut-off values of 40 and 60 are also in use, matching the three highest categories for annoyance and the two highest categories for high annoyance. The percentage highly annoyed, i.e. the percentage of persons with a response exceeding 72, is the most widely used indicator of the prevalence of annoyance in a population, although percentages using other cut-offs or the mean annoyance may also be used *(10)*. In the case study included in this chapter, high annoyance is used as the annoyance indicator. Using a lower cut-off value would give higher prevalence but

would be associated with a lower DW, resulting in either a higher or a lower estimate of the burden caused by noise annoyance. An important reason for using highly annoyed as the cut-off is the expectancy that only for rather severe annoyance may it be possible to gain consensus on a DW that can be meaningfully distinguished from zero.

Provided it contributes significantly, annoyance due to environmental noise can be included in estimates of the burden related to environmental noise when (*a*) the noise exposure of the population is known, (*b*) exposure–response relationships are available for estimating the annoyance on the basis of the exposures, and (*c*) a DW is attached to noise annoyance. In principle, it is also possible to replace steps (*a*) and (*b*) by direct estimates of annoyance prevalence through an annoyance survey in the population concerned (outcome-based approach).

Traffic noise exposure

Within the framework of Directive 2002/49/EC *(1)*, exposure data have been provided by agglomerations with more than 250 000 inhabitants, as reported by the Noise Observation and Information Service for Europe (NOISE) of the European Environment Agency (EEA) *(11)*. While not all Member States have reported yet, and some differences between Member States may be attributed to methodological differences rather than differences in exposure, these data provide an indication of the exposure distribution within large urban areas in the EU. The distribution of exposure to road traffic noise in Member States was used based on 110 million people, the total number of inhabitants in the agglomerations for which a report had been provided up to June 2010 *(11)*. It is assumed here that the observed exposure distribution may apply to the total urban population within the EU living in cities or agglomerations with more than 50 000 inhabitants, which is estimated to be around 285 million people (57% of the total EU population).

Exposure–response relationship

The EU Position Paper on dose–response relationships between transportation noise and annoyance *(12)* presented synthesis curves for noise annoyance from aircraft, road traffic and railway noise, with their 95% confidence intervals taking into account the variation between individuals and studies. These curves were based on all studies examined by Schultz *(13)* and Fidell et al. *(14)* for which L_{den} (and L_{dn}), and the percentage of "highly annoyed" persons (%HA) meeting certain minimal requirements could be derived, augmented by a number of additional studies *(10)*. The raw data from a total of 54 studies from Europe, North America and Australia investigating noise annoyance from road traffic, aircraft and railways were analysed. The percentage of "highly annoyed" persons (%HA) as a function of noise exposure indicated by L_{den} was found to be the following.

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Aircraft:
$\%HA = -9.199 \cdot 10^{-5} (L_{den} - 42)^3 + 3.932 \cdot 10^{-2} (L_{den} - 42)^2 + 0.2939 (L_{den} - 42)$

Road traffic:
$\%HA = 9.868 \cdot 10^{-4} (L_{den} - 42)^3 - 1.436 \cdot 10^{-2} (L_{den} - 42)^2 + 0.5118 (L_{den} - 42)$

Railways:
$\%HA = 7.239 \cdot 10^{-4} (L_{den} - 42)^3 - 7.851 \cdot 10^{-3} (L_{den} - 42)^2 + 0.1695 (L_{den} - 42)$

Data below 45dB and above 75dB (L_{den}) were excluded because the risk of unreliable noise data is high at very low levels, whereas the risk of selection of "survivors" is high at very high levels. The confidence intervals found were narrow, indicating that, even though there is considerable variation between individuals and between studies, the uncertainty regarding the relationships between noise exposure and annoyance is rather limited.

In the same way, and based on the same data, Miedema & Oudshoorn *(10)* established the following relationships for L_{dn}.

Aircraft:
$\%HA = -1.395 \cdot 10^{-4} (L_{dn} - 42)^3 + 4.081 \cdot 10^{-2} (L_{dn} - 42)^2 + 0.342 (L_{dn} - 42)$

Road traffic:
$\%HA = 9.994 \cdot 10^{-4} (L_{dn} - 42)^3 - 1.523 \cdot 10^{-2} (L_{dn} - 42)^2 + 0.538 (L_{dn} - 42)$

Railways:
$\%HA = 7.158 \cdot 10^{-4} (L_{dn} - 42)^3 - 7.774 \cdot 10^{-3} (L_{dn} - 42)^2 + 0.163 (L_{dn} - 42)$

Disability weight

Given the limited number of studies on a DW for annoyance, and the sensitivity of the environmental burden attributed to noise annoyance for small changes in DW, a tentative DW of 0.02 is proposed with a relatively large uncertainty interval (0.01–0.12). The minimum value (0.01) is based on the value used by de Hollander et al. *(15)* and by Stassen et al. *(16)* in environmental burden of disease calculations. The maximum value (0.12) is based on the mean DW found for severe annoyance by Van Kempen (cited in Knol & Staatsen) *(17)*, who did a pilot study among 13 medical experts, working according to a protocol by Stouthard et al. *(18)*. De Hollander *(19)* expanded this study to 35 environmental physicians, epidemiologists and public health professionals and also assessed a mean DW of 0.12 (median: 0.07; standard deviation: 0.16; range 0–0.35) using the same protocol. The relatively high DW for annoyance in these studies may be explained by the presentation of the definition of annoyance with the description that annoyance could lead to various symptoms such as being not (95%) or mildly (5%) anxious or depressed, and having no (95%) to some (5%) cognitive impairment. In addition, Müller-Wenk *(20)* found a mean DW of 0.033 (median: 0.03; range: 0.01–0.12) for communication disturbance based on a survey of 42 Swiss physicians, which may apply to annoyance related to daytime noise exposure. Based on these data and taking a "conservative approach", here only severe cases of annoyance (highly annoyed) are given DW 0.02 for estimation of burden in terms of DALYs.

EBD calculations

Here we provide a method for estimating the environmental burden of disease for noise, estimating the prevalence of noise annoyance by combining exposure data with the exposure–response relationships for noise annoyance. One year is proposed as the duration for exposure causing severe annoyance, as annoyance is an effect that disappears when the noise stops. Age was not considered, assuming that children are annoyed in the same way as adults. While this assumption seems justified, since children showed similar patterns of annoyance to those of their parents *(21)*, it may lead to a slight overestimation since annoyance does not appear to be a relevant concept for infants.

We calculated the DALYs for noise annoyance using the exposure distribution in L_{den} presented by EEA *(11)* for large agglomerations (> 250 000 inhabitants), the exposure–response relationships for annoyance (with expected percentage of highly annoyed people at the midpoint of the category, as a function of L_{den} in the range 42–80 dB(A)) and a range of DWs. This calculation suggests that there are about 587 000 DALYs lost due to noise-induced annoyance within the EU population living in urban areas. Taking 0.01 and 0.12 as the extremes of the range for DWs, the credible range for the DALYs is 0.29–3.52 million (Tables 6.1–6.4). It should be noted that the burden in rural areas or small town with less than 50 000 inhabitants is not included here, and that we took a very conservative assumption about the exposure distribution below 50 dB(A).

Table 6.1. DALYs for highly annoyed people due to road traffic noise in the EU

Exposure category L_{den} (dB(A))	Percentage of population exposed [a]	Percentage of people highly annoyed [b]	Number of cases per million [b]	DALYs lost in the urban population [c]		
				DW = 0.01	DW = 0.02	DW = 0.12
< 55	50	2.77	13 835	39 430	78 859	473 155
55–59	17	8.16	13 868	39 524	79 047	474 285
60–64	19	12.96	24 621	70 170	140 341	842 044
65–69	9	20.08	18 068	51 494	102 989	617 933
70–74	4	30.25	12 100	34 485	68 969	413 815
> 75	1	30.25 [d]	3 025	8 621	17 242	103 454
Total	100		85 517	243 724	487 448	2 924 686

[a] The source of exposure data is the Noise Observation and Information Service for Europe (NOISE) as of June 2010.

[b] The percentage and number of cases were calculated using the mid-level value of each exposure category. For the category of < 55 dB(A), the mid-level value was conservatively set to 48 dB(A).

[c] DALYs were calculated for the 285 million persons living in agglomerations with > 50 000 inhabitants.

[d] As the exposure–response function does not apply to the range over 75 dB(A), the percentage of people highly annoyed in this exposure category was assumed to be the same as in the 70–74 dB(A) category.

Table 6.2. DALYs for highly annoyed people due to rail traffic noise in the EU

Exposure category L_{den} (dB(A))	Percentage of population exposed [a]	Percentage of people highly annoyed [b]	Number of cases per million [b]	DALYs lost in the urban population [c]		
				DW = 0.01	DW = 0.02	DW = 0.12
< 55	95	0.89	8 462	24 116	48 233	289 397
55–59	3	3.44	1 031	2 938	5 877	35 261
60–64	1	6.41	641	1 827	3 655	21 929
65–69	1	11.22	1 122	3 198	6 396	38 374
70–74	0	18.41	0	0	0	0
> 75	0	18.41 [d]	0	0	0	0
Total	100		11 256	32 080	64 160	384 960

[a] The source of exposure data is the Noise Observation and Information Service for Europe (NOISE) as of June 2010.

[b] The percentage and number of cases were calculated using the mid-level value of each exposure category. For the category of < 55 dB(A), the mid-level value was conservatively set to 48 dB(A).

[c] DALYs were calculated for the 285 million persons living in agglomerations with > 50 000 inhabitants.

[d] As the exposure–response function does not apply to the range over 75 dB(A), the percentage of people highly annoyed in this exposure category was assumed to be the same as in the 70–74 dB(A) category.

Table 6.3. DALYs for highly annoyed people due to air traffic noise in the EU

Exposure category L_{den} (dB(A))	Percentage of population exposed [a]	Percentage of people highly annoyed [b]	Number of cases per million [b]	DALYs lost in the urban population [c]		
				DW = 0.01	DW = 0.02	DW = 0.12
< 55	96	3.16	30 327	33 360	66 719	400 315
55–59	3	13.66	4 098	11 679	23 358	140 147
60–64	1	21.76	2 176	6 201	12 401	74 408
65–69	0	31.54	0	0	0	0
70–74	0	42.93	0	0	0	0
> 75	0	42.93 [d]	0	0	0	0
Total	100		36 601	17 880	35 759	214 555

[a] The source of exposure data is the Noise Observation and Information Service for Europe (NOISE) as of June 2010.

[b] The percentage and number of cases were calculated using the mid-level value of each exposure category. For the category of < 55 dB(A), the mid-level value was conservatively set to 48 dB(A).

[c] DALYs were calculated for the 285 million persons living in agglomerations with > 50 000 inhabitants.

[d] As the exposure–response function does not apply to the range over 75 dB(A), the percentage of people highly annoyed in this exposure category was assumed to be the same as in the 70–74 dB(A) category.

Table 6.4. DALYs for highly annoyed people due to all traffic noise in the EU[a]

Source of traffic noise	DALYs		
	DW = 0.01	DW = 0.02	DW = 0.12
Road	243 724	487 448	2 924 686
Rail	32 080	64 160	384 960
Air	17 880	35 759	214 555
Total	293 684	587 367	3 524 201

[a] For the 285 million population living in agglomerations with > 50 000 inhabitants.

Uncertainties, limitations and challenges

Alternative approaches

The burden in terms of DALYs may also be directly estimated on the basis of noise annoyance survey data in the population concerned, if available. However, we expect that the approach starting with the noise exposure levels will be most feasible in the future with the increase of the noise exposure mapping effort. Moreover, it is less sensitive to the idiosyncrasies of the different surveys conducted in different populations and the differences in the processing of the data obtained with the surveys, and it is less sensitive to temporary factors affecting the response of a population surveyed. Therefore, provided that the noise exposure assessment is sufficiently harmonized, the approach that estimates the prevalence of noise annoyance by combining exposure data with the exposure–response relationships for noise annoyance appears to be most promising.

Choice of the exposure–response relationship for annoyance

Various authors have synthesized existing data from community annoyance surveys to develop an exposure–response relationship for use in environmental impact analyses and related community planning efforts, such as Schultz *(13)*, Fidell et al. *(14)* and Miedema & Oudshoorn *(10)*. Schultz recognized the preliminary nature of his original synthesis curve, and did not expect it to remain the final word for long *(19)*. The most comprehensive of these meta-analyses is clearly that published in 2001 by Miedema & Oudshoorn *(10)*. There are, however, two types of qualification that have to be made, which are not elaborated on here:

- the relationships can be refined by taking into account non-acoustical factors and, probably more relevant, acoustical factors that can be affected by policy other than the exposure at the most exposed side, such as sound insulation of the dwelling or the presence or absence of a quiet side *(7)*; and

- there are strong indications that the exposure–response relationships for aircraft noise have changed, so that the curves presented here probably underestimate the annoyance at a given aircraft noise exposure level *(20)*.

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Uncertainty with respect to the exposure-response relationship

One cause of doubt regarding the predictability of noise annoyance is that the studies show a large variation in individual annoyance reactions to the same noise exposure level. The other cause of doubt is that attempts to integrate the results from different studies show that there is a large variation in the relationships found in different studies. The large individual variation and the large study variation suggest that it is difficult to predict annoyance with sufficient accuracy. Indeed, the annoyance response of a particular individual or group of individuals can be predicted on the basis of the exposure only with a large amount of uncertainty. This uncertainty can be described by the prediction interval for individuals or groups around the exposure–response curves.

Nevertheless, in most cases, the uncertainty regarding individual or group reactions is not what matters for noise policy. Most policy, including that based on estimates of the burden of disease due to environmental noise, is made with a view to the overall reaction to exposures in a (reference) population. This means that it is not the uncertainty with respect to the prediction of an individual or group reaction that is important, but the uncertainty regarding the exact relationship between exposure and response in the (reference) population. The accuracy of the estimation of this relationship is described by the confidence interval around the curve. If properly established, the confidence interval takes into account the variation between individuals as well as the variation between studies. As found by Miedema & Oudshoorn *(10)*, this results in relatively narrow confidence intervals (as opposed to the wide prediction intervals for individuals or groups).

Applications and limitations of the exposure-response relationship

According to the EU Position Paper, which also recommends the exposure–response relationships presented here, they are only to be used for aircraft, road traffic and railway noise and for assessing long-term, stable situations *(12)*. They can be utilized for strategic assessments, in order to estimate the effects of noise on populations in terms of annoyance. They are not applicable to local, complaint-type situations or to the assessment of the short-term effects of a change of noise climate. The curves have been derived for *adults*. The curves are not recommended for specific sources such as helicopters, low-flying military aircraft, train shunting, shipping, or aircraft on the ground (taxiing) *(12)*.

Conclusions

Compared to other effects of environmental noise and also compared to effects of environmental factors in general, there are relatively many data directly obtained from exposed humans in the field from which exposure–response relationships for noise annoyance could be derived. It appears that, with the increasing effort on noise mapping, more and better noise exposure data will become available so that, by combining them with the relationships, the prevalence of annoyance can be estimated. The third ingredient for estimating the burden due to environmental noise appears the most difficult. It is hard to weigh "annoyance" and it is difficult to relate it to existing weighted outcomes. We used the limited data on the weights available, giving the indication that about 0.5 million DALYs are lost yearly among the urban population in EU countries owing to the occurrence of noise annoyance.

REFERENCES

1. 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. *Official Journal of the European Communities,* 2002, L 189:12–25.
2. *Guidelines for community noise.* Geneva, World Health Organization, 1999 (http://whqlibdoc.who.int/hq/1999/a68672.pdf, accessed 22 July 2010).
3. Job RFS. The role of psychological factors in community reaction to noise. In: Vallet M, ed. Noise as a public health problem, Vol. 3. INRETS, Arcueil Cedex, France, 1993:47–79.
4. Fields JM et al. Guidelines for reporting core information from community noise reaction surveys. *Journal of Sound and Vibration,* 1997, 206:685–695.
5. Fields JM et al. Standardized general-purpose noise reaction questions for community noise surveys: research and recommendation. *Journal of Sound and Vibration,* 2001, 242:641–679.
6. Öhrström E. Longitudinal surveys on effects of changes in road traffic noise. *Journal of the Acoustical Society of America,* 2004, 122:719–729.
7. Öhrström E et al. Effects of road traffic noise and the benefit of access to quietness. *Journal of Sound and Vibration,* 2006, 295:40–59.
8. Staatsen BAM et al. *Assessment of health impacts and policy options in relation to transport-related noise exposures.* Bilthoven, RIVM, 2004 (RIVM report 815120002/2004).
9. *Acoustics – description, measurement and assessment of environmental noise – Part 1: basic quantities and assessment procedures.* Geneva, International Organization for Standardization, 2003.
10. Miedema HME, Oudshoorn CGM. Annoyance from transportation noise: relationships with exposure metrics L_{dn} and L_{den} and their confidence intervals. *Environmental Health Perspectives,* 2001, 109:409–416.
11. Noise Observation and Information Service for Europe (NOISE) [web site]. Copenhagen, European Environment Agency 2009 (http://noise.eionet.europa.eu/index.html, accessed 31 July 2010).
12. European Commission. *Position Paper on dose response relationships between transportation noise and annoyance.* Luxembourg, Office for Official Publications of the European Communities, 2002 (http://ec.europa.eu/environment/noise/pdf/noise_expert_network.pdf, accessed 31 July 2010).
13. Schultz TJ. Synthesis of social surveys on noise annoyance. *Journal of the Acoustical Society of America,* 1978, 64:377–405.
14. Fidell S, Barber DS, Schultz TJ. Updating a dosage-effect relationship for the prevalence of annoyance due to general transportation noise. *Journal of the Acoustical Society of America,* 1991, 89:221–233.
15. de Hollander AE et al. An aggregate public health indicator to represent the impact of multiple environmental exposures. *Epidemiology,* 1999, 10:606–617.
16. Stouthard MEA et al. Disability weights for diseases in the Netherlands. Rotterdam, Department of Public Health, Erasmus University, 1997.
17. Knol AB, Staatsen BAM. *Trends in the environmental burden of disease in the Netherlands 1980–2020.* Bilthoven, RIVM, 2005 (RIVM report 500029001/2005).
18. van Kempen EE et al. Children's annoyance reactions to aircraft and road traffic noise. *Journal of the Acoustical Society of America,* 2009, 125:895–904.
19. Fidell S. The Schultz curve 25 years later: a research perspective. *Journal of the Acoustical Society of America,* 2003, 114:3007–3015.
20. Janssen SA, Vos H. *A comparison of recent surveys to aircraft noise exposure–response relationships.* Delft, TNO, 2009 (TNO-034-DTM-2009-1799).

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7. CONCLUSIONS

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Environmental noise: a public health problem

Environmental noise, also known as noise pollution, is among the most frequent sources of complaint regarding environmental issues in Europe, especially in densely populated urban areas and residential areas near highways, railways and airports. In comparison to other pollutants, the control of environmental noise has been hampered by insufficient knowledge of its effects on humans and of exposure–response relationships, as well as a lack of defined criteria. In 1999, WHO published its *Guidelines for community noise (1).*

The European Parliament and Council adopted Directive 2002/49/EC of 25 June 2002 *(2)* with the main aim of providing a common basis for tackling noise problems across the EU. This Directive defines environmental noise as unwanted or harmful outdoor sound created by human activities, including noise from road traffic, railway traffic airports and industrial sites, and focuses on three action areas: the determination of exposure to environmental noise through noise mapping, based on common assessment methods; the adoption of action plans by the Member States based on noise-mapping results; and public access to information on environmental noise and its effects.

Among the various effects of environmental noise, health effects are a growing concern of both the general public and policy-makers in the Member Status in Europe. Most of the assessments performed so far to evaluate the impact of environmental noise have been based on the annoyance it causes. Its consideration as a public health problem with measurable health outcomes has been limited *(3).*

In 2009, WHO published the *Night noise guidelines for Europe (4).* This publication presented new evidence of the health damage of nighttime noise exposure and recommend threshold values that, if breached at night, would threaten health. An annual average night exposure not exceeding 40 dB outdoors is recommended in the guidelines.

Considering the scientific evidence on the threshold of night noise exposure indicated by L_{night} as defined in Directive 2002/49/EC, a L_{night} value of 40 dB should be the target of the night noise guidelines to protect the public, including the most vulnerable groups such as children, the chronically ill and the elderly. A L_{night} value of 55 dB is recommended as an interim target for countries that cannot follow night noise guidelines in the short term for various reasons and where policy-makers choose to adopt a stepwise approach. These guidelines can be considered an extension to the previous WHO *Guidelines for community noise (1).*

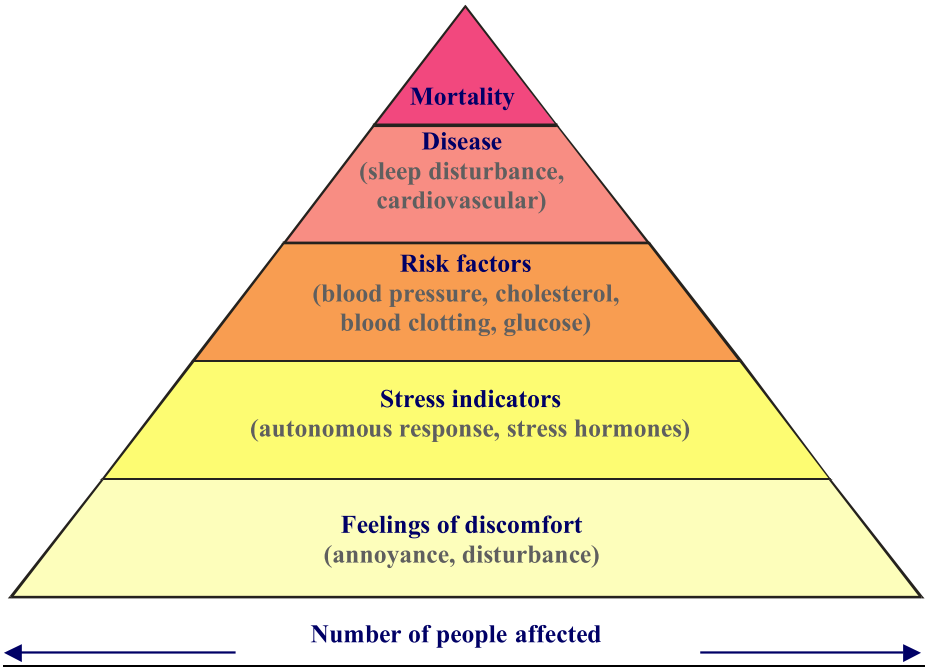
Over the past few years, the working group of experts convened by the European Centre for Environment and Health, Bonn Office and supported by the Joint Research Centre of the European Commission, has collaborated to estimate the burden

of disease from environmental noise, using available evidence and data to inform policy-makers and the public about the health impacts of noise exposure in Europe. The chapters in this publication contain the summary of synthesized reviews of evidence on the relationship between environmental noise and specific health effects. Following the EBD methodology of WHO, the health impacts of environmental noise were estimated using exposure–response relationships, exposure distribution, background prevalence of disease and DWs. For each chapter on specific health outcome, a case study is provided. Policy-makers and their advisers can use these chapters as good practice guidance for the process of quantifying specific health risks of environmental noise.

Effects of environmental noise on selected health outcomes

The severity of health effects due to noise versus the number of people affected is schematically presented by Fig. 7.1. Annoyance, sleep disturbance, cardiovascular disease, cognitive impairment, hearing impairment and tinnitus were initially selected by the working group as health outcomes related to environmental noise.

Fig. 7.1. Severity of health effects of noise and number of people affected



Source: Babisch *(3)*.

Sufficient evidence was available to perform calculations of burdens of such outcomes as annoyance, sleep disturbance and cardiovascular disease. The epidemiological evidence was not as sufficient but was still enough for assuming the relationship of environmental noise to cognitive impairment and tinnitus. The epidemiological studies linking hearing impairment to environmental noise exposure are so sparse that any generalization can be considered exploratory and speculative. Therefore, following the recommendations of the peer-reviewers, the chapter on hearing impairment was not included in this publication.

Cardiovascular disorders

The noise indicators used for noise mapping in the EU can – in principle – be used for a quantitative risk assessment regarding cardiovascular risk if exposure–response relationships are known. Only two end-points – hypertension and ischaemic heart disease – should be considered at this stage. If necessary, different exposure–response curves could be used for different exposures. The noise indicator L_{den} may be useful for assessing and predicting annoyance in the population. However, non-weighted day and night noise indicators may be more appropriate for health-effect-related research and risk quantification.

Cognitive impairment

Scientific evidence indicates the adverse effects of chronic noise exposure on children's cognition. There is no generally accepted criterion for quantification of the degree of cognitive impairment into a DW. However, it is possible to make a conservative estimate of loss in DALYs using the methods presented in this chapter. It is important to consider the assumptions, uncertainties and limitations of the methods when interpreting the estimated values of EBD.

Sleep disturbance

Although self-reported sleep disturbance may not reflect the total impact of nighttime noise on sleep, it is the effect for which exposure–response relationships on the basis of L_{night} are available for the most important noise sources. Furthermore, while it is hard to weigh self-reported sleep disturbance, it may be even harder to assign a DW to physiological changes indicating a certain degree of sleep fragmentation. Now that exposure data from noise mapping will become available as well as the exposure–response relationships, the prevalence of self-reported sleep disturbance can be estimated.

Tinnitus

There is a method to estimate burden of tinnitus from environmental noise based on expert opinion, which will be useful as a starting point using conservative assumptions and approaches.

Annoyance

There are relatively many data directly obtained from exposed humans in the field from which exposure–response relationships for noise annoyance could be derived. It is hard to weigh "annoyance" and it is difficult to relate it to existing DW values. However, if the national and local authorities are willing to take into account the most common complaints of environmental noise, they could assign an acceptable DW value to annoyance, and estimate EBD accordingly.

Estimated DALYs for western European countries

It is estimated that DALYs lost from environmental noise in the EU countries are 60 000 years for ischaemic heart disease, 45 000 years for cognitive impairment of children, 903 000 years for sleep disturbance, 21 000 years for tinnitus and 587 000 years for annoyance. Sleep disturbance and annoyance mostly related to road traffic noise comprise the main burdens of environmental noise in western Europe. If all

of these impacts are considered together, the interval estimate would be 1.0–1.6 million DALYs.[9] The total burden of health effects from environmental noise would be greater than one million years in western Europe, even with the most conservative assumptions that avoid any possible duplication.

Uncertainties, limitations and challenges

The process of risk assessment involves the gathering, synthesizing and interpretation of available evidence. The EBD process, as applied by WHO, is one way of synthesizing this evidence in a standardized manner. EBD methods depend on the availability of data, information, and specific assumptions. To obtain valid and reliable estimates of EBD, good data are needed on the distribution of exposure, on outcomes and on the exposure–response relationship. In the European region, more and better data are available on the distribution of environmental noise, and it is expected that the process of ongoing implementation of EU Directive 2002/49/EC will provide higher quality data in standardized formats comparable between the countries. Regarding outcomes, high-quality data are available for some (e.g. cardiovascular disease) but not for others (e.g. tinnitus). Established exposure–response relationships exist for annoyance, sleep disturbance (subjective), cognitive impairment (children) and cardiovascular disease.

Selection of health effects

Unfortunately, the quality and the quantity of the evidence and data are not the same across the different health outcomes. Other than for cardiovascular disease, obtaining prevalence estimations for the conditions discussed in this publication posed some difficulties. Most of the subclinical conditions are not recorded in routine mortality and morbidity statistics. For tinnitus, the proportion caused by leisure noise rather than occupational noise was difficult to estimate. And conditions such as cognitive impairment in children, sleep disturbance and annoyance are difficult to characterize, let alone estimate the proportion caused by environmental noise. Nevertheless, this publication brings together the best literature and available data and provides transparent justifications of the estimates using conservative assumptions.

Some other outcomes have been suggested as being associated with environmental noise, including hearing impairment, psychiatric conditions such as depression and anxiety, next-day effects of sleep disturbance such as motor accidents. As more evidence accumulates on whether these conditions are indeed associated with environmental noise, further refinements of the estimates in this volume can be made.

Noise exposure indicators

The EU adopted harmonized noise metrics across its Member States: L_{den} to assess annoyance and L_{night} to assess sleep disturbance *(1)*. These metrics are used for strategic mapping of exposure in the EU Member States and are common across all transport sources and other sources of environmental noise. The quality of the exposure data produced through the first round of strategic noise maps in EU may not be optimal in terms of validity and reliability. This will have an unavoidable impact

9 The extent to which years lost from different effects are additive across different outcomes is unclear. The different health outcomes might have synergistic rather than antagonistic when the combined effects occur in a person. Therefore, it would be a conservative approach to add the DALYs of different outcomes not considering synergistic effects.

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on the accuracy and precision of any risk assessment using these exposure data. With the full implementation of Directive 2002/49/EC, L_{den} and L_{night} are widely accepted as standard indicators of noise exposure in Europe *(6)*. Many previous studies used other metrics that can be converted to L_{den} and L_{night} with some assumptions. However, this conversion from old to new indicators will contribute to the uncertainties of the estimate.

Exposure–response relationships

Although the exposure–response relationships presented in this publication are based on the available evidence at the time of the working group meetings, there are uncertainties especially when they are derived from limited numbers of studies. It should be noted that the exposure–response relationships will need to be updated using the results of future studies.

Confounding factors and effect modifiers

Most epidemiological studies are prone to bias if confounding factors are not properly controlled by design or statistical methods. Confounding factors include age, gender, smoking, obesity, alcohol use, socioeconomic status, occupation, education, family status, military service, hereditary disease, medication, medical status, race and ethnicity, physical activity, noisy leisure activities, stress-reducing activities, diet and nutrition, housing conditions (crowding) and residential status. Future epidemiological research will have to consider effect modifiers (vulnerable groups, sensitive hours of the day, coping mechanisms, different noise sources, etc.) as well as potential confounding factors.

Combined exposure to noise, air pollution and chemicals

The health impacts of the combined exposure to noise, air pollutants and chemicals are rarely considered in epidemiological studies. Combined exposures occur, for example, when people are exposed to road traffic where noise and air pollution co-exist. The stressors that might be considered in the context of combined exposure with noise include: indoor air pollutants (environmental tobacco smoke, volatile organic compounds), outdoor air pollutants (particulate matter, carbon monoxide, sulphur dioxide, nitrogen dioxide), asphyxiants (carbon monoxide, hydrogen cyanide), solvents (xylene, styrene, toluene, benzene, etc.), heavy metals (lead, mercury), pesticides (organophosphates), variables related to housing (biological agents), and vibration.

An international workshop organized by the Joint Research Centre of the European Commission in cooperation with EEA and WHO in 2007 *(7)* concluded that the best knowledge on the health effects due to combined exposure to noise and solvents or heavy metals exists in occupational environments. However, there are few studies showing combined effects of noise and air pollutants in urban environments. Some data exist only on respiratory disorders caused by combined effects of noise and outdoor air pollutants, balance disorders caused by occupational exposure to noise and solvents, and effects on human growth caused by combined effects of noise and heavy metals. The workshop concluded that a substantial amount of research is needed to determine the health effects of combined exposure to environmental noise and other environmental pollutants.

Total burden from environmental noise

In general, care should be taken to avoid "double counting" when DALYs from different outcomes are totalled to estimate an overall burden of disease from an environmental risk factor. In the case of environmental noise, this should not be a big problem. For example, the burdens of annoyance during the daytime and sleep disturbances at night can be safely added up. Nevertheless, because of the different qualities of the evidence underlying the different EBD calculations, special care should be taken when making direct comparisons between DALYs for different outcomes.

If DALYs caused by environmental noise are compared with those from other pollutants, it is important to take into account the approximations and assumptions made in the calculation process. More information on these issues has been summarized in documents on the methodology of EBD *(8)*.

Health inequality and vulnerable groups

Some noise exposures may be worse for some subgroups than for others. Issues such as the lower housing prices near noisy roads mean that the effect of noise is not uniformly distributed throughout the population. Except for a chapter on cognitive impairment in children, this publication did not explore the additional burdens in potentially vulnerable subgroups such as older people and lower socioeconomic groups.

Uses of this publication

The evidence and methods for quantifying the health impacts of environmental noise presented and illustrated in this volume can be used by policy-makers, planners and engineers to measure the magnitude of health problems related to noise pollution in society today. Because many European countries have already produced strategic noise maps and action plans on noise control according to Directive 2002/49/EC *(2)*, the good practices of risk assessment presented in this volume can be readily applied to the national and local situations in many countries. In countries where all the required data for a complete calculation of burden of disease may not be available, this publication demonstrates a range of options that can be used to make estimations according to which components of the risk assessment are accessible.

Although this publication has been prepared with a European focus in terms of policy, available data and legislation, the processes of risk assessment illustrated here can also be used outside Europe as long as the assumptions, limitations and uncertainties described in the various chapters are carefully taken into account.

The effects of neighbourhood noise were not addressed in this publication as they need to be better characterized and measured in future studies. In addition, the effects of leisure noise were not considered because there is very little information available on the prevalence of voluntary exposure to leisure noise through amplified music at concerts and other public events and through personal music players.

Noise and the Parma Declaration on Environment and Health

There is overwhelming evidence that exposure to environmental noise has adverse effects on the health of the population. Recognizing the special need to protect children from the harmful effects of noise, the Parma Declaration adopted at the Fifth Ministerial Conference on Environment and Health *(9)* called on all stakeholders to work together to reduce the exposure of children to noise, including that from personal electronic devices, from recreation and traffic (especially in residential areas), at child care centres, kindergartens and schools and in public recreational settings. This publication provides an evidence base for the future development of suitable guidelines on noise by WHO, as was urged by the Member States in the Parma Declaration. The evidence on burden of disease presented here will inform the new European health policy, Health 2020, which will be presented for endorsement at the WHO Regional Committee for Europe in 2012.

REFERENCES

1. *Guidelines for community noise.* Geneva, World Health Organization, 1999 (http://www.who.int/docstore/peh/noise/guidelines2.html, accessed 21 July 2010).
2. 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. *Official Journal of the European Communities,* 2002, L 189:12–25.
3. de Hollander AE et al. An aggregate public health indicator to represent the impact of multiple environmental exposures. *Epidemiology,* 1999, 10:606–617.
4. *Night noise guidelines for Europe.* Copenhagen, WHO Regional Office for Europe, 2009 (http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf, accessed 7 October 2010)
5. Babisch W. The noise/stress concept, risk assessment and research needs. *Noise & Health,* 2002, 4(16): 1–11.
6. Noise Observation and Information Service for Europe (NOISE) [web site]. Copenhagen, European Environment Agency, 2009 (http://noise.eionet.europa.eu/index.html, accessed 15 February 2011).
7. Kephalopoulos S et al., eds. *Proceedings of the International Workshop on "Combined Environmental Exposure: Noise, Air Pollution, Chemicals", Ispra, Italy, 15–16 January 2007.* Luxembourg, Office for Official Publications of the European Communities, 2007.
8. Prüss-Üstün A et al. *Introduction and methods: assessing the environmental burden of disease at national and local levels.* Geneva, World Health Organization, 2003.
9. *Parma Declaration on Environment and Health,* the Fifth Ministerial Conference on Environment and Health, Parma, Italy, 10–12 March 2010 (http://www.euro.who.int/__data/assets/pdf_file/0011/78608/E93618.pdf, accessed 7 October 2010)

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Burden of Disease from Environmental Noise

The health impacts of environmental noise are a growing concern among both the general public and policy-makers in Europe. This publication provides technical support to policy-makers and their advisers in the quantitative risk assessment of environmental noise, using evidence and data available in Europe. It contains the summary of synthesized reviews of evidence on the relationship between environmental noise and specific health effects, including cardiovascular disease, cognitive impairment, sleep disturbance, tinnitus, and annoyance. For each outcome, the environmental burden of disease methodology, based on exposure–response relationship, exposure distribution, background prevalence of disease and disability weights of the outcome, is applied to calculate the burden of disease in terms of disability-adjusted life-years. The results indicate that at least one million healthy life years are lost every year from traffic-related noise in the western part of Europe. Owing to a lack of exposure data in south-east Europe and the newly independent states, it was not possible to estimate the disease burden in the whole of the WHO European Region. The procedure of estimating burdens presented in this publication can be used by international, national and local authorities in prioritizing and planning environmental and public health policies.

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Exhibit B — Medscape (2024). Noise Pollution and Chronic Disease Slideshow. https://reference.medscape.com/slideshow/Noise-Pollution-Chronic-Disease-6019132

Pollution and Cardiovascular Disease

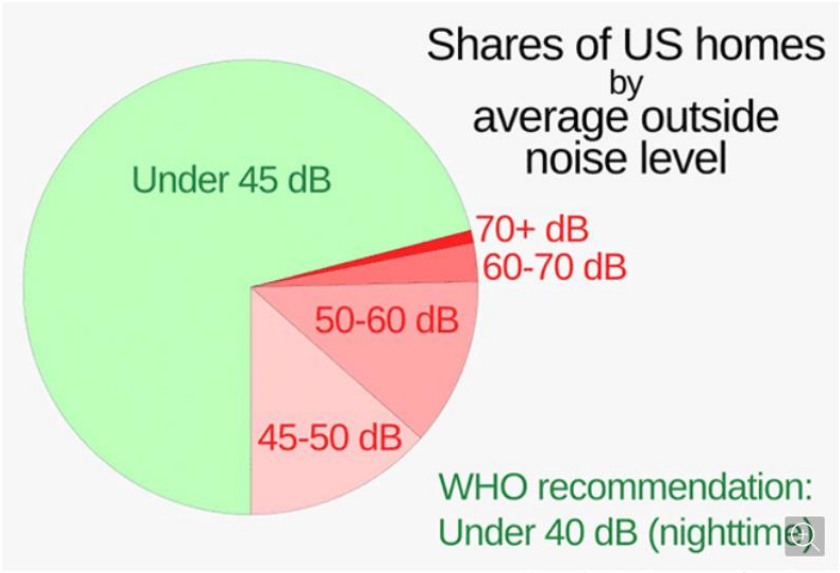
Increasing evidence shows that various forms of pollution, including noise, air, water, soil, and light, are linked to an increased risk of cardiovascular morbidity and mortality.[1,2] In 2022, the *Lancet* Commission progress report on pollution and health found that pollution continued to account for 9 million deaths per year — or 1 in 6 deaths worldwide — stating that "the impact of pollution on health remains much greater than that of war, terrorism, malaria, HIV, tuberculosis, drugs, and alcohol, and the number of deaths caused by pollution are on par with those caused by smoking."[3]

Given that cardiovascular disease (CVD) is the single largest contributor to the burden of noncommunicable disease, the cardiovascular consequences of pollution in all its forms have a significant unfavorable impact on global health.[4]

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Average outside noise levels, US homes. Image from Wikimedia

The Burden of Noise Pollution

Search

Noise Pollution and Chronic Disease

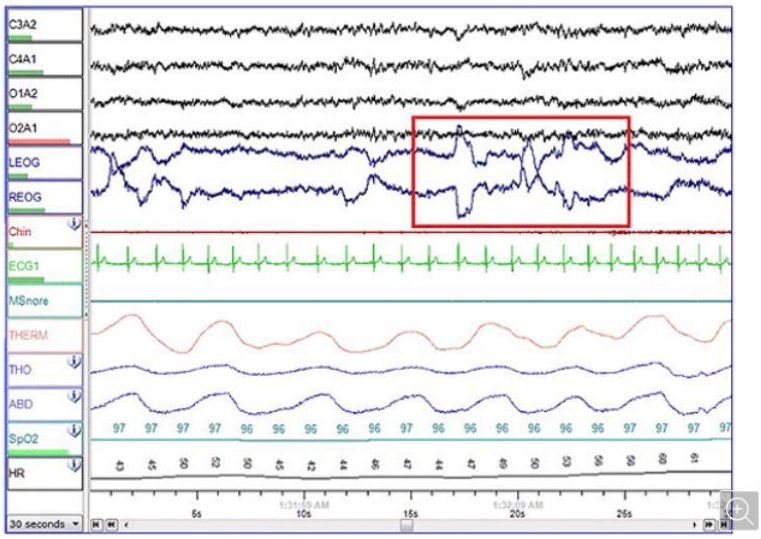
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The Burden of Noise Pollution

Noise pollution has only recently been recognized as a form of pollution that contributes to the risk of chronic diseases, such as CVD. A substantial number of people worldwide are now exposed to high noise levels; for instance, in 2020, the European Environment Agency (EEA) reported that at least 20% of the population in the European Union lives in settings where traffic noise levels are harmful to health.[5] According to the EEA report, an estimated 113 million people are affected by long-term traffic noise levels of at least 55 dB throughout the day and night, and 22 million are exposed to high levels of railway noise, with another 4 million exposed to high levels of aircraft noise and slightly less than 1 million subjected to high levels of industrial noise pollution.[5]

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Polysomnograph demonstrating REM sleep (red box). Image from Wikimedia

Noise Pollution and Sleep Disturbance

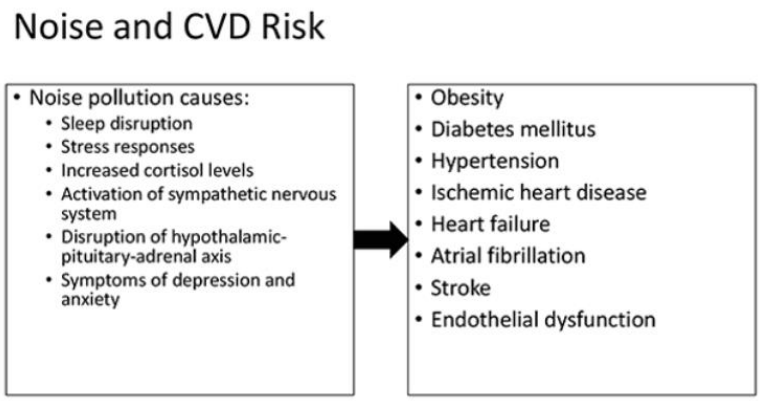
Polysomnograph demonstrating REM sleep (red box). Image from Wikimedia

Noise Pollution and Sleep Disturbance

Nighttime noise levels at or above 50 dB can cause sleep disturbance, and the link between disturbed sleep and poor CVD outcomes has been extensively studied and demonstrated.[1] The indirect pathway of the noise stress concept introduced by Wolfgang Babisch describes the stress reaction in response to noise levels between 50 and 60 dB.[6] Although direct hearing damage occurs at sound pressure levels above 100 dB, the lower noise levels that activate the indirect pathway can disturb communication and sleep. This, in turn, can lead to emotional stress, which is associated with increased cortisol levels and activation of the sympathetic nervous system, all of which increase CVD risk.[1,6]

Noise Pollution and Chronic Disease

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Noise pollution causes physiologic responses that increase CVD risk. Image from Dr Yasmine Ali

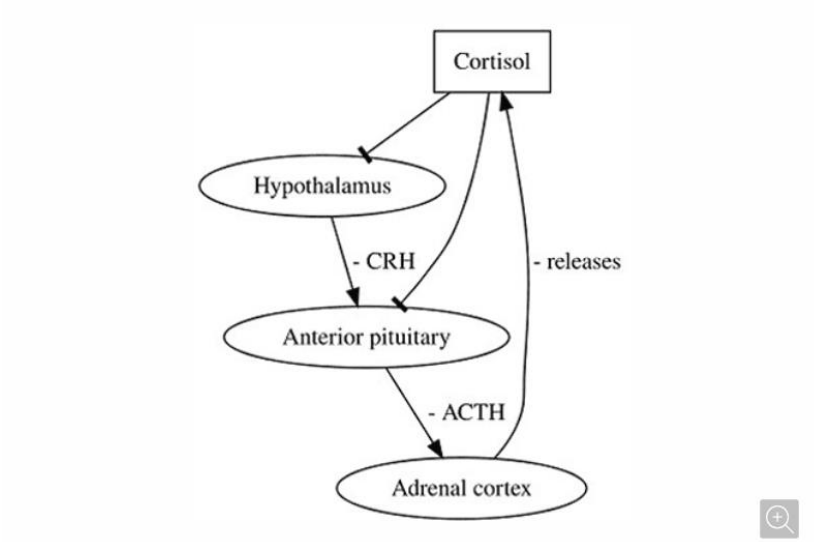
Noise Pollution and Chronic Disease

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Noise pollution causes physiologic responses that increase CVD risk. Image from Dr Yasmine Ali

Noise and CVD Risk Factors

Noise pollution increases CVD risk through the development of CVD risk factors as well as CVD itself. As previously noted, sleep disruption due to noise pollution is associated with the development of obesity, diabetes, hypertension, and atrial fibrillation.[6] The World Health Organization has also reported that the most significant connection between noise pollution and CVD is the development of ischemic heart disease.[6,7] There is also a moderate association between noise and heart failure as well as stroke.[7] Studies have demonstrated an association between the incidence and mortality of heart failure and transportation noise from road traffic, railway, and aircraft, ranging from a 2% to 8% increased risk per 10 dB.[6]



Hypothalamic-pituitary-adrenal axis. Image from Wikimedia

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Noise Pollution and Chronic Disease

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Hypothalamic-pituitary-adrenal axis. Image from Wikimedia

Noise and Metabolic Risk Factors

Both psychological stress and sleep disturbance caused by noise pollution can disrupt the hypothalamic-pituitary-adrenal (HPA) axis, leading to increased serum cortisol, which in turn can result in metabolic disease.[1,6] Chronic elevation of cortisol promotes visceral adiposity, insulin resistance, and dyslipidemia through enhanced gluconeogenesis and lipogenesis while simultaneously impairing glucose uptake in peripheral tissues.

Additionally, sustained HPA axis activation contributes to endothelial dysfunction and increased sympathetic nervous system activity, creating a pathophysiologic cascade that elevates cardiovascular risk independent of traditional risk factors.[1,8]

Symptoms of diabetes. Image from Wikimedia

Noise Exposure Increases Risk of Diabetes

Given the disruption of the HPA axis and resulting insulin resistance with impaired glucose uptake in peripheral tissues, it is unsurprising that the risk of type 2 diabetes, a known risk factor for CVD, is also increased by noise exposure.[1] A meta-analysis of observational studies found a 6% increase in diabetes risk per 5 dB increase in noise exposure, with particularly strong associations for aircraft noise (17% increase per 5 dB) and road traffic noise (7% increase per 5 dB).[9]

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Noise Pollution and Chronic Disease

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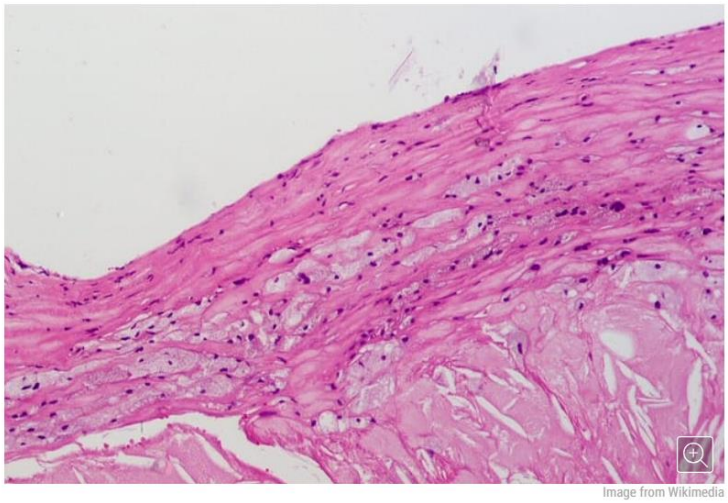


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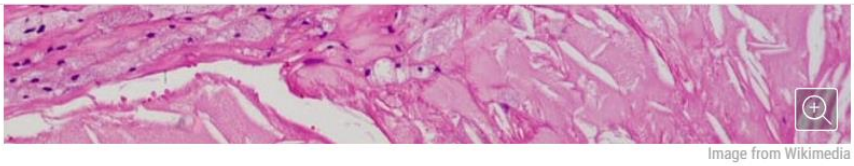


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Noise Causes Endothelial Dysfunction

Noise exposure also causes endothelial dysfunction and resulting atherosclerosis through the mechanisms noted above and the development of arterial stiffness and worsened hypertension.[1] This is compounded by sleep disruption caused by excess noise exposure and by metabolic dysfunction caused by the sleep disruption, as well as by inflammation and oxidative stress resulting from all of the above.[10] Oxidative stress has been implicated as an underlying mechanism of the endothelial dysfunction caused by aircraft and railway noise, and a finding that this dysfunction responds to the antioxidant vitamin C.[1]

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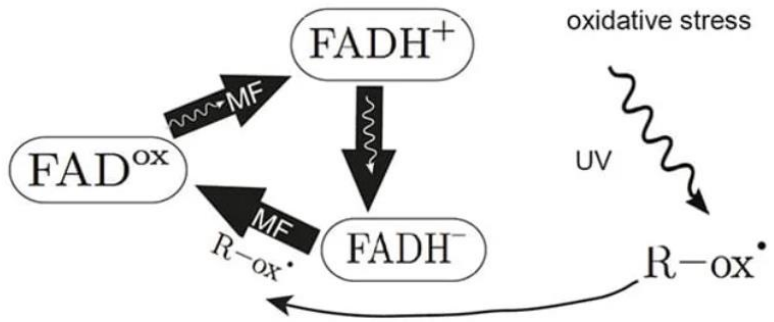


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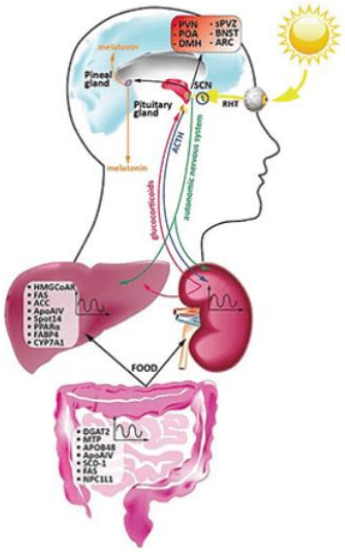
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Oxidative Stress From Noise Pollution

Prolonged exposure to noise-induced stress causes oxidative stress and chronic inflammation, which are involved in the progression of noise-induced vascular dysfunction, circadian rhythm disruption, mitochondrial dysfunction, cell death, and accelerated aging, all of which contribute to increased CVD risk.[10] Oxidative stress and inflammation have been found to contribute to traffic noise-induced vascular and cerebral dysfunction through uncoupling of nitric oxide synthases.[11]

Noise Pollution and Chronic Disease

Yasmine Ali, MD, MSCI | January 30, 2026 | Contributor Information



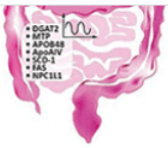
Noise pollution disrupts the interplay between the central and peripheral circadian clocks and the autonomic nervous system. Image from Wikimedia/National Institutes of Health

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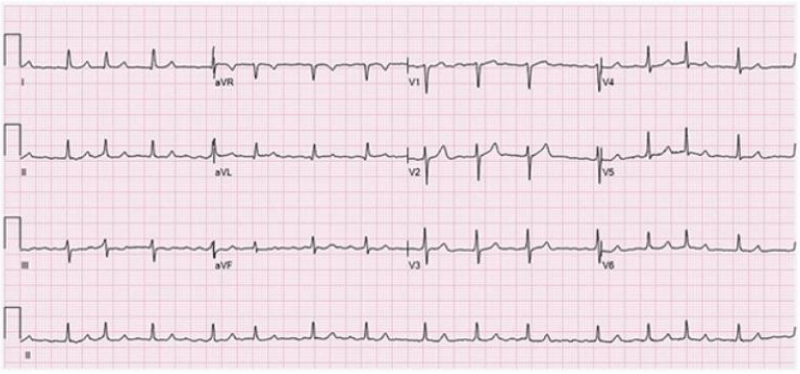
Noise pollution disrupts the interplay between the central and peripheral circadian clocks and the autonomic nervous system. Image from Wikimedia/National Institutes of Health

Noise Pollution Disrupts Circadian Rhythm

Mechanistic studies have found that transportation noise causes disturbances of the cerebral and vascular circadian rhythm. Dysregulation of circadian clock genes in the aorta and kidney after noise exposure has been observed, along with increased DNA-methylation and upregulation of pathways related to inflammation and immune responses.[1,12]

Noise Pollution and Chronic Disease

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Atrial fibrillation with controlled ventricular response. Image from Wikimedia

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Atrial fibrillation with controlled ventricular response. Image from Wikimedia

Noise Exposure and Atrial Fibrillation

Sleep disruption, psychological stress, metabolic dysfunction, hypertension, and endothelial and vascular dysfunction all resulting from noise pollution cause an increased risk of atrial fibrillation.[1] A meta-analysis of cohort studies demonstrated that exposure to the highest levels of environmental noise was associated with a significant 5% increased risk of atrial fibrillation, with each 10 dB increment in noise exposure conferring an additional 1%-2% increase in risk.[13]

Noise Pollution and Chronic Disease

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Social determinants of health. Image from CDC

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Social determinants of health. Image from CDC

Sociodemographic Disparities in Noise Exposure

Significant sociodemographic disparities exist in noise exposure. Studies show associations between noise levels and neighborhood racial and economic composition, with noise pollution being found at greater levels in historically redlined areas and communities of color,[14] further compounding cardiovascular health disparities created by social determinants of health.[15] Experts suggest these findings "can inform efforts to address these disparities through noise pollution policymaking." [14]

1. Miller MR, Landrigan PJ, Arora M, et al. Water, soil, noise, and light pollution: JACC focus seminar, part 2. JACC. 2024;83:2308-2323. Source

2. Miller MR, Landrigan PJ, Arora M, et al. Environmentally not so friendly: Global warming, air pollution, and wildfires. JACC. 2024;83:2291-2307. Source

3. Fuller R, Landrigan PJ, Balakrishnan K, et al. Pollution and health: A progress update. Lancet Planet Health. 2022;6:e535-e547. Source

4. NCD Alliance. Cardiovascular diseases. Available at: https://ncdalliance.org/explore-ncds/ncds/cardiovascular-disease. Accessed January 27, 2026.

5. European Environment Agency. Environmental noise in Europe. Available at: https://www.eea.europa.eu/en/analysis/publications/environmental-noise-in-europe Accessed January 27, 2026.

6. Munzel T, Sorensen M, Daiber A. Transportation noise pollution and cardiovascular disease. Nat Rev Cardiol. 2021;18:619-636. Source

7. Munzel T, Kröller-Schön S, Oelze M, et al. Adverse cardiovascular effects of traffic noise with a focus on nighttime noise and the new WHO noise guidelines. Annu Rev Public Health. 2020;41:309-328. Source

8. Feng LS, Wang YM, Liu H, et al. Hyperactivity in the hypothalamic-pituitary-adrenal axis: An invisible killer for anxiety and/or depression in coronary atherosclerotic heart disease. J Integr Neurosci. 2024;23:222. Source

9. Sakhvidi MJZ, Sakhvidi FZ, Mehrparvar AH, et al. Association between noise exposure and diabetes: A systematic review and meta-analysis. Environ Res. 2018;166:647-657. Source

10. Arregi A, Vegas O, Lertxundi A, et al. Road traffic noise exposure and its impact on health: Evidence from animal and human studies — chronic stress, inflammation, and oxidative stress as key components of the complex downstream pathway underlying noise-induced non-auditory health effects. Environ Sci Pollut Res. 2024;31:46820-46839. Source

11. Daiber A, Kröller-Schön S, Oelze M, et al. Oxidative stress and inflammation contribute to traffic noise-induced vascular and cerebral dysfunction via uncoupling of nitric oxide synthases. Redox Biol. 2020;34:101506. Source

12. Daiber A, Frenis K, Kuntic M, et al. Redox regulatory changes of circadian rhythm by the environmental risk factors traffic noise and air pollution. Antioxid Redox Signal. 2022;37:679-703. Source

13. Song Q, Guo X, Sun C, et al. Association between noise exposure and atrial fibrillation: A meta-analysis of cohort studies. Environ Sci Pollut Res Int. 2022;29:57030-57039. Source

14. Collins TW, Grineski SE. Race, historical redlining, and contemporary transportation noise disparities in the United States. J Expo Sci Environ Epidemiol. 2025;35:50-61. Source

15. Powell-Wiley T, Baumer Y, Baah FO, et al. Social determinants of cardiovascular disease. Circ Res. 2022;130:782-799. Source

Image Sources

i. Image created by Dr Yasmine Ali

ii. https://commons.wikimedia.org/wiki/File:20230609_Average_noise_levels_outside_US_homes.svg

iii. https://commons.wikimedia.org/wiki/File:Sleep_Stage_REM.png

iv. Image from Dr Yasmine Ali

v. https://commons.wikimedia.org/wiki/File:HPA-axis_-_Hypothalamus,_Pituitary_and_Adrenal_cortex_Axis.svg

vi. https://commons.wikimedia.org/wiki/File:Main_symptoms_of_diabetes.svg

vii. https://commons.wikimedia.org/wiki/File:Atherosclerosis,_HE_4.JPG

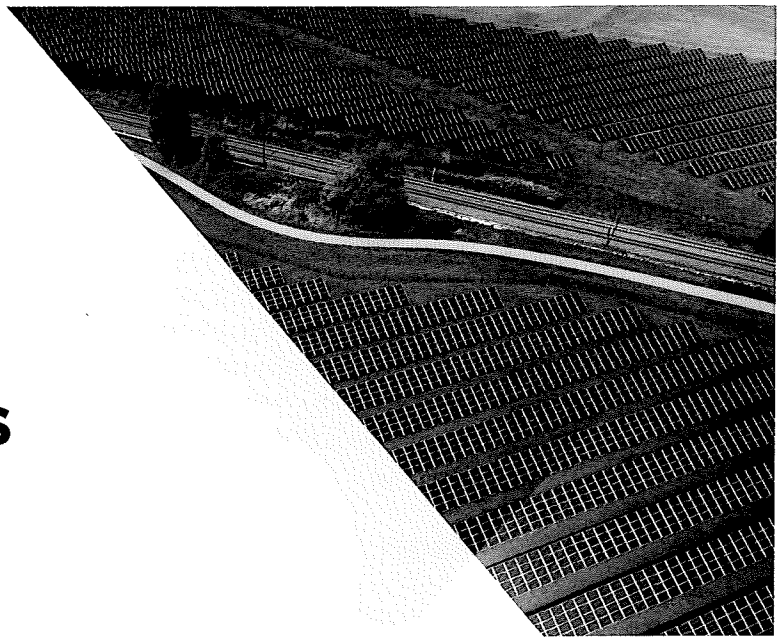
viii. https://commons.wikimedia.org/wiki/File:FAD_reaction.png

ix. https://commons.wikimedia.org/wiki/File:Interplay_between_the_central_and_peripheral_circadian_clocks.jpg

x. https://commons.wikimedia.org/wiki/File:ECG_Atrial_Fibrillation_90_bpm.jpg

xi. https://www.cdc.gov/public-health-gateway/php/about/social-determinants-of-health.html

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International Energy Producer

Modeling Noise to Advance New York's Clean Energy Goals

Case Study

Across the United States, communities are moving toward cleaner energy futures. This is no more apparent than in New York, which has set an ambitious goal of sourcing 70% of its electricity from renewable resources by 2030. Large solar projects are central to achieving this target, delivering new capacity to the grid while reducing reliance on fossil fuels.

One of the most significant recent investments in this effort is a utility-scale solar facility in western New York. Developed by a leading renewable energy company with a national footprint, the project is designed to generate enough clean electricity to power tens of thousands of households. Its scale makes it both a milestone in the state's renewable energy transition and a project requiring careful planning to move from vision to reality.

The Challenge

Bringing a project of this scale to life required more than installing solar panels and connecting to the grid. It also meant meeting New York's stringent permitting requirements and addressing concerns of the surrounding community.

Residents weighed the promise of clean energy against uncertainty about how the project might affect their daily lives. Would the hum of transformers or the operation of inverters be annoying? Would noise from construction activities be disruptive? These were not abstract questions but tangible concerns raised during the permitting process.

State regulators also set clear expectations. New York's Section 94-c permitting framework requires solar developers to demonstrate that projects will meet specific sound-level thresholds at homes and property lines. These standards establish protective limits (e.g., ensuring non-participating residences do not experience long-term sound levels above 45 dBA). Demonstrating compliance is not optional; it is a critical prerequisite for project approval.

At the same time, the project itself was technically complex. With approximately 370,000 solar panels, nearly 50 inverter skids, two large substation transformers, and hundreds of megawatts of generating capacity, accurately predicting sound levels across the relatively large project area was no small task. Background noise levels also vary seasonally in rural western New York, requiring extensive field monitoring.

The challenge, then, was to provide regulators with rigorous, defensible evidence that the project would meet or exceed state noise standards and help minimize noise impacts to the community. Meeting this challenge required specialized noise control engineering expertise.

RSG's Solution

To support project approval and protect community quality of life, RSG delivered a comprehensive noise impact assessment that combined rigorous fieldwork, advanced modeling, and practical mitigation strategies. Our team of board-certified acousticians guided the developer through each stage of the permitting process, ensuring compliance with state standards while addressing local concerns head-on.

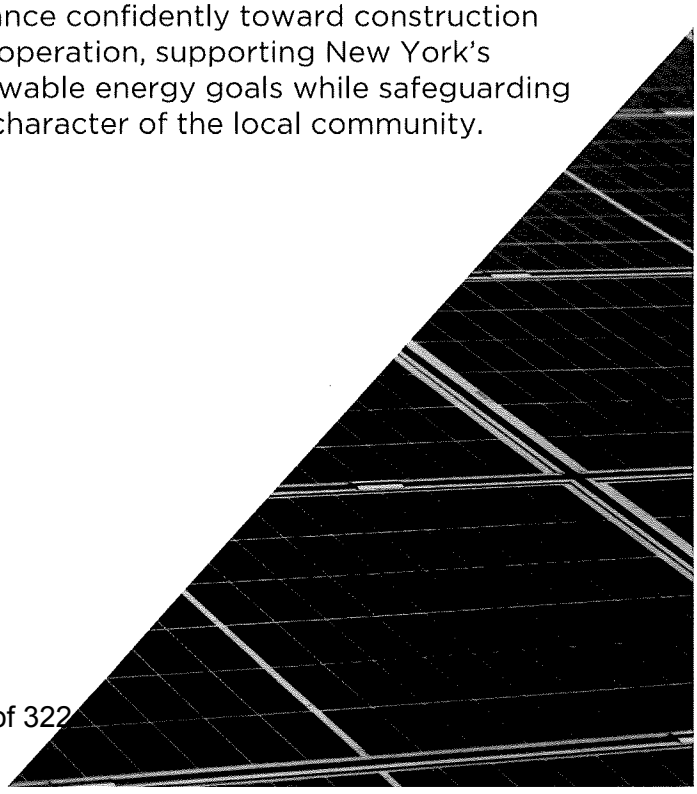
The work began with on-the-ground sound monitoring. RSG deployed precision instruments to capture background sound levels across multiple seasons, accounting for variations in weather, land use, and community activity. These measurements were the foundation for a transparent and defensible baseline against which project sound could be evaluated.

From there, our engineers built detailed models of how sound from the project's major equipment would propagate across the surrounding landscape. Using industry-standard acoustical software and conservative assumptions, we simulated both typical and worst-case conditions. This modeling incorporated not only direct sound from equipment but also potential tonal characteristics that could increase annoyance in sensitive areas.

With these results in hand, RSG worked with the project team to identify and incorporate mitigation strategies. These included specifying quieter transformer designs, ensuring appropriate sound enclosures for auxiliary equipment, and adjusting equipment placement to minimize impacts on nearby residences. We also assessed potential construction noise and recommended best practices such as limiting work hours, maintaining equipment mufflers, and staging activities away from homes whenever possible.

Finally, RSG documented the findings in clear, regulator-ready reports. Our analysis demonstrated that, with the recommended design and mitigation measures, the project would meet or exceed all applicable New York Section 94-c sound standards. Equally important, the reports provided assurance to community members that their concerns were taken seriously and addressed.

Through this process, RSG helped transform potential barriers into solutions. By combining technical rigor with a focus on community trust, we enabled the project to advance confidently toward construction and operation, supporting New York's renewable energy goals while safeguarding the character of the local community.



POLICY STATEMENT Organizational Principles to Guide and Define the Child Health Care System and/or Improve the Health of all Children

American Academy of Pediatrics
DEDICATED TO THE HEALTH OF ALL CHILDREN™

Preventing Excessive Noise Exposure in Infants, Children, and Adolescents

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Noise affects people of all ages. Noise-induced hearing loss, a major problem for adults, is also a problem for young people. Sensorineural hearing loss is usually irreversible. Environmental noise, such as traffic noise, can affect learning, physiologic parameters, sleep, and quality of life. Children and adolescents have unique vulnerabilities. Infants and young children must rely on adults to remove them from noisy situations; children may not recognize hazardous noise exposures; teenagers often do not understand consequences of high exposure to music from personal listening devices or attending concerts and dances. Personal listening devices are increasingly used, even by small children. Environmental noise has disproportionate effects on underserved communities. This statement and its accompanying technical report review common sources and effects of noise as well as specific pediatric exposures. Because noise exposure often starts in infancy and effects are cumulative, more attention to noise in everyday activities is needed starting early in life. Pediatricians can potentially lessen harms by raising awareness of children's specific vulnerabilities to noise. Safer listening is possible. Noise exposure is underrecognized as a serious public health issue in the United States. Greater awareness of noise hazards is needed at a societal level.

BACKGROUND

Definitions

Sound is created by vibrations that travel through a medium, such as air or water. Characteristics of sound include frequency, intensity, periodicity, and duration.[1] Intensity is perceived as loudness; frequency is also referred to as pitch. Frequency is measured in cycles per second; the unit of this is the Hertz (Hz). Speech frequencies generally are in the range of 250 to 8000 Hz. Sound intensity is measured in Pascals (Pa) or decibels (dB). The dynamic

abstract

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range of normal human hearing extends from a minimal audible intensity of about 0.00002 Pa or about 1.9 dB (softest) to the threshold of pain at about 20 Pa or 120 dB (loudest). This range is expressed in a logarithmic scale represented in units of dB SPL (sound pressure level). The logarithmic scale means that there is a 10-fold difference in sound energy with a 10-dB difference, a 100-fold difference with a 20-point difference, and so forth.

The perceived intensity of sound varies with the frequency of the sound being heard. An equivalency curve is used to determine the measure of sound intensity, referred to as the decibel weighted by the A scale, "A-weighted dB," or "dBA." Comparisons can, thus, be made about the frequencies of sound perceived by the human ear. The loudness of human speech is approximately 50 to 60 dB SPL.

Noise is often defined as unwanted or objectionable sound.[1] Characteristics of noise include intensity (measured in dBA) and duration (length of time exposed). The meaning of sound to an individual often determines a person's reaction to the same sound. "One person's music is another's noise."[1]

Noise Categories

Occupational noise is experienced in the workplace.

Environmental noise usually refers to noise from outdoor settings generated by human activity, mostly powered by fossil fuels. Sources include vehicular traffic, railways, airplanes and airports, industrial sites, wind farms, and leaf blowers[2] and lawn mowers. Environmental noise exposure has been characterized as "one of the most important environmental stressors affecting public health throughout the world."[3]

Indoor noise sources include equipment, appliances, infant sleep machines, video games, toys, and televisions.

Recreational noise is noise sought for pleasure.[4] Sources include personal listening devices (PLDs); music at parties, dances, and concerts; sports events; and recreational firearm use.

Occupational Standards

Understanding occupational standards helps to contextualize pediatric noise exposures. Federal agencies set evidence-based recommended exposure limits (RELs) to protect workers from exposures to hazardous agents at work. The REL for occupational noise was set at 85 dBA as an 8-hour time-weighted average, with exposures greater than this considered hazardous.[5] This REL aims to protect workers from developing noise-induced hearing loss (NIHL) over a 40-year career. Because approximately 8% of workers could still develop hearing loss at this level,[6] hearing protection is recommended when levels are >85 dBA regardless of duration.[7] The occupational limit for hazardous noise exposure of ≥85 dBA over 8 hours is not meant to protect the public from general environmental noise or recreational noise, such as listening to music with earbuds or attending noisy events.[8] It also is not meant to apply to infants, children, and adolescents in their various exposure settings.

Disparities in Exposures

Studies in the United States and internationally demonstrate sociodemographic disparities in noise exposure. Most studies show that exposures are higher in people of lower socioeconomic status and in those belonging to historically marginalized racial and ethnic groups.[9,10] According to the World Health Organization (WHO), the prevalence of hearing loss in children decreases exponentially as national income increases, and there is an inverse relationship between prevalence of disabling hearing loss in children and parents' literacy rates.[11]

Excessive environmental noise exposure has been framed as a disability rights issue for people with hearing loss, tinnitus, and hyperacusis. Noisy situations worsen the ability of people with hearing impairments to understand speech; noise worsens symptoms in people with tinnitus and hyperacusis. Elevated environmental noise levels turn these disorders into disabilities in restaurants, social dance event spaces, and other venues. These sensory impairments meet the legal standard of having disabilities. Advocates have stated that legislation and regulations are needed to establish ambient noise standards that then must be enforced.[12,13]

Noise as a Public Health Issue

Noise is perceived at an individual level, but when a critical mass of individuals experiences noise that causes hearing problems, disturbs cognition, and reduces well-being, then noise becomes a public health concern.[14] Substantial evidence links noise to health effects, more than for many environmental hazards. Although commonly encountered, excessive noise exposure is treated differently than other pollutants.[15] Few communities consider health risks of noise in policy making, and noise often is not on clinicians' agendas. High noise levels at recreational and celebratory events often are accepted—and frequently sought out—rather than viewed as potentially hazardous.

CHILDREN'S UNIQUE SUSCEPTIBILITIES

Noise exposure is a pediatric issue because of the susceptibility of the developing auditory system and because effects on hearing and quality of life at early developmental stages can affect a child's life trajectory. Studies in immature laboratory animals reveal heightened susceptibilities to noise compared with adult animals, illustrating the concept of "critical periods" of vulnerability.[16] External ear anatomy in young children differs from adult anatomy; smaller ear canals more greatly intensify higher frequency sounds.[17] Children have differences in behavior and development, with long life spans during which cumulative exposures may manifest. Children and youth often have excessive exposures through PLDs. Children with developmental differences,

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such as those with autism spectrum disorder, often have increased sensitivity to noise[18,19]; they may display atypical play methods with noisy toys, such as prolonged and repetitive use, potentially increasing risk of hearing damage.[20] Hyperacusis (increased sensitivity to sound at levels that would not trouble most individuals), misophonia (excessive and inappropriate emotional responses to specific "trigger" sounds), and phonophobia (phobia to specific sounds or classes of sounds) have been described in these children. Auditory processing issues are also reported in children with attention-deficit/hyperactivity disorder (ADHD), including hypersensitivity and hyposensitivity to sounds.[21,22]

NOISE EFFECTS

Hearing Loss

Sensorineural hearing loss (SNHL) is caused by damage to the hair cells of the cochlea or to the auditory nerve. Excessive noise exposure is one cause of SNHL. Damage to hair cells is permanent and usually cannot be restored with medical treatment.[23–25] NIHL can occur after high-intensity traumatic noises or after less-loud noises experienced over time. SNHL can occur after a single loud sound near the ear. Hearing loss more commonly results over time from damage caused by repeated exposures to loud sounds. The louder the sound, the shorter the amount of time it takes for damage to occur. The longer the exposure, the greater the risk for hearing loss (especially if hearing protection is not used or if there is not enough time for the ears to rest between exposures).[26] Continuous exposure to hazardous noise levels tends to cause maximum damage to high-frequency areas of the cochlea and is usually most severe around 4000 Hz.

NIHL impacts understanding of speech. Consonants are disproportionately affected in higher frequencies, whereas lower frequency vowel sounds remain relatively normal. Because softly spoken, high-frequency consonants such as "f," "s," and "h" convey more of the intelligibility of words in speech compared with vowels, an individual with NIHL can have difficulty understanding in background noise and when following higher-pitched voices.

Hearing Loss in Adults

Hearing loss is the third most common chronic physical condition in US adults. Hearing loss is linked to cognitive decline, Alzheimer disease, dementia, and Parkinson disease.[27,28] The Centers for Disease Control and Prevention analyzed data collected from adults ages 20 to 69 years using questionnaires and audiometric tests to determine the presence of audiometric notches indicative of NIHL. An audiometric notch is a deterioration in the hearing threshold (the softest sound a person can hear); high-frequency notches suggest NIHL. Nearly 1 in 4 adults (24%) had notches, suggesting a high prevalence of NIHL. People with NIHL often did not recognize this: almost one-quarter of participants reporting good or excellent hearing had bilateral (5.5%) or unilateral (18.0%) notches. This study indicates that NIHL hearing loss is a significant but often unrecognized problem in adults.[6] The high prevalence of notches (almost 1 in 5) among young adults suggests that early life interventions are needed.

Hearing Loss in Children and Adolescents

Several studies confirm that hearing loss is common in children, adolescents, and young adults. Even small amounts of hearing loss can have profound, negative effects on speech, language comprehension, communication, classroom learning, and social development.[29,30]

One study using national data examined changes in hearing loss prevalence in US children and adolescents (12 to 19 years old) from 1988 to 2010 and associated risk factors including reported noise exposures. The prevalence of hearing loss of >15 dB increased from 17.0% to 22.5% from 2007 to 2008 but decreased to 15.2% from 2009 to 2010. The most current data, thus, illustrated that about 1 in 6 middle and high school students had evidence of hearing loss. This study did not demonstrate a consistent association between exposure to loud music with an increased risk of hearing loss.[31]

Studies in youth do not consistently show positive associations between reported noise exposure and hearing loss. Adolescents and young adults, however, typically underestimate symptoms caused by loud sound, tinnitus, and temporary hearing impairment during music exposure. Youth typically underreport concern for these symptoms.[32] Although more research is needed to demonstrate the association of noise exposure with early hearing loss, it is likely that noise contributes to hearing loss in children and adolescents. Pediatricians, therefore, may play important roles in counseling about preventable noise exposures.

Nonauditory Effects

Physiologic Effects

Stress resulting from noise is believed to cause dysregulation of the autonomic nervous and endocrine systems, thus affecting long-term cardiovascular health. The pituitary-adrenal-cortical and sympathetic-adrenal-medullary axes are activated by noise, leading to a response including the release of cortisol. Noise-related effects on the cardiovascular system may also result from decreases in sleep quantity and quality. An assessment of studies conducted by the WHO revealed an association of higher road traffic noise with increased risk of ischemic heart disease in adults.[33] Research about effects on noise on children's blood pressure showed positive but not significant associations between exposure to road traffic and children's blood pressure.

Sleep

Exposure to noise leads to fragmented sleep and decreased total sleep time with reductions in daytime alertness, performance,

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quality of life, and overall health. Chronically disturbed or curtailed sleep is associated with these negative outcomes; sleep disturbance is one of the most important nonauditory effects of environmental noise. Most studies in children examining the relationship of noise to sleep conclude that noise may lead to self-reports of poorer sleep.[34]

Effects on Learning

Although environmental noise is less likely to affect children's hearing—hearing loss is more likely to result from excessive recreational exposures—environmental noise affects learning. Background noise can disrupt cognitive tasks, especially short- and long-term memory.[35] Loud noise exposure has lasting effects on cognitive function (memory, attention, reaction time) even after the noise exposure is withdrawn. Noise negatively impacts speech comprehension and speech intelligibility.[36,37]

Annoyance

Annoyance is estimated as the second major health effect of noise exposure after sleep disturbance.[38] In adults, there were significant correlations between traffic noise levels and measures of annoyance. There are fewer studies in children of these relationships.

Disability-Adjusted Life Years

The WHO calculated the "burden of disease" from environmental noise in the European Union expressed in disability-adjusted life years, " … the sum of the potential years of life lost due to premature death and the equivalent years of 'healthy' life lost by virtue of being in states of poor health or disability." Conservatively estimated disability-adjusted life years lost were "61 000 years for ischemic heart disease, 45 000 years for cognitive impairment of children, 903 000 years for sleep disturbance, 22 000 years for tinnitus, and 654 000 years for annoyance in the European Union Member States and other western European countries." The WHO estimates that "at least 1 000 000 healthy life years are lost every year from traffic-related noise in western Europe."[39]

SPECIFIC PEDIATRIC EXPOSURES

Infant "sleep machines" (ISMs or "white noise" machines) produce sound in the location where the infant sleeps to soothe the infant and mask other noises. Several studies show potential benefits in ease in falling asleep, decreasing crying, and increasing pain threshold. One study of 14 ISMs, however, raised concern that sound levels of 3 machines exceeded occupational limits and that hearing damage could occur if machines were played for >8 hours. If ISMs are used, it may be safer to locate them as far away as possible from the infant, set the volume as low as possible, and limit duration of use.[40]

"Background noise exposure" occurs when the TV is on when the child is occupied with another activity. One study showed that the average child was exposed to almost 4 hours of background TV daily.[41] Researchers conclude that background TV is disruptive to young children's play even when they are not overtly paying attention to it.[42]

Toys can be excessively noisy. In 2021, 19 of 24 toys chosen for the Sight and Hearing Association's 24th Annual Noisy Toys List tested louder than 85 dB, " … the level set by the National Institute of Occupational Health and Safety (NIOSH) for mandatory hearing protection." To keep homes quieter and children's toys "ear-safe," the Sight and Hearing Association recommended adjusting volume control on toys, placing tape over speakers, removing batteries, or returning toys that are too loud. Standards for noise set for occupational settings may not be suitable to evaluate toy safety.[43]

In preschools and classrooms, noise may be especially harmful to younger children who are developing language and auditory discrimination skills.[44] Recommendations for early care and education settings include accommodating children to maintain the decibel level ≤35 dB for at least 80% of the time.[45] "Classroom acoustics"—how sounds travel in classrooms—are affected by factors including students talking and aspects of design such as ceiling type, floor rugs, and air ducts. Poor classroom acoustics can result from background noise and reverberation—how sound bouncing off surfaces acts in a room after the sound first occurs.[46,47] In the United States, recommended guidelines for an unoccupied enclosed classroom for typically developing children with normal hearing were <35 dBA according to the American National Standards Institute and <30 dBA according to the American Speech Language-Hearing Association. Actual noise levels ranged from 30 to 65.9 dBA in unoccupied classrooms and from 55 to 85 dBA in occupied classrooms. The speech intelligibility rating in many US classrooms is less than 75%, meaning that listeners with normal hearing can only understand 75% of words read from a list.[48] Even children with normal hearing suffer in these situations. Children with learning disabilities, children with auditory processing issues, and children for whom English is a second language generally have more difficulty. Young children, who are not able to "predict from context" because of their limited vocabulary and experience, are less able than older children to "fill in" missing thoughts.[48]

Personal listening devices, popular with youth, can expose listeners to hazardous noise levels. Maximum volume outputs of PLDs can be >125 dBA; average listening levels of young adults range from 71 to 105 dBA. In one study of adolescents and young adults, almost 60% of participants exceeded the 100% daily noise dose (defined as the occupational standard), particularly in the presence of background noise[49]; background noise often results in the user

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increasing volume. Many younger children use headphones for entertainment and during remote learning sessions. There is no mandatory standard to restrict the maximum sound output for headphones or other listening devices sold in the United States. Many manufacturers claim to limit the volume of headphones to 85 dB, but some headphones can produce volumes high enough to be hazardous to hearing in minutes (using occupational standards).[50] Although many headphones have volume-reduction features, some have design flaws allowing children to bypass them.[51, 52] Information for parents about setting volume controls on various devices is available. Noise cancellation is another important feature, because children may turn up volume in the presence of background noise.[53]

Recreational firearm use is a high-risk situation for NIHL. Approximately 3.8 million children ages 6 to 15 years went target shooting with firearms in 2015; 1.4 million engaged in hunting activities in 2016.[54] Peak SPLs from firearms range from approximately 140 to 175 dB. Most recreational firearms generate 150 to 165 dB peak SPLs. Researchers have advocated for the development and dissemination of accurate information to support hearing loss prevention efforts for people engaging in shooting sports.[55]

Hospital settings are generally louder than most homes and offices. Noise exposure in the NICU is most studied among pediatric hospital settings. Noise sources include telephones, ventilators, pumps, monitors, incubators, alarms, air conditioners, and an infant's crying in an incubator. Preterm infants may be especially sensitive. Physiologic changes in preterm infants exposed to NICU noise include behavioral and vital sign changes,[56–58] impaired tactile learning,[59] and disrupted sleep.[60] Standards for NICU noise levels aim to promote speech intelligibility, speech privacy, physiologic stability, uninterrupted sleep, and freedom from acoustic distraction.[61] Most NICU sound reduction strategies aim to reduce the sound reaching newborn infants' ears to $<$45 dB.[61]

MRI technology, an alternative to computed tomography scanning, may pose a risk because of prolonged noise exposure generated from the polarizing gradient magnetic fields during imaging. Noise generated by loud coils,[62] characterized as "banging," "clicking," or "squawking," can be disturbing and unnerving. Hearing protection during MRI is critical, because noise in the scanner can reach the level of a jackhammer.[63]

STANDARDS FOR ENVIRONMENTAL NOISE

The WHO published guidelines to protect the public from environmental noise-induced health problems.[64] In contrast, environmental noise exposure in the United States has been less emphasized. There are no federal regulations regarding exposure to nonoccupational noise.[6] State and local governments are tasked with responding to concerns and protecting the public from exposure to excessive environmental noise.[65]

CONCLUSIONS

Much akin to knowledge and perceptions about smoking and secondhand smoke more than a half century ago, noise exposure is not generally seen as hazardous by the public.[66] More education is needed to begin changing this perception. The responsibility for raising awareness and creating safe listening environments lies with the public health community, governments, device manufacturers, and others.[67]

NIHL and other consequences of excessive noise exposure are preventable. Safer listening is possible. Pediatricians can play important roles in promoting appropriate acoustic environments, safer listening while using PLDs, and educating patients, parents, legislators, and others about hazardous exposures. It is important to emphasize that noise exposure comprises not only intensity, but that duration and frequency also must also be considered. For more background information and a summary of available research, see the accompanying technical report.[68]

RECOMMENDATIONS FOR PEDIATRICIANS

1. Preserving hearing is a lifelong endeavor. Pediatricians can incorporate information about noise and advice about preventing excessive exposure into health supervision practices.
2. The most prevalent exposure encountered is likely to be from personal listening devices. Listening to music is very important to many people. Excessive and/or prolonged exposure to high volumes, however, can result in hearing loss, tinnitus, and/or hyperacusis. Pediatricians can discuss potential hazards of PLDs during confidential adolescent interviews or when examining ears. Use of PLDs can also be discussed with parents of younger children. A child should be able to hear when spoken to and should take breaks from the device.
3. The dose of noise—the duration of exposure, not just the volume—is significant. As one increases, the other should decrease.[69] The standard of 85 dB over 8 hours used in occupational settings does not mean that this is safe for young listeners. The frequency of exposure also must be considered.
4. Advice to caregivers of young children includes avoiding or leaving excessively noisy venues, such as concerts, sporting events, or fireworks displays, or using hearing protection such as protective earmuffs, even on young infants. When parents and children attend these types of events, hearing protection is recommended regardless of the duration of exposure.[4] Using earplugs can be considered if they are properly inserted. However, earplugs can pose a choking hazard to younger children. Parents can also be encouraged to advocate for reduced noise spaces in early child care and education settings and for

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using earmuffs or over-the-ear headsets for children with audio sensitivity.
5. Children should be shielded from impulse noise whenever possible. When impulse noise is expected (eg, firearms, explosives, etc), double hearing protection (ie, ear plugs and earmuffs) has been recommended to reduce the risk of hearing loss.[4]
6. Pediatricians can counsel parents who use infant sleep machines or noise machines about safe use.
7. Noise exposure can be incorporated into discussions of age-appropriate toys, video games, tablets and other devices, and screen time. Discussions can include information about volume control, frequency and duration of use, and noise-canceling technologies.
8. Adolescents employed in noisy occupations or engaged in shooting sports can be counseled about the importance of using hearing protection; adolescents attending excessively noisy events can be counseled to use ear protection or to relocate further away from the speakers.
9. Pediatricians can consider recommending formal hearing evaluations for children with a history of excessive noise exposure or for children with tinnitus or hyperacusis.
10. Hearing protection can be made available to families and health care providers in hospital settings when needed. Ear plugs can be provided for any pediatric patient undergoing an MRI scan.
11. Pediatricians involved in quality improvement initiatives to reduce noise exposure can focus on behavioral, structural, and/or operational changes based on resources and institutional needs. Noise levels can be monitored to identify specific areas or activities that produce excessive noise.
12. Pediatricians can advocate for adherence to noise abatement strategies in new hospital construction.
13. Pediatricians can encourage consideration of noise burden when purchasing new equipment.
14. Pediatricians involved in educational efforts can incorporate information about the hazards of noise exposure into medical education.
15. Where relevant, pediatricians can incorporate information about noise effects into federal, state, and local advocacy efforts.

RECOMMENDATIONS TO MEDICAL AND OTHER ORGANIZATIONS

1. Organizations should be cognizant of and monitor noise levels at national and other events to ensure that levels do not exceed recommended standards.

RECOMMENDATIONS FOR GOVERNMENT

1. Federal, state, and local governments should mount campaigns to increase the public's awareness of hazardous noise exposures. This includes promoting information directed at parents, children, and youth about the potential hazards of PLDs.
2. The federal government should set standards for the volume of toys and sleep machines used by infants and children. Volume standards should not be based solely on adult occupational standards but should consider the special vulnerabilities of infants and children.
3. Although occupational standards exist, there currently are no federal regulations or standards in the United States to protect the public from environmental noise hazards. More assertive action is needed at the federal level to protect the public. Particular attention is needed for the most vulnerable populations.

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ABBREVIATIONS

dB: decibel
dBA: decibel weighted by the A scale
Hz: Hertz
ISM: infant sleep machine
NIHL: noise-induced hearing loss
Pa: Pascal
PLD: personal listening device
REL: recommended exposure limit
SNHL: sensorineural hearing loss
SPL: sound pressure level
WHO: World Health Organization

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REFERENCES

1. World Health Organization. Children and noise. Available at: https://apps.who.int/iris/handle/10665/336966. Accessed June 15, 2022
2. Walker E, Banks JL. Characteristics of lawn and garden equipment sound: a community pilot study. *J Environ Toxicol Stud.* 2017;1(1):10.16966/2546-6430.106
3. Murphy E, King EO. *Environmental Noise Pollution: Noise Mapping, Public Health and Policy.* Elsevier; 2014
4. Roberts B, Neitzel RL. Noise exposure limit for children in recreational settings: Review of available evidence. *J Acoust Soc Am.* 2019;146(5):3922
5. The National Institute for Occupational Safety and Health. Occupational noise exposure. Available at: https://www.cdc.gov/niosh/docs/98-126/pdfs/98-126.pdf?id=10.26616/NIOSHPUB98126. Accessed January 18, 2021
6. Carroll YI, Eichwald J, Scinicariello F, et al. Vital signs: noise-induced hearing loss among adults—United States, 2011–2012. *MMWR Morb Mortal Wkly Rep.* 2017;66(5):139–144
7. American Conference of Governmental Industrial Hygienists. *A Guide for the Control of Audible Sound Hazards.* 1st ed. American Conference of Governmental Industrial Hygienists, Physical Agents Committee; 2020
8. Kardous C, Themann CL, Morata TC, et al. Understanding noise exposure limits: occupational vs general environmental noise. Available at: https://blogs.cdc.gov/niosh-science-blog/2016/02/08/noise/. Accessed January 17, 2021
9. Dreger S, Schüle SA, Hilz LK, Bolte G. Social inequalities in environmental noise exposure: a review of evidence in the WHO European Region. *Int J Environ Res Public Health.* 2019;16(6):1011
10. Casey JA, Morello-Frosch R, Mennitt DJ, Fristrup K, Ogburn EL, James P. Race/ethnicity, socioeconomic status, residential segregation, and spatial variation in noise exposure in the contiguous United States. *Environ Health Perspect.* 2017;125(7):077017
11. World Health Organization. Prevalence of deafness and blindness. Available at: https://www.who.int/pbd/deafness/estimates/en/. Accessed February 27, 2021
12. Fink D. Disability rights aspects of ambient noise for people with auditory disorders. In: Proceedings from the 12th Congress of the International Commission on the Biological Effects of Noise; June 18–22, 2017; Zurich, Switzerland
13. Fink D. Disability rights aspects of ambient noise for people with auditory disorders under the Americans with Disabilities Act. *Proc Mtgs Acoust.* 2017;31:015001
14. Centers for Disease Control and Prevention. Loud noise can cause hearing loss. Available at: https://www.cdc.gov/nceh/hearing_loss/public_health_scientific_info.html. Accessed September 27, 2020
15. Neitzel R. Chronic health effects and injury associated with environmental noise pollution. Available at: https://www.cdc.gov/nceh/hearing_loss/docs/CDCPresentationNeitzel-508.pdf. Accessed January 24, 2021
16. Eggermont JJ. Defining and determining sensitive periods. *Acta Otolaryngol Suppl.* 1986;429:5–9
17. Kruger B. An update on the external ear resonance in infants and young children. *Ear Hear.* 1987;8(6):333–336
18. Williams ZJ, He JL, Cascio CJ, Woynaroski TG. A review of decreased sound tolerance in autism: Definitions, phenomenology, and potential mechanisms. *Neurosci Biobehav Rev.* 2021;121:1–17
19. Potgieter I, Fackrell K, Kennedy V, Crunkhorn R, Hoare DJ. Hyperacusis in children: a scoping review. *BMC Pediatr.* 2020;20(1):319
20. McLaren SJ, Page WH, Parker L, Rushton M. Noise producing toys and the efficacy of product standard criteria to protect health and education outcomes. *Int J Environ Res Public Health.* 2013;11(1):47–66

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21. Ghanizadeh A. Sensory processing problems in children with ADHD, a systematic review. *Psychiatry Investig*. 2011;8(2):89–94

22. Ralli M, Romani M, Zodda A, et al. Hyperacusis in children with attention deficit hyperactivity disorder: a preliminary study. *Int J Environ Res Public Health*. 2020;17(9):3045

23. Wong AC, Ryan AF. Mechanisms of sensorineural cell damage, death and survival in the cochlea. *Front Aging Neurosci*. 2015;7:58

24. Eggermont JJ. Cochlea and auditory nerve. *Handb Clin Neurol*. 2019;160:437–449

25. National Institute on Deafness and Other Communication Disorders. How do we hear? Available at: https://www.nidcd.nih.gov/health/how-do-we-hear. Accessed May 19, 2022

26. Centers for Disease Control and Prevention. What causes hearing loss? Available at: https://www.cdc.gov/nceh/hearing_loss/what_noises_cause_hearing_loss.html. Accessed October 20, 2021

27. Loughrey DG, Kelly ME, Kelley GA, Brennan S, Lawlor BA. Association of age-related hearing loss with cognitive function, cognitive impairment, and dementia: a systematic review and meta-analysis. *JAMA Otolaryngol Head Neck Surg*. 2018;144(2):115–126

28. Weuve J, D'Souza J, Beck T, et al. Long-term community noise exposure in relation to dementia, cognition, and cognitive decline in older adults. *Alzheimers Dement*. 2021;17(3):525–533

29. World Health Organization. Childhood hearing loss. Strategies for prevention and care. Available at: https://www.who.int/docs/default-source/imported2/childhood-hearing-loss–strategies-for-prevention-and-care.pdf?sfvrsn=cbbbb3cc_0. Accessed June 15, 2022

30. Centers for Disease Control and Prevention. Proceedings from the National Workshop on Mild and Unilateral Hearing Loss: Workshop Proceedings; July 26–27, 2005; Breckenridge, CO

31. Su BM, Chan DK. Prevalence of hearing loss in US children and adolescents. Findings from NHANES 1988-2010. *JAMA Otolaryngol Head Neck Surg*. 2017;143(9):920–927

32. Shargorodsky J, Curhan SG, Curhan GC, Eavey R. Change in prevalence of hearing loss in US adolescents. *JAMA*. 2010;304(7):772–778

33. Kempen EV, Casas M, Pershagen G, Foraster M. WHO environmental noise guidelines for the European Region: a systematic review on environmental noise and cardiovascular and metabolic effects: a summary. *Int J Environ Res Public Health*. 2018;15(2):379

34. Basner M, McGuire S. WHO environmental noise guidelines for the European Region: a systematic review on environmental noise and effects on sleep. *Int J Environ Res Public Health*. 2018;15(3):519

35. Mama Y, Fostick L, Icht M. The impact of different background noises on the production effect. *Acta Psychol (Amst)*. 2018;185:235–242

36. Zeydabadi A, Askari J, Vakili M, Mirmohammadi SJ, Ghovveh MA, Mehrparvar AH. The effect of industrial noise exposure on attention, reaction time, and memory. *Int Arch Occup Environ Health*. 2019;92(1):111–116

37. Brammer AJ, Laroche C. Noise and communication: a three-year update. *Noise Health*. 2012;14(61):281–286

38. Guski R, Schreckenberg D, Schuemer R. WHO Environmental noise guidelines for the European Region: a systematic review on environmental noise and annoyance. *Int J Environ Res Public Health*. 2017;14(12):1539

39. World Health Organization. Burden of disease from environmental noise. Available at: https://www.who.int/publications/i/item/burden-of-disease-from-environmental-noise-quantification-of-healthy-life-years-lost-in-europe. Accessed May 26, 2022

40. Hugh SC, Wolter NE, Propst EJ, Gordon KA, Cushing SL, Papsin BC. Infant sleep machines and hazardous sound pressure levels. *Pediatrics*. 2014;133(4):677–681

41. Lapierre MA, Piotrowski JT, Linebarger DL. Background television in the homes of US children. *Pediatrics*. 2012;130(5):839–846

42. Schmidt ME, Pempek TA, Kirkorian HL, Lund AF, Anderson DR. The effects of background television on the toy play behavior of very young children. *Child Dev*. 2008;79(4):1137–1151

43. Sight & Hearing Association. Noisy toys list. Available at: http://sightandhearing.org/Services/NoisyToysList%C2%A9.aspx. Accessed March 25, 2023

44. Maxwell LE, Evans GW. Design of child care centers and effects of noise on young children. Available at: https://www.researchgate.net/publication/234627450_Design_of_Child_Care_Centers_and_Effects_of_Noise_on_Young_Children. Accessed May 29, 2022

45. American Academy of Pediatrics, American Public Health Association, National Resource Center for Health and Safety in Child Care and Early Education. *Caring for Our Children: National Health and Safety Performance Standards: Guidelines for Early Care and Education Programs*. 4th ed. American Academy of Pediatrics; 2019

46. American Speech-Language-Hearing Association. Classroom acoustics. Available at: https://www.asha.org/practice-portal/professional-issues/classroom-acoustics/. Accessed September 24, 2022

47. Mealings K. Classroom acoustic conditions: understanding what is suitable through a review of national and international standards, recommendations, and live classroom measurements. In: Proceedings from the Second Australasian Acoustical Societies' Conference; November 9–11, 2016; Brisbane, Australia

48. Acoustical Society of America. Classroom acoustics. Available at: https://acousticalsociety.org/wp-content/uploads/2020/07/Classroom-Acoustics.pdf. Accessed May 29, 2022

49. Jiang W, Zhao F, Guderley N, Manchaiah V. Daily music exposure dose and hearing problems using personal listening devices in adolescents and young adults: a systematic review. *Int J Audiol*. 2016;55(4):197–205

50. Louis CS. Children's headphones may carry risk of hearing loss. Available at: https://www.nytimes.com/2016/12/06/health/headphones-hearing-loss-kids.html. Accessed May 30, 2022

51. Dragan L. The best kids' headphones. Available at: https://www.nytimes.com/wirecutter/reviews/best-kids-headphones/#how-we-tested. Accessed September 21, 2021

52. Biersdorfer JD. Turning down the volume for young ears. Available at: https://www.nytimes.com/2017/08/10/technology/personaltech/volume-controls-music-headphones.html. Accessed May 30, 2022

53. Lambden D. 7 best headphones for kids for safe listening. Available at: https://www.clearliving.com/hearing/technology/best-headphones-for-kids/. Accessed May 30, 2022

54. US Department of the Interior Fish and Wildlife Service, US Department of Commerce. 2016 national survey of fishing, hunting and

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wildlife-associated recreation. Available at: https://www.census.gov/library/publications/2018/demo/fhw-16-nat.html. Accessed May 30, 2022

55. Meinke DK, Finan DS, Flamme GA, et al. Prevention of noise-induced hearing loss from recreational firearms. *Semin Hear.* 2017;38(4):267–281
56. Williams AL, Sanderson M, Lai D, Selwyn BJ, Lasky RE. Intensive care noise and mean arterial blood pressure in extremely low-birth-weight neonates. *Am J Perinatol.* 2009;26(5):323–329
57. Hassanein SMA, El Raggal NM, Shalaby AA. Neonatal nursery noise: practice-based learning and improvement. *J Matern Fetal Neonatal Med.* 2013;26(4):392–395
58. Zahr LK, Balian S. Responses of premature infants to routine nursing interventions and noise in the NICU. *Nurs Res.* 1995;44(3):179–185
59. Lejeune F, Parra J, Berne-Audéoud F, et al. Sound interferes with the early tactile manual abilities of premature infants. *Sci Rep.* 2016;6:23329
60. Kuhn P, Zores C, Langlet C, Escande B, Astruc D, Dufour A. Moderate acoustic changes can disrupt the sleep of very preterm infants in their incubators. *Acta Paediatr.* 2013;102(10):949–954
61. White RD; Consensus committee on recommended design standards for advanced neonatal care. Recommended standards for newborn ICU design, 9th edition. *J Perinatol.* 2020;40(Suppl 1):2–4
62. Children's Hospital of Philadelphia. MRI sounds. Available at: https://www.chop.edu/health-resources/mri-sounds. Accessed September 25, 2022
63. Salerno S, Granata C, Trapenese M, et al. Is MRI imaging in pediatric age totally safe? A critical reprisal. *Radiol Med.* 2018;123(9):695–702
64. World Health Organization. Environmental noise guidelines for the European Region. Executive summary. Available at: https://www.euro.who.int/__data/assets/pdf_file/0009/383922/noise-guidelines-exec-sum-eng.pdf. Accessed March 27, 2021
65. Hammer MS, Swinburn TK, Neitzel RL. Environmental noise pollution in the United States: developing an effective public health response. *Environ Health Perspect.* 2014;122(2):115–119
66. Fetterman M. Noise exposure is becoming 'the new secondhand smoke'. Available at: https://www.washingtonpost.com/national/health-science/noise-exposure-is-becoming-the-new-secondhand-smoke/2018/05/11/dd080c30-52d3-11e8-9c91-7dab596e8252_story.html. Accessed June 18, 2022
67. International Telecommunications Union. ITU-T H.870–H.879. Guidelines for safe listening devices/systems. Available at: https://itu.int/rec/T-REC-H.870. Accessed May 30, 2022
68. Balk SJ, Bochner RE, Ramdhanie MA, Reilly BK; American Academy of Pediatrics, Council on Environmental Health and Climate Change, Section on Otolaryngology – Head and Neck Surgery. Preventing excessive noise exposure in infants, children, and adolescents. *Pediatrics.* 152(5):e2023063753
69. Cohen J. How to protect kids' ears from constant headphone use. Available at: https://www.nytimes.com/2020/05/21/parenting/children-headphones-hearing-loss.html??mc=aud_dev&ad-keywords=auddevgate&gclid=Cj0KCQjwqp-LBhDQARIsAO0a6aJgHye0dWhhLuxlYGThibImnGPzQ5xSXTJ9BWeEoAzclumc1XL10iYaAgNKEALw_wcB&gclsrc=aw.ds. Accessed May 30, 2022

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Noise Impact Analysis of the Proposed Headlands Solar Energy Facility

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Prepared: September 4, 2025
Project No. 2025-029 & 030

EXECUTIVE SUMMARY

Ranger Power is proposing the Headlands Solar Energy Facility in Conway and Cohoctah Townships, Livingston County, Michigan. The primary noise sources will be 62 inverters and a substation transformer. This study was conducted to evaluate potential noise impacts on nearby residents.

Noise criteria were reviewed at the federal, state, and local levels. Michigan Public Act 233 (PA 233) sets a statewide standard of 55 dBA (hourly average, A-weighted) at the nearest nonparticipating dwelling. The U.S. Environmental Protection Agency (EPA) recommends average exposure levels at or below DNL 55 [55 dB(A) daytime / 45 dB(A) nighttime] as generally protective of public health. Both Conway and Cohoctah Townships, however, maintain stricter local ordinances for projects under 50 MW, with property-line limits of 40 dBA daytime and 35 dBA nighttime.

Field measurements documented low existing ambient levels in Conway and Cohoctah, consistent with their rural setting. Measurements revealed average ambient daytime sound levels of 41 to 45 dB(A) which include insect and bird sounds (biogenic sounds). With biogenic sounds filtered out, average ambient daytime sound levels were 37 to 41 dB(A).

Reference measurements at an operating solar facility in Corunna Township confirmed that inverter noise is tonal, distinct, and clearly audible under favorable atmospheric conditions. The measurements showed inverter sound levels of 40 to 42 dB(A) with the inverters at an approximate distance of 1000-feet. Projected inverter sound levels at key residences in Livingston County are expected to be similar to existing average sound levels. Furthermore, the inverter sound levels are expected to exceed the existing persistent background (L_{90}) sound levels by as much as 20 dB, though remain within PA 233 and EPA thresholds.

The analysis concludes that while the Headlands Solar Facility will comply with state noise limits and EPA acceptable criteria and is not expected to create significant health risks, it will exceed Conway and Cohoctah Township's more restrictive ordinance if PA 233 is repealed. While the overall level of the inverters will not be perceived as high, some residents are likely to perceive inverter noise as intrusive, particularly due to its tonal character and having sound levels greater than background ambient conditions. This perceived intrusiveness may diminish over time as people grow accustomed to the change in soundscape.

This analysis is dependent on the use of inverters with sound level outputs comparable to the Sungrow 3600UD units or those measured in Corunna Township. The use of alternate inverters, substation equipment, or other components with higher noise emissions would invalidate these conclusions and be viewed less favorably.

Mitigation measures such as specifying quieter inverters, maintaining setbacks of 1,000 feet or more, orienting equipment away from residences, or incorporating sound barriers and enclosures are recommended to minimize community impacts and improve long-term compatibility.

1. PURPOSE & DESCRIPTION

Ranger Power is proposing to develop the Headlands Solar Energy Facility in Conway and Cohoctah Townships, Livingston County, MI. The primary noise sources from the facility are expected to be 62 Sungrow 3600UD inverters and a substation with a primary step-up transformer. It is expected that these sources will produce audible noise at nearby residential properties.

The purpose of this study is to evaluate the potential noise impacts of the proposed facility on local residents. To complete this evaluation, we conducted the following tasks:

- Reviewed the Headlands Solar Pre-Construction Noise Analysis prepared by Hankard Environmental, Inc. (Verona, Wisconsin)
- Collected baseline sound level measurements in Conway and Cohoctah Townships to document existing environmental sound conditions
- Measured noise from an existing solar energy facility at residential properties in Corunna Township, Shiawassee County, Michigan
- Projected noise levels from the proposed inverters at representative residential properties in Conway and Cohoctah Townships
- Compared the resulting noise projections to applicable criteria and baseline sound levels

2. APPLICABLE NOISE CRITERIA

Michigan Regulations (Public Act 233)

The Clean and Renewable Energy and Energy Waste Reduction Act (Public Act 233) establishes specific noise limits for solar energy facilities in Michigan. The Act requires that:

> "*The solar energy facility does not generate a maximum sound in excess of 55 average hourly decibels as modeled at the nearest outer wall of the nearest dwelling located on an adjacent nonparticipating property. Decibel modeling shall use the A-weighted scale as designed by the American National Standards Institute.*"

In addition, the Michigan Public Service Commission requires that applications under PA233 include a predictive noise study. This study must account for:

- Tonal noise penalty: +5 dB adjustment applied to tonal sources (such as inverters).
- Façade reflection factor: +6 dB adjustment to represent sound pressure doubling at building walls.

Together, these adjustments effectively increase the modeled inverter sound levels by 11 dB. As a result, actual measured sound levels of the installed solar facility would likely result in

sound levels that did not exceed 50 dB(A) at the nearest dwelling outer wall, and 44–47 dB(A) and a similar distance from the noise source away from the dwelling.

Compliance with PA233 is achieved so long as the measured sound level of solar facility related noise remains below 55 dB(A), averaged over a one-hour period, at the nearest nonparticipating residence outer wall.

Conway Township's Noise Ordinance – Solar Energy Systems

The Conway Township Solar Energy System Ordinance establishes two distinct sets of noise regulations depending on project size and the applicability of Michigan Public Act 233 of 2023 (PA 233). This approach establishes a Compatible Renewable Energy Ordinance (CREO) to comply with state law for large-scale projects while maintaining stricter local standards for smaller facilities and preserving a fallback framework if PA 233 is ever repealed.

For utility-scale projects of 50 megawatts (MW) or greater, jurisdiction lies with the Michigan Public Service Commission (MPSC) under PA 233. In these cases, Conway Township incorporates the state standard, which limits noise to 55 dBA, hourly average (A-weighted), measured at the nearest dwelling on a non-participating property. This ensures that the Township's ordinance is compatible with PA 233 and avoids preemption by state authority.

For projects under 50 MW, which remain under local zoning jurisdiction, Conway imposes more restrictive standards. Specifically, noise from a solar energy facility may not exceed the following limits at the property line:

- 40 dBA (Lmax) during daytime hours (7:00 a.m. to 9:00 p.m.)
- 35 dBA (Lmax) during nighttime hours (9:00 p.m. to 7:00 a.m.)

These limits are based on instantaneous maximum levels rather than averaged measurements and apply at property lines rather than dwellings, representing a significantly more stringent threshold than PA 233.

Cohoctah Township Ordinance

The Cohoctah Township Solar Energy System ordinance is substantially similar to the Conway Township Solar Energy System ordinance. The primary ordinance establishes instantaneous property-line limits of 40 dBA Lmax during the day (7:00 a.m.–9:00 p.m.) and 35 dBA Lmax at night (9:00 p.m.–7:00 a.m.), with provisions allowing the Township to require evergreen berms for additional mitigation.

In 2024, Cohoctah Township adopted amendments to align with Michigan Public Act 233 of 2023 (PA 233), creating their CREO. Under the amendment, beginning November 29, 2024, systems with a nameplate capacity of 50 MW or greater must comply with PA 233 standards, including a modeled noise limit of 55 dBA Leq (hourly, A-weighted) at the nearest dwelling on

an adjacent nonparticipating property. The stricter property-line limits remain applicable to systems under 50 MW or if PA 233 is repealed or not in effect.

EPA Noise Levels

To promote the reduction of noise pollution, the U.S. Environmental Protection Agency (EPA) was tasked with studying the effects of environmental noise on public health and welfare. This effort led to the publication of a foundational report titled: *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety*, commonly referred to as the "*Levels Document*."

The EPA's research evaluated a range of noise impacts, including: speech interference, activity disruption, annoyance, and community responses to environmental noise.

From these analyses, the EPA concluded that a Day-Night Average Sound Level (DNL) of 55 dB(A) or lower is protective for outdoor speech communication and corresponds to a level at which fewer than 10% of the population report being highly annoyed by environmental noise.

DNL (Day-Night Sound Level) is a 24-hour average sound level metric that applies a 10 dB penalty to nighttime hours (10:00 p.m. to 7:00 a.m.) to reflect increased sensitivity to noise during typical rest periods. Based on this weighting, the EPA's protective levels correspond to:

- An average daytime sound level of 55 dB(A)
- An average nighttime sound level of 45 dB(A)

It is important to note that these levels are not regulatory standards, but rather scientifically derived health-protective benchmarks. The EPA explicitly states that these values:

- Were developed without consideration of economic or technical feasibility
- Are conservative by design, intended to protect sensitive individuals
- Include an additional margin of safety to account for uncertainties in population response

While not legally binding, the *Levels Document* remains a widely accepted reference in setting community noise goals, particularly for land use planning and public health considerations. It should be noted that these levels developed by the U.S EPA were largely based on transportation-related noise sources, such as road traffic, aircraft, rail and industrial.

3. THE COMPLEXITIES OF NOISE IMPACT

At its most basic level, noise impact can be described as a change in sound level that adversely affects those exposed to it. This simple definition, however, overlooks the complexities associated with the perception of noise. While certain acoustic attributes are widely recognized as undesirable, such as high overall levels, distinct tonal elements, or impulsive sounds, noise impact often goes beyond measurable quantities.

Annoyance relates to the subjective interpretation of sound. Two sounds of equal loudness may be perceived very differently depending on multiple factors including: listener sensitivity, the context in which the noise occurs, and personal attitudes toward the source. For example, the low-frequency hum of industrial equipment may be tolerable to some but highly disruptive to others, especially in quiet residential settings.

The complexity is further compounded by non-acoustic factors, including time of day, regional expectations, and the relationship between the receiver and the noise source. A community accustomed to regular train traffic may adapt to its presence, while the same sound introduced to a new environment could generate strong opposition. In this sense, noise impact is a product of both measurable quantities and subjective experience.

From a planning and regulatory standpoint, these complexities underscore the importance of establishing noise limits as a tool for managing community impact and expectations. Absolute silence is not practical as communities rely on infrastructure, industry, and commerce, all of which generate sound to one degree or another. The objective, therefore, is not to eliminate noise but to manage it to levels that are considered reasonable, protective of public health, and compatible with surrounding land uses.

Noise limits serve as a framework for balancing progress with livability. They provide measurable criteria against which proposed developments can be evaluated, ensuring that growth and economic activity can proceed without imposing unacceptable burdens on residents. When applied consistently, noise standards also provide predictability for developers, operators, and communities, reducing conflict and clarifying expectations.

In practice, this means that a new facility or infrastructure project must be assessed not only against existing background conditions but also against the regulatory thresholds established by applicable laws, typically local ordinance. Where noise exceeds the established limits, noise controls can be introduced to achieve compliance. This approach recognizes that noise may be an inevitable product of development, and the effects should be managed to maintain a fair balance between the well-being of residents and economic growth.

By enacting Public Act 233, the State of Michigan established a clear policy in support of renewable energy infrastructure. As part of this legislation, the State determined that a noise limit of 55 dB(A) represents an acceptable threshold to protect the health and well-being of residents. However, this limit was adopted as a uniform standard and does not account for variations in pre-existing ambient sound levels. In rural communities, where background sound levels can be significantly lower than in suburban or urban environments, the introduction of renewable energy systems will likely result in a significant increase in ambient

sound levels. Many residents in Conway and Cohoctah are sensitive to this discrepancy and have voiced concerns that the current standard does not adequately reflect the quiet settings of their communities.

The purpose of this study is to evaluate the potential noise impacts of the proposed Headlands Solar Energy facility within this context. Specifically, our analysis considers not only compliance with the 55 dB(A) limit established under PA 233, but also the change in sound levels relative to existing ambient conditions. By doing so, the study provides a more comprehensive assessment of potential community impacts and the extent to which residents may be affected than has been presented to date.

4.1 AMBIENT SOUND LEVELS IN CONWAY AND COHOCTAH TOWNSHIPS

Environmental sound levels were measured at two locations: one in Conway Township and another in Cohoctah Township. Measurements were conducted in accordance with *ANSI S12.9, Part 2: Quantities and Procedures for Description and Measurement of Environmental Sound - Measurement of Long-Term, Wide-Area Sound,* and *ANSI S12.9, Part 3: Short-Term Measurements with an Observer Present*.

Measurements were performed using a calibrated Brüel & Kjær Model 2270 Environmental Noise Analyzer equipped with a Larson Davis outdoor microphone assembly, including a Model 2541 laboratory-grade, ½-inch free-field precision microphone. System calibration was verified both before and after the measurement period using a Brüel & Kjær Type 4231 Acoustic Calibrator. The measurement system exceeds the performance requirements for Type 1 (precision-grade) instrumentation as specified in *ANSI S1.4*.

The measurement system was positioned at residential properties that are likely to be impacted by noise from the proposed Headlands Solar Project. The purpose of these measurements is to establish ambient sound levels in the absence of a solar energy facility.

The measurement locations are:

- 9788 N Marsh Road, Conway Township
- 10785 Fleming Road, Cohoctah Township

A graphical presentation of these measurement positions is provided in **EXHIBITS 1 & 2**.

Sound monitoring was conducted continuously over a 48-hour period at each measurement position. At the location off N Marsh Road, measurements were conducted from August 1st through August 2nd, 2025. At the location off of Fleming Road, measurements were conducted from August 4th through August 5th, 2025.

In this time period during our measurements, noise from insects, such as crickets, cicadas, and katydids, was prevalent. As these insect sounds are seasonal, and less likely to occur at other times of the year, we analyzed the measurements without, and with a biogenic filter

(removes the influence of insect and some bird sounds). The biogenic filter we used minimizes sounds at 2000 Hz and above. As katydid and some bird sounds occur in broader frequency ranges below 2000 Hz, not all of these sounds were filtered out. The purpose of this filter is to provide a better understanding of what background sound levels are likely to be at other times of the year when insect and bird sounds are less prominent.

The results of the measurements have been presented as time history plots of the measured sound levels over the course of a 24-hour period. The sound level data descriptions provided are:

- 1-minute Leq sound levels (sound Levels averaged over a 1-minute period)
- 1-hour L_{eq} sound levels (sound Levels averaged over a 1-hour period)
- 1-hour L_{10} sound levels (the sound level exceeded 10% of the time in a 1-hour period, representing a statistically high sound level value that is due to transient events)
- 1-hour L_{90} sound levels (the sound level exceeded 90% of the time in a 1-hour period, representing a consistent background sound level in the absence of transient events)

The results of these measurements are provided in **EXHIBITS 3A through 6B**. Note that exhibits designated with an 'A' do not employ the biogenic filter, while those designated with a 'B' do employ the filter.

The atmospheric conditions during these measurements were largely calm with no significant effect to the sound level measurements. There were a few periods of elevated wind: August 1st between 10AM and 1PM, and August 5th between 3PM and 6PM. Details of the atmospheric conditions are presented in APPENDIX A.

4.2 DISCUSSION OF AMBIENT SOUND LEVEL MEASUREMENTS

A summary of the daytime ambient sound levels measured in Conway and Cohoctah townships are presented below in Table 1.

TABLE 1 – AMBIENT SOUND LEVELS IN LIVINGSTON COUNTY

Ambient Sound Levels		Daytime Average Sound Levels (7AM - 10PM)		
Measurement Location	*Dataset*	*Leq*	*L10*	*L90*
N Marsh Rd, Conway Twp	Full	45.1	46.8	36.6
N Marsh Rd, Conway Twp	Filtered*	41.3	43.4	30.1
Fleming Rd, Cohoctah Twp	Full	41.5	43.9	34.9
Fleming Rd, Cohoctah Twp	Filtered*	36.8	38.2	26.3
**Biogenic Filter Eliminating Sound at 2k Hz and Above*				

Generally, the sound levels in Livingston County are low. Given the rural nature of the areas measured, this is not surprising. The typical sources of sound found in our measurements are: birds, insects, local vehicular traffic, small aircraft, and resident related activities. The full (unfiltered) dataset sound levels provided are representative of mid to late summer seasonal conditions. The biogenic filtered dataset sound levels represent estimated sound levels at other times of the year when insect and bird sounds are less prominent. These values are likely a bit higher than actual sound levels at other times of the year due to the broader range of katydid and some bird sounds that were not filtered out.

5.1 SOLAR ENERGY FACILITY SOUND LEVELS

To provide a real-world basis for evaluating the expected noise from the proposed Headlands Solar Energy Facility, we conducted sound level measurements at 3496 N Byron Rd in Corunna Township, Shiawassee County, Michigan. This property is directly adjacent to the operating Assembly Solar energy facility with solar panels and inverters to the north, south and west. This location provides a representative condition that directly documents the types of sound residents in Livingston County are likely to experience in proximity to solar equipment.

It should be noted that the sound produced by inverters can vary based on the capacity, the manufacturer and the model. We are unaware of the manufacturer or the model used for the Assembly Solar Energy facility. Without better information, we are assuming that the Headlands Solar project will use inverters with similar, or lower, sound emissions to the stated Sungrow 3600UD, or those used for the Assembly Solar facility.

The measurements were performed outdoors at a central location on the residential property where sound from the adjacent solar arrays, inverters, and transformers could be heard. Details of the measurement location are provided in **EXHIBIT 7.** The surrounding land use and acoustic environment are similar to conditions expected in Conway and Cohoctah Townships.

Measurements were performed with the same sound measurement system as the ambient sound measurements. Measurements started on August 9th, 2025 at 12PM and continued until August 10th at 6:02 AM, when the measurement system unexpectedly stopped recording. The results of these measurements are provided in **EXHIBITS 8A** (unfiltered) & **8B** (filtered). An additional period of measurements was recorded on August 12, 2025 from 10:27 AM to 11:45 AM. The results of these measurements are provided in **EXHIBITS 9A** (unfiltered) & **9B** (filtered).

At the time of the measurements, atmospheric conditions were predominantly clear, with temperatures ranging from 76 to 87 degrees Fahrenheit, and wind from the south to south-southwest at 6 to 13 MPH. Under these conditions, the solar array should have been operating at a level near full capacity for this location, and sound propagation was favorable from inverters to the south of the measurement location. While our study was limited in the

length of time we studied the Assembly Solar energy facility, sound propagation conditions were favorable such that the sound levels we measured are likely near the highest sound levels expected in that location.

5.2 RESULTS OF SOLAR FACILITY MEASUREMENTS

A summary of the daytime ambient sound levels measured in Corunna Township adjacent to the solar energy facility are presented below in Table 2.

TABLE 2 – AMBIENT SOUND LEVELS NEAR A SOLAR ENERGY FACILITY

Ambient Sound Levels		Daytime Average Sound Levels (7AM - 10PM)		
Measurement Location	*Dataset*	*Leq*	*L10*	*L90*
Byron Rd, Corunna Twp	Full	44.1	47.4	38.4
Byron Rd, Corunna Twp	Filtered*	41.5	42.6	38.0
**Biogenic Filter Eliminating Sound at 2k Hz and Above*				

Audibility and Sound Character

The inverter noise was clearly audible during the measurement period. The sound has a tonal quality, with dominant tones identified in the 630 Hz and 1250 Hz one-third octave frequency bands. This falls into a range where human hearing tends to be most sensitive. The loudness of the inverter noise fluctuates with atmospheric conditions, primarily wind speed and direction. During the measurements, winds were from the south to south-southwest at speeds of 6 to 13 miles per hour. These conditions resulted in noise transmission primarily from the inverter to the south, 940 feet away.

Measurement Data and Exhibits

The presence of insect noise in the 2,500–16,000 Hz range masked portions of the measured inverter sound levels. As a result, the inverter noise is not clearly distinguishable in the unfiltered data shown in **EXHIBIT 8A**.

To address this, a biogenic filter was applied to the measurement data. As shown in **EXHIBIT 8B & 9B**, the filtered results provide a clearer representation of inverter operation. In particular, the data show a distinct reduction in sound level at 10:44 p.m. on August 9th, when the inverters shut down for the night. At that time, the biogenic-filtered sound level dropped from approximately 42 dB(A) to 30 dB(A), confirming the absence of inverter noise and demonstrating the impact potential when insect sounds are less prominent.

EXHIBIT 10A provides the spectral sound level at 3496 N Byron Road, with and without the solar energy facility inverters operating. **EXHIBIT 10B** provides a similar spectral sound comparison, though biogenic (insect) noise has been removed to simulate times of the year

when insect noise is not present. From these spectral plots, we can see that the ambient sound levels near the solar energy facility will dominate ambient sound levels in the absence of transient sound events, and in the absence of insect noise.

6. REVIEW OF THE HEADLANDS SOLAR PRE-CONSTRUCTION NOISE ANALYSIS

A pre-construction noise analysis was conducted for the Headlands Solar Project. This study was conducted by Hankard Environmental. Based on our review of this report, the prediction of the solar energy facility installation was conducted in a manner consistent with current engineering standards for noise prediction, following the standard ISO 9613, and employing the requisite assumptions from the Michigan Public Service Commission application and filing procedures.

The methods used in this prediction are conservative, favoring the protection of residents. The methodology in the environmental noise prediction standard, ISO 9613, assumes favorable sound propagation from the noise source to all receivers. Additionally, the modeling assumes the inverters and transformers are tonal and imposes a +5dB penalty to these noise sources. Sound level predictions at the facades of homes adds 6 dB for pressure doubling at sound reflective surfaces.

Based on our review of this report, and our experience with environmental noise prediction, we find that the results of this noise analysis are correctly determined to the degree presented. Furthermore, actual measured sound levels are likely to be less than those predicted by the study due to the tonal penalty applied.

7 PROJECTED INVERTER NOISE IN LIVINGSTON COUNTY

Although the measurements at the Assembly Solar facility were taken in proximity to six inverters, our observations under south to south-southwest winds (6-13 mph) indicated that the dominant sound source was the inverter located 940 feet to the south. Under these conditions, the northern inverters were completely inaudible, while the inverters to the south-southeast and southwest were only occasionally audible as the wind direction shifted.

From the solar facility sound level measurements, the hourly-averaged sound levels ranged from 37 to 42 dB(A). This range of sound levels reflects variation in the ease of sound propagation as well as the degree of contribution from multiple inverter sources. Assuming an overall average of 40 dB(A) for inverter sound level, with the dominant inverter located 940 feet away, we projected the typical free-field inverter sound levels based on geometric diverging sound propagating properties of point noise sources at various distances provided in Table 3 below.

These “ANTICIPATED TYPICAL” inverter sound levels represent sound levels from a single inverter under generally favorable sound propagating conditions. Actual sound levels may be higher with additional inverters and more favorable propagating conditions.

Based on the ambient sound level measurements conducted in Conway and Cohoctah Townships, average daytime sound levels in the absence of biogenic sounds are between 37 and 41 dB(A). The background (L_{90}) sound levels in the absence of biogenic sounds are between 26 and 30 dB(A). Inverter sounds are expected to be audible against the background sound levels, and in many cases will be similar to existing average sound levels. In some locations, where multiple inverters have influence, and/or more favorable sound propagating conditions exist, inverter sound levels may approach the sound levels predicted by the pre-construction noise analysis, though are not expected to exceed these values and are likely to occur for relatively short periods.

TABLE 3 – ANTICIPATED TYPICAL INVERTER SOUND LEVELS UNDER GENERALLY FAVORABLE PROPAGATION CONDITIONS

Distance from Inverter	*Anticipated Free-field Sound Level*
400 Feet	47 dB(A)
450 Feet	46 dB(A)
500 Feet	45 dB(A)
600 Feet	44 dB(A)
750 Feet	42 dB(A)
940 Feet	40 dB(A)
1200 Feet	38 dB(A)
1500 Feet	36 dB(A)
1900 Feet	34 dB(A)
2400 Feet	32 dB(A)
3000 Feet	30 dB(A)

Receptor 77[1] Noise Prediction

The pre-construction noise analysis identified 8051 W Mohrle Road as one of the locations expected to receive the highest inverter noise levels from the Headlands Solar Project. The predicted free-field sound level near the home is 49 dB(A), with a façade-adjusted ("pressure doubled") level of 55 dB(A). Based on Table 3 projections and the receptor's distance of approximately 400 feet from the nearest inverter, we anticipate typical measured free-field inverter sound levels of 47 dB(A) under favorable sound propagating conditions.

This is expected to exceed average ambient sound levels by 7 to 10 dB, and background sound levels by 17 to 21 dB. This indicates the inverters will be clearly audible under favorable propagating conditions. As the inverter is planned to be located to the southeast, prevailing wind conditions are likely to be predominantly unfavorable for the inverter noise transmission to this residence. Typical sound levels are likely to lower.

[1] Receptors #77 & 260 as identified in the Headlands Solar Pre-Construction Noise Analysis

Receptor 260[1] Noise Prediction

10785 Fleming Road is also predicted to receive some of the highest inverter noise levels. The pre-construction analysis estimated a free-field level of 49 dB(A) and a façade-adjusted level of 55 dB(A). This property is directly comparable to the 3496 N Byron Road site, where Assembly Solar operating measurements were conducted. Both locations are, or will be, surrounded by numerous inverters at similar distances. Based on measured Assembly Solar facility data, we anticipate typical inverter hourly average free-field sound levels between 37 and 42 dB(A) at this residence.

With baseline average daytime ambient sound levels of 37 dB(A) and background sound levels of 26 dB(A), inverter sound levels are likely to exceed average ambient sound levels by 5 dB, and the background sound levels by 16 dB. Under favorable propagating conditions, the inverter noise will be clearly audible. As multiple inverters are planned to be located to the northwest, west, and southwest, prevailing wind will tend to create favorable sound propagating conditions most of the time.

8. CONCLUSION

The measured and projected sound levels from the proposed solar energy facility fall within State of Michigan regulatory thresholds and are consistent with U.S. Environmental Protection Agency (EPA) guidance on community noise exposure. As such, inverter noise is not expected to pose a significant health concern for residents in Livingston County.

However, Conway Township's solar ordinance establishes stricter noise limits than the State or EPA standards. Our analysis indicates that inverter noise levels, particularly under favorable propagation conditions, are likely to exceed those local limits if PA 233 is repealed.

Additionally, the tonal character of inverter noise at 630 Hz and 1250 Hz makes it more distinct than broadband sounds. Our field observations confirm that inverter noise will be clearly audible under favorable propagation conditions, and its presence will be most apparent during evening hours when ambient sound levels decline, and when other biogenic sounds are less prominent.

The analysis of this study is dependent on the use of inverters with sound level outputs comparable to the Sungrow 3600UD units or those measured in Corunna Township. The use of alternate inverters, substation equipment, or other components with higher noise emissions would invalidate these conclusions and be viewed less favorably.

Perception of New Noise Sources

Because of its tonal and intermittent qualities, inverter noise will be distinct and clearly audible and is likely to be perceived as an unwelcome addition to the local soundscape. Residents near proposed inverter locations may experience the noise as intrusive, even at relatively modest sound levels. This perceptual impact poses a concern for community annoyance, though is expected to wane over time as the inverter noise becomes part of the environment.

Potential Mitigation

To help reduce the potential for community annoyance, several mitigation measures can be considered in the project planning. These include:

- Specifying lower sound producing inverters
- Establishing a minimum setback distance of 1,000 feet between inverters and residents
- Orient inverters such that cooling ventilation inlet/outlets are directed away from residences
- Incorporating engineered sound barriers to block direct sound paths
- Employing ducted silencers or acoustic enclosures to reduce tonal noise emissions at the source

Applying one or more of these measures can substantially control the level of inverter noise and the relative impact created in the community. This can improve community acceptance and long-term compatibility of the facility with surrounding residents.

EXHIBIT 1

AERIAL IMAGE OF THE MEASUREMENT LOCATION AT 9788 N MARSH ROAD, CONWAY TOWNSHIP, MI

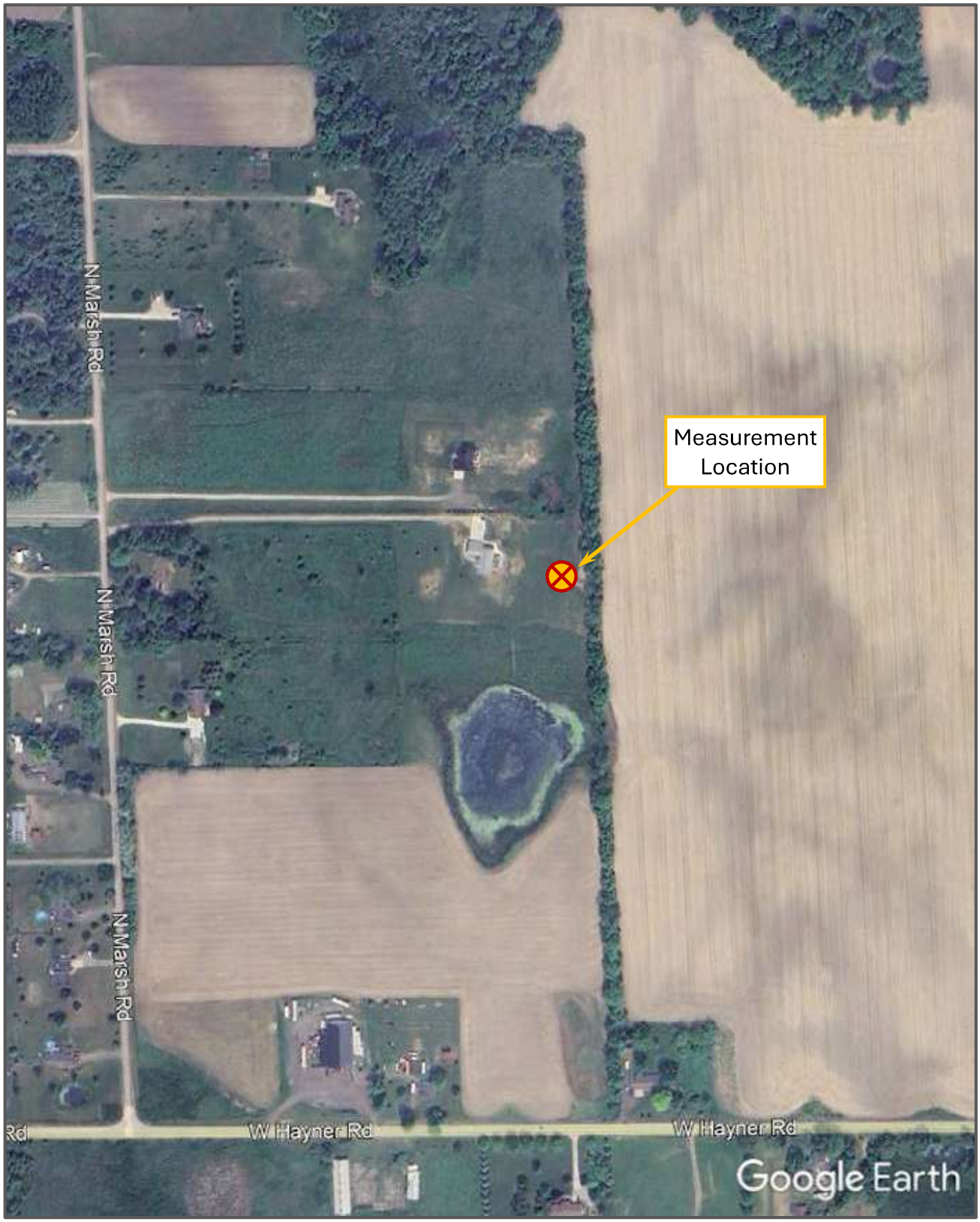


EXHIBIT 2

AERIAL IMAGE OF THE MEASUREMENT LOCATION AT 10785 FLEMING ROAD, COHOCTAH TOWNSHIP, MI

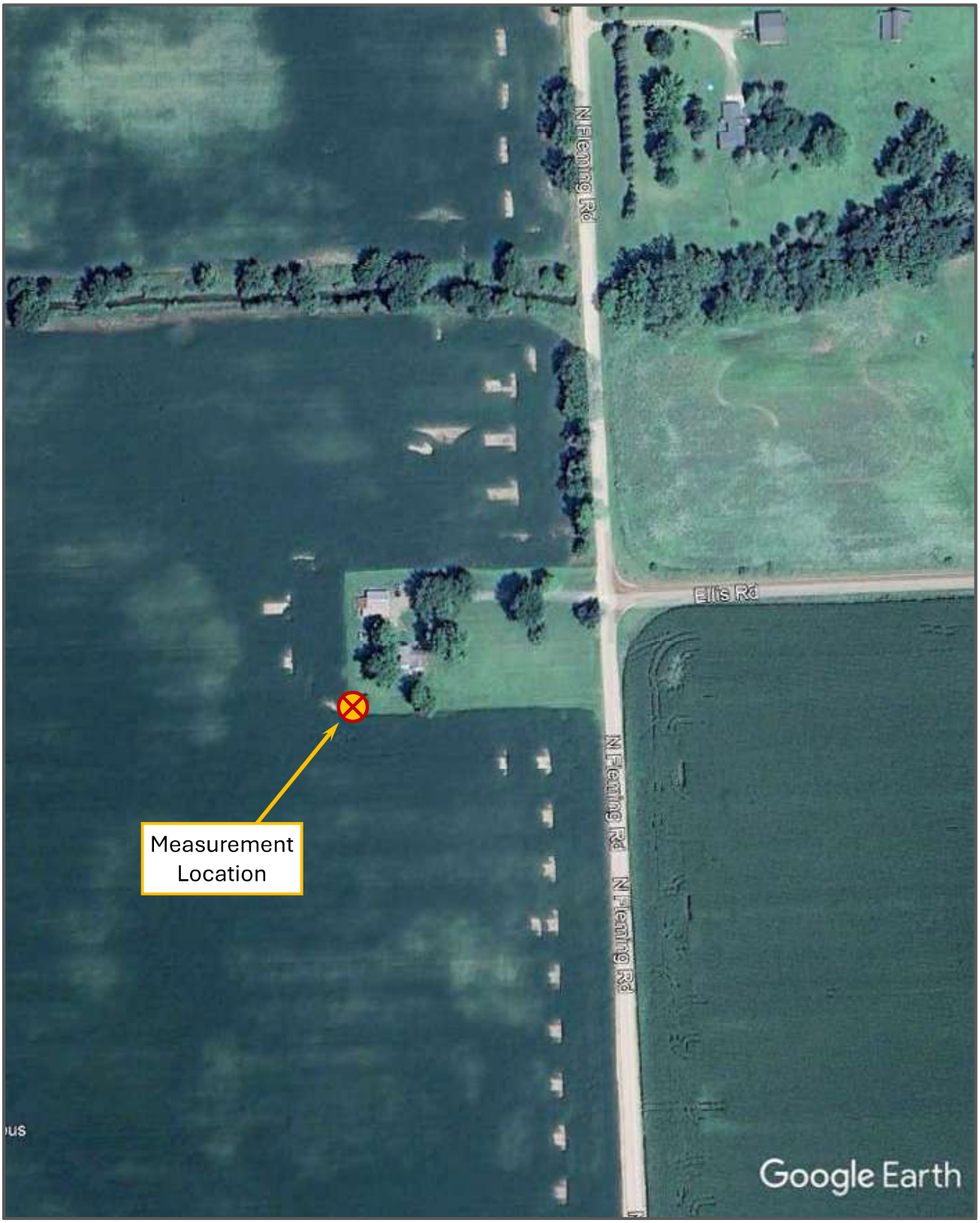


EXHIBIT 7

AERIAL IMAGE OF THE MEASUREMENT LOCATION AT 3496 N BYRON ROAD, CORUNNA, MI – MEASURING INVERTER SOUND LEVELS

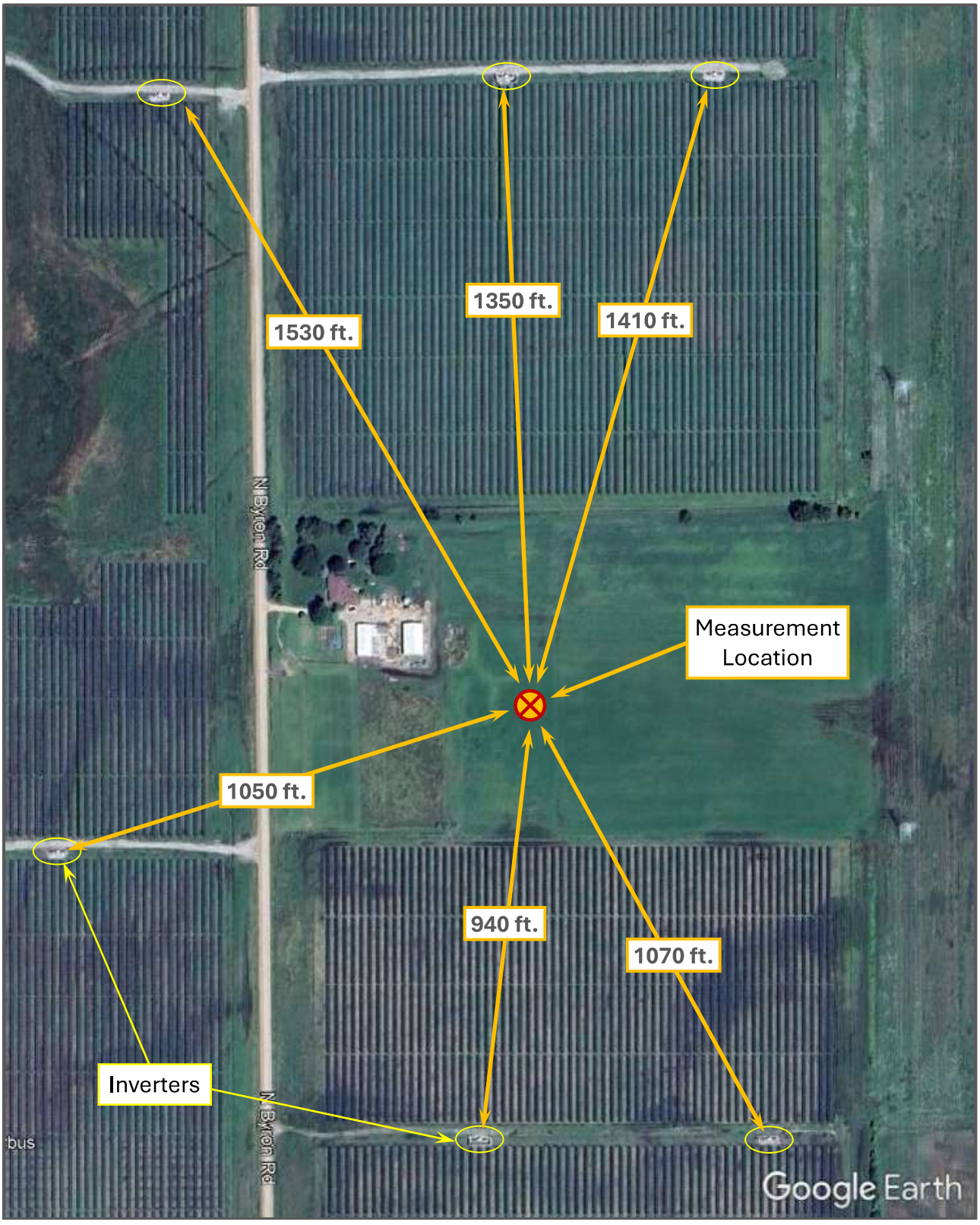
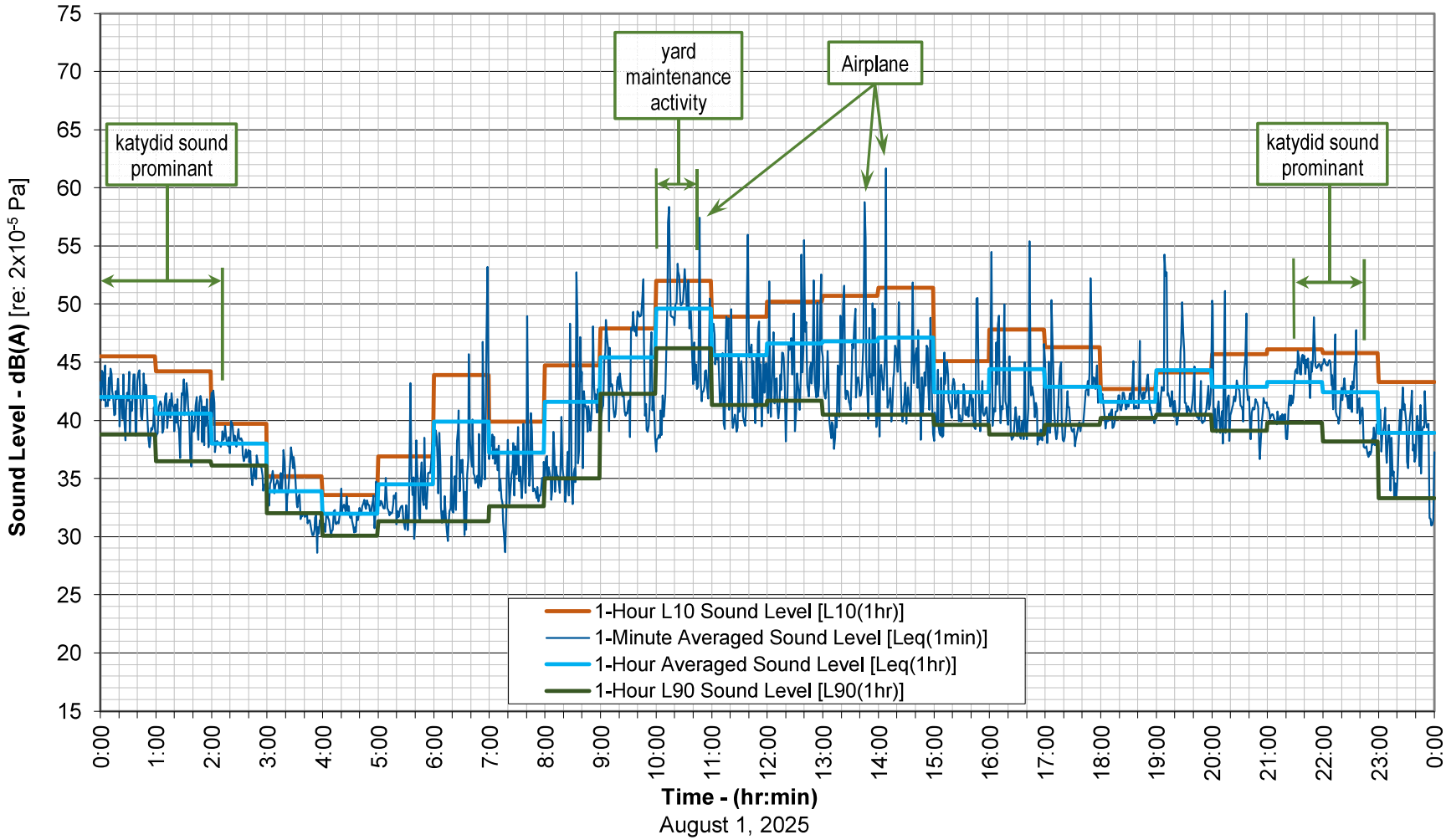


EXHIBIT 3A

Ambient Sound Levels at 9788 N Marsh Road

Measured at a Position 1460-ft North of W Hayner Road, and 1240-ft East of N Marsh Road

Study Conducted For: Conway & Cohoctah Townships

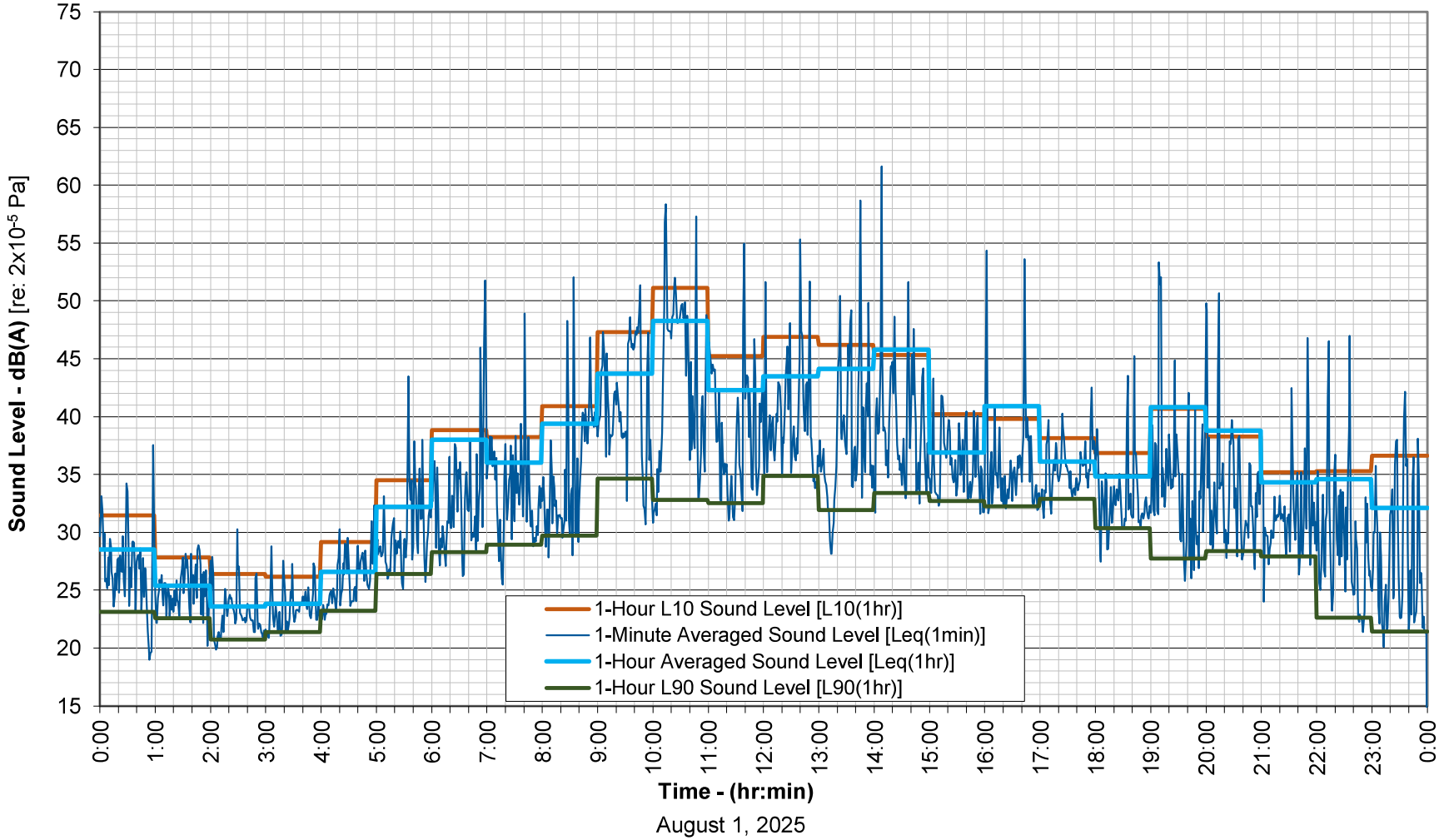


August 1, 2025

EXHIBIT 3B

Ambient Sound Levels at 9788 N Marsh Road
With Biogenic Filtering (removing sound at 2000 Hz and above)
Measured at a Position 1460-ft North of W Hayner Road, and 1240-ft East of N Marsh Road

Study Conducted For: Conway & Cohoctah Townships



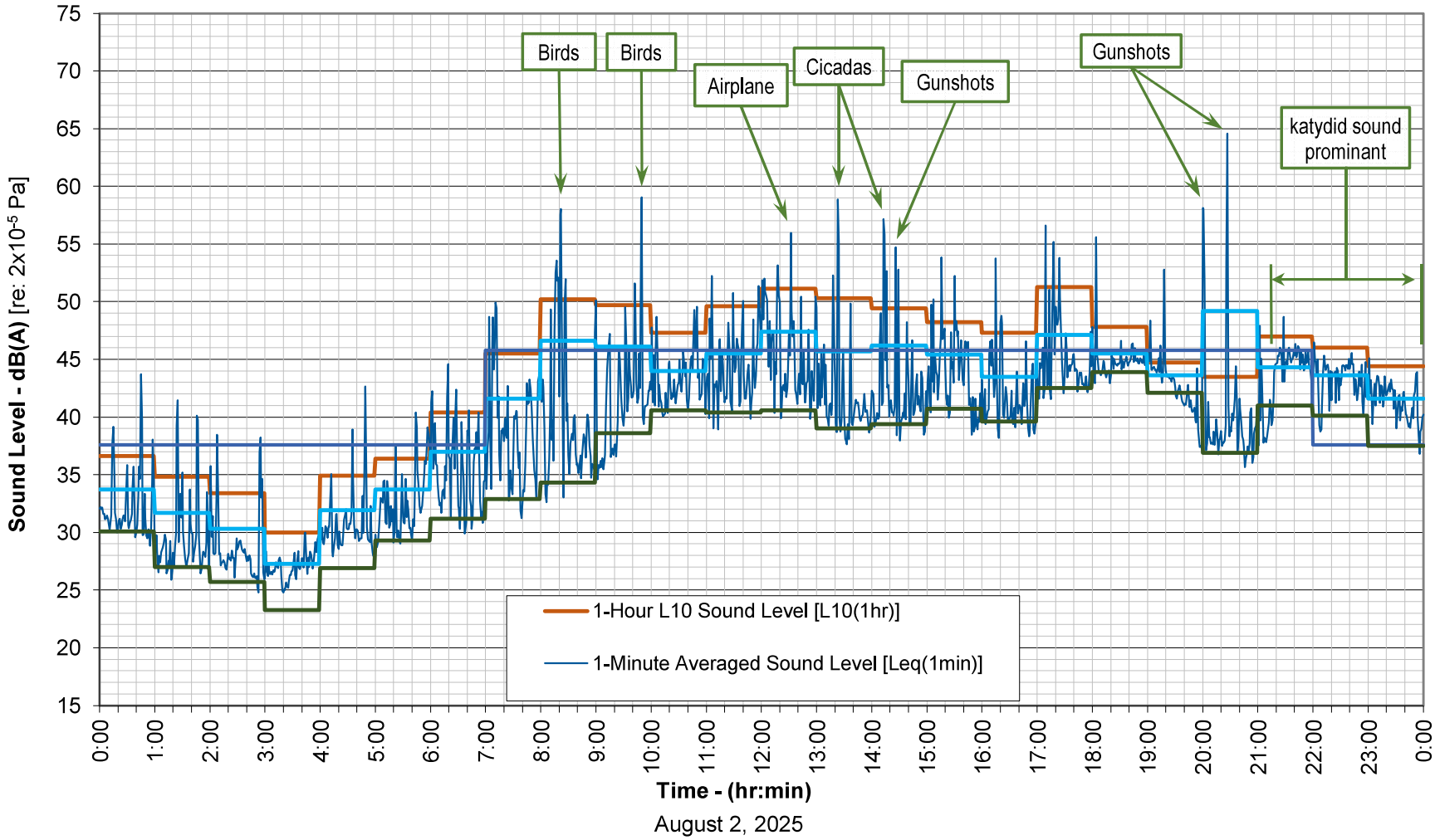
August 1, 2025

EXHIBIT 4A

Ambient Sound Levels at 9788 N Marsh Road

Measured at a Position 1460-ft North of W Hayner Road, and 1240-ft East of N Marsh Road

Study Conducted For: Conway & Cohoctah Townships

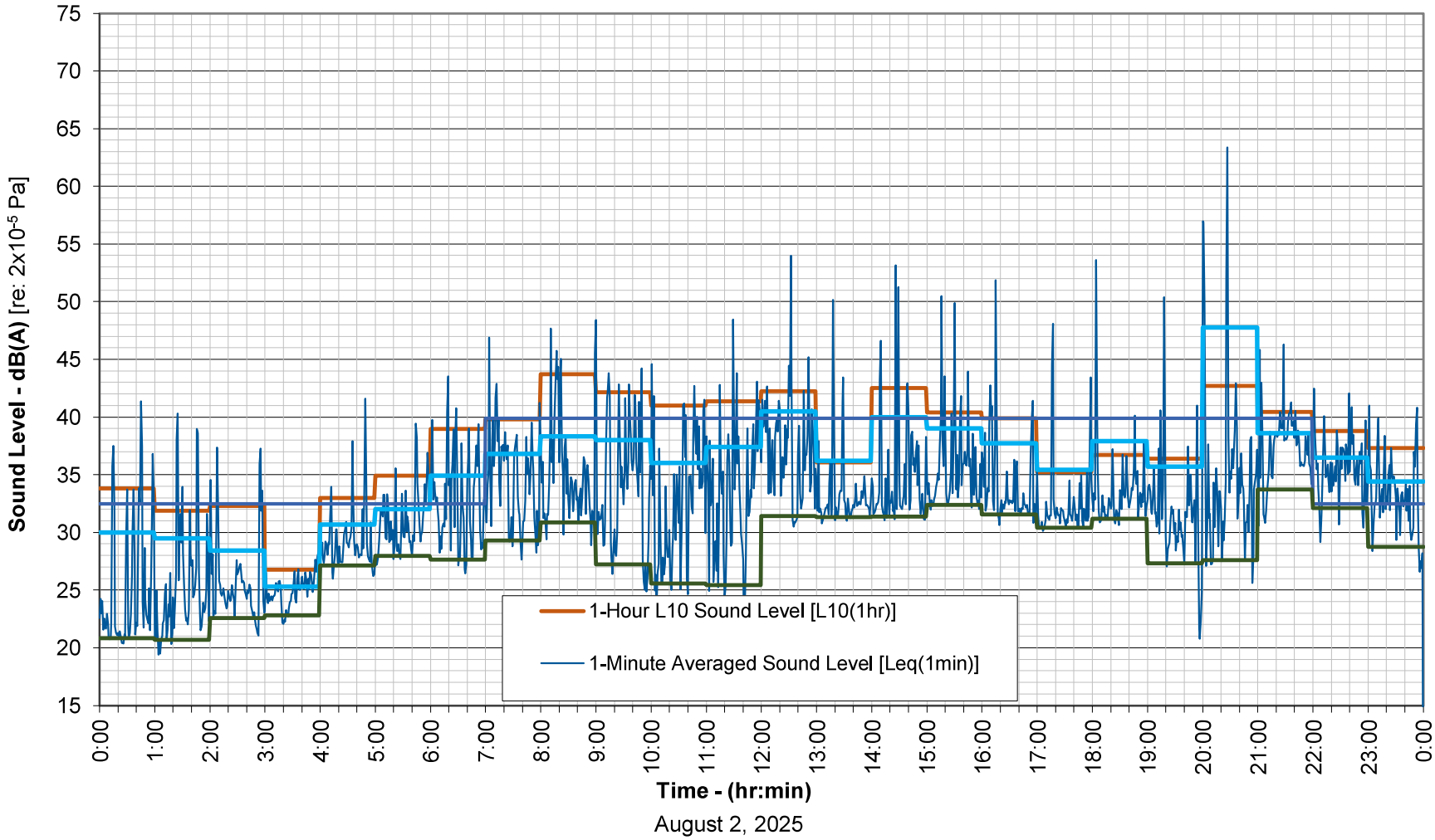


August 2, 2025

EXHIBIT 4B

Ambient Sound Levels at 9788 N Marsh Road
With Biogenic Filtering (removing sound at 2000 Hz and above)
Measured at a Position 1460-ft North of W Hayner Road, and 1240-ft East of N Marsh Road

Study Conducted For: Conway & Cohoctah Townships



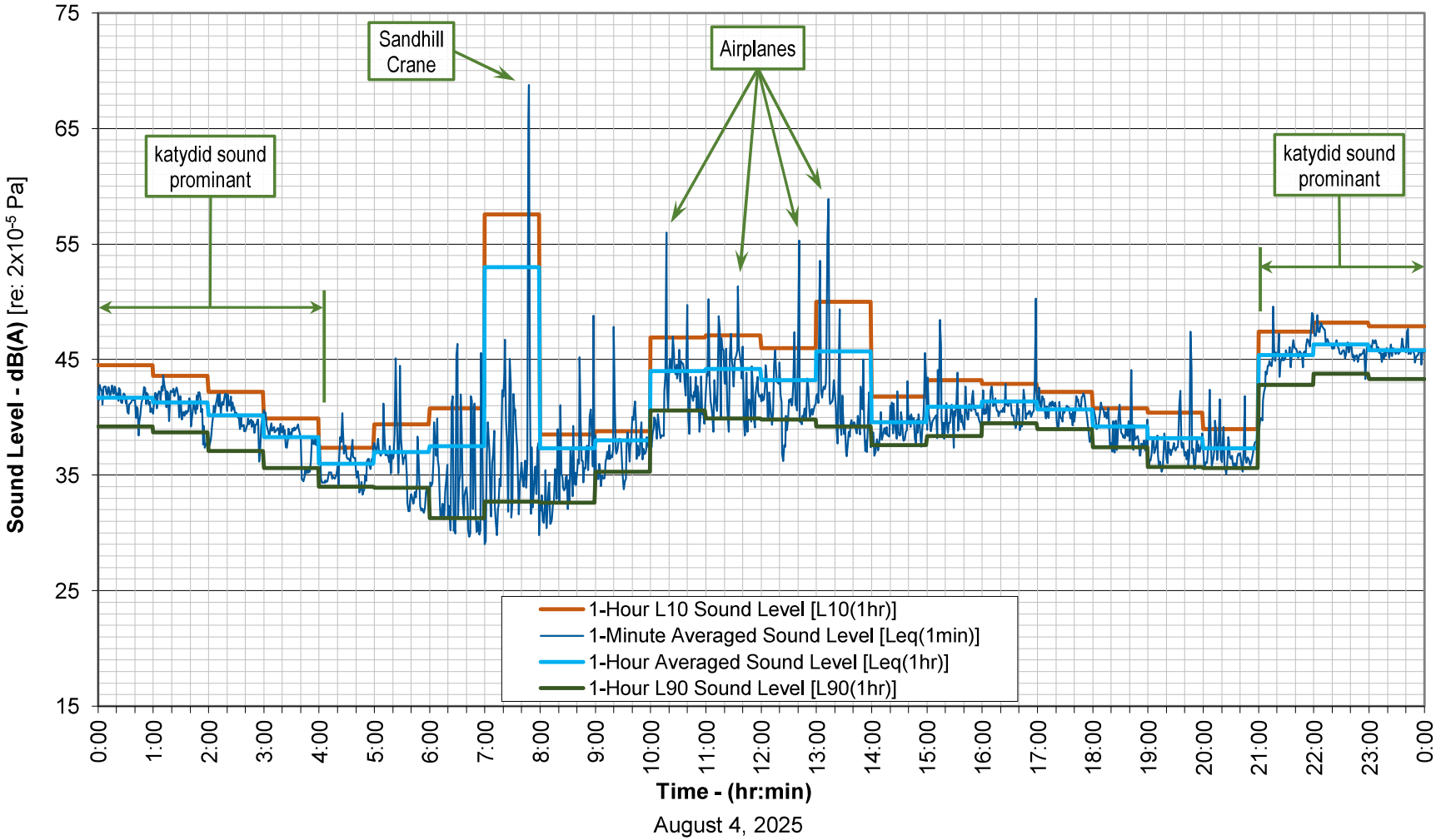
August 2, 2025

EXHIBIT 5A

Ambient Sound Levels at 10785 Fleming Road

Measured at a Position 1450-ft South of Stoner Road, and 380-ft West of Fleming Road

Study Conducted For: Conway & Cohoctah Townships

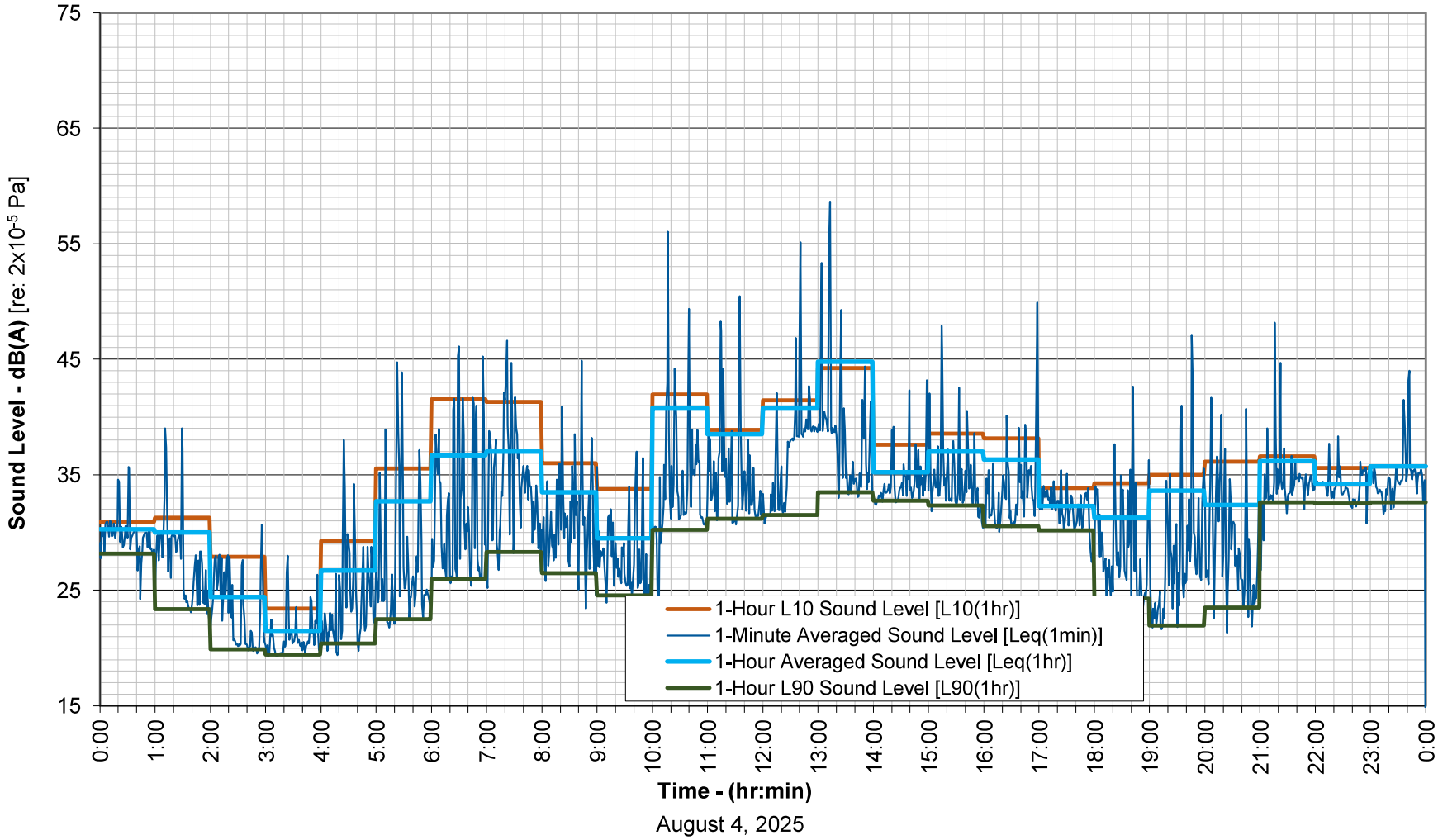


August 4, 2025

EXHIBIT 5B

Ambient Sound Levels at 10785 Fleming Road
With Biogenic Filtering (removing sound at 2000 Hz and above)
Measured at a Position 1450-ft South of Stoner Road, and 380-ft West of Fleming Road

Study Conducted For: Conway & Cohoctah Townships



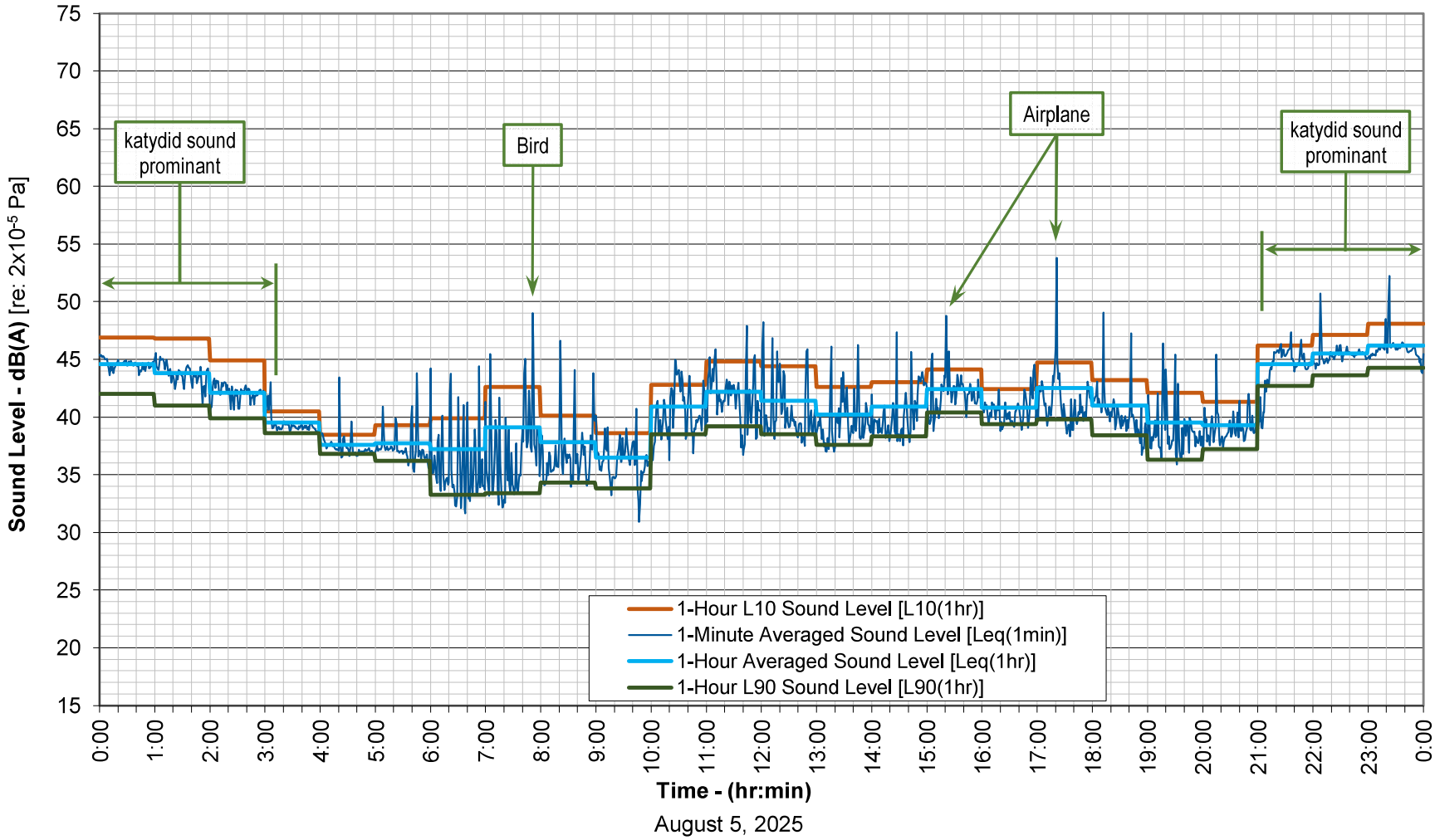
August 4, 2025

EXHIBIT 6A

Ambient Sound Levels at 10785 Fleming Road

Measured at a Position 1450-ft South of Stoner Road, and 380-ft West of Fleming Road

Study Conducted For: Conway & Cohoctah Townships

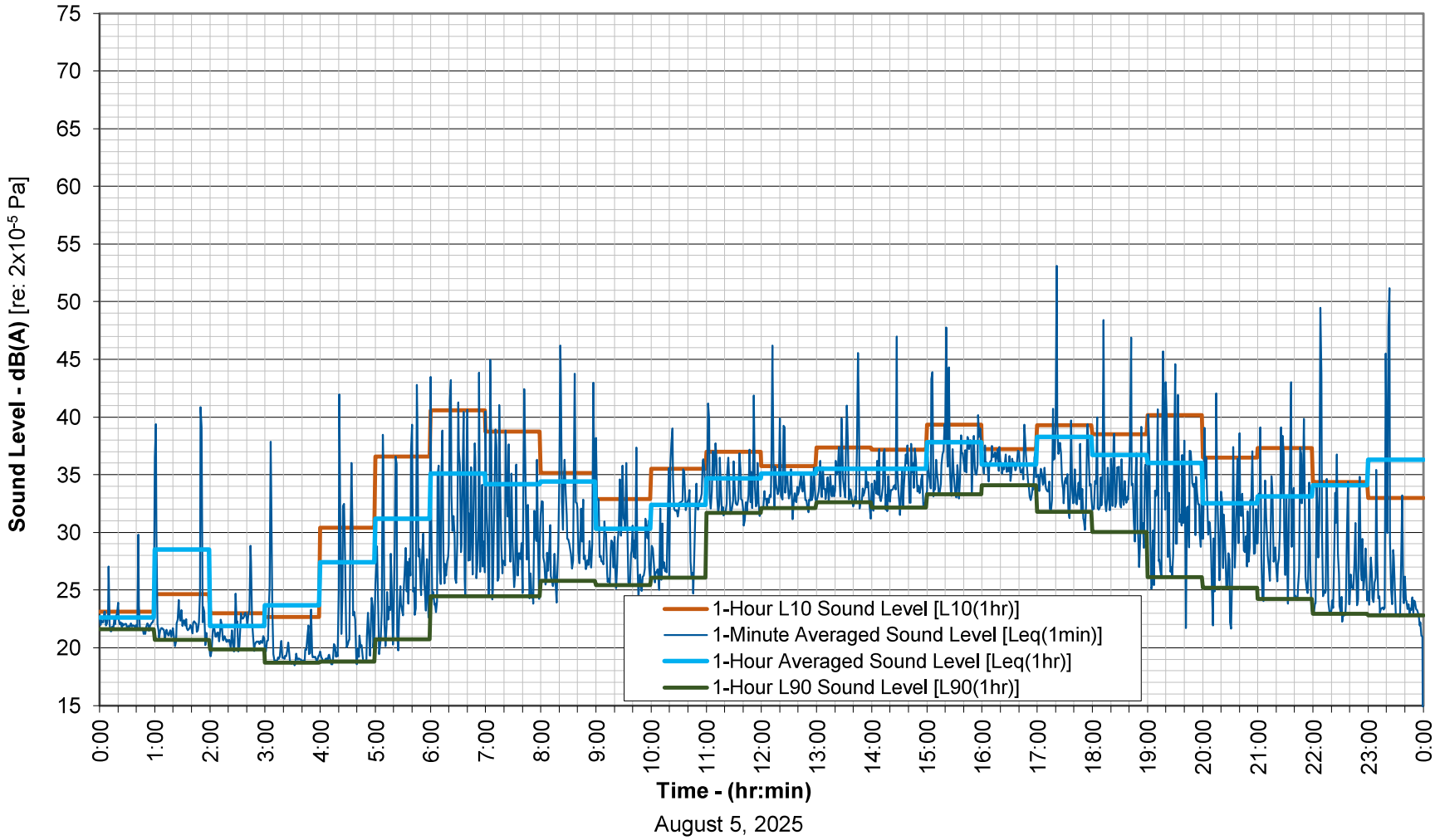


August 5, 2025

EXHIBIT 6B

Ambient Sound Levels at 10785 Fleming Road
With Biogenic Filtering (removing sound at 2000 Hz and above)
Measured at a Position 1450-ft South of Stoner Road, and 380-ft West of Fleming Road

Study Conducted For: Conway & Cohoctah Townships



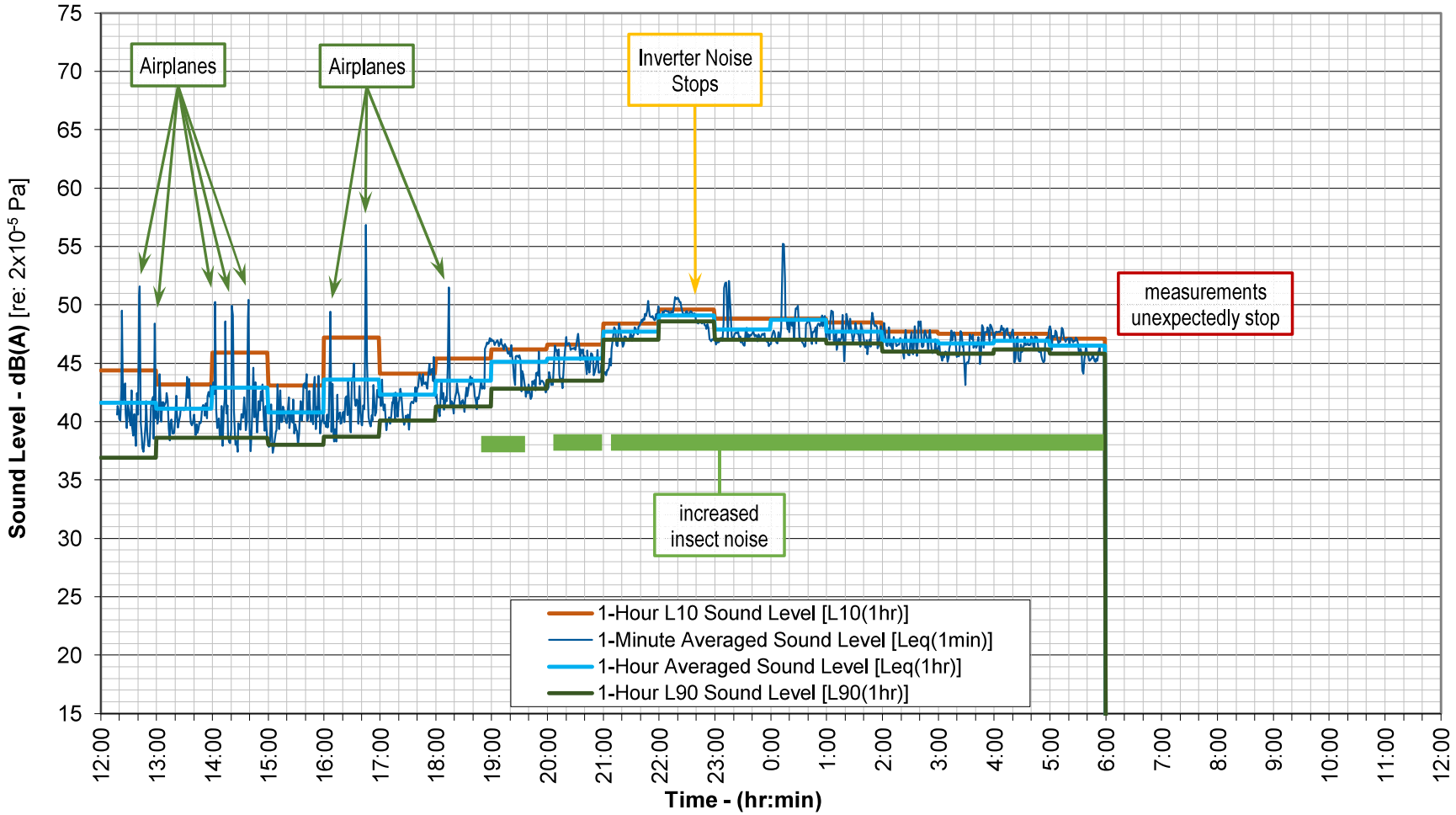
August 5, 2025

EXHIBIT 8A

Ambient Sound Levels at 3496 N Byron Rd

Measured at a Position 3010-ft South of E Juddville Road, and 560-ft East of N Byron Road

Study Conducted For: Conway & Cohoctah Townships

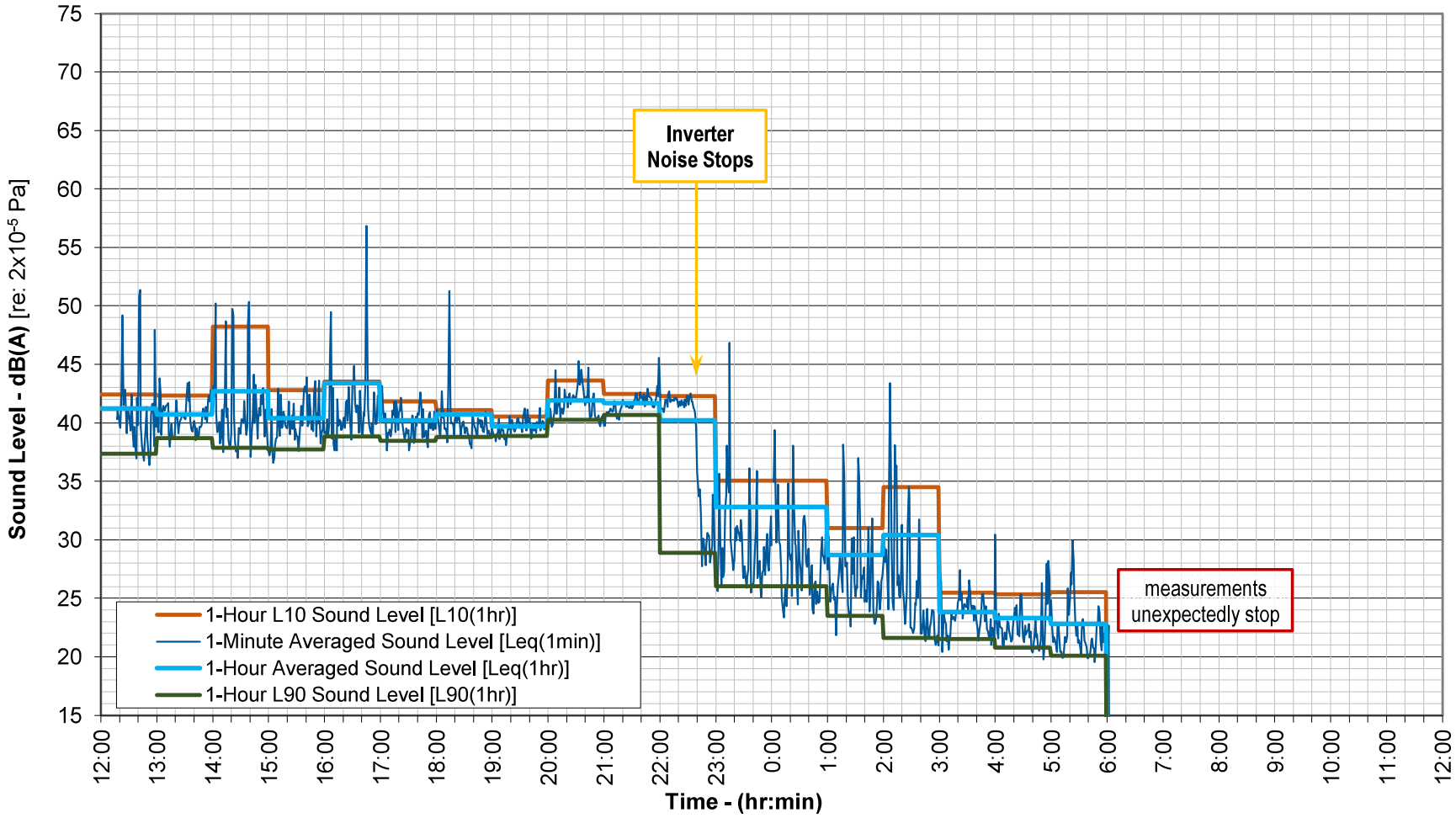


August 9 | August 10, 2025

EXHIBIT 8B

Ambient Sound Levels at 3496 N Byron Rd
With Biogenic Filtering (removing sound at 2000 Hz and above)
Measured at a Position 3010-ft South of E Juddville Road, and 560-ft East of N Byron Road

Study Conducted For: Conway & Cohoctah Townships



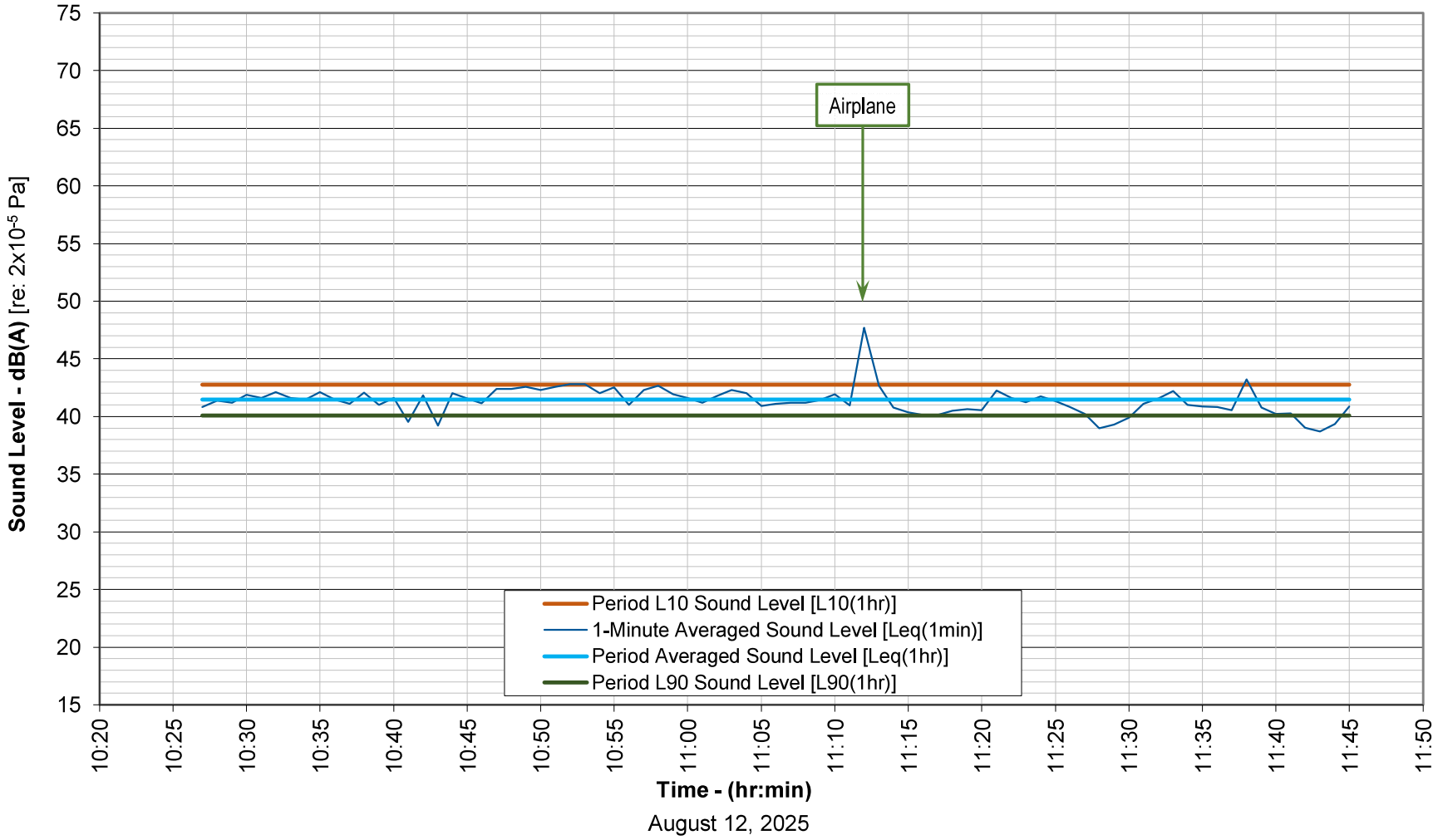
August 9 | August 10, 2025

EXHIBIT 9A

Ambient Sound Levels at 3496 N Byron Rd

Measured at a Position 3010-ft South of E Juddville Road, and 560-ft East of N Byron Road

Study Conducted For: Conway & Cohoctah Townships

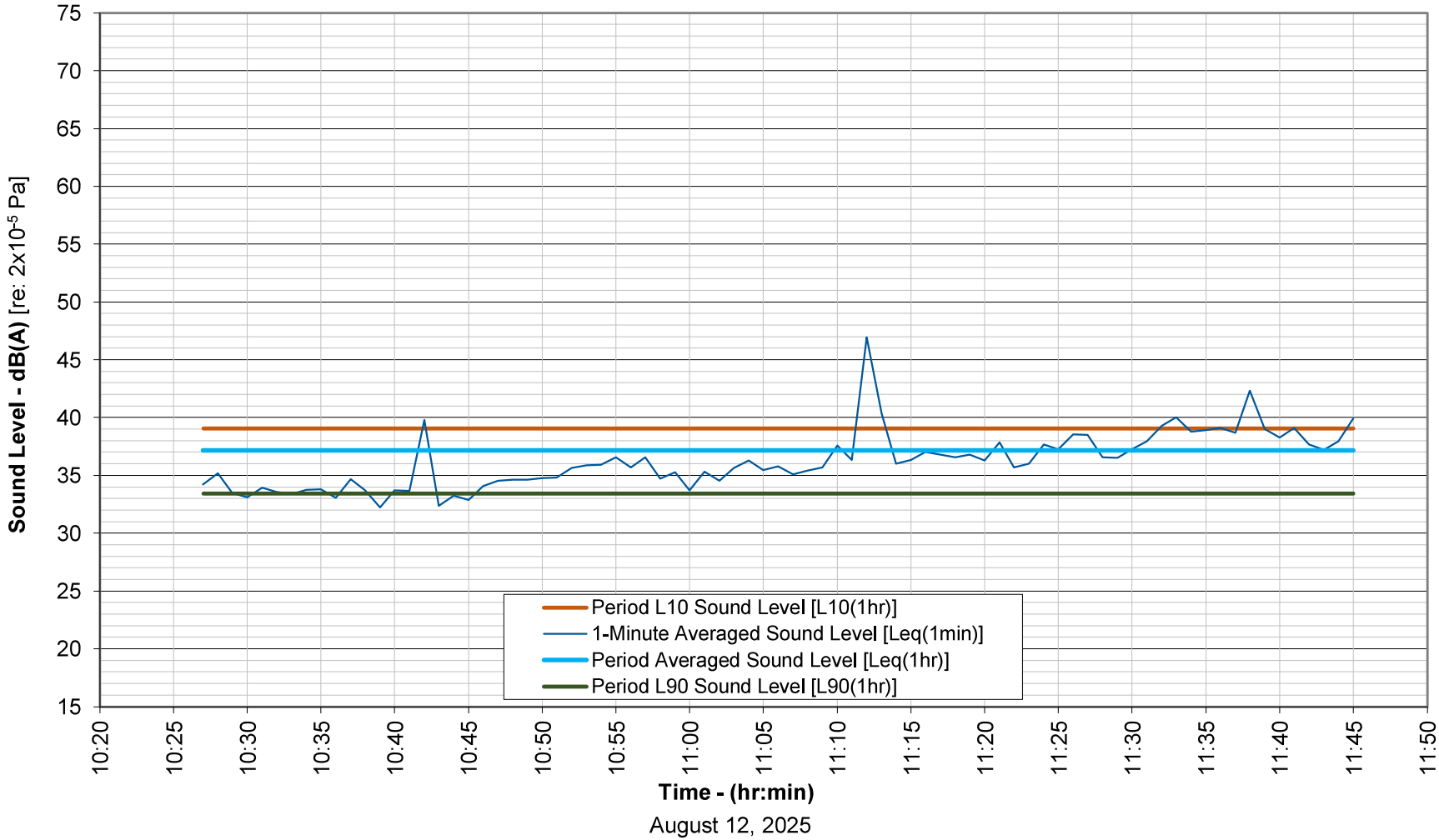


August 12, 2025

EXHIBIT 9B

Ambient Sound Levels at 3496 N Byron Rd
With Biogenic Filtering (removing sound at 2000 Hz and above)
Measured at a Position 3010-ft South of E Juddville Road, and 560-ft East of N Byron Road

Study Conducted For: Conway & Cohoctah Townships

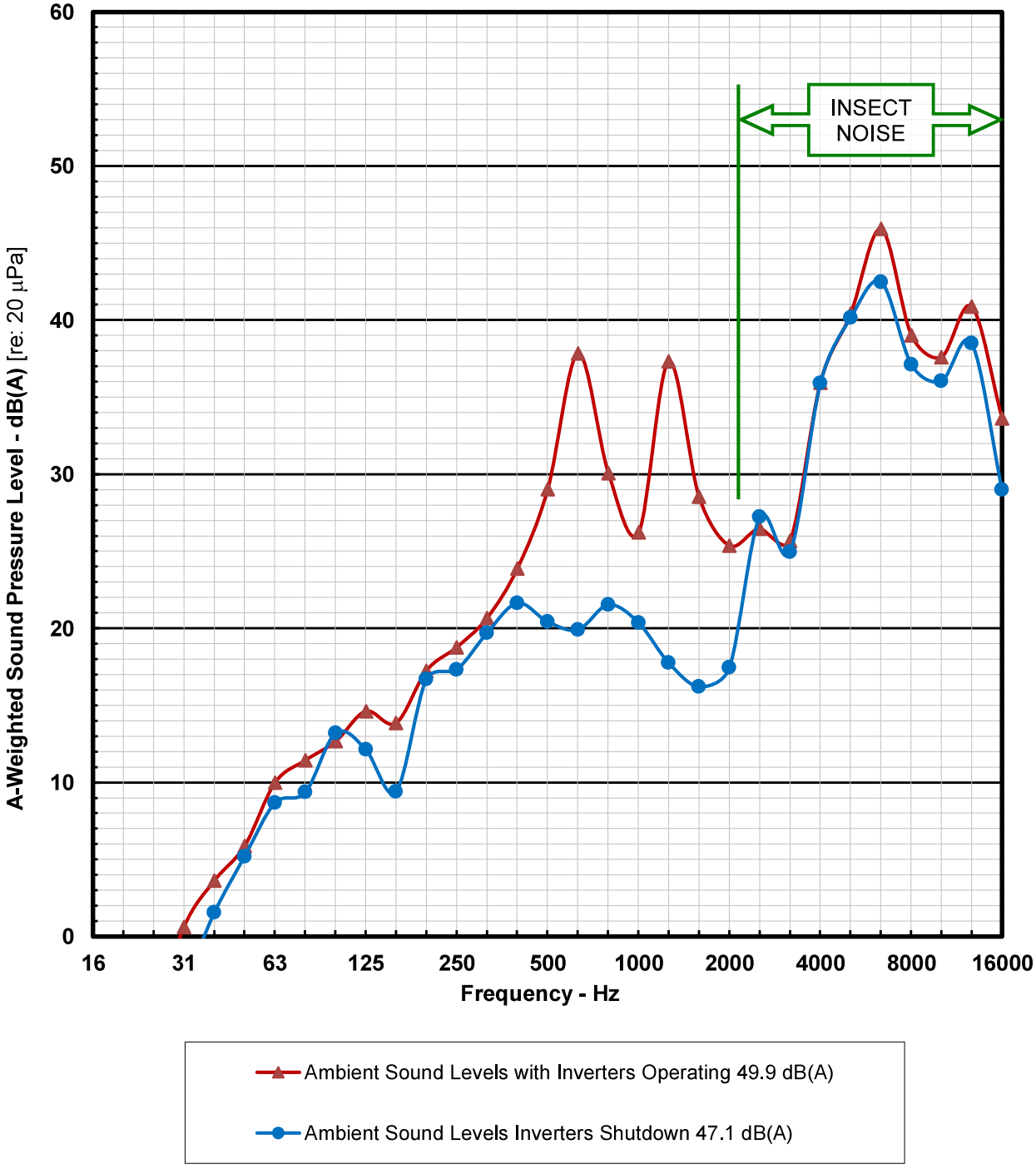


August 12, 2025

EXHIBT 10A

ONE-THIRD OCTAVE BAND SOUND LEVELS OF SOLAR ENERGY FACILITY INVERTER NOISE IMPACT
(ONE-THIRD OCTAVE BANDS)

Study Conducted for: Conway & Cohoctah Townships

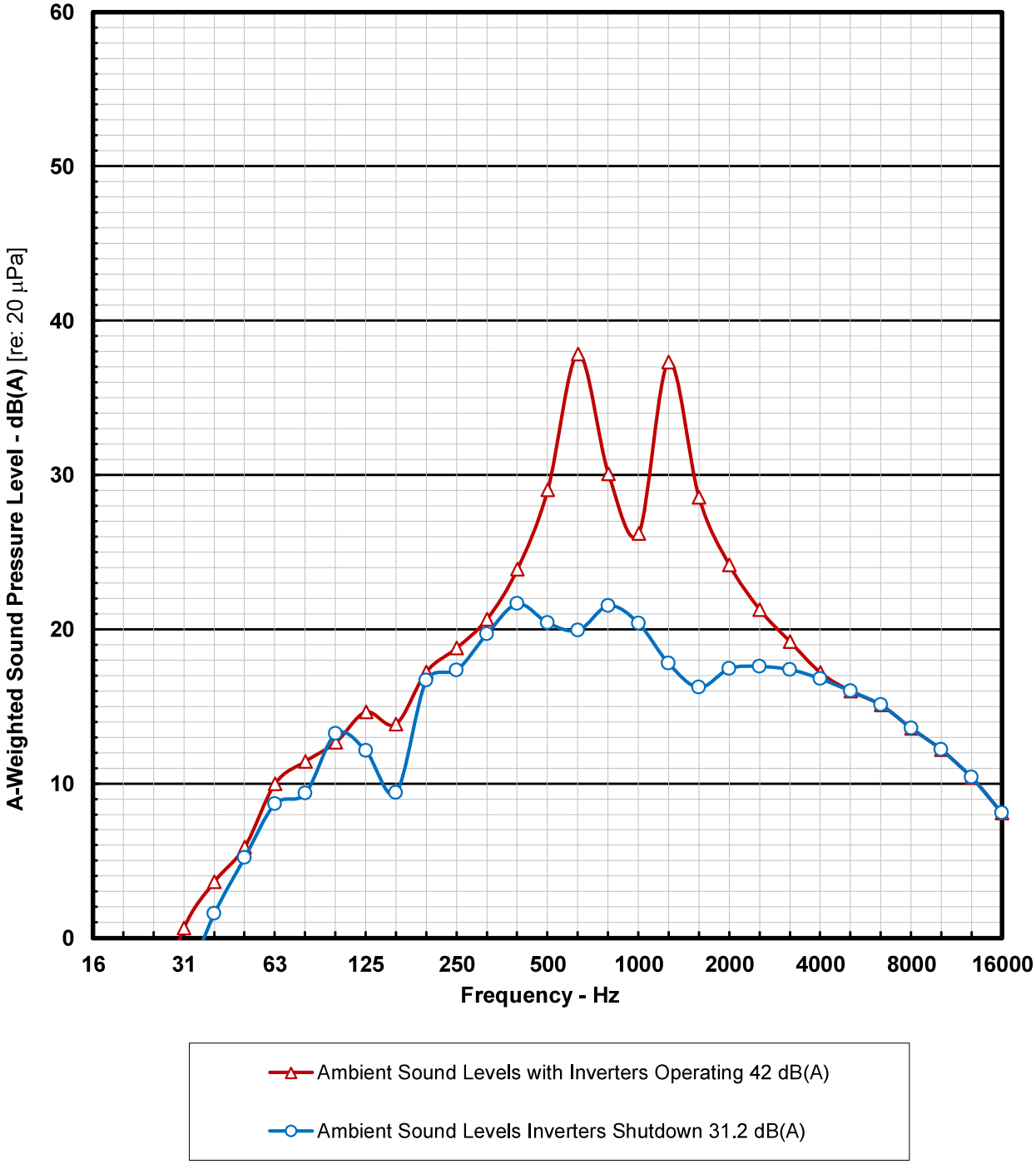


EXHIBT 10B

ONE-THIRD OCTAVE BAND SOUND LEVELS OF SOLAR ENERGY FACILITY INVERTER NOISE IMPACT WITH BIOGENIC SOUNDS REMOVED

(AMBIENT SOUND LEVELS SIMULATED AT 2000 HZ AND ABOVE)

Study Conducted for: Conway & Cohoctah Townships



Atmospheric Conditions at Capital Region Intl. Airport Weather Station

Friday, August 1, 2025

Time	Temp.	Dew Point	Humidity	Wind Dir.	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:53 AM	63 °F	53 °F	70 %	ENE	6 mph	0 mph	29.36 in	0.0 in	Cloudy
1:53 AM	61 °F	53 °F	75 %	NNE	5 mph	0 mph	29.37 in	0.0 in	Mostly Cloudy
2:53 AM	59 °F	53 °F	81 %	N	5 mph	0 mph	29.36 in	0.0 in	Fair
3:53 AM	58 °F	52 °F	81 %	NNW	3 mph	0 mph	29.37 in	0.0 in	Fair
4:53 AM	56 °F	52 °F	87 %	N	3 mph	0 mph	29.37 in	0.0 in	Fair
5:53 AM	56 °F	52 °F	87 %	CALM	0 mph	0 mph	29.39 in	0.0 in	Fair
6:53 AM	55 °F	52 °F	89 %	CALM	0 mph	0 mph	29.41 in	0.0 in	Fair
7:53 AM	58 °F	53 °F	84 %	N	5 mph	0 mph	29.42 in	0.0 in	Fair
8:53 AM	63 °F	54 °F	72 %	NNE	6 mph	0 mph	29.43 in	0.0 in	Fair
9:53 AM	67 °F	55 °F	66 %	NNE	8 mph	0 mph	29.43 in	0.0 in	Fair
10:53 AM	71 °F	54 °F	55 %	NE	9 mph	0 mph	29.44 in	0.0 in	Fair
11:53 AM	72 °F	51 °F	48 %	ENE	13 mph	18 mph	29.45 in	0.0 in	Fair
12:53 PM	74 °F	49 °F	41 %	NE	12 mph	0 mph	29.45 in	0.0 in	Partly Cloudy
1:53 PM	75 °F	50 °F	41 %	ENE	10 mph	0 mph	29.43 in	0.0 in	Partly Cloudy
2:53 PM	75 °F	52 °F	44 %	NNE	8 mph	0 mph	29.44 in	0.0 in	Fair
3:53 PM	74 °F	52 °F	46 %	N	6 mph	0 mph	29.44 in	0.0 in	Partly Cloudy
4:53 PM	75 °F	53 °F	46 %	N	9 mph	0 mph	29.43 in	0.0 in	Fair
5:53 PM	74 °F	51 °F	45 %	VAR	5 mph	0 mph	29.43 in	0.0 in	Partly Cloudy
6:53 PM	74 °F	51 °F	45 %	NNE	7 mph	0 mph	29.41 in	0.0 in	Partly Cloudy
7:53 PM	71 °F	50 °F	47 %	NNE	5 mph	0 mph	29.41 in	0.0 in	Fair
8:53 PM	68 °F	51 °F	55 %	NNE	3 mph	0 mph	29.42 in	0.0 in	Fair
9:53 PM	62 °F	53 °F	72 %	CALM	0 mph	0 mph	29.43 in	0.0 in	Fair
10:53 PM	60 °F	54 °F	80 %	CALM	0 mph	0 mph	29.44 in	0.0 in	Fair
11:53 PM	57 °F	53 °F	87 %	CALM	0 mph	0 mph	29.44 in	0.0 in	Fair

Atmospheric Conditions at Bishop Intl. Airport Weather Station

Friday, August 1, 2025

Time	Temp.	Dew Point	Humidity	Wind Dir.	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:53 AM	63 °F	52 °F	67 %	NNE	7 mph	0 mph	29.44 in	0.0 in	Cloudy
1:53 AM	61 °F	52 °F	72 %	NE	6 mph	0 mph	29.44 in	0.0 in	Partly Cloudy
2:53 AM	59 °F	52 °F	78 %	NNE	6 mph	0 mph	29.44 in	0.0 in	Fair
3:53 AM	58 °F	52 °F	81 %	N	5 mph	0 mph	29.45 in	0.0 in	Fair
4:53 AM	57 °F	52 °F	83 %	N	5 mph	0 mph	29.45 in	0.0 in	Fair
5:53 AM	56 °F	52 °F	87 %	N	3 mph	0 mph	29.47 in	0.0 in	Fair
6:53 AM	55 °F	52 °F	89 %	WNW	5 mph	0 mph	29.48 in	0.0 in	Fair
7:53 AM	60 °F	54 °F	80 %	N	5 mph	0 mph	29.49 in	0.0 in	Fair
8:53 AM	65 °F	55 °F	70 %	N	6 mph	0 mph	29.50 in	0.0 in	Fair
9:53 AM	70 °F	58 °F	65 %	NNE	13 mph	0 mph	29.50 in	0.0 in	Fair
10:53 AM	72 °F	54 °F	53 %	NE	12 mph	0 mph	29.51 in	0.0 in	Fair
11:53 AM	73 °F	53 °F	49 %	NNE	14 mph	21 mph	29.52 in	0.0 in	Mostly Cloudy
12:53 PM	75 °F	52 °F	44 %	ENE	9 mph	0 mph	29.52 in	0.0 in	Fair
1:53 PM	73 °F	50 °F	44 %	NE	7 mph	0 mph	29.51 in	0.0 in	Partly Cloudy
2:53 PM	77 °F	51 °F	40 %		0 mph	0 mph	29.50 in	0.0 in	Fair
3:53 PM	74 °F	51 °F	45 %	ENE	12 mph	0 mph	29.51 in	0.0 in	Mostly Cloudy
4:53 PM	77 °F	52 °F	42 %	VAR	5 mph	0 mph	29.50 in	0.0 in	Partly Cloudy
5:53 PM	76 °F	51 °F	42 %	N	9 mph	0 mph	29.50 in	0.0 in	Fair
6:53 PM	75 °F	51 °F	43 %	ENE	9 mph	0 mph	29.49 in	0.0 in	Mostly Cloudy
7:53 PM	72 °F	51 °F	48 %	NNE	6 mph	0 mph	29.49 in	0.0 in	Fair
8:53 PM	69 °F	50 °F	51 %	NNE	7 mph	0 mph	29.49 in	0.0 in	Fair
9:53 PM	63 °F	51 °F	65 %	E	5 mph	0 mph	29.51 in	0.0 in	Fair
10:53 PM	63 °F	52 °F	67 %	E	3 mph	0 mph	29.52 in	0.0 in	Fair
11:53 PM	60 °F	53 °F	78 %	CALM	0 mph	0 mph	29.52 in	0.0 in	Fair

Atmospheric Conditions at Capital Region Intl. Airport Weather Station

Saturday, August 2, 2025

Time	Temp.	Dew Point	Humidity	Wind Dir.	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:53 AM	57 °F	53 °F	87 %	CALM	0 mph	0 mph	29.44 in	0.0 in	Fair
1:53 AM	56 °F	53 °F	90 %	CALM	0 mph	0 mph	29.44 in	0.0 in	Fair
2:53 AM	55 °F	52 °F	89 %	CALM	0 mph	0 mph	29.44 in	0.0 in	Fair
3:53 AM	54 °F	52 °F	93 %	CALM	0 mph	0 mph	29.44 in	0.0 in	Fair
4:53 AM	53 °F	51 °F	93 %	CALM	0 mph	0 mph	29.45 in	0.0 in	Fair
5:53 AM	52 °F	51 °F	97 %	CALM	0 mph	0 mph	29.45 in	0.0 in	Fair
6:53 AM	52 °F	50 °F	93 %	CALM	0 mph	0 mph	29.46 in	0.0 in	Fair
7:53 AM	56 °F	53 °F	90 %	CALM	0 mph	0 mph	29.45 in	0.0 in	Fair
8:53 AM	61 °F	54 °F	78 %	CALM	0 mph	0 mph	29.46 in	0.0 in	Fair
9:53 AM	67 °F	54 °F	63 %	CALM	0 mph	0 mph	29.46 in	0.0 in	Fair
10:53 AM	71 °F	52 °F	51 %	NNW	3 mph	0 mph	29.45 in	0.0 in	Fair
11:53 AM	73 °F	50 °F	44 %	VAR	3 mph	0 mph	29.45 in	0.0 in	Fair
12:53 PM	75 °F	49 °F	40 %	N	6 mph	0 mph	29.44 in	0.0 in	Fair
1:53 PM	75 °F	47 °F	37 %	N	6 mph	0 mph	29.42 in	0.0 in	Fair
2:53 PM	76 °F	50 °F	40 %		0 mph	0 mph	29.40 in	0.0 in	Fair
3:53 PM	76 °F	49 °F	38 %	CALM	0 mph	0 mph	29.39 in	0.0 in	Fair
4:53 PM	77 °F	51 °F	40 %	NE	6 mph	0 mph	29.38 in	0.0 in	Fair
5:53 PM	76 °F	51 °F	42 %	NE	7 mph	0 mph	29.36 in	0.0 in	Fair
6:53 PM	75 °F	51 °F	43 %	ENE	6 mph	0 mph	29.34 in	0.0 in	Haze
7:53 PM	73 °F	54 °F	51 %	CALM	0 mph	0 mph	29.34 in	0.0 in	Haze
8:53 PM	68 °F	56 °F	65 %	CALM	0 mph	0 mph	29.34 in	0.0 in	Haze
9:53 PM	65 °F	56 °F	73 %	CALM	0 mph	0 mph	29.34 in	0.0 in	Fair
10:53 PM	63 °F	54 °F	72 %	CALM	0 mph	0 mph	29.33 in	0.0 in	Fair
11:53 PM	60 °F	56 °F	86 %	CALM	0 mph	0 mph	29.33 in	0.0 in	Fair

Atmospheric Conditions at Bishop Intl. Airport Weather Station

Saturday, August 2, 2025

Time	Temp.	Dew Point	Humidity	Wind Dir.	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:53 AM	57 °F	53 °F	87 %	SSE	3 mph	0 mph	29.52 in	0.0 in	Fair
1:53 AM	56 °F	53 °F	90 %	CALM	0 mph	0 mph	29.52 in	0.0 in	Fair
2:53 AM	54 °F	52 °F	93 %	CALM	0 mph	0 mph	29.51 in	0.0 in	Fair
3:53 AM	52 °F	51 °F	97 %	CALM	0 mph	0 mph	29.52 in	0.0 in	Fair
4:53 AM	53 °F	51 °F	93 %	CALM	0 mph	0 mph	29.53 in	0.0 in	Fair
5:53 AM	52 °F	51 °F	97 %	CALM	0 mph	0 mph	29.53 in	0.0 in	Fair
6:53 AM	50 °F	49 °F	96 %	CALM	0 mph	0 mph	29.53 in	0.0 in	Fair
7:53 AM	55 °F	54 °F	96 %	CALM	0 mph	0 mph	29.53 in	0.0 in	Fair
8:53 AM	60 °F	56 °F	86 %	CALM	0 mph	0 mph	29.53 in	0.0 in	Fair
9:53 AM	66 °F	58 °F	75 %	CALM	0 mph	0 mph	29.53 in	0.0 in	Fair
10:53 AM	72 °F	55 °F	55 %	CALM	0 mph	0 mph	29.53 in	0.0 in	Fair
11:53 AM	75 °F	51 °F	43 %	VAR	5 mph	0 mph	29.52 in	0.0 in	Fair
12:53 PM	76 °F	53 °F	45 %	VAR	3 mph	0 mph	29.51 in	0.0 in	Fair
1:53 PM	76 °F	51 °F	42 %	N	5 mph	0 mph	29.49 in	0.0 in	Fair
2:53 PM	77 °F	54 °F	45 %	VAR	6 mph	0 mph	29.48 in	0.0 in	Fair
3:53 PM	78 °F	54 °F	43 %	N	9 mph	0 mph	29.46 in	0.0 in	Fair
4:53 PM	77 °F	52 °F	42 %	VAR	3 mph	0 mph	29.45 in	0.0 in	Haze
5:53 PM	77 °F	54 °F	45 %	CALM	0 mph	0 mph	29.44 in	0.0 in	Fair
6:53 PM	76 °F	54 °F	46 %	NNW	3 mph	0 mph	29.42 in	0.0 in	Fair
7:53 PM	74 °F	54 °F	50 %	N	3 mph	0 mph	29.42 in	0.0 in	Fair
8:53 PM	69 °F	59 °F	70 %	CALM	0 mph	0 mph	29.42 in	0.0 in	Fair
9:53 PM	64 °F	58 °F	80 %	CALM	0 mph	0 mph	29.42 in	0.0 in	Fair
10:53 PM	61 °F	57 °F	87 %	CALM	0 mph	0 mph	29.42 in	0.0 in	Fair
11:53 PM	61 °F	57 °F	87 %	CALM	0 mph	0 mph	29.41 in	0.0 in	Fair

Atmospheric Conditions at Capital Region Intl. Airport Weather Station

Monday, August 4, 2025

Time	Temp.	Dew Point	Humidity	Wind Dir.	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:53 AM	62 °F	59 °F	90 %	CALM	0 mph	0 mph	29.25 in	0.0 in	Mostly Cloudy
1:53 AM	61 °F	58 °F	90 %	CALM	0 mph	0 mph	29.25 in	0.0 in	Fair
2:53 AM	60 °F	58 °F	93 %	CALM	0 mph	0 mph	29.25 in	0.0 in	Fair
3:53 AM	58 °F	56 °F	93 %	CALM	0 mph	0 mph	29.25 in	0.0 in	Fair
4:53 AM	58 °F	56 °F	93 %	CALM	0 mph	0 mph	29.26 in	0.0 in	Fair
5:53 AM	57 °F	56 °F	96 %	ENE	3 mph	0 mph	29.27 in	0.0 in	Mist
6:44 AM	56 °F	55 °F	97 %	CALM	0 mph	0 mph	29.27 in	0.0 in	Mist
6:53 AM	57 °F	56 °F	96 %	CALM	0 mph	0 mph	29.27 in	0.0 in	Mist
7:08 AM	57 °F	56 °F	96 %	CALM	0 mph	0 mph	29.27 in	0.0 in	Mist
7:53 AM	59 °F	57 °F	93 %	CALM	0 mph	0 mph	29.27 in	0.0 in	Mist
8:53 AM	66 °F	59 °F	78 %	CALM	0 mph	0 mph	29.29 in	0.0 in	Fair
9:53 AM	72 °F	60 °F	66 %	E	5 mph	0 mph	29.29 in	0.0 in	Haze
10:53 AM	75 °F	57 °F	53 %	NNE	6 mph	0 mph	29.29 in	0.0 in	Haze
11:53 AM	76 °F	57 °F	52 %	ENE	9 mph	0 mph	29.29 in	0.0 in	Haze
12:53 PM	78 °F	53 °F	42 %	VAR	7 mph	0 mph	29.28 in	0.0 in	Fair
1:53 PM	79 °F	54 °F	42 %	SE	6 mph	0 mph	29.28 in	0.0 in	Fair
2:53 PM	79 °F	54 °F	42 %	SE	7 mph	0 mph	29.27 in	0.0 in	Fair
3:53 PM	79 °F	55 °F	44 %	ENE	3 mph	0 mph	29.27 in	0.0 in	Mostly Cloudy
4:53 PM	79 °F	57 °F	47 %	ENE	6 mph	0 mph	29.25 in	0.0 in	Fair
5:53 PM	79 °F	59 °F	50 %	NE	8 mph	0 mph	29.25 in	0.0 in	Fair
6:53 PM	77 °F	60 °F	56 %	NE	3 mph	0 mph	29.25 in	0.0 in	Partly Cloudy
7:53 PM	76 °F	61 °F	60 %	NE	5 mph	0 mph	29.25 in	0.0 in	Partly Cloudy
8:53 PM	73 °F	61 °F	66 %	NE	3 mph	0 mph	29.26 in	0.0 in	Haze
9:53 PM	70 °F	62 °F	76 %	NE	5 mph	0 mph	29.27 in	0.0 in	Partly Cloudy
10:53 PM	69 °F	61 °F	75 %	ENE	6 mph	0 mph	29.28 in	0.0 in	Cloudy
11:53 PM	68 °F	60 °F	76 %	ENE	6 mph	0 mph	29.29 in	0.0 in	Haze

Atmospheric Conditions at Bishop Intl. Airport Weather Station

Monday, August 4, 2025

Time	Temp.	Dew Point	Humidity	Wind Dir.	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:53 AM	62 °F	59 °F	90 %	CALM	0 mph	0 mph	29.34 in	0.0 in	Fair
1:53 AM	61 °F	58 °F	90 %	CALM	0 mph	0 mph	29.34 in	0.0 in	Fair
2:53 AM	57 °F	56 °F	96 %	CALM	0 mph	0 mph	29.34 in	0.0 in	Haze
3:07 AM	60 °F	59 °F	96 %	CALM	0 mph	0 mph	29.34 in	0.0 in	Haze
3:53 AM	59 °F	58 °F	96 %	CALM	0 mph	0 mph	29.35 in	0.0 in	Haze
4:53 AM	56 °F	55 °F	97 %	CALM	0 mph	0 mph	29.35 in	0.0 in	Haze
5:51 AM	54 °F	54 °F	100 %	CALM	0 mph	0 mph	29.36 in	0.0 in	Haze
6:07 AM	56 °F	56 °F	100 %	S	3 mph	0 mph	29.37 in	0.0 in	Haze
6:20 AM	56 °F	55 °F	97 %	CALM	0 mph	0 mph	29.37 in	0.0 in	Haze
6:43 AM	56 °F	55 °F	97 %	CALM	0 mph	0 mph	29.37 in	0.0 in	Haze
6:49 AM	57 °F	57 °F	100 %	CALM	0 mph	0 mph	29.36 in	0.0 in	Haze
7:53 AM	60 °F	59 °F	96 %	CALM	0 mph	0 mph	29.37 in	0.0 in	Haze
8:53 AM	67 °F	62 °F	84 %	CALM	0 mph	0 mph	29.37 in	0.0 in	Haze
9:53 AM	73 °F	61 °F	66 %	ENE	5 mph	0 mph	29.38 in	0.0 in	Fair
10:53 AM	76 °F	61 °F	60 %	E	5 mph	0 mph	29.39 in	0.0 in	Haze
11:53 AM	77 °F	60 °F	56 %	CALM	0 mph	0 mph	29.39 in	0.0 in	Haze
12:53 PM	79 °F	59 °F	50 %	VAR	3 mph	0 mph	29.38 in	0.0 in	Haze
1:53 PM	80 °F	60 °F	50 %	E	8 mph	0 mph	29.37 in	0.0 in	Haze
2:53 PM	80 °F	61 °F	52 %	E	8 mph	0 mph	29.36 in	0.0 in	Haze
3:53 PM	81 °F	61 °F	50 %	ESE	9 mph	0 mph	29.35 in	0.0 in	Haze
4:53 PM	80 °F	58 °F	47 %	ESE	9 mph	0 mph	29.35 in	0.0 in	Haze
5:53 PM	80 °F	58 °F	47 %	E	7 mph	0 mph	29.35 in	0.0 in	Haze
6:53 PM	78 °F	60 °F	54 %	E	8 mph	0 mph	29.34 in	0.0 in	Fair
7:53 PM	76 °F	62 °F	62 %	ESE	7 mph	0 mph	29.35 in	0.0 in	Smoke
8:53 PM	74 °F	60 °F	62 %	E	7 mph	0 mph	29.36 in	0.0 in	Smoke
9:53 PM	72 °F	61 °F	68 %	ENE	10 mph	0 mph	29.37 in	0.0 in	Smoke
10:53 PM	70 °F	59 °F	68 %	E	9 mph	0 mph	29.39 in	0.0 in	Smoke
11:53 PM	67 °F	59 °F	76 %	E	7 mph	0 mph	29.39 in	0.0 in	Haze

Atmospheric Conditions at Capital Region Intl. Airport Weather Station

Tuesday, August 5, 2025

Time	Temp.	Dew Point	Humidity	Wind Dir.	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:53 AM	66 °F	60 °F	81 %	ENE	6 mph	0 mph	29.30 in	0.0 in	Haze
1:53 AM	65 °F	60 °F	84 %	CALM	0 mph	0 mph	29.31 in	0.0 in	Cloudy
2:53 AM	63 °F	60 °F	90 %	NNE	3 mph	0 mph	29.31 in	0.0 in	Fair
3:53 AM	62 °F	59 °F	90 %	CALM	0 mph	0 mph	29.31 in	0.0 in	Fair
4:53 AM	60 °F	58 °F	93 %	CALM	0 mph	0 mph	29.31 in	0.0 in	Fair
5:53 AM	60 °F	57 °F	90 %	NNE	3 mph	0 mph	29.32 in	0.0 in	Mostly Cloudy
6:53 AM	61 °F	58 °F	90 %	CALM	0 mph	0 mph	29.34 in	0.0 in	Mist
7:53 AM	61 °F	59 °F	93 %	NNE	3 mph	0 mph	29.35 in	0.0 in	Mist
8:53 AM	65 °F	61 °F	87 %	NNE	3 mph	0 mph	29.37 in	0.0 in	Haze
9:53 AM	69 °F	61 °F	75 %	NE	6 mph	0 mph	29.37 in	0.0 in	Fair
10:53 AM	74 °F	59 °F	59 %	NE	5 mph	0 mph	29.37 in	0.0 in	Haze
11:53 AM	77 °F	59 °F	54 %	NE	9 mph	0 mph	29.37 in	0.0 in	Haze
12:53 PM	80 °F	61 °F	52 %	ENE	9 mph	0 mph	29.36 in	0.0 in	Haze
1:53 PM	82 °F	60 °F	47 %	ENE	7 mph	0 mph	29.35 in	0.0 in	Haze
2:53 PM	81 °F	59 °F	47 %	ENE	13 mph	17 mph	29.34 in	0.0 in	Haze
3:53 PM	83 °F	59 °F	44 %	NNE	8 mph	18 mph	29.33 in	0.0 in	Haze
4:53 PM	80 °F	60 °F	50 %	NNE	8 mph	0 mph	29.32 in	0.0 in	Haze
5:53 PM	81 °F	61 °F	50 %	NE	12 mph	0 mph	29.32 in	0.0 in	Haze
6:53 PM	77 °F	64 °F	64 %	NNE	10 mph	0 mph	29.33 in	0.0 in	Haze
7:53 PM	74 °F	65 °F	73 %	N	6 mph	0 mph	29.33 in	0.0 in	Haze
8:53 PM	72 °F	64 °F	76 %	NNE	5 mph	0 mph	29.34 in	0.0 in	Haze
9:53 PM	72 °F	61 °F	68 %	NE	8 mph	0 mph	29.35 in	0.0 in	Mostly Cloudy
10:53 PM	68 °F	60 °F	76 %	NE	9 mph	0 mph	29.36 in	0.0 in	Fair
11:53 PM	68 °F	62 °F	81 %	ENE	7 mph	0 mph	29.36 in	0.0 in	Cloudy

Atmospheric Conditions at Bishop Intl. Airport Weather Station

Tuesday, August 5, 2025

Time	Temp.	Dew Point	Humidity	Wind Dir.	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:53 AM	65 °F	59 °F	81 %	E	7 mph	0 mph	29.40 in	0.0 in	Haze
1:53 AM	64 °F	59 °F	84 %	E	3 mph	0 mph	29.40 in	0.0 in	Haze
2:53 AM	63 °F	60 °F	90 %	ENE	6 mph	0 mph	29.40 in	0.0 in	Fair
3:53 AM	62 °F	60 °F	93 %	E	5 mph	0 mph	29.40 in	0.0 in	Fair
4:53 AM	60 °F	59 °F	96 %	E	5 mph	0 mph	29.41 in	0.0 in	Fair
5:53 AM	61 °F	59 °F	93 %	E	6 mph	0 mph	29.41 in	0.0 in	Fair
6:53 AM	62 °F	60 °F	93 %	NNE	5 mph	0 mph	29.43 in	0.0 in	Mist
7:53 AM	65 °F	62 °F	90 %	NNE	5 mph	0 mph	29.43 in	0.0 in	Mist
8:53 AM	69 °F	63 °F	81 %	NE	9 mph	0 mph	29.44 in	0.0 in	Fair
9:53 AM	73 °F	63 °F	71 %		0 mph	0 mph	29.44 in	0.0 in	Haze
10:53 AM	76 °F	63 °F	64 %		0 mph	0 mph	29.45 in	0.0 in	Fair
11:53 AM	78 °F	62 °F	58 %		0 mph	0 mph	29.45 in	0.0 in	Fair
12:53 PM	82 °F	64 °F	54 %		0 mph	0 mph	29.44 in	0.0 in	Fair
1:53 PM	83 °F	63 °F	51 %	NE	9 mph	0 mph	29.43 in	0.0 in	Fair
2:53 PM	83 °F	63 °F	51 %	ENE	12 mph	0 mph	29.43 in	0.0 in	Mostly Cloudy
3:53 PM	81 °F	62 °F	52 %	NE	8 mph	0 mph	29.42 in	0.0 in	Mostly Cloudy
4:53 PM	83 °F	62 °F	49 %	ENE	15 mph	22 mph	29.41 in	0.0 in	Partly Cloudy
5:53 PM	83 °F	61 °F	47 %	E	13 mph	0 mph	29.41 in	0.0 in	Mostly Cloudy
6:53 PM	80 °F	58 °F	47 %	E	10 mph	0 mph	29.41 in	0.0 in	Mostly Cloudy
7:53 PM	77 °F	59 °F	54 %	ESE	6 mph	0 mph	29.43 in	0.0 in	Cloudy
8:53 PM	75 °F	59 °F	57 %	ESE	7 mph	0 mph	29.43 in	0.0 in	Cloudy
9:53 PM	75 °F	60 °F	60 %	ENE	7 mph	0 mph	29.43 in	0.0 in	Cloudy
10:53 PM	72 °F	63 °F	73 %	E	8 mph	0 mph	29.44 in	0.0 in	Partly Cloudy
11:53 PM	67 °F	62 °F	84 %	E	3 mph	0 mph	29.44 in	0.0 in	Fair

Atmospheric Conditions at Bishop Intl. Airport Weather Station

Saturday, August 9, 2025

Time	Temp.	Dew Point	Humidity	Wind Dir.	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:53 AM	73 °F	68 °F	84 %	SSE	6 mph	0 mph	29.27 in	0.0 in	Fair
1:53 AM	74 °F	69 °F	85 %	S	6 mph	0 mph	29.27 in	0.0 in	Fair
2:53 AM	73 °F	69 °F	87 %	S	7 mph	0 mph	29.27 in	0.0 in	Fair
3:53 AM	73 °F	69 °F	87 %	S	6 mph	0 mph	29.27 in	0.0 in	Fair
4:53 AM	73 °F	69 °F	87 %	S	5 mph	0 mph	29.27 in	0.0 in	Fair
5:53 AM	73 °F	68 °F	84 %	SSW	6 mph	0 mph	29.29 in	0.0 in	Fair
6:53 AM	73 °F	68 °F	84 %	SSW	5 mph	0 mph	29.31 in	0.0 in	Fair
7:53 AM	74 °F	68 °F	82 %	SSW	6 mph	0 mph	29.29 in	0.0 in	Fair
8:53 AM	77 °F	69 °F	76 %	S	8 mph	0 mph	29.29 in	0.0 in	Fair
9:53 AM	81 °F	70 °F	69 %	S	8 mph	0 mph	29.26 in	0.0 in	Fair
10:53 AM	84 °F	71 °F	65 %	SSW	9 mph	18 mph	29.26 in	0.0 in	Fair
11:53 AM	87 °F	71 °F	59 %	SSW	12 mph	0 mph	29.26 in	0.0 in	Fair
12:53 PM	88 °F	70 °F	55 %	SSW	9 mph	0 mph	29.27 in	0.0 in	Partly Cloudy
1:53 PM	90 °F	70 °F	52 %	S	7 mph	0 mph	29.26 in	0.0 in	Fair
2:53 PM	89 °F	69 °F	52 %	SSW	8 mph	0 mph	29.27 in	0.0 in	Partly Cloudy
3:53 PM	89 °F	69 °F	52 %	SSW	13 mph	0 mph	29.26 in	0.0 in	Mostly Cloudy
4:53 PM	88 °F	69 °F	53 %	SSW	10 mph	0 mph	29.24 in	0.0 in	Fair
5:53 PM	89 °F	70 °F	53 %	SSW	8 mph	0 mph	29.23 in	0.0 in	Fair
6:53 PM	88 °F	69 °F	53 %	SSW	8 mph	0 mph	29.22 in	0.0 in	Fair
7:53 PM	85 °F	70 °F	61 %	S	8 mph	0 mph	29.23 in	0.0 in	Fair
8:53 PM	82 °F	70 °F	67 %	SSW	6 mph	0 mph	29.26 in	0.0 in	Fair
9:53 PM	76 °F	69 °F	79 %	S	7 mph	0 mph	29.27 in	0.0 in	Fair
10:53 PM	78 °F	70 °F	76 %	S	8 mph	0 mph	29.25 in	0.0 in	Fair
11:53 PM	77 °F	69 °F	76 %	S	7 mph	0 mph	29.26 in	0.0 in	Fair

Atmospheric Conditions at Bishop Intl. Airport Weather Station

Tuesday, August 12, 2025

Time	Temp.	Dew Point	Humidity	Wind Dir.	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:53 AM	72 °F	68 °F	87 %	CALM	0 mph	0 mph	29.19 in	0.0 in	Fair
1:53 AM	73 °F	69 °F	87 %	SW	5 mph	0 mph	29.19 in	0.0 in	Fair
2:53 AM	72 °F	67 °F	84 %	SW	3 mph	0 mph	29.19 in	0.0 in	Fair
3:53 AM	73 °F	69 °F	87 %	CALM	0 mph	0 mph	29.20 in	0.0 in	Fair
4:53 AM	71 °F	70 °F	96 %	S	5 mph	0 mph	29.18 in	0.0 in	Fair
5:53 AM	72 °F	70 °F	93 %	SSW	7 mph	0 mph	29.18 in	0.0 in	Fair
6:53 AM	72 °F	69 °F	91 %	WSW	5 mph	0 mph	29.18 in	0.0 in	Fair
7:53 AM	73 °F	70 °F	90 %	WSW	3 mph	0 mph	29.19 in	0.0 in	Fair
8:53 AM	78 °F	71 °F	79 %	S	7 mph	0 mph	29.18 in	0.0 in	Partly Cloudy
9:08 AM	0 °F	0 °F	0 %	SSW	6 mph	0 mph	29.17 in	0.0 in	Fair
9:53 AM	0 °F	0 °F	0 %	SSW	6 mph	0 mph	29.17 in	0.0 in	Fair
10:53 AM	0 °F	0 °F	0 %	WSW	9 mph	0 mph	29.17 in	0.0 in	Fair
11:53 AM	87 °F	71 °F	59 %	WSW	8 mph	18 mph	29.16 in	0.0 in	Mostly Cloudy
12:50 PM	79 °F	68 °F	69 %	NNW	15 mph	26 mph	29.17 in	0.0 in	Cloudy
12:53 PM	78 °F	68 °F	71 %	NNW	13 mph	24 mph	29.17 in	0.0 in	Cloudy
1:34 PM	76 °F	72 °F	87 %	NNE	8 mph	0 mph	29.15 in	0.1 in	Rain
1:53 PM	78 °F	72 °F	81 %	N	7 mph	0 mph	29.14 in	0.1 in	Thunder in the Vicinity
2:10 PM	79 °F	71 °F	77 %	NNW	7 mph	0 mph	29.14 in	0.0 in	Mostly Cloudy
2:53 PM	80 °F	72 °F	76 %	NE	5 mph	0 mph	29.12 in	0.0 in	Fair
3:53 PM	83 °F	70 °F	65 %	CALM	0 mph	0 mph	29.11 in	0.0 in	Fair
4:53 PM	85 °F	70 °F	61 %	CALM	0 mph	0 mph	29.07 in	0.0 in	Fair
5:53 PM	81 °F	68 °F	65 %	S	18 mph	28 mph	29.08 in	0.0 in	Thunder

Review of State Noise Limits Pertaining to Solar Fields*

State	dBA limit	Reference Point	Link
Indiana	50	outer wall of non-participating dwelling	https://www.in.gov/oed/files/Handout-Commercial-Solar-Energy-Ready-Community-2023.9.pdf
Michigan	55	outer wall of non-participating dwelling	https://legislature.mi.gov/Home/RenderDoc?objectName=mcl-295-2008-8.
New York	45	outside of non-participating residence	https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B61702B1D-BA86-42C7-B980-54D671323C06%7D
Ohio	40	non-participating sensitive receptor	https://codes.ohio.gov/ohio-administrative-code/rule-4906-4-09
Oregon	36	see code for details	https://www.oregon.gov/deq/rulemaking/pages/noise2024.aspx

*Note: Other States may have general noise/nuisance limits. This research pertains specifically to noise emitted by solar fields.

Draft Position Statement on Noise Limits Under Public Act 233 of 2023 — UPDATED

Executive Summary

Public Act 233 (PA 233) sets a statewide modeled limit of **55 dBA Leq (1-hour)** at the nearest nonparticipating dwelling. Current public-health evidence shows this level is **not sufficiently protective**, particularly in quiet rural communities or for vulnerable groups (infants, children, adolescents). The **World Health Organization (WHO)** links environmental noise well below 55 dBA with sleep disturbance, annoyance, cardiovascular effects, and cognitive impacts in children (Exhibit A).

New national and international evidence — including the **Medscape chronic disease review** — links environmental noise to hypertension, metabolic dysfunction, cardiovascular disease, and chronic stress-mediated inflammation (Exhibit B).

Comparative siting practice further demonstrates that Michigan's statewide limit is unusually high. **Multiple states set lower limits** for solar facilities (40–50 dBA), and several use setbacks and receptor-based protections (Exhibit F). Additionally, a **large body of Michigan municipalities** has independently adopted limits between **30–45 dBA**, reflecting a much more protective approach aligned with rural acoustics and WHO health guidelines (Exhibit G).

Given the combined evidence, we recommend **≤40 dBA daytime / ≤35 dBA nighttime** limits at nonparticipating dwellings, reductions for tonal noise, and enhanced protections for schools, daycares, and other sensitive uses.

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1) Public-Health Evidence: Harms Occur Below 55 dBA

WHO estimates over one million healthy-life years lost annually in western Europe due to chronic environmental noise, especially from sleep disturbance and cardiovascular disease (Exhibit A). Noise impacts occur even within the **40–55 dB** range, with **30–40 dB** affecting vulnerable populations at night.

Recent clinical summaries (Medscape) identify environmental noise as a **multi-system chronic stressor**, contributing to:
• hypertension
• cardiovascular disease
• metabolic disorders
• sleep fragmentation
• stress-related inflammation
(Exhibit B)

These findings support limits **well below** PA 233's 55 dBA.

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2) Comparative Practice: New York's §94-c Sets More Protective Limits

New York's §94-c renewable-siting framework requires **≤45 dBA** long-term levels at nonparticipating residences, supported by ISO-based modeling and seasonal baseline monitoring (Exhibit C).

State-level comparisons also show Michigan as an outlier:

- **Indiana — 50 dBA** at nonparticipating dwellings
- **Michigan — 55 dBA**
- **New York — 45 dBA**
- **Ohio — 40 dBA** for sensitive receptors
- **Oregon — 36 dBA** (varies; code-based)
  (Exhibit F)

Michigan's 55 dBA limit is one of the least protective nationally.

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3) Children & Adolescents: Unique Vulnerabilities Demand Stronger Protections

According to the American Academy of Pediatrics, noise affects children beginning in infancy and accumulates across development, interfering with:
• cognition
• attention
• reading and memory
• speech comprehension
• sleep
• physiologic stress
(Exhibit D)

Classroom standards (<35 dBA ANSI; <30 dBA ASHA) further illustrate the need for quieter environments—levels incompatible with a 55 dBA project limit.

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4) Why Michigan's Rural Context Requires Lower Numeric Limits

Rural Michigan townships commonly exhibit **L90 backgrounds in the mid-20s to low-30s dBA**, and filtered daytime ambients around **40 dBA**. Thus a 55 dBA limit permits **+15 to +25 dB** elevation above ambient—an intrusive change to the soundscape (Exhibit E).

Additionally, **municipal data across Michigan** show that townships overwhelmingly choose **30–45 dBA** maximum limits for solar noise when setting their own ordinances. Examples include:

- Montcalm Township: **40 dBA Lmax**
- Marion Township: **40 dBA day / 35 dBA night**
- Almer Township: **40 dBA Lmax, instantaneous**
- Garfield Township: **45 dBA Lmax at center-sited inverters**
- Deerfield Township: **40 dBA Lmax**
- Boone County (IN): **45 dBA property line**
- Shiawassee County: **40 dBA Lmax**
  (Exhibit G)

These local choices demonstrate that **55 dBA is inconsistent with common Michigan rural practice** and with public-health evidence.

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5) Policy Recommendations

- **Residential Limits:**
  ≤ **40 dBA** (day) / ≤ **35 dBA** (night) at nonparticipating dwellings; apply a **5 dB tonal penalty**.
- **Comparative Benchmark:**
  ≤ **45 dBA** as an upper bound, consistent with New York §94-c.
- **Sensitive Receptors:**
  ≤ **35 dBA day / 30 dBA night** for schools, daycares, healthcare sites.
- **Modeling & Compliance:**
  Require seasonal baseline monitoring, ISO-based propagation modeling, cumulative impact assessment, and transparent mitigation documentation.
- **Mitigation Toolkit:**
  Acoustic enclosures; barriers; equipment orientation away from receptors.

References / Exhibits

Exhibit A

World Health Organization. (2011). *Burden of disease from environmental noise: Quantification of healthy life years lost in Europe.*

Exhibit B

Medscape. (2024). *Noise Pollution and Chronic Disease* (Slideshow).

Exhibit C

Resource Systems Group, Inc. (n.d.). *Modeling noise to advance New York's clean energy goals.*

Exhibit D

Balk, S. J., Bochner, R. E., Ramdhanie, M. A., & Reilly, B. K. (2023). *Preventing excessive noise exposure in infants, children, and adolescents. Pediatrics, 152*(5).

Exhibit E

K & S Engineers, LLC. (2025). *Noise impact analysis of the proposed Headlands Solar Energy Facility.*

Exhibit F — State-by-State Noise Limits Table

State-level solar-noise limits including Indiana (50 dBA), Michigan (55 dBA), New York (45 dBA), Ohio (40 dBA), Oregon (36 dBA).
Sourced from your provided state comparison table.

Exhibit G — Municipal Noise Limits Summary

Comprehensive list of Michigan and Indiana township solar-noise limits (30–45 dBA), drawn from email correspondence PDF.
Includes Montcalm, Sidney, Marion, Almer, Garfield, Deerfield, Boone County, Shiawassee, Brady Township, Fort Gratiot, Ingham, Locke, Montrose, Thetford, Venice, and numerous others.

PA 233 Noise Limits — Briefing

Key Ask

Adopt more protective residential noise limits for large renewable energy facilities: Day ≤40 dBA and Night ≤35 dBA at the nearest nonparticipating dwelling; apply tonal penalties and align an upper bound with New York's ≤45 dBA standard.

Why Change Now

• WHO: Noise below 55 dBA is linked with sleep disturbance, annoyance, cardiovascular disease, and cognitive impacts; night-time >55 dB L_night is increasingly dangerous (World Health Organization, 2011).

• Pediatrics: Children are uniquely vulnerable; occupational limits don't protect infants, children, or adolescents; effects start in infancy and are cumulative (Balk et al., 2023).

• Practice: New York §94-c applies ≤45 dBA at homes with rigorous baseline monitoring, ISO-based modeling, and mitigation (Resource Systems Group, n.d.).

What We Propose

1. Limits: Day ≤40 dBA; Night ≤35 dBA at residences; +5 dB tonal penalty or equivalently lower numeric limits when tonality is present; benchmark ≤45 dBA as upper bound; add protections for schools/daycares.

2. Special Protections: Stricter targets near schools, daycares, and healthcare (e.g., Day ≤35 dBA / Night ≤30 dBA).

3. Modeling & Compliance: Seasonal baseline measurements; ISO-based propagation modeling capturing tonality and cumulative sources; transparent reporting and community-facing summaries.

4. Mitigation Toolkit: Quieter equipment specifications; acoustic enclosures/barriers; equipment orientation away from receivers as needed.

Evidence Snapshot

• WHO burden: ≥1,000,000 healthy life-years lost annually in western Europe due to environmental noise; sleep disturbance accounts for the largest share (World Health Organization, 2011).

• Night thresholds: Adverse effects begin in the 40–55 dB L_night band; vulnerable groups are more affected; >55 dB is increasingly dangerous (World Health Organization, 2011).

• Pediatric health & learning: Environmental noise degrades sleep and classroom learning; infants and children require lower background levels; occupational limits are not applicable (Balk et al., 2023).

• Siting practice: New York's ≤45 dBA residential limit is achievable with rigorous modeling/mitigation and provides a defensible benchmark (Resource Systems Group, n.d.).

Executive Summary

Michigan PA233 sets a 55 dBA Leq limit; evidence from WHO, AAP, NY §94-c, and the Headlands Study shows rural ambients far lower and tonal inverter noise exceeding L90 by 16–21 dB. Many Michigan jurisdictions adopt 30–45 dBA limits.

Headlands Solar Study Key Findings (K & S Engineers, LLC., 2025)

• Rural filtered daytime ambients: 36.8–41.3 dBA; L90 backgrounds: 26.3–30.1 dBA.

• Tonal inverter noise at 630 Hz and 1250 Hz measured 40–42 dBA at ~1000 ft.

• Projected inverter sound: 47 dBA at 400 ft; 40 dBA at 940 ft.

USA Solar Noise Limits

• Indiana: 50 dBA; NY: 45 dBA; Ohio: 40 dBA; Oregon: 36 dBA.

Michigan Jurisdiction Noise Limits (Original Metrics)

Examples: Conway: 40/35 Lmax; Cohoctah: 40/35 Lmax; Montcalm: 40 Lmax; Marion: 40/35 Lmax; Garfield: 45 Lmax; Moore: 40 Leq; Deerfield: 40 Lmax; Brady: 40 Lmax; Fort Gratiot: 45 Leq; Leslie: 45 Leq day/40 Leq night; Locke: 40/35 Lmax; Montrose: 40 Leq; Thetford: 45 dBA; Venice: 40 Lmax; Davison: 50 dBA; Iosco: 40/35 Lmax; Macon: 30 dBA.

Recommendations

Adopt ≤40 dBA day / ≤35 dBA night limits; apply tonal penalties; benchmark ≤45 dBA as upper bound; add protections for schools/daycares.

FAQs (for Board/Public)

Q: Won't lower limits block renewable projects?
A: No. Projects in New York routinely meet ≤45 dBA at homes via quieter equipment, strategic siting, and enclosures; similar tools can meet ≤40/35 dBA in low-ambient areas (Resource Systems Group, n.d.).

Q: Why focus on night?
A: Sleep is the primary pathway for health risk. WHO shows large population burdens from sleep disturbance; protecting night-time is the most effective, equitable approach (World Health Organization, 2011).

Q: Why special protections for children?
A: AAP guidance shows children are uniquely susceptible; protections at homes/schools/daycares align with health and education goals (Balk et al., 2023).

References (APA)

Balk, S. J., Bochner, R. E., Ramdhanie, M. A., & Reilly, B. K. (2023). Preventing excessive noise exposure in infants, children, and adolescents. Pediatrics, 152(5), e2023063752.

K & S Engineers, LLC. (2025). *Noise impact analysis of the proposed Headlands Solar Energy Facility (Project No. 2025-029 & 030).* Prepared for Conway & Cohoctah Townships.

Resource Systems Group, Inc. (n.d.). Modeling noise to advance New York's clean energy goals. RSG.

World Health Organization. (2011). Burden of disease from environmental noise: Quantification of healthy life years lost in Europe. WHO Regional Office for Europe.

NOISE LIMITS POSITION

Health Advisory Committee • Public Act 233 (2023)





PURPOSE & POLICY CONTEXT

Why this briefing

Build informed support for adopting and advocating stricter renewable-energy noise limits that better protect Livingston County residents.

Current baseline

Michigan Public Act 233 models a statewide limit of 55 dBA Leq (1-hour) at the nearest nonparticipating dwelling.

Public health context

Evidence shows harms below 55 dBA—especially in quiet rural soundscapes—impacting sleep, cardiovascular stress, and children.



The impacts of noise on health



World Health Organization

- Environmental noise a major public health threat
- Impacts beginning in the 40–55 dBA range and nighttime exposures as low as 30–40 dBA affecting vulnerable groups
- More than 1M healthy life years are lost annually in Western Europe from sleep disturbance, cardiovascular disease, and chronic annoyance.

Exhibit A: World Health Organization. (2011). *Burden of disease from environmental noise: Quantification of healthy life years lost in Europe.*



Medscape Review, 2024

Describes noise as a chronic multisystem stressor linked to the following:

- Hypertension
- Cardiovascular disease
- Metabolic dysfunction
- Inflammation–driven by stress-pathway activation,
- Circadian disruption
- Fragmented sleep from persistent environmental sources

Exhibit B: Medscape. (2024). *Noise Pollution and Chronic Disease* (Slideshow).

CHILD NOISE VULNERABILITY

Developmental Impacts

- Noise affects children from infancy and can disrupt cognition, attention, reading, memory, speech comprehension, sleep, and stress regulation.

Learning Standards

- Classroom guidance targets ≤35 dBA (ANSI) and ≤30 dBA (ASHA), indicating that higher limits—and intermittent or tonal noise—can impair focus and rest.

Recommended Limits

- For sensitive receptors (homes, daycares, playgrounds, healthcare), the committee recommends 35 dBA day and 30 dBA night to protect long-term developmental health.

Exhibit D: Balk, S. J., Bochner, R. E., Ramdhanie, M. A., & Reilly, B. K. (2023). *Preventing excessive noise exposure in infants, children, and adolescents. Pediatrics, 152*(5).



RURAL SOUND LIMITS

Baselines vs community tolerance

Rural baselines are quiet

Michigan rural background or ambient noise often sits in the mid-20s to low-30s dBA (filtered daytime near ~40 dBA).

55 dBA is a large step change

It can allow +15 to +25 dB over the natural soundscape—clearly perceptible and often intrusive.

Local ordinances show preference

Many Michigan townships adopt 30–45 dBA limits (e.g., Montcalm, Marion, Almer, Deerfield), aligning with rural quality-of-life.

Exhibit E: K & S Engineers, LLC. (2025). *Noise impact analysis of the proposed Headlands Solar Energy Facility.*
Exhibit G: **Exhibit G — Municipal Noise Limits Summary**

MICHIGAN VS OTHER STATES

Numeric limits: Michigan is higher

Michigan's 55 dBA statewide limit is less protective than peer states: NY 45 dBA (nonparticipants), IN 50 dBA, OH 40 dBA (sensitive receptors), and OR as low as 36 dBA in some contexts.

Evidence-driven approaches exist

New York's 94-c framework pairs lower thresholds with ISO-based acoustic modeling and seasonal baseline monitoring—reflecting a precautionary, public-health-aligned standard.

Why it matters in rural areas

Lower limits better preserve quiet rural baselines and community character; aligning Michigan with peers can improve trust, reduce conflict, and strengthen evidence-based governance.

Exhibit C Resource Systems Group, Inc. (n.d.). *Modeling noise to advance New York's clean energy goals.*
Exhibit F: **State-by-State Noise Limits Table**



RECOMMENDED NOISE LIMITS

Residences (nonparticipating)

≤40 dBA day, ≤35 dBA night; add a 5 dB penalty for tonal/disruptive noise.

Sensitive receptors

Schools, daycares, healthcare: ≤35 dBA day, ≤30 dBA night.

Modeling & mitigation

Seasonal baseline monitoring; ISO-based modeling; cumulative impacts

Conclusion:

A 55 dBA limit is not a safe threshold for chronic evening/night exposure. Health-protective limits align closer to the Health Advisory Committee recommendation: **40 dBA day** and **35 dBA night** at nonparticipating dwellings.





WHY COUNTY SUPPORT MATTERS

Evidence supports stricter limits

Adverse health effects are documented below 55 dBA, especially with chronic and nighttime exposure. Michigan's current standard is an outlier compared to other states and many municipalities.

County endorsement drives action

Support from the Board of Commissioners and Health Department can shape state discussion, guide implementation, and elevate public health expertise—enabling renewable energy that remains health-protective.

Call to action

Acknowledge the evidence and Livingston County's rural context; endorse stricter noise limits to protect long-term health and set a standard for responsible governance.

References / Exhibits

Exhibit A

World Health Organization. (2011). *Burden of disease from environmental noise: Quantification of healthy life years lost in Europe.*

Exhibit B

Medscape. (2024). *Noise Pollution and Chronic Disease* (Slideshow).

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State-level solar-noise limits including Indiana (50 dBA), Michigan (55 dBA), New York (45 dBA), Ohio (40 dBA), Oregon (36 dBA). Sourced from your provided state comparison table.

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Comprehensive list of Michigan and Indiana township solar-noise limits (30–45 dBA), drawn from email correspondence (from Sarah Porter to Michael Brown Supervisor of Conway County, MI) PDF.
Includes Montcalm, Sidney, Marion, Almer, Garfield, Deerfield, Boone County, Shiawassee, Brady Township, Fort Gratiot, Ingham, Locke, Montrose, Thetford, Venice, and numerous others.

Future Impacts/ considerations- Data Centers

- **Construction noise is loud and continuous**, generated by heavy machinery used to build the facilities.
- **Operational noise comes from diesel generators and HVAC systems**, producing a persistent hum that can be heard by nearby residents and wildlife.
- **Noise levels may exceed 90 decibels**, surpassing the threshold (85 dB) considered harmful to human hearing.
- **Chronic noise exposure contributes to health problems**, including: Hearing loss, Increased stress, Insomnia, Decreased overall quality of life



Pavlinich, E. J. (2026, February 27). *The dangers of data centers*. Environmental Health Project. https://www.environmentalhealthproject.org/post/the-dangers-of-data-centers

Low-Frequency Noise Travel & Ordinance Violations

- Data center HVAC systems produce low-frequency hum that can **travel up to 2.5 miles**, potentially **violating noise ordinances** of 55–60 dB.
- Low-frequency sound is difficult for the brain to filter out, increasing annoyance and physiological stress. **Community-Reported Health Effects**
- Residents near data centers report **stress, sleep disruption, and difficulty sleeping** due to constant background noise. Prolonged construction periods (10–20 years in some regions) add long-term exposure to harmful noise levels. **Noise-Driven School Impacts**
- Noise can disrupt school operations, with research showing **HVAC-generated noise potentially impairing classroom learning environments**.
- Soundproofing one affected elementary school was estimated to cost **$20 million**.



Tao Y, Gao P. Global data center expansion and human health: A call for empirical research. Eco Environ Health. 2025 May 27;4(3):100157. doi: 10.1016/j.eehl.2025.100157. PMID: 40687513; PMCID: PMC12273412.

RESOLUTION **NO:** [Title]

LIVINGSTON COUNTY **DATE:** Click or tap to enter a date.

Resolution Authorizing an Agreement with Emergency Vehicles Plus to Provide a New Ambulance – Emergency Medical Services

WHEREAS, Livingston County EMS has experienced a continued increase in service demand requiring additional ambulances to maintain effective and timely emergency medical response; and

WHEREAS, the department has an opportunity to purchase a new ambulance to expand the fleet, from our current vendor Emergency Vehicles Plus, who is currently under the HGAC contract. This will ensure adequate coverage and improve response times to the community; and

WHEREAS, the addition of this new ambulance aligns with our long-term goals and will bring the department's fleet size closer to the level that has been targeted for several years; and

WHEREAS, the purchase of this ambulance was not included in the 2026 budget, but the department has maintained a sufficient fund balance to allow for this expenditure without negatively impacting operations; and

WHEREAS, the total cost of the new ambulance is estimated to be $399,505, and funds are available within the EMS fund balance to support this purchase.

THEREFORE, BE IT RESOLVED that the Livingston County Board of Commissioners hereby authorizes the purchase of one new ambulance for Livingston County EMS at a total cost not to exceed $399,505.

BE IT FURTHER RESOLVED the Board of Commissioners authorizes any budget amendments or transfers needed to effectuate the above.

# # #

MOVED:
SECONDED:
CARRIED:

LIVINGSTON COUNTY EMS

1911 Tooley Road ✱ Howell MI 48855
Business (517) 546-6220 ✱ Fax (517) 546-6788 ✱ Emergency 911

DAVID FELDPAUSCH
DIRECTOR
dfeldpausch@livgov.com

AMY CHAPMAN
DEPUTY DIRECTOR
achapman@livgov.com

Memorandum

To: **Livingston County Board of Commissioners**

From: **Amy Chapman, EMS Deputy Director**

Date: **March 30, 2026**

Re: **New Ambulance Purchase**

For your consideration, we would like to move forward with the purchase of a new ambulance to meet growing service demands. Over the past several years, we've worked diligently to maintain a healthy EMS fund balance, ensuring we're prepared for important investments like this one.

Our current fund balance sits at $7.4 million, or 44.6% of our 50% goal, a strong position that reflects careful planning and responsible budgeting. This stability allows us to move ahead with the purchase of $399,504.45 without straining our day-to-day operations or future plans.

With the addition of this ambulance, we will be much closer to the fleet size we've been aiming for. This will add the 24th ambulance to the fleet with 25 ambulances being our goal. By expanding our ambulance fleet, mileage is distributed more evenly across all vehicles, leading to lower maintenance cost and extended service life. It's a significant milestone after many years of striving to catch up with community growth and service demand. This purchase will help us maintain reliable response times, improve service coverage, and continue meeting the expectations of our residents.

Thank you for your continued support as we continue to build a stronger, more responsive EMS system for Livingston County.

EMERGENCY VEHICLES PLUS

3/12/26

Dear Livingston County EMS,

Thank you for the opportunity to provide you with quotes on your upcoming ambulance purchase. We are proud to present to you the following quotes on our Wheeled Coach products. EV Plus is proud of our REV Corporation affiliation and are pleased to offer you this product and our wide range of services to our customers. From parts and technical support, to our Mobile Service Technicians, we are committed to our customers for the duration.

The following units are proposed for your consideration. Please note, these units include everything listed in the forthcoming work orders and Sales Drawings, plus the following; Transportation to your facility upon completion, AliArc bumper/grille guard, your graphics, Modem (Sierra Wireless XR80), Dell Rugged Laptop and Havis Dock, and the changes you desired. Prices are as follows

2026 Wheeled Coach Type III Ford E450 7.3 litre V8 gas, 6-speed transmission 170” x 72” x 98” wide

$323,111.00

(
Deduct for Dell Rugged Laptop and Havis Dock

$1,900.00

Subtotal

$321,211.00

Stryker Power Pro II and Power Load, installed

$78,293.45

Total

$399,504.45

Terms; 10% deposit with order, balance C.O.D. upon acceptance at delivery.
All discounts and rebates have already been deducted.

Thank you in advance for your consideration. Should you have any questions or concerns, please feel free to contact me.

Sincerely,

Scott A. Schalow, Ambulance Sales Manager, Emergency Vehicles Plus, Holland, MI

670 East 16th St. Holland, MI 49423
1-800-320-9749 / 616-396-1391 Fax

EMERGENCY VEHICLES PLUS



670 East 16th St. Holland, MI 49423
1-800-320-9749 / 616-396-1391 Fax

RESOLUTION **NO:** [Title]

LIVINGSTON COUNTY **DATE:** Click or tap to enter a date.

Resolution Authorizing an Agreement with Bound Tree Medical to Provide Medical Supplies – Emergency Medical Services

WHEREAS, the EMS Department has a continuing need to purchase medical supplies necessary for patient care; and

WHEREAS, the EMS Department's previous contract for medical supplies with Bound Tree Medical expired in February 2026; and

WHEREAS, the EMS Department currently obtains medical supplies from Bound Tree Medical through the Southeast Michigan Emergency Medical Supplies Cooperative (SMEMS) with extensions available through the MITN Purchasing Cooperative; and

WHEREAS, the estimated annual expenditure for EMS medical supplies is approximately $320,000 for Fiscal Year 2026; and

WHEREAS, the MITN contract was executed in February 2026 for a two (2) year term, with the option for four (4) additional one (1) year renewals for emergency medical supplies and equipment.

THEREFORE, BE IT RESOLVED that the Livingston County Board of Commissioners hereby authorizes the EMS Department to utilize the MITN contract with Bound Tree Medical for the purchase of medical supplies, in an amount not to exceed $320,000 for Fiscal Year 2026, with the option to exercise up to three (3) additional one-year renewals contingent upon available budgeted funds.

BE IT FURTHER RESOLVED that the Chairman of the Livingston County Board of Commissioners, or the County Administrator if Policy Permits, is authorized to sign all forms, assurances, contracts/agreements, renewals and future amendments for monetary and contract language adjustments related to the above upon review and/or preparation of Civil Counsel.

BE IT FURTHER RESOLVED the Board of Commissioners authorizes any budget amendments or transfers needed to effectuate the above.

# # #

MOVED:
SECONDED:
CARRIED:

LIVINGSTON COUNTY EMS

1911 Tooley Road ✱ Howell MI 48855
Business (517) 546-6220 ✱ Fax (517) 546-6788 ✱ Emergency 911

DAVID FELDPAUSCH
DIRECTOR
dfeldpausch@livgov.com

AMY CHAPMAN
DEPUTY DIRECTOR
achapman@livgov.com

Memorandum

To: **Livingston County Board of Commissioners**

From: **Amy Chapman, EMS Deputy Director**

Date: **March 30, 2026**

Re: **Renewal of a MITN Contract for Medical Supplies- Bound Tree Medical**

Attached for your consideration is a resolution to renew our medical supply contract. The EMS Department has an ongoing need to purchase medical supplies and our previous contract with Bound Tree Medical, through the MiTN cooperative, ended in February 2026 and we are wanting to renew this contract.

A new MITN contract was put in place in February 2026 and sent to our Legal for review. It runs for two years and can be renewed for up to four more years after that. Based on our usual needs, we expect to spend up to $320,000 on medical supplies during Fiscal Year 2026.

We're asking the Board to approve continued use of the MiTN cooperative contract with Bound Tree Medical, at a cost not to exceed our budgeted $320,000 for this fiscal year, and to allow for up to three additional one-year renewals.

This will ensure we can continue to provide the necessary medical equipment and supplies without interruption to patient care.

FARMINGTON HILLS Michigan

DEPARTMENT OF CENTRAL SERVICES

January 27, 2026

To: All interested Vendors

Re: rfp-fh-25-26-2525, Emergency Medical Supplies and Equipment

This correspondence will serve as notice that the aforementioned bid has been awarded by the Farmington Hills City Council to Bound Tree Medical for a period of two (2) years with four (4) additional one (1) year options upon mutual consent.

cc: Carly Lindhal

CITY OF FARMINGTON HILLS
DEPARTMENT OF CENTRAL SERVICES
PURCHASING DIVISION

31555 ELEVEN MILE ROAD
FARMINGTON HILLS, MI 48336-1165
www.fhgov.com

FARMINGTON HILLS Michigan

PHONE 248-871-2435

EMERGENCY MEDICAL SUPPLIES & EQUIPMENT AGREEMENT

THIS AGREEMENT, made and entered into this **27** day of **January, 2026** , by and between the City of Farmington Hills, Oakland County, Michigan, on behalf of the SMEMS COOPERATIVE and the MITN Purchasing Cooperative, Party of the First Part, hereinafter called OWNER, and Party of the Second Part,

BOUND TREE MEDICAL hereinafter called the CONTRACTOR.

WITNESSETH, that the Contractor and the Owner, for the consideration hereinafter named agree as follows:

ARTICLE I - THE WORK

It is agreed that the Contractor shall furnish all the labor, materials to deliver products shown and called for in the Invitation to Bid titled:

FH-25-26-2525 Emergency Medical Supplies and Equipment

prepared by the City of Farmington Hills, Central Services Department, Oakland County, Michigan, acting as, and in these Contract Documents entitled, the Contract Manager, and shall do everything required by the Contract Documents.

ARTICLE II - THE TIME

It is agreed that the Contractor shall begin work under this Contract upon receipt of written notice to proceed and that the contractor will fulfill all contract requirements for a period of **two (2)** years from date of contract award. It is further agreed that The City of Farmington Hills acting on behalf of the Southeast Michigan Emergency Medical Supplies Cooperative and MITN Purchasing Cooperative may opt to extend the pricing, terms and conditions of this contract **for four (4) one year renewals after the contract completion date.**

ARTICLE III - OWNER'S RIGHT TO CANCEL

It is agreed that if at any time the Contractor should abandon this work; or if he should be adjudged a bankrupt, or if his performance of this Contract is being unnecessarily or unreasonably delayed; or if he should make a general assignment for the benefit of his creditors; or if a receiver should be appointed on account of his insolvency; or if he should persistently or repeatedly fail to fulfill portions of the contract requirements the Owner shall have the right to cancel the Contract with seven ten (10) days written notice. Failure to perform specified duties listed herein after two (2) written notices shall constitute grounds for cancellation

ARTICLE IV - ASSIGNMENT OF CONTRACT

It is agreed that the Contractor shall not assign or transfer this Contract or sublet any part of the work embraced in it, except with the written consent of the Owner to do so.

ARTICLE V – THIRD PARTY BENEFICIARIES

There are no third party beneficiaries to this Agreement, and nothing expressed or referred to in this Agreement will be construed to give any person or entity other than the parties to this Agreement any legal or equitable right, remedy, or claim under or with respect to this Agreement or any provision of this Agreement. This Agreement and all of its provisions and conditions are for the sole and exclusive benefit of the parties named.

ARTICLE VI - THE CONTRACT SUM

And it is agreed that, in consideration of the faithful and entire performance by the Contractor of his obligations under this contract, the Owner, shall pay to him, at the time and in the manner hereinafter stipulated, an amount as determined by the measured quantities and the respective unit prices herein named within thirty (30) days of receipt of the Contractor's invoices. Requested to do so, supported if requested, by sworn statements, satisfactory evidence that all persons who have supplied labor.

It is further agreed that volume estimates listed in the specification document are as such just estimates and that the Owner will not be held responsible to meet any volume estimate listed to receive contract pricing.

The person representing the Contractor who will submit written invoices for payment is designated as:

Victoria Dodson. The person representing the Owner to whom invoices are to be submitted and questions regarding payment shall be designated by each entity after award.

It is agreed that no issues regarding payment of invoices shall affect the delivery of goods and services No orders shall be held by the Contractor by the Owner shall be deemed or construed as an acceptance of any part of the work under this contract.

IN WITNESS WHEREOF, the parties have caused these presents to be signed personally or by their duly authorized officers or agents and their seals affixed and duly attested the day and year first written above for **Emergency Medical Supplies and Equipment.**

CITY OF FARMINGTON HILLS - MUNICIPALITY

WITNESSES

_____ **BY: Karen Mondora, Acting City Manager/Date**

_____ **BY: Carly Lindahl, City Clerk/Date**

****

CONTRACTOR

WITNESSES

_____ BY Corey Case / Chief Marketing Officer 01/29/2026
Contractor/Date

_____ BY: Christopher Fyffe / Manager, Bids & Contracts 01/29/2026
Contractor/Date

Contractor's signature (s) must be notarized:

STATE OF Ohio)

COUNTY OF Franklin)

Subscribed and sworn to before me this 29th day of January 2026

Casey Lynn Shows
Notary Public

Franklin County, Ohio

My Commission Expires: December 4, 2030

NOTARIAL SEAL STATE OF OHIO

Casey Lynn Shows
Notary Public, State of Ohio
My Commission Expires:
December 4, 2030

Bound Tree

FARMINGTON HILLS Michigan

CITY OF FARMINGTON HILLS

PURCHASING DIVISION

EMERGENCY MEDICAL SUPPLIES

RFP-FH-25-26-2525

DUE – DECEMBER 3, 2019 10:00AM

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    - Non-Iran Linked Business
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Section B - Discount Proposal

1. Core List Pricing
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4. Information and Links for Price Lists

FARMINGTON HILLS Michigan

DEPARTMENT OF CENTRAL SERVICES

November 12, 2025

TO: **Suppliers/Contractors**

FROM: **Michelle Aranowski – Director of Central Services**

RE: **#rfp-fh-25-26-2525 –Emergency Medical Supplied - ADDENDUM #1**

Please be advised of the following amendment to the above referenced RFP. **Responses are due Wednesday, December 3, 10:00 a.m. E.S.T. Please include this signed Addendum sheet with all copies of your bid**. Responses will then be publicly opened and available for inspection. If you have any questions, please contact Michelle Aranowski at (248) 871-2426 or maranowski@fhgov.com. Thank you for your interest in the City of Farmington Hills.

ADDENDUM- #1

CLARIFICATIONS

1. The due date has been extended to **Wednesday, December 3, 2025 @ 10:00 a.m. E.S.T.**
2. You do not have to bid on every item to be considered.
3. The extra line under each item is for a generic or a city approved equivalent.
4. The cooperative is not opposed to awarding to multiple vendors. (In the past, we have awarded to 1 vendor because they were able to fulfill the corelist.)
5. The delivery locations will be over 300 locations.

CORRECTION

1. Page 8, 34. A:

34. CONTRACT SPECIFICATIONS

A. The estimated aggregate volume per year, for the manufacturer's listed herein, for the current cooperative members ~~(Attachment A)~~ **(over 300 entities)** are $2 million dollars.

ADDITION

1. Add the following to the last line of the corelist:

i-gel Plus O2 Resus Pack, MED Adult, incl size 3 i-gel O2, for Pts 30-60kg

FARMINGTON HILLS Michigan

DEPARTMENT OF CENTRAL SERVICES

ACCEPTANCE OF ADDENDUM #1

Company Bound Tree Medical, LLC

Signed _____

Printed Rob Meriweather

Date 12/02/2025

Purchasing • Information Systems •Telecommunications • Mail Services
31555 West Eleven Mile Road • Farmington Hills MI 48336 • Phone 248.871.2430 • Fax 248.871.2431



EMERGENCY MEDICAL SUPPLIES AND EQUIPMENT

Section A - General

QUALIFICATIONS, HISTORY, OVERVIEW

BOUND TREE MEDICAL'S QUALIFICATIONS

ABOUT BOUND TREE MEDICAL

Bound Tree Medical originated in 1978, when David Currier, an entrepreneur, politician and former Emergency Medical Technician, started a small emergency medical supply company in Henniker, New Hampshire.

DECADES OF GROWTH

When David Currier founded Bound Tree Medical, he was serving as a Henniker Selectman. A Selectman is a member of the executive arm of the government of New England towns in the United States. Since the early 1700s, Selectmen have been required to perambulate - to make an official inspection by foot - of the Henniker town boundaries at least every five years.

At the town's northeast boundary point was a large white oak tree - a bound tree. It had served as a guidepost for the Selectmen since 1752 when what was originally called "Town Number Six" was first surveyed. The historical significance of the tree prompted David to name his new business "Bound Tree Corporation".

"Four Decades of Growth – A strong reputation for quality products and reliable customer service helped the company flourish throughout the 80s, 90s and early 2000s. A series of strategic mergers and acquisitions further stimulated the company's growth. Pharmaceuticals and specialty I.V. therapy products for emergency medical services (EMS) care providers were added to the product mix, and Bound Tree continued expanding its services for the EMS market. In 2008, Bound Tree Medical and Tri-anim Health Services, Inc., another well-respected medical supply company, became subsidiaries of Sarnova, Inc, a leading specialty provider of healthcare products across the EMS and acute care continuum.

WHAT IT MEANS FOR YOU

With 47 years of experience, Bound Tree Medical truly understands the EMS industry. We are passionate about EMS and the communities they serve. With over 27,000 products from 600 manufacturers, the breadth and depth of our organization enable us to provide you with a full spectrum of quality EMS products and resources — efficiently and cost effectively.

BOUND TREE MEDICAL TIMELINE

1978 – Founded by David Currier in Henniker, New Hampshire.
1995 – Merged with ALS in Tempe, Arizona to become Bound Tree/ALS.
2001 – Merged with Parr Emergency Products, in Galloway, Ohio to become Bound Tree Parr, LLC.
– Acquired PMX Medical, the emergency medical business of Pro Med Company, located in Salt Lake City, Utah; changed name to Bound Tree Medical, LLC.
2002 – Entered into a long-term strategic agreement with Sun Belt Medical Supply, Inc. for the supply of pharmaceuticals and related products to the pre-hospital marketplace.
2007 – Bound Tree Medical Europe Ltd acquired the assets of Galls® Europe Ltd; appointed a distributor of Galls® and DynaMed™ throughout Europe.
2008 – Became part of new holding company, Sarnova, Inc.
2009 – Acquired Blue Ridge Medical, Inc., a national supplier of pharmaceuticals to the EMS community.
2011 – Acquired Alliance Medical, Inc. (AllMed).
2013 – Acquired Progressive Medical International (PMI).
2018 – Bound Tree celebrated 40 years of being Your Partner in EMS.
2019 – Bound Tree acquired Southeastern Emergency Equipment on January 23, 2019.
Bound Tree acquired EMS business from Concordance Healthcare Solutions on June 20, 2019.
2024 – Emergency Medical Products (EMP) was integrated into Bound Tree on April 1, 2024.
Bound Tree acquired QuadMed, Inc on July 1, 2024

BOUND TREE MEDICAL'S ABILITY

Bound Tree recognizes and understands the challenges that City of Farmington Hills is facing today and believes we can provide solutions and services to help mitigate and solve many of them. We will offer you 100% of our resources and abilities. There is no other company that can offer the same combination of competitive pricing, exceptional customer service, online ordering, disaster preparedness, inventory solutions, reporting, and exceptional fill rates as Bound Tree. As Your Partner in EMS for 40 years, we've made it our mission to help you save minutes and save lives. We strive to understand your unique needs and provide you with the right products, services and support.

THE RIGHT PRODUCTS

Curaplex® by Bound Tree – Aside from offering national, well-known brands, Bound Tree's Curaplex portfolio of products is an advantage to your business, providing what you need when it comes to product availability, price, selection and quality on the items you use the most. Curaplex® is designed for customers who want the best value but aren't willing to compromise on quality and patient care.

Pharmaceuticals – Bound Tree sells a full line of EMS pharmaceuticals including Class II, III, and IV scheduled drugs. As a leader in the industry, we have VAWD accreditation from the National Association of Boards of Pharmacy and are compliant with FDA Pedigree requirements as set forth by the Drug Supply Chain Security Act. We also provide weekly pharmaceutical backorder reports with up-to-date industry information.

Recertified Equipment – Bound Tree's offers recertified AEDs, defibrillators, ECG monitors, infusion pumps, pulse oximeters, suction units, ventilators, and vital sign monitors from leading manufacturers. Our highly trained biomedical technicians painstakingly recertify all critical care equipment to ensure a quality product at a savings of up to 50% of new equipment. This will be beneficial when you need service on your IV pumps or if you find the need for additional ones.

THE RIGHT SERVICES

Operative IQ Inventory Management – Operative IQ improves productivity by connecting the functional areas of your operation. It allows people to share information, reduce labor hours and material costs, improve service levels and communication, and make informed business decisions.

UCapIt Controlled Medical Supply Dispensing – UCapIt allows EMS, Pharmaceutical and other medical professionals the ability to restock their units 24/7 and have real-time usage and inventory tracking. Annual savings using the UCapIt dispenser have been realized up to 30% related to shrink, expiration management and overhead.

Controlled Substances Ordering System – The Controlled Substances Ordering System (CSOS) was developed by the DEA for the electronic transmission of Class II controlled substances orders. This allows for a significant reduction in the number of ordering errors, faster transaction times and lower costs due to order accuracy and decreased paperwork.

THE RIGHT SUPPORT

Sales Support Team – City of Farmington has a dedicated Account Manager, who along with being readily available, will provide quarterly business reviews to maintain performance, maximize results and adjust to any changing needs and requirements City of Farmington may have. Our Customer Service Team is trained and available 7:30 am – 8:00 pm ET to respond to customer inquiries regarding items, availability, shipment, delivery, and product substitutions when needed in the event of longer-term backorders.

Bound Tree University – Our Bound Tree EDU provides 5 Free CE accredited courses, to help drive employee retention and on-going training. With 150+ hours of recorded classes available on-demand and live classes five days a week, it meets all the requirements for NREMT, State license, CFRN, and now FP-C and CCP-C as well (meets w requirements for full renewal).

THE RIGHT INFRASTRUCTURE

BoundTree.com – The Bound Tree website offers convenient 24/7/365 access to product information and ordering, supply lists, order history, electronic requisitions, and email notifications. We also offer Electronic Data Interchange (EDI) compatibility.

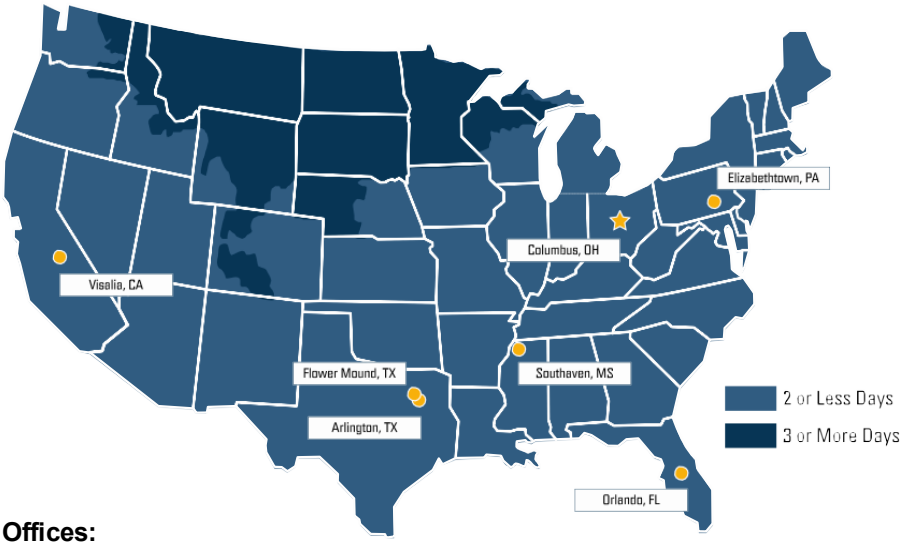
Nationwide Distribution – For operational efficiency and faster disaster response, Bound Tree operates 5 distribution centers nationwide. Ninety-six percent of all our customers can be reached using UPS Ground within 2 business days.

Medical Device Kitting –Bound Tree operates an FDA approved medical device kitting facility. Curaplex® pre-assembled kits solve a variety of your everyday challenges, so you spend less time worrying about the details and more time focusing on patient care. Curaplex® kits give you the ability to respond quickly to emergency scenarios by providing immediate access to the supplies you need. Custom Kitting solutions are also available.

Disaster Support – Call Bound Tree's Disaster Support Hotline at 800-863-0953 to report major incidents and identify medical supply needs. Once reported, Bound Tree Medical personnel will take immediate measures to assist in relief efforts. Our Disaster Response Team was activated several times during the recent hurricanes helping to supply relief efforts.

DISTRIBUTION CENTER INFORMATION

Bound Tree operates 5 distribution centers strategically positioned for operational efficiency and disaster response. 96% of all of our customers can be reached using UPS Ground within 2 business days.



Offices:

Bound Tree Medical Headquarters
Bound Tree Medical 5000 Bradenton Ave.
Dublin, OH 43017
Phone: 800.533.0523
Fax: 800.257.5713
Web: www.boundtree.com

Distribution Centers:

California
2237 N. Plaza Drive
Visalia, CA 93291

Indiana
1033 Collins Rd, Ste A
Greenwood, IN 46143

Pennsylvania
1605 Zeager Road, Suite 101
Elizabethtown, PA 17022

Texas
2911 S. Great Southwest Parkway, Ste 200
Grand Prairie, TX 75052

Florida
2619 Ignition Drive, Ste 2
Jacksonville, FL 32218

Texas, Kitting Facility
2911 S. Great Southwest Pkwy, Ste 200B
Grand Prairie, TX 75052

National References

Jessica Barnhart, Medical Supply Specialist
City of Columbus Division of Fire
2028 Williams Road
Columbus, Ohio 43207
614-616-4699
Jbarnhart@columbus.gov

Charlene Sifford, Director Global Purchasing
Priority Ambulance
910 Callahan Road, Suite 101
Knoxville, TN 37912
865-440-0996
csifford@priorityambulance.com

Lieutenant Jerami Bennett
Baltimore City Fire Department
3500 West Northern Parkway
Baltimore, MD 21215
410-396-2718
Jerami.Bennett@baltimorecity.gov

Barbara Tripp, Fire Chief
City of Tampa Fire Department
808 East Zack Street
Tampa, FL 33602
352-406-2573
barbara.tripp@tampagov.net

Lieutenant Ryan Jamison
San Francisco Fire Department
1415 Evans Avenue
San Francisco, CA 34124
626-271-4974
Ryan.Jamison@sfgov.org

Douglas Isaacs, MD, Deputy Medical Director
Fire Department City of New York
9 Metro Tech Center
Brooklyn, NY 11201
718-999-2790
doug.isaacs@fdny.nyc.gov

THE RIGHT SUPPORT

Bound Tree is committed to providing City of Farmington Hills with best-in-class support. This includes a dedicated team focused on your success. Mesa will have ready access to your account manager and our manufacturing partners for help in in-service training at no cost.



WILLIAM WAITE – ACCOUNT MANAGER

I joined the Bound Tree Team in June 2020 as the Indiana Account Manager before moving into the Southeast Michigan Territory in the summer 2022. Before Bound Tree, I spend several years working with a transportation and logistics firm out of Chicago and Detroit. I also spend several years with a northern Michigan Fire Department. We were a career ALS department; however, I was only on the BLS side. Working alongside our Paramedics in the back of the Ambulance, I gained valuable knowledge and experiences that now help me today! I will be your contact for all things related to item selection, pricing, product questions/demonstration, and business consultations. I live locally, so I am available to meet at any time.



DON ADAMS – VICE PRESIDENT OF SALES, EASTERN US

Don has over thirty years of Municipal, Fire, and Private EMS experience as a licensed Paramedic and Instructor Coordinator in the State of Michigan. Don is a past president of the Michigan Association of Ambulance Services and was the 1996 Michigan Paramedic of the Year. He Joined Bound Tree in 2012 as an Account Manager, was promoted in 2016 to Regional Sales Director, and most recently took the helm as the Vice President of Sales for the Eastern US. Don's goal is simple – to help all of his account managers and their customers create a valued partnership that helps bring better products and care to the patient.



EDWARD DRAPER – REGIONAL SALES DIRECTOR

Ed joined the Bound Tree team in October of 2016. I spent most of my life working in the fire and EMS industry, working predominantly on the West side of the state, and just before coming the Bound Tree, I was the Chief Administrator of a Fire-Based EMS Agency near Traverse City. I spent over 20 years in the industry and learn more every day about how to better advocate for my partners and help them manage their business. I look forward to being your partner and learning more about what your organization does to uniquely help the people you serve.



MADISON MESSINA – CUSTOMER SERVICE REPRESENTATIVE

I joined Bound Tree in January 2023 as a sales support specialist and began working with the SEMI team in February 2025. I was promoted to Customer Care Lead in the summer of 2025. During my time here, I've really come to appreciate how meaningful our customer relationships truly are, and I'm looking forward to strengthening ours in the coming weeks, months, & years ahead. I'll sever as your to-to contact for order inquires, exchanges, returns, product availability requests, any website-related questions, or additional issues or concerns you may have.

LOGAN KIRBY – CUSTOMER CARE MANAGER



I joined the Bound Tree team in July of 2018 as a Customer Care Supervisor. Before joining the team, I was a Customer Service Supervisor at Verizon Wireless for 6 years and gained a great deal of experience identifying customer pain points and formulating new processes to streamline and improve. I am extremely passionate about the work we do here and am always looking for new way to enhance the customer experience. I'll be your contact for any escalated issues, working in close partnership with our team to ensure we are proactive in creating the best experience for you.



KRYSTA MARTIN – CREDIT AND COLLECTIONS ANALYST

I joined the Bound Tree team in November of 2019. I am the mother of 5 children. I'm most an empty nester! Before coming to Bound Tree, I was an Assistant Manager at US Bank. I had been in the banking industry for 20 years and had decided that I wanted to do something new. I'll be your contact for questions related to invoicing, payments and terms, credit limits, and for updating your accounts payable contacts.



CHRIS FYFFE – BIDS AND CONTRACTS MANAGER

Chris Fyffe, Bids and Contracts Manager, has been with Bound Tree Medical for just shy of eight years. In his tenure with Bound Tree, he has been involved with pricing, quotations, bids, and deal management activities. In addition to his experience with the distribution of medical supplies, he has worked in transportation logistics, and retail management. His goal is help all of customers create a valued partnership that helps bring better products and care to the patient.

Welcome Southeast Michigan Fire and EMS!

We are thrilled to partner with you and support your mission to provide exceptional emergency care. At Bound Tree Medical, we don't just want to be the place you call for supplies—we strive to be a trusted partner who understands your unique needs and helps you deliver life-saving care efficiently and effectively.

Our Commitment to You

Every EMS organization has its own processes, challenges, and priorities. Our goal is to understand yours deeply so we can respond quickly and provide tailored solutions when you need them most. We are here to ensure your operations run smoothly, with the right products and support at the right time.

Why Bound Tree Medical

Exclusive Focus on Pre-Hospital Care: Our warehouses are stocked exclusively with EMS-specific products, increasing the likelihood that the items you need are available and ready to ship. Most orders arrive within 1 business day.

Nationwide Distribution Network: With strategically located warehouses across the country, we ensure fast delivery and continuity of operations—even during natural disasters or pandemics.

Account Support: Account Managers and Leadership are available 24/7/365. See contact information below.

Dedicated Customer Care: Our experienced team is available Monday–Friday, 8 AM–8 PM EST to assist with orders, questions, and concerns.

Comprehensive Product Offering: From airway management and trauma supplies to pharmaceuticals and advanced monitoring equipment, we provide everything you need for pre-hospital emergency care.

Technology Solutions: We offer inventory management tools, machines, and software, online ordering, and customizable reporting to help streamline your supply chain.

Education & Training Resources: Bound Tree supports EMS professionals with continuing education opportunities, clinical resources, and product training.

Disaster Response Hotline: Our Emergency Disaster Support Program is here to help you in disasters such as hurricanes, tornadoes, fires, floods, blizzards, MCI's, and more. This program enables you to call our Disaster Support Hotline 24 hours a day, 7 days a week, to speak to a live operator to report major incidents and identify your medical supply needs. Phone: **888-8345-6640 and/or 810-588-3424**

Now, let's meet a few of the people you'll be working with on a regular basis:

William Waite

810-588-3424
william.waite@boundtree.com
www.linkedin.com/in/williamkwaite

Skills

- Michigan Firefighter 1 & 2
- AHA CPR & First Responder
- FEMA/NIMS Emergency Training
- Award Winning Sales Professional
- Microsoft Office Suite
- PowerBI
- Consultative Selling
- Industry SME
- Territory Planning
- D365 CRM

Experience

MAY 2020 TO PRESENT

Account Manager - Michigan / Bound Tree Medical

- Lateral transfer to SE MI May 2022
- Consistent YOY top performer
- Responsible for account management, new business development, prepare proposals and conduct sales presentations, negotiate pricing and manage rebates, provide product information and demonstrations, analyze internal reports, meet monthly, quarterly, and annual sales quotas.

MARCH 2015 – JUNE 2020

Managed Services Business Analyst / Redwood Logistics

- Hired as an Operations Analyst
- Promoted to Dedicated Operations Lead May 2016
- Promoted to Implementation Coordinator in November 2018
- Promoted to Managed Services Business Analyst January 2020
- Facilitate successful implementations and startups for new TMS clients
- Work closely with all stakeholders on new customer implementations - ensuring solutions meet business needs and requirements for the customer and internal teams
- Act as liaison between internal departments and end users with the client
- Gather information, document requirements and illustrate workflows in Confluence and Lucid chart systems
- Perform technical tasks within the TMS. Environment creation and configuration
- Lead client and vendor demos and trainings on MG TMS workflow/process via Webinar or in person
- Create training materials for the clients and internal departments
- Perform special studies and projects to improve internal processes and practices
- Subject Matter Expert (SME) in the Managed Service workflow and process
- Write new and rewrite existing SOPs for process improvements

- Identify opportunities to improve operational efficiency between client and internal operations team
- Participate in carrier management processes, such as selection, qualification, and performance evaluation
- Deliver a monthly, quarterly and annual report to senior management on industry trends, carrier performance, project status and how to maximize those trends by altering company procedure and process
- Write or revise standard operating procedures (SOP) for logistics operational processes
- Identify areas for process improvement and cost savings to ensure expectations are met
- Prepares reports by collecting, analyzing, and summarizing information

MAY 2012 – MARCH 2015

On-Site Logistics Account Manager / Universal Truckload Service

- Hired as a Fleet Manager, overseeing 25+ drivers and 8 terminal operations
- Promoted to Account Manager working on-site at Union Pacific Railroad in Omaha, NE
- Oversaw daily operations on a multimillion-dollar account while providing cost saving opportunities for UPRR through FTL and IMDL shipments
- Acting liaison for invoice discrepancies
- Ensure freight is invoiced properly and promptly with set terms
- First line of communication between all parties: client, drivers, shipper and consignee
- Offer guidance to contracted drivers on the best ways to maximize their earnings, while delivering a high level of customer service
- Work closely with the maintenance team to find ways to reduce downtime due to repairs or lack of routine maintenance
- Keeping the client informed on the industry and market changes and how it will affect future capacity and expense
- Manage the movement of the client's goods, ensuring that they are picked up and delivered on time to the client's satisfaction
- Work quickly and effectively to resolve problems that may develop on a shipment; be proactive
- Work with competitors to service the client on large projects requiring 12+ drivers for railroad crew moves

Activities

- Mentor with Magnus Charitable Trust
- Amateur Player on Golfweek Amateur Tour
- Macomb County Training Committee
- Volunteer with PAWS Chicago
- Motorcycle enthusiasts
- Customer Relationship Management (CRM)

Summary

Award-winning Regional Sales Director with over a decade of driving multimillion-dollar growth in healthcare and medical supply sales. Proven record of building high-performing teams, exceeding quotas, and expanding market share across 9 states. Recognized for CRM expertise, strategic planning, and mentoring future leaders. Currently pursuing MBA/MS in Data Science to strengthen data-driven sales leadership.

Work Experience

Regional Sales Director – Bound Tree Medical / Sarnova | Feb 2022–Present

- Directed $37M annual sales revenue across 9 states while leading a team of 10 account managers.
- Achieved *Top Region Curaplex Growth CY24*; expanded span of control requiring additional FTEs.
- Recognized as award-winning sales leader for consistent quota attainment and market expansion.
- CRM Subject Matter Expert; created national dashboards boosting staff productivity and efficiency.

Michigan Account Manager – Bound Tree Medical / Sarnova Oct 2016–Feb 2022

- Achieved 100%+ to plan annually; *Account Manager of the Year 2018 & 2019*.
- First to build a $1M Curaplex territory, sustained for 2 consecutive years.
- Recognized as *Top Account Manager in Curaplex Growth 2019* and *Net New Account Expert*.
- Ranked #1 in Cardiac Science AED orders 2018–2020.
- Featured in *Repertoire Magazine Rep Corner* (Jan 2019).
- Perennial Incentive Trip Winner for top-tier performance.

Chief EMS Administrator – Blair Township Emergency Services Jun 2013–Nov 2016

- Directed strategic planning, organizational leadership, and operational oversight for 40+ staff.
- Managed budgets, payroll, scheduling, orientation, reporting, and education programs.
- Introduced patient ventilators and prehospital POC lactate monitoring for sepsis treatment.
- Increased average daily revenue by 28%, reduced accounts receivable days by 28%, and boosted cash receipts by 20%.

Emergency Services & Healthcare Leadership – Multiple Agencies 1997–2016

- Progressive roles in EMS, firefighting, and healthcare education.
- Served as Assistant Fire Chief, EMS Director, Instructor Coordinator, and Proprietor of EMS Education business.
- Delivered QA/QI programs, paramedic training, and social media strategy for EMS outreach.

Education

- MBA/MS Data Science (in progress), Eastern University – Expected 2027
- Professional Certificate in Supervisory Management – Michigan State University, 2020
- BASc Public Safety & Healthcare Management – Siena Heights University, 2016 (Summa Cum Laude)
- AAS Paramedic – West Shore Community College, 2014 (Dean's List, 4.0 GPA)
- Paramedic Certificate – Baker College of Cadillac, 2005 (Cum Laude)
- EMS Instructor Coordinator – Platinum Educational Group, 2008
- Firefighter I & II – Michigan Firefighter's Training Council, 2002
- EMT Certification – Munson Regional EMS Education, 200



*Edward**Draper***

Holt, MI 48842
231.735.5078
MedicDraper@Gmail.com
www.LinkedIn.com/in/MedicDraper

Transformational Leader

Award Winning Sales Account Manager

Emotionally Intelligent

Paramedic Firefighter

Licensed EMS Educator

Public Speaker

Psychology Enthusiast

Cardiology Enthusiast

Social Media Marketing

Life-Long Student

DIsc

ESTJ

I am known for being fair, firm, and clear. A unifier who is customer and people-focused leader who strives to inspire the team to grow professionally & personally.

I am a proactive visionary who enjoys using analytics to increase efficiency and reduce costs while increasing profit. I believe deeply in consistent personal growth creating an environment for team-over-self mentality.

I am authentically committed to creating a noble vision which inspires others to facilitate conditions where those around me express ideas for process and organizational improvement.

I believe character is the most important attribute someone can have, which means I pour my heart into ensuring I say what I mean and mean what I say. I expect others to hold themselves to this same standard. I admit when I'm wrong and learn each and every day.



EdwardDraper

Holt, MI 48842
231.735.5078
MedicDraper@Gmail.com

What Others Say About Me:

Open-Minded

Genuine

Relentless

Passionate

Strategic

Mentor

Inspiring

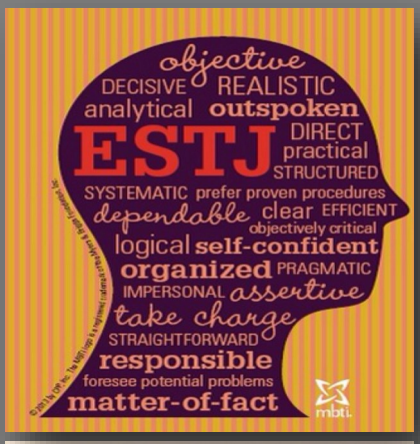
Relationship Builder / Manager

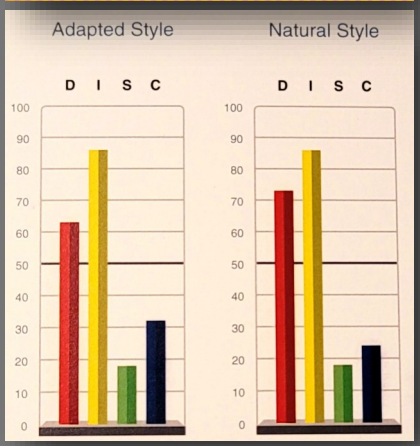
Partner Advocate

Charismatic

Self-Aware

Tactician







Paula (PW) White
Leadership & Music / AA-ISP Advisory Board / #GirlsClub Thought Leader / SalesClass.ai Contributor
October 21, 2020, Paula (PW) worked with Ed in different groups

From the time Ed Draper began to work at Bound Tree, I knew he was going to be highly successful. Ed has the drive, tenacity, and a creative edge people look for in a sales organization. He is phenomenal with his customers by bring service and value to each one individually. Ed also thinks outside the box and encourages a team atmosphere. Thank you Ed for all you do!



Nick Lemcool
East Bay Ambulance Director, Paramedic, Instructor/ Coordinator
October 1, 2020, Nick reported directly to Ed

I have worked with Ed on many different aspects and positions. When Ed was a firefighter/ paramedic, Ed was one of my many preceptors during paramedic clinical and externship. When Ed was promoted to EMS Administrator, I worked under him. Through his quick thinking and out of the box thinking he is able to overcome challenges quickly and effectively. When Ed moved on from public safety I have been able to maintain contact with Ed and think of him as one of my important mentors, calling on him often for guidance and to bounce ideas off of. Ed is always there when you call and is an active listener. Any organization would be lucky to have Ed on their team.



Tyler Bajtka
Firefighter/ Paramedic at Traverse City Fire Dept
July 25, 2019, Tyler reported directly to Ed

Ed has been an amazing mentor and leader to me from the very begining of my career! He's willing to give it all to develop, guide, educate, challenge, and most importantly patient enough to listen to any person. Anyone is lucky to cross paths with him, as he will leave you believing you can be the best you!



Richard Hollingworth
Vice President Sales
May 17, 2019, Richard worked with Ed but at different companies

Not often you start a recommendation with a comment about friendship. But Ed is first and foremast a good friend and Mentor, even though I met Ed through work, we developed a close relationship that was built on core values that I respect: A work ethic that's second to non, a level of knowledge in his respective field that he is willing to share, and a desire to improve and ask questions, Ed seeks to understand rather than to respond. When Ed talks, I listen.

As the last recommendation Ed got pointed out, I would not hesitate to hire Ed, he would be a capable and inspiring senior sales executive or Sales Leader. I would also be fortunate to work for Ed should our career paths match.



Arthur Ebel
Field Sales Manager - EMS at SSCOR, Inc.
May 16, 2019, Arthur worked with Ed in different groups

Ed is an outstanding representative of what a salesperson (Account Manager) should be and I, myself, have learned selling techniques from his example. I can see Ed advancing within his sales career and I hope to be able to continue having the opportunity to work alongside Ed as I move forward in my career endeavors. If I was a Sales Director of a company, I would hire Ed, because I know he would give 100% effort to achieving a high degree of success.



Joe Lachowski
National Park Service
January 23, 2019, Joe worked with Ed but at different companies

In addition to being professional, well spoken, smart and fun, Ed is one of the hardest working individuals I know. Once he sets his mind on a goal, he works relentlessly to accomplish it. He takes roadblocks and obstacles in stride and does not let them throw him off track. He is flexible and able to adapt and overcome on the fly.

Ed also has the gift of recognizing when others need a boost or support to accomplish their goals. An encouraging word, a funny joke, a quick on the job training or a professional invite for a valuable opportunity all seem to appear just when you need them thanks to Ed. Thanks to his efforts, I have been able to grow and develop my skills more than I could have without him. Ed is a strong and valued member of any team and will be a great benefit wherever he goes.

DRA

DONALD RAYMOND ADAMS

837 Mystic Woods Drive, Howell Michigan
donaldad@mac.com – 810.397.7551

SUMMARY

Proven and time-tested visionary leader that is humble and has effective executive leadership traits, expert abilities, ability to listen, learn, and lead to achieve competitive results - Goal focused with a track record of developing underperforming and overperforming teams, and markets to meet revenue and profitability targets - Aptitude to execute and drive team contribution from day one.

SKILLS

sales leadership; learning and adaptability; coaching and mentoring; performance management; P/L budgets; negotiations; employee engagement; strategic planning; customer engagement and retention; hiring and recruiting top talent; analytics; process improvement and development

EDUCATION

MIT Sloan School of Management
Executive Education Graduate

SIENA HEIGHTS UNIVERSITY/UNIVERSITY OF MICHIGAN
Bachelors of Applied Science – Public Safety / Public Adm

LICENSES – Paramedic, Paramedic Instructor, Firefighter, Police Motor Carrier, Death Scene Investigator

WORK EXPERIENCE

AREA VICE PRESIDENT OF SALES – EASTERN US
Sarnova / Bound Tree Medical | 2012 (2020 role) – Present

Executive level oversight and leadership of a national, market leading sales team focused on being the best partner in specialty medical equipment sales and distribution to those who save and improve patient lives. Accountable for $400M+ in sales revenue, five director level reports and six regional sales teams comprised of 53 clinical field account managers serving over 7000 high value accounts in the eastern United States. Primary customer segments include private and public Ambulance, Fire, Police, Air Medical and Hospital Health Systems.

Historical Team Achievements: Record company sales production 2021, 2022, 2023, 2024 exceeding revenue, gross profit and EBITDA four consecutive years. FY2020 – FY 2024 all teams achieving plan.

Personal Achievements: Patricia Industries Executive Development selection, Perennial President Club and Incentive Trip Winner 2020-2024, Regional Sales Director of the Year 2018, Account Manager of the Year 2015, Two-time Quarterly Sarnova Star award winner, 2015 Gilmore Award Winner. Multiple other sales and benchmark awards.

DIRECTOR OF EMERGENCY SERVICES / CLINICAL EDUCATION
McLaren Health Care Corporation | 1992 – 2012

Executive level position with fiscal and operational responsibility of six departments in one of the nation's top ten health systems. Emergency Department Education, EMS Education, Institute for Medical Simulation, American Heart Association Training Programs - ACLS/PALS/BLS, Internal Medicine Physician Education, Central Telemetry Unit and Critical Care Rapid Response Teams. Director level oversight of six managerial direct reports and multiple FTE's; responsible for quality of care and performance management.

EXECUTIVE DIRECTOR
Lapeer County EMS | 1996 – 2001

Chief Executive of a municipal owned ambulance service providing emergency medical transportation to the citizens of Lapeer County. Four director level direct reports with over 100 personnel. Lapeer County was CAAS Accredited in 2000 and was only the fifth EMS service to ever receive a perfect score with no citations or recommendations.

Brett M. Justice

1296 Daylily Dr. Holt, Michigan 48842 • (734) 637-7542 • dtfd240@gmail.com

Core Competencies

Leadership
Negotiation
Decision-Making and Problem Resolution
Customer Service
Advanced Communication
Clinical Expertise and Education
Implementation and Execution
Relationship-Building

Relevant Experience

Bound Tree Medical • Dublin, Ohio
Account Manager - Michigan *January 2024 - Present*

Utilizing the knowledge from past positions to better understand potential pain points in EMS operations and the ordering of medical supplies to better help obtain the correct solution

- Grow business through current and new customers
- Increase revenue
  - Increase of around 20%
- Increase gross profit
  - Increase of around 22%

Heart-Savers League • Holt, Michigan
Owner *October 2023 – Present*

Focusing on the education of CPR, First-Aid, ACLS, and PALS programs for medical professionals and lay public individuals in communities for better community outcomes.

- Budgeting for equipment and time management
- Building and maintaining client relationships
- Keeping up on new science for the best customer education

Delhi Township Fire Department • Holt, Michigan
Lieutenant, Paramedic I/C, and EMS Training Liaison *October 2007 – February 2024*

Experienced in influence, adaptability, data analytics, negotiations, execution of strategies, and community outreach.

- Collaborate with appropriate stakeholders to dissect data and improve customer service and patient advocacy of a diverse population
- Confer with employees and administration to assess equipment needs and training requirements
- Initiated new data collection programs and implemented change based on evidence
- Present to applicable stakeholders on emergency medical and fire service trends and needs
- Lead and inspire new and current personnel to build the best version of themselves

Lansing Community College • Lansing, Michigan

Interim Program Director/Part-Time Adjunct Faculty *August 2012 – Present*

- As the Interim EMS Program Director, I focus on many attributes to progress student outcomes:
    - Faculty management and student engagement
    - Discussion with College, State, and National Stakeholders to improve student and college growth.
    - Budget items to ensure fiscal responsibility and stay on the leading edge of new tech.
    - Organize materials for State, CoAEMSP, and NREMT reviews, visits, and approvals.
    - Continuing diversity, equality, and inclusion (DEI) into all programs.

- Skilled in learning and teaching competencies, progress reports, corrective actions, and leadership practices.
    - Produced a curriculum centered on evidence-based practice.
    - Promoting patient advocacy with unyielding ethical and moral guidelines and new methodologies to enhance student outcomes
    - Inspire change in varied student and faculty populations to support evidence-based data

EDUCATION

Columbia Southern University Orange Beach, Alabama – B.S. ORGANIZATIONAL LEADERSHIP (2021) MAGNA CUM LAUDE

Lansing Community College, Lansing, MI – A.A.S. EMERGENCY MEDICAL SERVICES (2009) MAGNA CUM LAUDE; A.A.S. FIRE SCIENCE: (2009) MAGNA CUM LAUDE; A.A.S. FIRE SCIENCE/BASIC EMT (2012) MAGNA CUM LAUDE

Daniel H. O'Brien

231.633.2334 medic77-ems@usa.net

Summary of Qualifications:

- **18 years of experience as a full-time paramedic**
- **10 years of experience as a critical care provider (Flight)**
- **7 years of experience as an active Tactical Paramedic (TEMS)**
- **5 Years of Firefighter experience**
- **EMS management experience including purchasing and budget oversight**
- **State of Michigan Paramedic**
- **State of Michigan EMS Instructor/Coordinator (Paramedic I/C)**
- **State of Michigan Fire Fighter I & II (Ret.)**

Professional Experience:

Account Manager

May 2018- Current Bound Tree Medical Michigan

Account Manager for EMS Equipment Distribution Company, Outside Sales.

EMS Section Chief / Director of EMS*:

Dec 2016- May 2018 ***Blair Twp. EMS & Fire*** ***Blair, MI***

Operational, administrative, and budgetary oversight of EMS Dept.
Paramedic Instructor/Coordinator / Department Training Oversight
Firefighter
*Title change from EMS Director to EMS Chief Sept 2017 due to department restructuring

Fire Fighter / Paramedic / Tactical Paramedic:

Oct 2012- Dec 2016 ***Blair Twp. EMS & Fire*** ***Blair, MI***

Fire Fighter/Paramedic for municipal EMS and Fire Dept. serving suburban and rural areas of Grand Traverse County, MI.
Tactical Paramedic for Regional Emergency Response Team. (ERT Team 2)
Paramedic Instructor/Coordinator.
Part-time 2012- May 2015 / Fulltime 2015 – Dec 2016

Flight Paramedic / Tactical Paramedic:

Feb 2013- Dec 2017 ***North Flight EMS / NorthFlight-Aeromed*** ***Traverse City, MI***

Member of air-medevac service providing rotor and fixed wing inter-facility critical care and 911 scene responses.
Chairperson for North Flight's Safety Program. (Jan 2014 - July 2016).
Member of North Flight's Tactical Paramedic Program.
Per diem Paramedic (July 2016 – May 2018).

Flight Paramedic:

Nov 2006 – Jan 2013 ***Airmethods/LifeNet*** ***Harris, NY & Lansing, MI***

Full-time member of air-medevac service (Rotor Wing) that provides both Inter-facility Critical Care and 911 scene response.
Safety Committee member / New Hire Preceptor / Assisted in Base Supervisor duties as needed. (Harris, NY).
Controlled Substance / Narcotic Officer. (Harris, NY).

MICU Paramedic:

July 2009 – May 2012 ***Atlantic Health System*** ***Summit, NJ***

Per Diem member of hospital based MICU program providing 911 ALS services to the Urban and Suburban areas of Northeast NJ.

Paramedic / Tactical Paramedic:

Sept 2001- July 2009 ***Mobile Life Support Services*** ***Newburgh, NY***

Member of large EMS agency providing 911 services and Inter-facility transports.
Provided ALS care in the urban, suburban, and rural areas of the Lower Upstate New York region.
Designated "Fly Car" Paramedic (Echo Response Unit).
Field Training Officer and Paramedic Preceptor.
Member of Special Operations Response Team.
Member of inter-agency Tactical EMS Team.

Paramedic:

Aug 2000 – Sept 2001 ***Tallahassee Memorial Hospital*** ***Tallahassee, FL***

Member of hospital based ALS program for the City of Tallahassee, Florida.
Designated as a "Charge Paramedic" in this high volume 911 system.

Education:

Tallahassee Community College:

Jan 1997 – Aug 2000 ***Tallahassee, FL***

Associates in Applied Science for Emergency Medical Services Program (incomplete).
First Aid, Emergency Medical Technician, and Paramedic certificate programs.

Military Service:

United States Coast Guard:

Jan 1991 - Jan 1995 (Active Duty) ***Honorable Discharge***

Avionics Technician 3rd Class (AT3).
HH60-J Flight Mechanic (Helicopter Crew Chief).
Military Based Helicopter Search and Rescue / Maritime Law Enforcement duties.
(DD-214 available on request)

Awards and Accomplishments:

- **Bound Tree Medical Account Manager of the year 2018 (Stub Year)**
- **Bound Tree Medical President's Club 2018 SY, 2020**
- **Orange County Regional Medical Center "Life Saver Award" recipient**
- **New York State Distinguished Service Award recipient**
- **2004 Orange County, NY Paramedic of the Year**

STATE OF MICHIGAN

MDHHS Michigan Department of Health & Human Services

Bureau of Emergency Preparedness, EMS and Systems of Care

PURSUANT TO ACT 368 OF 1978, AS AMENDED, THIS

INSTRUCTOR/COORDINATOR-PARAMEDIC

LICENSE

IS ISSUED TO

DANIEL H O'BRIEN

LICENSE NUMBER
1735607

EXPIRATION DATE
03/31/2026

*****THIS LICENSE IS ONLY VALID IF PROVIDER LICENSE IS ACTIVE*****

THIS DOCUMENT IS DULY ISSUED UNDER THE LAWS OF THE STATE OF MICHIGAN

THE ISSUANCE OF THIS LICENSE SHOULD NOT BE CONSTRUED AS A WAIVER, DISMISSAL, OR ACQUIESCENCE TO ANY COMPLAINTS OR VIOLATIONS PENDING AGAINST THIS LICENSE

STATE OF MICHIGAN

MDHHS Michigan Department of Health & Human Services

Bureau of Emergency Preparedness, EMS and Systems of Care

PURSUANT TO ACT 368 OF 1978, AS AMENDED, THIS

INSTRUCTOR/COORDINATOR-PARAMEDIC

LICENSE

IS ISSUED TO

BRETT MORGAN JUSTICE

LICENSE NUMBER
1601996

EXPIRATION DATE
08/31/2028

*****THIS LICENSE IS ONLY VALID IF PROVIDER LICENSE IS ACTIVE*****

THIS DOCUMENT IS DULY ISSUED UNDER THE LAWS OF THE STATE OF MICHIGAN

THE ISSUANCE OF THIS LICENSE SHOULD NOT BE CONSTRUED AS A WAIVER, DISMISSAL, OR ACQUIESCENCE TO ANY COMPLAINTS OR VIOLATIONS PENDING AGAINST THIS LICENSE

BOUND TREE MEDICAL CERTIFICATIONS AND PERMITS

The next several pages will detail our certifications and permits. We have also attached copies for your reference.

VAWD Certified State and Nationally Licensed

Several of Bound Tree's Distribution Centers have received VAWD (Verified - Accredited Wholesale Distributors) accreditation from the National Association of Boards of Pharmacy (NABP). VAWD accreditation is achieved after a criteria compliance review that includes a rigorous evaluation of operating policies and procedures, licensure verification, survey of facility and operations, background checks and screening through the NABP Clearinghouse. Our accreditation demonstrates that we are following state and federal laws and that our prescription drugs are distributed safely and securely.

For a complete listing of VAWD-Accredited Facilities, please visit:
www.nabp.net/programs/accreditation/vawd/vawd-accredited-facilities

Compliance with DSCSA Requirements

Under the Drug Supply Chain Security Act (DSCSA), entities in the supply chain including manufacturers, wholesale distributors, and dispensers have responsibilities to meet the requirements of the DSCSA. As of May 1, 2015, all wholesalers are required by law, under the DSCSA, to provide transaction information, transaction history and transaction statements for the pharmaceuticals that they supply.

Bound Tree is compliant with these FDA standards which helps improve patient protection by preventing the distribution of substandard or ineffective drugs and while providing our customers with the product and transaction information they need to be in compliance with the FDA standards.

Under the DSCSA you are responsible for knowing that your prescription drug wholesale distributor is an authorized trading partner who holds a valid state or federal license. Bound Tree Medical is licensed federally and in all 50 states. Purchasing from a licensed and VAWD accredited distributor like Bound Tree Medical makes great strides to ensure none of your purchases will ever be counterfeited, contaminated, improperly stored and transported, ineffective, and/or unsafe.

Wholesale Distributor licenses can be searched online:
www.fda.gov/Drugs/DrugSafety/DrugIntegrityandSupplyChainSecurity/ucm281446.htm

Controlled Substance Ordering System (CSOS)

Class II Controlled Substances can be ordered through our secure electronic Controlled Substances Ordering System (CSOS) without the supporting paper DEA Form 222! The DEA's CSOS program is the only allowance for electronic ordering of Class II controlled substances. To participate in CSOS, the DEA registrant must first acquire a CSOS digital certificate from the DEA. Once the certificate is received, Class II orders can be placed through our secured website: e222.boundtree.com.

For more information about CSOS please visit: www.deaecom.gov

Bound Tree will continue to accept paper 222 forms for those who wish to utilize that method for ordering.

LEGAL STATUS BIDDER

Fill out the appropriate section below for your company and strike out the other three. Provide additional sheets if more space is needed for your responses.

Corporation:
State and County in which incorporated: _____

Official title of person signing proposal: _____

Address of signer: _____

Full names, addresses and titles of all the corporation's directors and officers:

_____

_____

_____

Partnership:
State and County in which established: _____

Official title of person signing proposal: _____

Address of signer: _____

Full names, addresses and titles of all partners:

_____

_____

_____

Limited Liability Company (LLC):
State and County in which established: Ohio, Franklin County

Official title of person signing proposal: _____

Address of signer: 5000 Bradenton Ave, Dublin, OH 43017

Full names, addresses and titles of all members and managers of the LLC:

Brian LaDuke, CEO - 5000 Bradenton Ave. Dublin, OH 43017

Rob Meriweather, President, EP - 5000 Bradenton Ave. Dublin, OH 43017

Shawn Saylor, Treasurer-5000 Bradenton Ave. Dublin, OH 43017

CITY OF FARMINGTON HILLS
DEPARTMENT OF CENTRAL SERVICES
PURCHASING DIVISION

31555 ELEVEN MILE ROAD
FARMINGTON HILLS, MI 48336-1165
www.fhgov.com

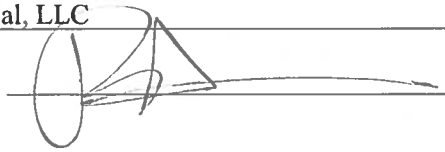
PHONE 248-871-2435

NON-IRAN LINKED BUSINESS CERTIFICATION

Pursuant to Michigan law before accepting any bid or proposal or entering into any contract for goods & services with any prospective firm, the firm must certify that it is not an "Iran Linked Business".

By signing below, I certify and agree on behalf of myself and the company submitting this bid the following: (1) that I am duly authorized to legally bind the company submitting this bid; and (2) that the company submitting this bid is not an "Iran Linked Business," and that term is defined in section 2€ of the Iran Economic Sanctions Act, being Michigan Public Act No.517 of 2012; and (3) That I and the firm submitting this proposal will immediately comply with any further certifications or information submissions requested by the City in this regard.

Company Name: Bound Tree Medical, LLC

Authorized Representative Signature: 

Printed: Rob Meriweather

Date: 12/02/2025

CITY OF FARMINGTON HILLS
DEPARTMENT OF CENTRAL SERVICES
PURCHASING DIVISION

31555 ELEVEN MILE ROAD
FARMINGTON HILLS, MI 48336-1165
www.fhgov.com

PHONE 248-871-2435

VENDOR QUESTIONNAIRE

Please give the following information regarding your proposal for this bid:

1. Name of Company Bound Tree Medical, LLC

2. Number of years' experience in this work: 47 years

3. List the Fire Departments that you have contracted with for this type of work during the past three (3) years.

   Name: City of Columbus Division of Fire Contact Person: Jessica Barnhard, Medical Supply Specialist

   Phone #: 614-616-4699 E-mail address: Jbarnhart@columbus.gov

   Name: Priority Ambulance Contact Person: Charlene Sifford, Director Global Purchasing

   Phone #: 865-440-0996 E-mail address: csifford@priorityambulance.com

   Name: Baltimore City Fire Department Contact Person: Lieutenant Jerami Bennett

   Phone #: 410-396-2718 E-mail address: Jerami.Bennett@baltimorecity.gov

4. Name of your bank and other financial references:

   JP Morgan Chase

5. List states and categories in which your organization is legally qualified to do business. Indicate registration or license numbers, if applicable.

   a. pharmaceuticals, licensed to sell controlled substances in all 50 states, DEA - RB0351700

6. Have you ever failed to complete any work awarded to you? No

   a. If so, note when, where and why?

7. Within the last five years, has any officer or partner of your organization ever been an officer or partner of another organization when it failed to complete a contract? No

   a. If so, where and why?

8. Please list total number of employees (part time and full time) your company employs

Total Company part time _____ & full time 300

9. Please list total number of Southeast Michigan employees (part time and full time) your company employs and the number of southeast Michigan based warehouses and employees the company operates that will service this contract.

Total Southeast Michigan part time _____ & full time 3

10. Please list the location of warehouses or store fronts that will service this contract.

Warehouse and/or store front location(s) Primary warehouse would be Elizabethtown, PA and the secondary would be Greenwood, IN. Bound Tree Medical, LLC has multiple sales representatives who who live in Michigan and the surrounding states.

11. Please list the names and qualifications of the representative(s) who will be assigned to this contract. Please include numbers of years with your company, experience and training/education.

12. Please include a detailed list of contacts with phone & email including inside sales, service & accounts receivable).

William Waite - william.waite@boundtree.com, 810-588-3424

Edward Draper - edward.draper@boundtree.com, 313-919-0270

Donald Adams - donald.adams@boundtree.com, 810-444-1317

Heather Legg - heather.legg@boundtree.com, 614-760-5179

Customer Service - customerservice@boundtree.com, 800-533-0523

13. Vendor(s) must have a distribution model capable of delivering products statewide and a demonstrated sales presence within the state of Michigan.

Does your proposal comply? Yes_X_ No ____

14. Vendor (s) must have supplied products for public emergency response agencies, or commercial customers of similar size.

Does your proposal comply? Yes_X_ No ____

15. Vendor(s) should be able to provide the full range of supplies and equipment to meet the demands of all Agencies that participate in the cooperative purchasing program.

Does your proposal comply? Yes_X_ No ____

16. Generally describe your company's customer service strategy.

Bound Tree Medical, LLC has a dedicated team that processes all incoming orders as well as a group of customer service representative's answering phone calls to accept orders and answer questions. We have a deep commitment to help those that helps others, which is why customers have access to real-time pricing and stock availability 24 hours a day, 7 days a week. We strive to be the absolute best partner to our customers with the aim of doing whatever we can to make your lives easier. We do have a option to have subscription orders set up on the website.

17. Provide a detailed overview of your ordering process. This overview will include information on how your company will handle orders as listed in section 34. It will include information of how to place said orders, delivery and any info on web order placement.

Orders may be submitted via phone 800-533-0523, fax 800-257-5713 email customerservice@boundtree.com, on the web www.boundtree.com. Accounts can be made online and is where you can place orders, review order history, and run purchase summary reports when it is convenient for you. We do have the option of subscription orders set up on the website.

18. Provide information on your companies stocking capabilities.

Bound Tree Medical, LLC proudly has 5 warehouses located nationwide with full capabilities to receive, store and ship. We have a demand planning system to ensure products are delivered on-time.

19. Describe methods used to control and manage entity inventory. Include information on how your company manages obsolete items held by the entities.

Bound Tree Medical, LLC defines an item to be obsolete when there has been no movement for two years. Once an item's sales have begun to decrease or slow down, the buyer may reach out to the vendor for a product return. If fees are assessed, Sarnova will absorb these costs for shipping and restocking.

20. Provide information on any additional discounts, purchasing incentive programs, or rebates your company offers. This can include be, but is not limited to, additional discounts based on volume increase, a Core Item usage incentive/rebate, an Internet usage incentive/rebate, a green delivery incentive/rebate or a volume incentive/rebate.

Additional savings can be realized with the purchase of UCapIt machines and Operative IQ software.

21. Provide information on added value opportunities that your company may offer. This can include but is not limited to training for new for products, hosting educational meetings for agency employees, providing leased equipment, etc.

Bound Tree Medical, LLC provides free CEUs at www.BoundTreeUniversity.com

22. Is your Company willing to extend pricing and terms given to the agencies listed in this agreement to other local entities which are part of our purchasing cooperative?

Yes_X_ No ____

If "Yes" please complete the extension information below:

EXTENSION OF AWARD TO THE MITN PURCHASING COOPERATIVE

_____ is a member of the MITN
(Person, City, Township or Entity will fill in)

Purchasing Cooperative. If your company is awarded an items or a completed contract, the cooperative governmental entities may wish to use this contract and will use a purchase order or contract for any or all the item(s) awarded following minimum order/contract requirements set forth in the bid documents. Each entity will provide their own purchase order or contract and must be invoiced separately to the address indicated on the purchase order/contract.

If an award is made to Bound Tree Medical, LLC **, it is agreed that**
(Company)

The contract will be extended to any entity in The MITN Purchasing Cooperative under the same prices, terms, and conditions.

SHIPPING AND PRODUCT AUTHENTICATION

All orders are picked via Company pick ticket, which is used for quality, accuracy, customer verification and documentation.

Product with expiration dates are picked to ensure that product with the closest expiration date is shipped first ("first-expired/first-out" = FE/FO).

When the product is identified and picked, the picker verifies the product label against the pick ticket. This verification includes but is not limited to the following:

- Product item number, description, and NDC number.
- Product expiration date is verified as more than six (6) months remaining or per customer requirements.
- Product lot number or serial number.
- Unit of measure that has been ordered (example: each, case).

During the picking process, the product is carefully inspected for identity and to ensure the product has not been damaged, stored under improper conditions or has expired. After the order is picked, a quality check is performed to ensure that the following are accurate

The packing of product step is to ensure that the goods arrive to the customer without damage or any other integrity issues.

The packing process include the following factors:

- Verify product for accuracy.
- Ensure items are securely placed in proper shipping container.
- Ship product/order to customer via common carrier.

PRODUCT VERIFICATION

- Items ready for packing and shipping shall be inspected to verify that the proper product is being shipped, that the expiration date has not passed and that it is not damaged or has been held under improper conditions.
- Items shall be shipped in the original manufacturer cartons when appropriate. If items are repacked, proper cartons and packaging materials shall be used to minimize the chance of breakage or other damage to the contents.

SHIPPING PROCESS

Product is shipped by common carrier or may be shipped via a Company delivery vehicle.
All shipments of prescription products require signature by the customer upon delivery.
Prior to shipment/distribution, all outgoing shipment, specifically but not limited to prescription drugs, must be carefully inspected to verify identity and to ensure that there is no damage or product held under improper conditions.

DELIVERY OF PRODUCT AND SERVICES

Bound Tree Medical will be able to provide immediate access to medical supplies as required. There will be no delay in providing high-velocity items right away.

The only foreseen factors that could possibly inhibit or delay delivery of medical supplies are:

- Manufacturing Backorders: The local Bound Tree Account Manager will keep you completely apprised of any backorder situation, existing or imminent. As Chandler is acutely aware, this has recently been the case with pharmaceutical items. We will keep you constantly aware and offer alternatives when available. As allocation schedules are different for every distributor, we definitely understand you seeking these goods elsewhere, but hope that you will purchase from Bound Tree when able.
- Manufacturing Contracts: Bound Tree Medical has agreements with the large majority of EMS supply manufacturers. In the event that Chandler requires a specific manufacturer with which we do not have a relationship, we will attempt to effect an agreement with that manufacturer.
- It has been our experience that these sorts of situations arise infrequently. However, should Bound Tree Medical not be able to mitigate these circumstances, we definitely understand you seeking these goods elsewhere.
- In the event of backorders, Bound Tree Medical's system will automatically look to ship product from an alternate distribution center where available.
- In the event of manufacturing contract issues: Bound Tree Medical will attempt to establish contracts with manufacturers used by Chandler. In the event we cannot come to an agreement with a desired manufacturer, Bound Tree will offer alternatives, and will certainly understand if Chandler desires to seek elsewhere.

CUSTOMER SERVICE APPROACH

BTM recognizes that time is of the essence to our emergency care customers. Generally, orders received and processed before 2:00 pm local item are shipped the same day. We have a dedicated team that processes all incoming orders as well as a group of Customer Service Representative's answering phone calls to accept orders and answer questions.

CUSTOMER ADVOCACY

The Customer Advocacy Program is a program where advocates review transactional data but with the customer lens. We call it a white glove service or extra tier of dedicated customer service. As an advocate customer, an assigned staff member will review the customer fill rates, what is available, what is shipping from alternate locations and work closely with the buyers to ensure inventory availability wherever possible

to fulfill the customer's need. The Advocate will then generate reports for review on Bound Tree performance in additional areas such as holds applied to orders and timing / accuracy of the customer order; if errors are found, they will find why and help to remove the challenges. The final metric we look at as an advocate is of the total lines ordered what percent did we ship complete same day from the customer's default warehouse.

OVERVIEW OF BOUND TREE'S ORDERING PROCESS

Orders may be submitted via the below methods:
Phone: 800-533-0523
Fax: 800-257-5713
Email: **customerservice@boundtree.com**
Web: **www.boundtree.com**
Please find additional Customer Service and ordering information at the end of this tab

DELIVERY AND ARO

Below are the standard delivery methods that will be employed by Bound Tree Medical to support an award from Farmington Hills. The Standard delivery days is provided assuming receipt of order is placed prior to 3:00 p.m. EST. Each day, placing orders prior to 3:00 p.m. EST. Helps to ensure that they are placed into fulfillment same day.

Standard Delivery

Small Parcel

- Delivered by FedEx Ground
- Standard delivery from primary warehouse is 1-2 day

LTL Freight

- Delivered by R& L Carrier
- Standard delivery from primary warehouse is 1-2 day

Expedited Delivery

Small Parcel

- Delivered by FedEx Next Day
- Additional costs are dependent on actual dimensions and weight of cartons shipped

LTL Freight

- Delivered by R& L Carrier
- LTL –Next Day

On Time Delivery

Below are the standard on-time delivery and stock-out data from contracts or customers of similar size and scope to Chandler Supplies bid.

On Time Delivery rates
FedEx Ground - 98.5% on time
LTL via RL Carrier - 98.1% on time

STOCKING CAPABILITIES AND INVENTORY CONTROL METHODS

STOCKING CAPABILITES

- 5 warehouses located nationwide with full capabilities to receive, store and ship
- Same or next day shipping availability on stocked items.
- Climate controlled storage capabilities.
- Well-stocked inventory for customer's needs, including safety stock for any emergency and un-forecasted requirements
- Bulk storage available
- In the event of an emergency or natural disaster, multiple locations are licensed to ship to all states as an alternative to the primary shipping warehouse.

  Inventory Control Methods
- Establish monthly usage to determine stocking policies (order point or buy to order)
- Maintain an inventory/demand planning system that is driven by analysis and forecasting by buyers.
- Demand planning system utilizes lead times and safety stock levels to ensure product delivers before it is needed so items arrive in time for use.
- Ability to drop ship orders direct from manufacturer

MANAGEMENT OF OBSOLETE ITEMS

Bound Tree Medical defines an item to be obsolete when there has been no movement for two years. Before an item is considered obsolete, it is first deemed "excess" inventory. This inventory is reviewed in the overall network and then broken down to see if there is usage in any particular warehouse where product can be transferred. Once an item's sales have begun to decrease or slow down, the buyer may reach out to the vendor for a product return. If fees are assessed, Sarnova will absorb these costs for shipping and restocking. If an item becomes obsolete then it will go through an internal workflow process.

PROCESS OUT OF STOCK/BACKORDERED ITEMS

Information describing the process for out of stock/back-ordered/extended ship times items is illustrated below. Please note screenshots from our website illustrating the automated communications received through our online ordering system.

Based on feedback from our customers, we have enhanced our transactional communication over the past year. Although we have always provided some level of notification to our customer, the amount of information and scope of customer we send it to has been expanded.

Some of the key changes/enhancements we have rolled out in FY18 are:

- Added ETAs for backordered items
- Added tracking numbers on all shipments
- Photos of products in all order communication emails
- Backorder notifications sent weekly if changes occur in original ETA
- Shipment notification and backorder notification for all order types, not just web
- Timing of shipment notification changed to coincide with actual shipment rather than invoicing

The following highlights automated email notifications you will receive:

- Order Confirmation – acknowledges receipt of order, confirms lines
- Order Status – sent within 20 minutes generally, shows inventory status including ETAs for backorder, shipping location, etc.
- Shipment Notification – sent nightly for shipments made that day and includes tracking number that link directly to FedEx
- Backorder Update Notification – sent weekly for any back order with changes in original ETA

Below are examples of automated email notifications and communications.

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BTM Customer Order Communications
Order Status Notification

Bound Tree

Your Order Status

We are working to fulfill your order now!
Below is a summary of items allocated to your order.

If you have questions regarding the status of your order, please contact Customer Service at 800.533.0523 or email CustomerService@BoundTree.com

We'll send you a shipment notification email once your order has been shipped.

Please note: The item(s) you have ordered have been allocated to your order through our order-fulfillment system. Item allocation is subject to change. Items may ship from multiple warehouses. This email was automatically generated.

Order Information:
Account Number: 202277
Order Number: 38710598
Order Date: March 20, 2018
PO Number / Order Reference:

Ship to:
JESS
14 CORPORATE DR
HALFMOON, NY 12065-8607
US

Bill to:
TROY AMBULANCE SERVICE INC
PO BOX 438
ACCTS PAYABLE
COHOES, NY 12047-0438
US

Shipping Method: >$150 NO FRT

Drop ship – Item(s) will be shipped directly from the manufacturer
Long-term backorder – Item is currently on a manufacturer backorder. We will ship your item(s) once it's available for distribution.
Temporarily out of stock – This item is not currently in stock. We will ship your item(s) as soon as the product becomes available to us.

Remaining Items:



Item #: 660-05
Metoprolol, 5mg, 5mL Vial
By: OTHER MANUFACTURER

UOM	Qty Ordered:	Qty Allocated:	Qty Remaining:
BX	2	0	2

Out of Stock - Ready to ship in 1-2 months



Item #: 0593-03
Glucagon Kit 1mg contains 1 vial of 1mg Glucagon and 1 vial of 1ml Sterile Water. Glucagon is in powder form in a 1mg vial along with 1ml of sterile water for reconstitution
By: OTHER MANUFACTURER

UOM	Qty Ordered:	Qty Allocated:	Qty Remaining:
EA	1	0	1

Out of Stock - Ready to ship in 1-2 weeks

Allocated Items:



Item #: 2113-10240
Endotracheal Tubes, Cuffed w/Stylet, 4.0mm
By: CURAPLEX

UOM	Qty Ordered:	Qty Allocated:	Qty Remaining:	Allocated Location:
BX	1	1	0	Elizabethtown, PA

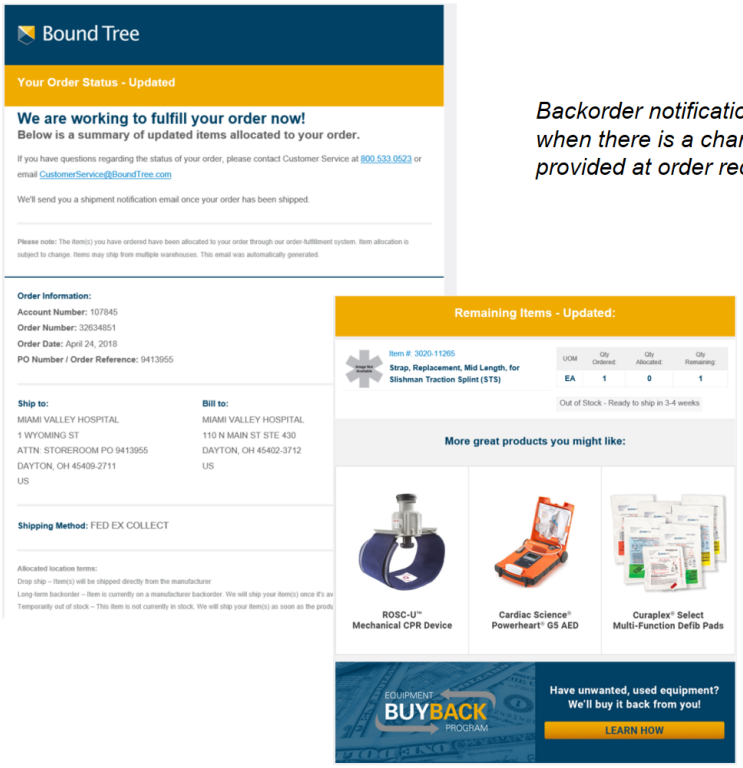


Item #: 2113-10250
Endotracheal Tubes, Cuffed w/Stylet, 5.0mm
By: CURAPLEX

UOM	Qty Ordered:	Qty Allocated:	Qty Remaining:	Allocated Location:
BX	1	1	0	Elizabethtown, PA

sarnova

BTM Customer Order Communications
Backorder Notification



Backorder notifications are sent when there is a change to the ETA provided at order receipt

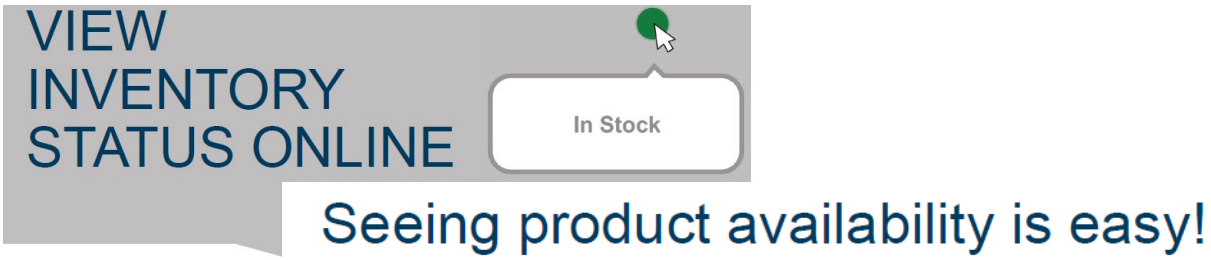
Self-Service Account Management Features

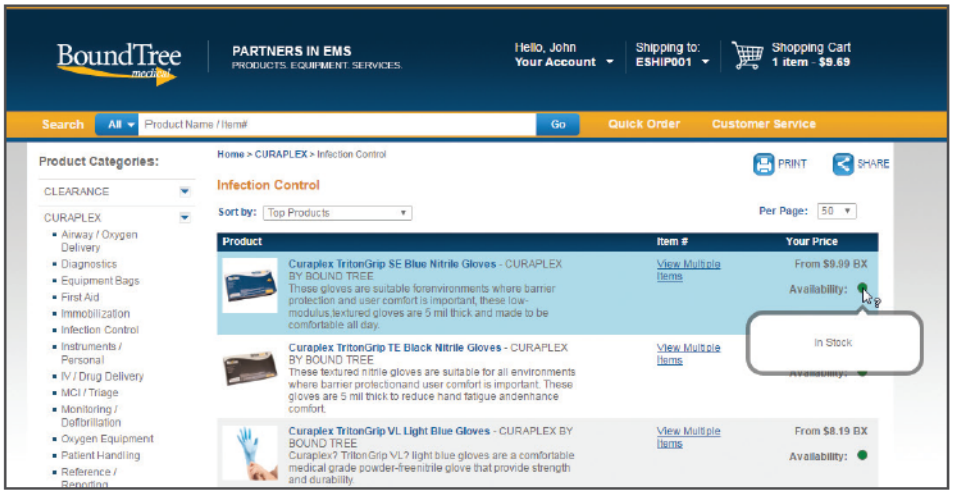
- Enhanced Account Dashboard – Convenient location and display of order history, supply lists, reports and account-specific info makes checking-up on an account's activity easier
- Improved Supply List Usability – Supply lists are sharable between individuals within an account, making it easier for you and the account to set them up and use
- Account Customization – Now available to all on request, customers can set quotas, par levels and permissions at ship-to level and even create custom catalogs, to truly customize their web ordering processes
- Check-Out – Now four easy steps all on one page, so customers can check-out more quickly
- Mobile Responsive – The site now displays effectively on small mobile devices for ease of anywhere shopping/ordering, even when out on a run
- Onsite HELP – The Help section of the site provides easy to view, self-help guides on website functionality

Enhanced Search and Product Details

- Faceted Search – This feature gives you the ability to narrow down searches with criteria to find items more quickly
- Product Comparison – Easy way to compare up to four items, displaying product features side-by-side to aid in product selection
- Product Photos – We've provided more and larger product photos to make identifying and selecting items more visual
- Product UOM – UOM is now clearly identified and selectable for each product, leading to fewer ordering mistakes!
- Product Info – Robust product descriptions, additional flyers and videos are added to the product pages, with related accessories and replacements listed on the product page for ease of shopping
- Product Availability – Inventory status displays wherever the product is shown on the site and customers are promoted to log in to see their availability

Below is a detailed illustration on how our product availability works on our website.





BOUND TREE MEDICAL WEBSITE & ACCESS

www.boundtree.com

Farmington can link to their account by registering and selecting “already have an account”. Enter their Account Number and Billing Zip Code. Registering will allow you to see your pricing and stock availability.

The Bound Tree website gives you full control over your account. You can place orders, review order history, and run purchase summary reports when it is convenient for you. You can also easily access the items you order most frequently by utilizing supply lists, saved carts or previously ordered items. These features make your online shopping experience quick and easy.

We want to make your online shopping experience even easier! Utilize our inventory status feature to see product availability before you place your order.

Customer Service and Ordering



Bound Tree Medical is focused on providing service to meet the needs of our customers throughout the United States. We have a deep commitment to help those that help others. The specialized market that we serve drives us to create the best possible solutions for our customers. We are here to serve you.

Our nationwide toll-free Customer Service line is 800-533-0523. Bound Tree Medical routes calls by origin of the zip code of the caller which, results in more customer awareness among those agents responding to customer calls.

There are a variety of methods to place orders and verify pricing:

1) Internet: Customers have access to real-time pricing and stock availability 24 hours a day, 7 days a week. www.boundtree.com
2) Email: Orders may be emailed to customer service at customerservice@boundtree.com.
3) Phone: Our dedicated team of customer service representatives can answer questions or take your orders from 7:30 AM to 8:00 pm EST.
4) Fax: Our nationwide toll-free fax line is available 24 hours a day at 800-257-5713.
5) Mail: Orders may be mailed to our corporate office. An order form is included in the back of our catalog for convenience.

The Customer Service Department is comprised of 45 staff members. Customer Service Representatives respond to inbound calls and make outbound calls to customers to provide information regarding product availability, shipment and delivery schedule changes. These same representatives are available to answer questions about shipments or process returns when necessary.

If an item goes onto a long-term backorder, Bound Tree will work to find equivalent substitute items for the backorder. If it is the customer preference to approve all substituted items, Bound Tree Customer Service will seek approval prior to shipping sub items.

Bound Tree Medical allows customers to purchase on open account. The proper account application must be completed and submitted. Bound Tree Medical will assign an account number to each application. Each account has one billing/payables address but may have several shipping/receiving addresses.

Customers may purchase by Master Card, VISA, Discover or American Express. Prepaid orders are also accepted.

Boundtree.com Overview

The Bound Tree website offers advanced ordering and account management features to help you easily manage your supplies 24/7 via desktop, phone or tablet. Your Account Manager and Customer Care representative can provide training and help you get set-up to utilize these robust site features to save you time:

Shopping/Purchasing

- **Mobile Responsiveness** – The Bound Tree website is fully responsive to any size media screen making it easy for you browse and purchase directly from your tablet or phone.
- **Search** – Search by item number or key word. The filtered search option allows you to narrow down your search by selecting multiple criteria like manufacturer, price, color, size, and more.
- **Product Pages** – Robust product descriptions, large photos, specification charts, videos and downloadable collateral provide details on products so that you can make informed decisions.
- **Product Availability** – Log in to see real-time inventory status on products throughout the site.
- **Product Comparison** – Easily compare product specifications for up to four products by clicking on the compare box next to any product listing.
- **Supply Lists** – Supply Lists allow users to access quickly the products they need to order with only a few clicks. When signed in, Supply Lists can be created easily from the Supply Lists page, a product detail page, the Quick Order form, or the Shopping Cart or simply upload a list. Denote your favorites for quick access and share lists with other users in your account.
- **Quick Order** – Quick Order enables you to order items quickly by simply entering a Bound Tree item number and quantity into a form.
- **Browsing History** – Signing into your account allows you to track and view the last 5 products that you looked at.
- **Checkout** – Checkout is just four easy steps on one page, so you can check out more quickly.

Account Management

- **Account Dashboard** – The Account Dashboard is home to your account information and settings. Access the things you care about most, like the status on your most recent order, your outstanding balance, and your favorite supply lists, quickly in one location.
- **User Management** – Add or remove users to your account, change permissions, and enable or disable your account registration access.
- **Order History and Invoices** – View and search order invoices from your Order History reports.
- **Saved Credit Cards** – Saved credit cards allow you to select a saved card during checkout rather than retyping your information every time you checkout.
- **Saved Carts** – Items added to your Shopping Cart will be available from any computer that has been signed in to your account.
- **Quotes** – View available product Quotes from your Account Dashboard.
- **Download as Quote** – The download as a quote feature allows you the ability to download your cart as an Microsoft Excel file and easily send the file to your Account Manager for a quote or use it internally to get a purchase order created within your organization.
- **Previously Ordered Items** – View, search, or add Previously Ordered Items directly to your Shopping Cart or Supply List.
- **Tracking Information** – Look at the tracking information on your orders so that you know when to expect them to arrive.
- **Reports** – View or download customized reports, such as Purchase Summary, Purchases by Month, Backordered Items, DSCSA Transactions and more.

Account Customization

- **Custom Categories** – Set-up and display your own custom categories for your users only.
- **Quotas** – Quotas are a quantity budget that allow organizations to cap the number of products user accounts can purchase in a certain period.
- **Par Levels** – Par levels allow organizations to set what quantity level their organization must keep in stock at all times.
- **Purchase Requests** – Send the contents of your Shopping Cart to other members within your organization for approval to purchase.
- **Replenishment Orders** – Replenishment Orders allow you to schedule regular deliveries of your favorite supplies and eliminate the need to frequently place the same order. You control how frequently the order is replenished and we take care of the rest.

Help and More Content

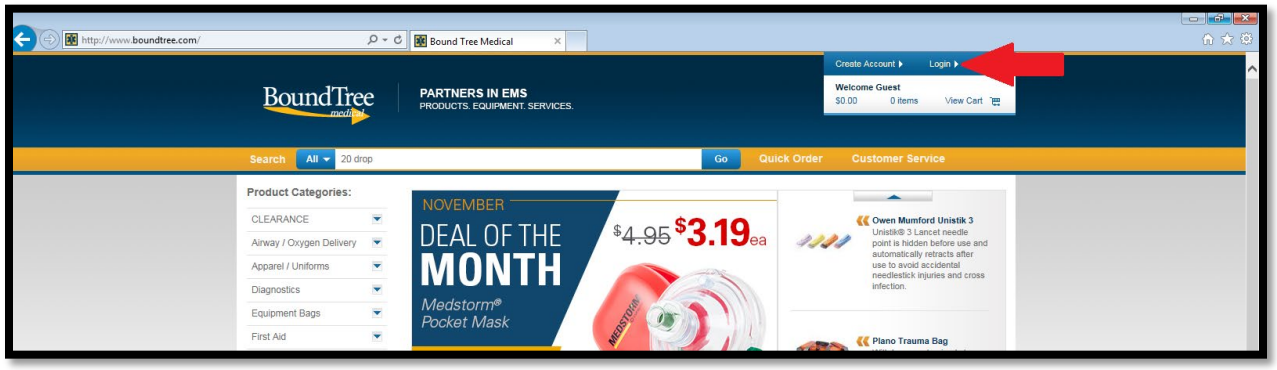
- **Online HELP** – Easy to view, how-to guides on website functionality located on the site for your convenience.
- **Online Catalogs** – View, download or request a printed catalog online.
- **Bound Tree University** – Bound Tree University is an educational resource located on the site that features free CEUs, articles, and videos on topics like cardiac care, sepsis detection, mass casualty incidents, and many more.

EMS SUPPLY ORDERING PROCEDURE

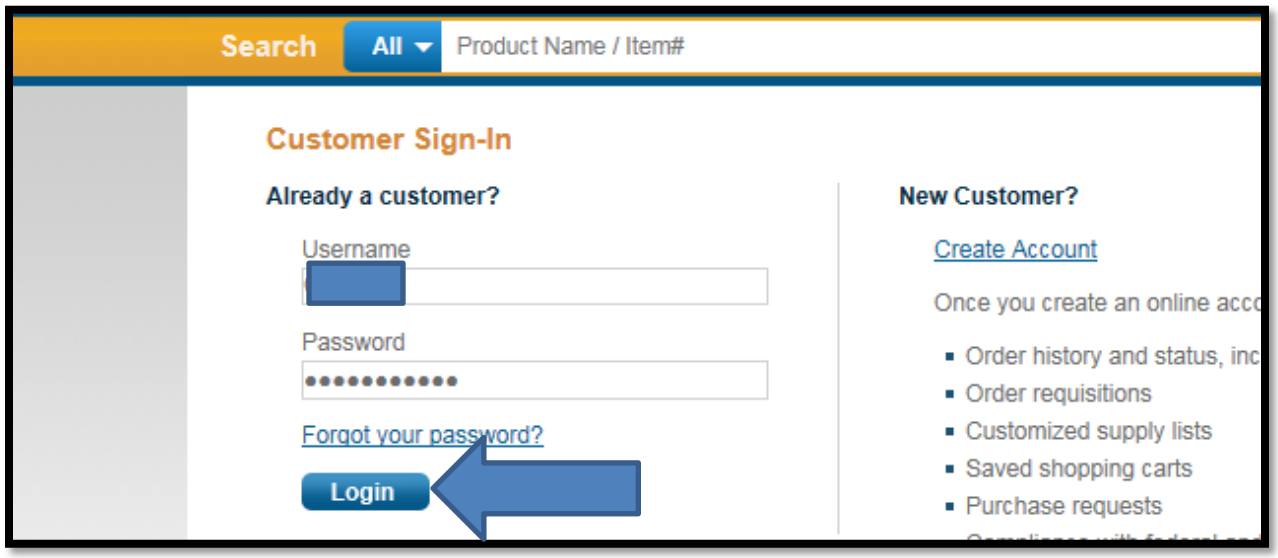
In an effort to simplify the ordering process, stations will now order most of their EMS supplies through the Bound Tree + website. The new ordering site is very similar to what we have been using and is accessed from the same login page on Bound Tree's site.

Placing a Weekly EMS Supply Order

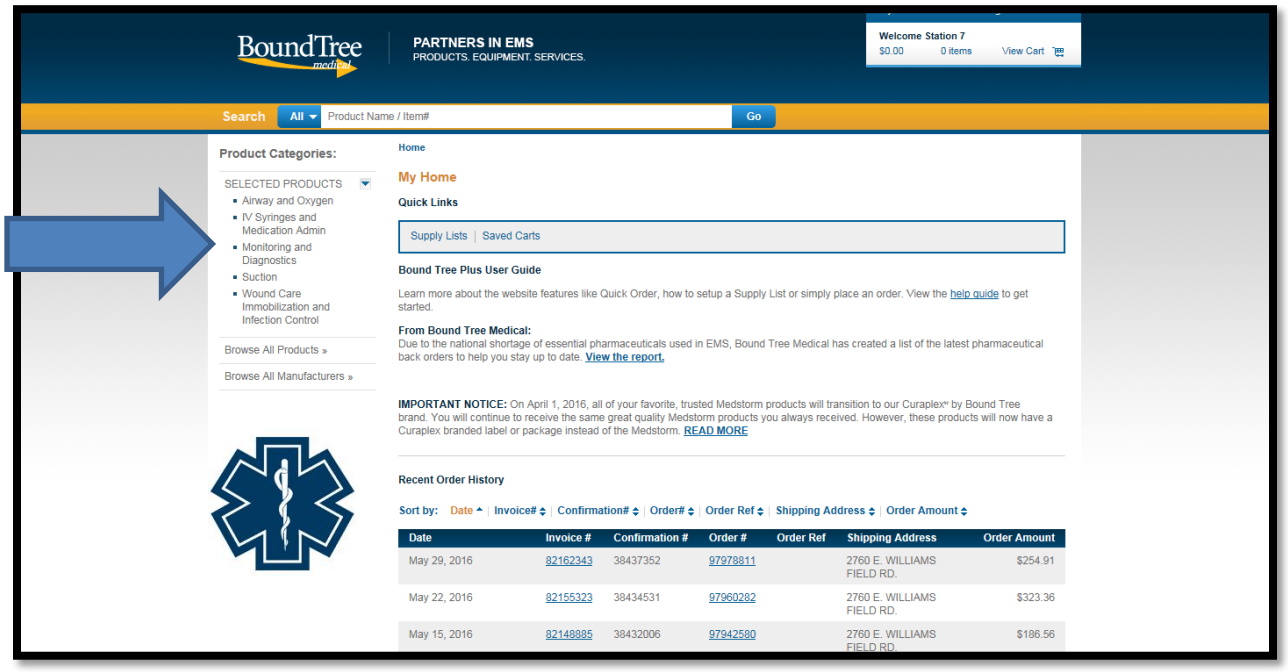
Open http://www.boundtree.com and select "Login" towards the top right of the screen.



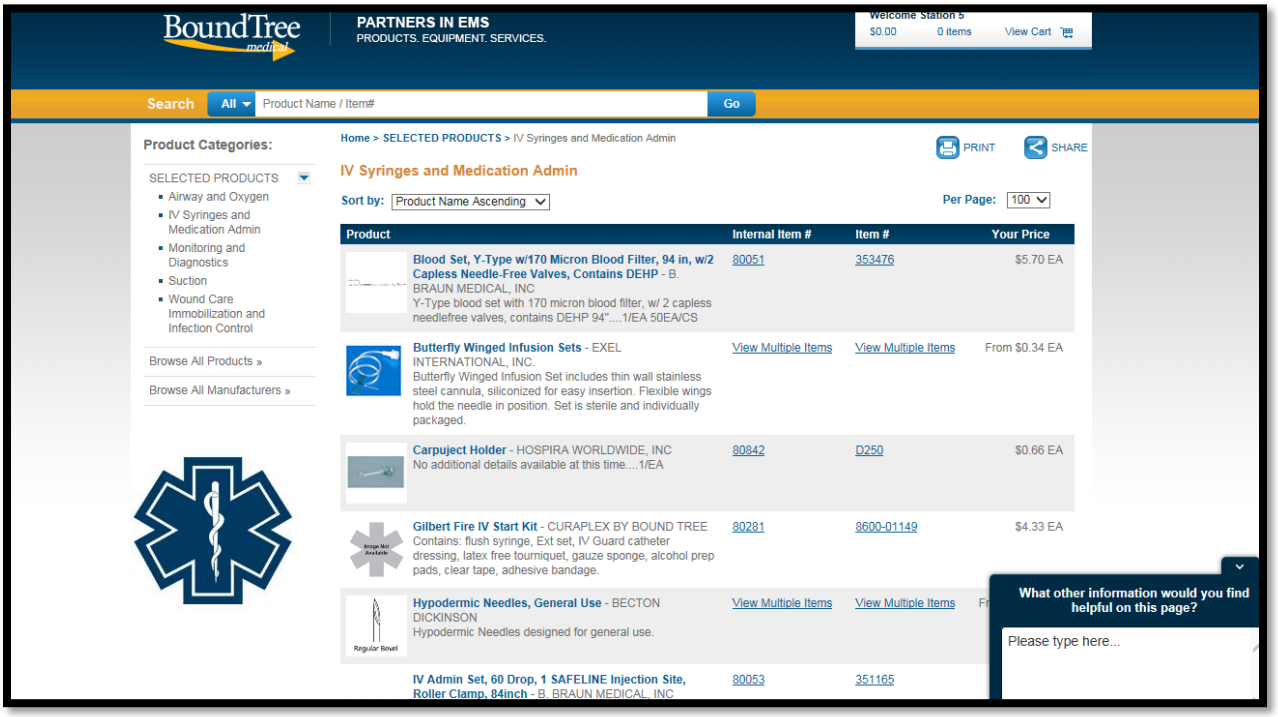
To login enter a Username and Password and hit the Login button. The Username is specific to the station you are ordering from, for example, for **********", for ********* "**********". The password for all stations is now "**********".



The supply lists are now located on the left side of the ordering screen and are very similar to the previous lists. Click on the desired category to see the items available.



Once a supply list is open, scroll down to find the desired item and click on it to open.



If the item you selected is available in different sizes such as IV catheters, you will see them listed and you can enter the desired quantity for each.



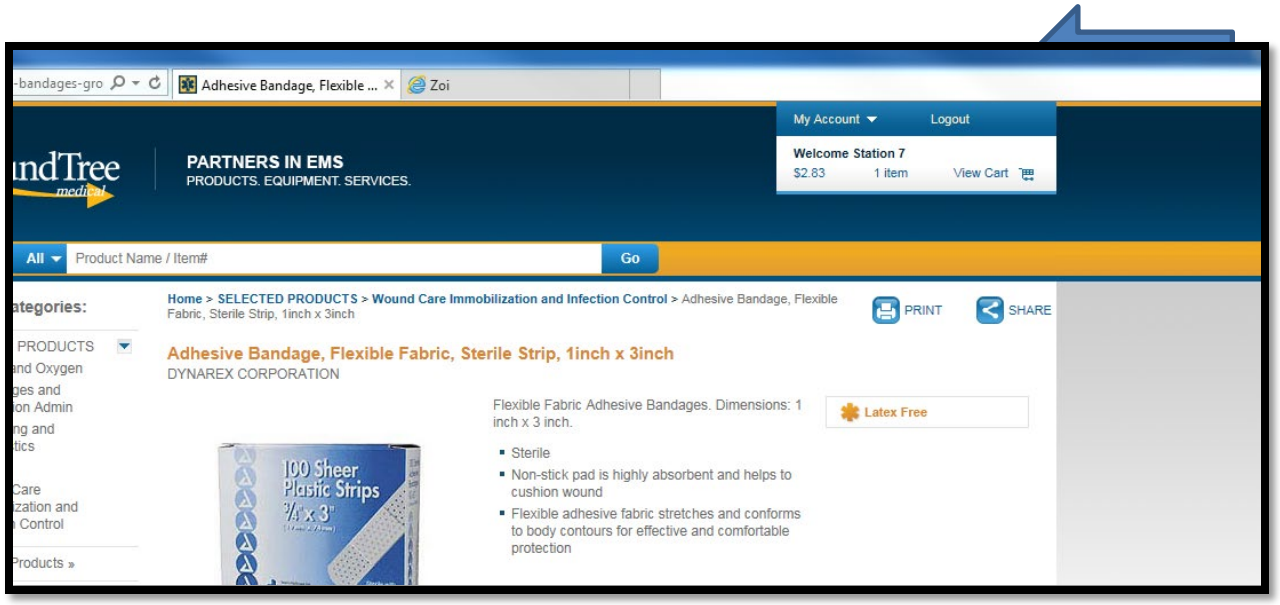
PLEASE NOTE: *In some instances, product photos may vary from actual product models, sizes and/or colors listed below.*

Product Usage Information *(Last Updated: 6/12/2016)* More Usage Reports

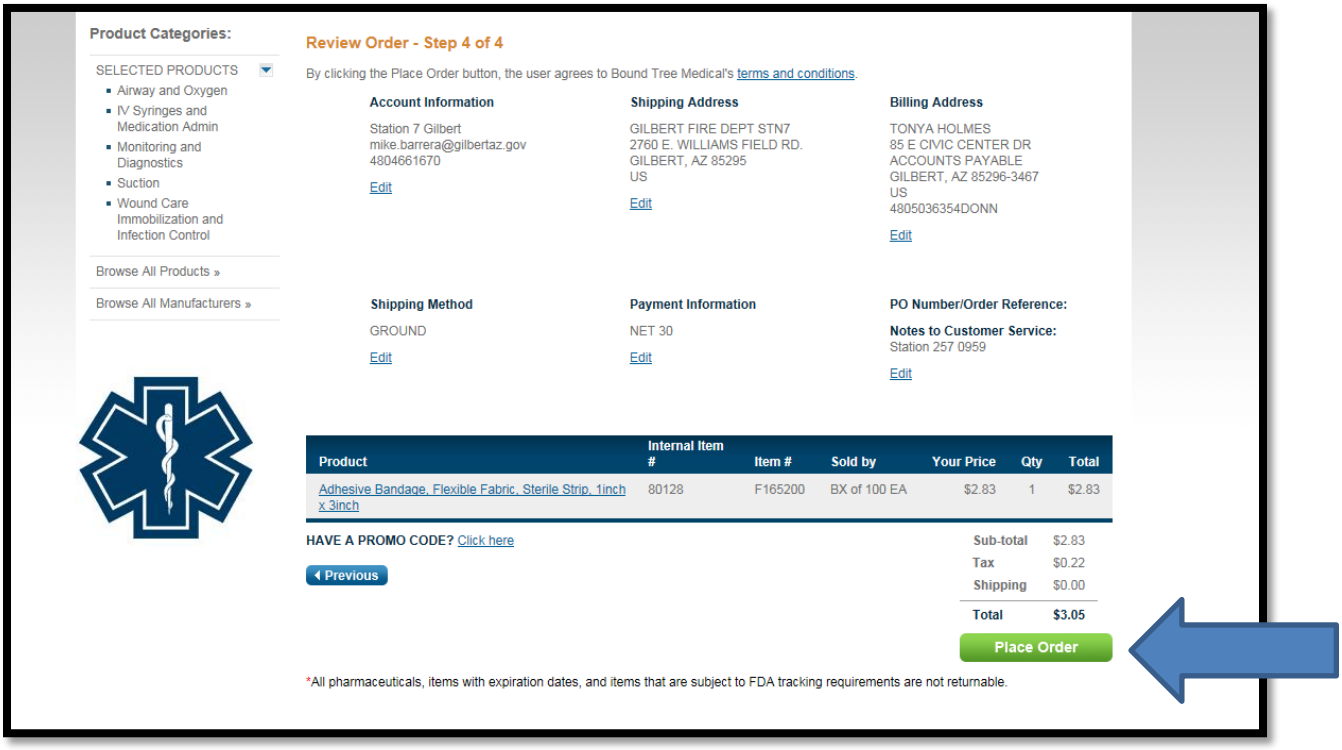
Internal Item #	Item #	Ordered this month	Ordered this year
80064	353063	1	5
80063	353060	4	50
80062	353066	0	0
80061	353065	0	0
80060	353062	1	15
80059	353068	0	12

Product	Internal Item #	Item #	Sold by	Your Price	Qty
Protectiv Plus IV Catheters, 24ga x 3/4inch	80064	353063	EA	$2.12	0
Protectiv Plus IV Catheters, 22ga x 1inch	80063	353060	EA	$2.12	0
Protectiv Plus IV Catheters, 20ga x 1 1/4inch	80062	353066	BX of 50 EA	$106.20	0
Protectiv Plus IV Catheters, 18ga x 1 1/4inch	80061	353065	BX of 50 EA	$106.20	0
Protectiv Plus IV Catheters, 16ga x 1 1/4inch	80060	353062	EA	$2.12	0
Protectiv Plus IV Catheters, 14ga x 1 1/4inch	80059	353068	EA	$2.12	0

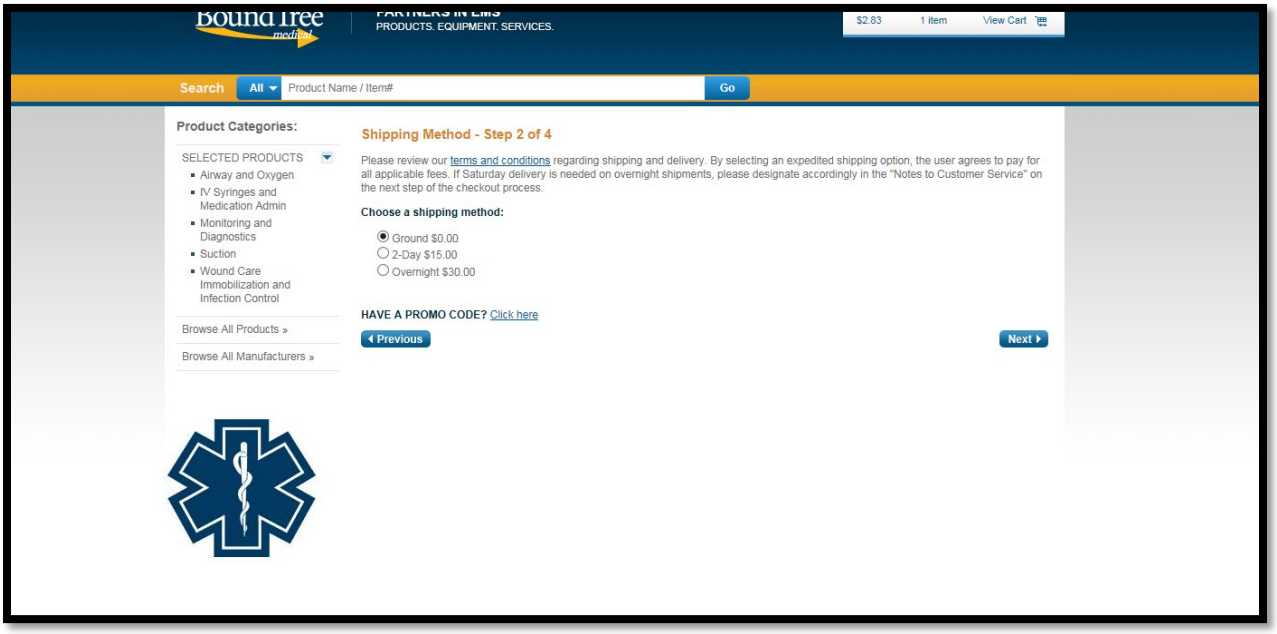
Repeat the same procedure for each Supply list until all items are in the cart. When you are ready to place the order, select “View Cart”.



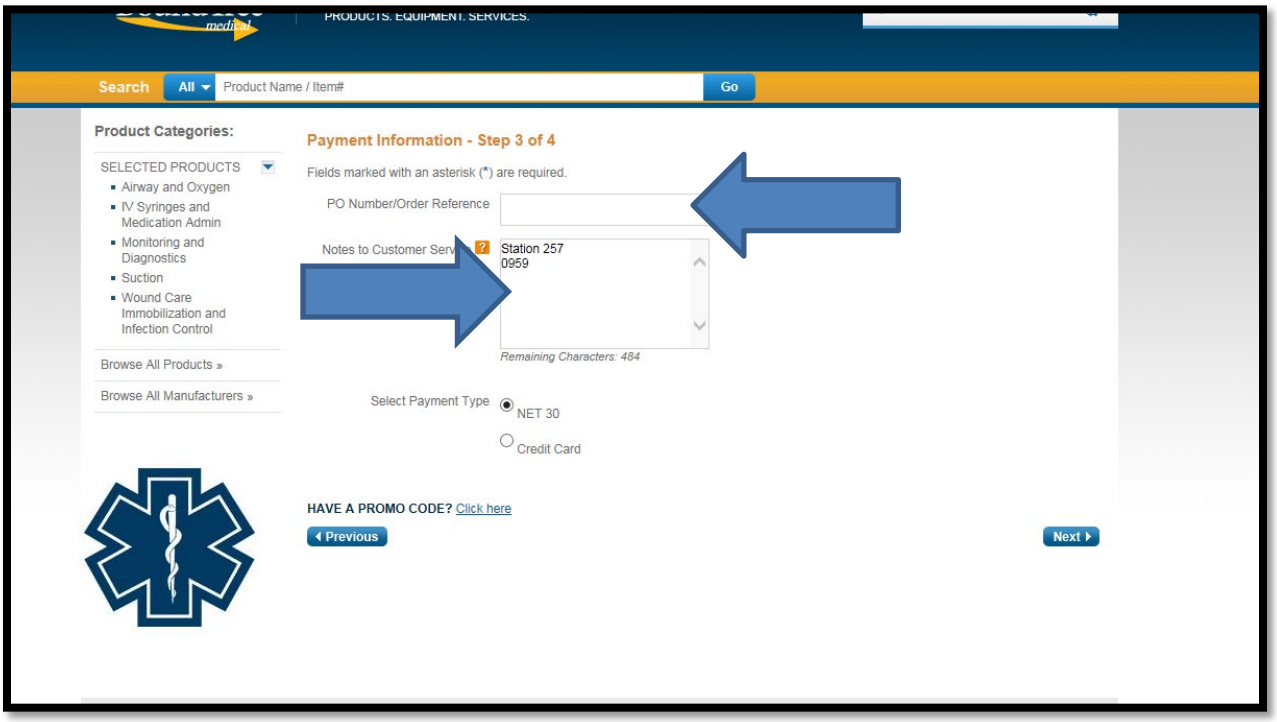
You can review your order one last time and then click “Place Order”.



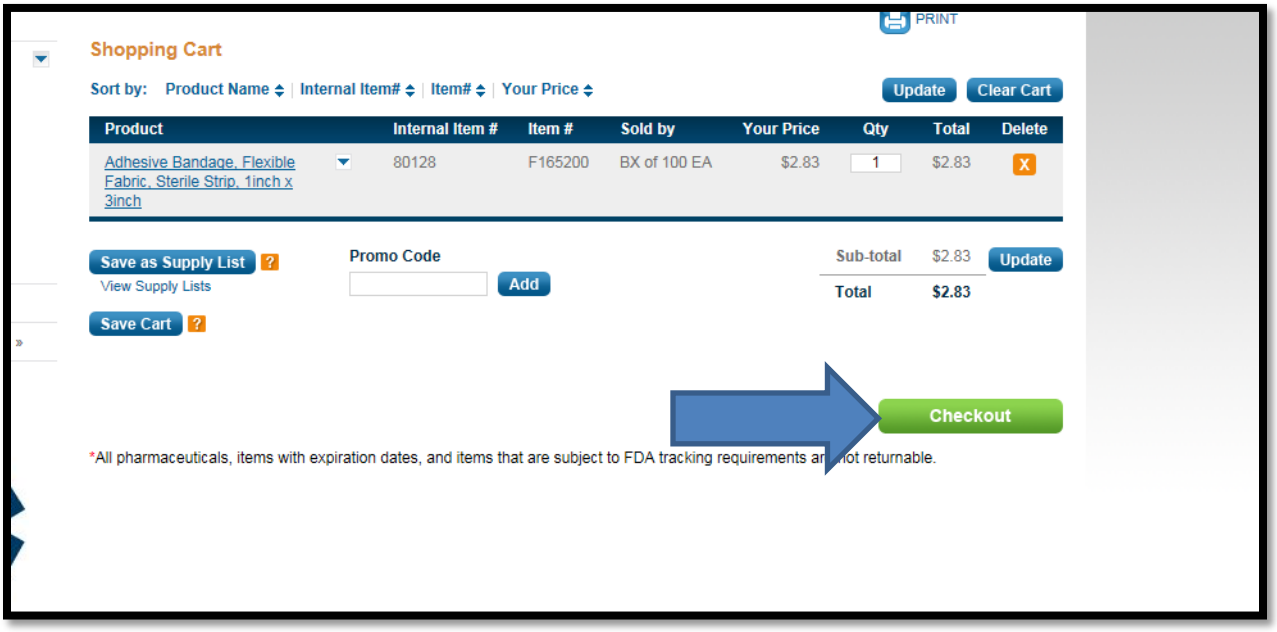
Leave the shipping method as ground, then click “Next”.



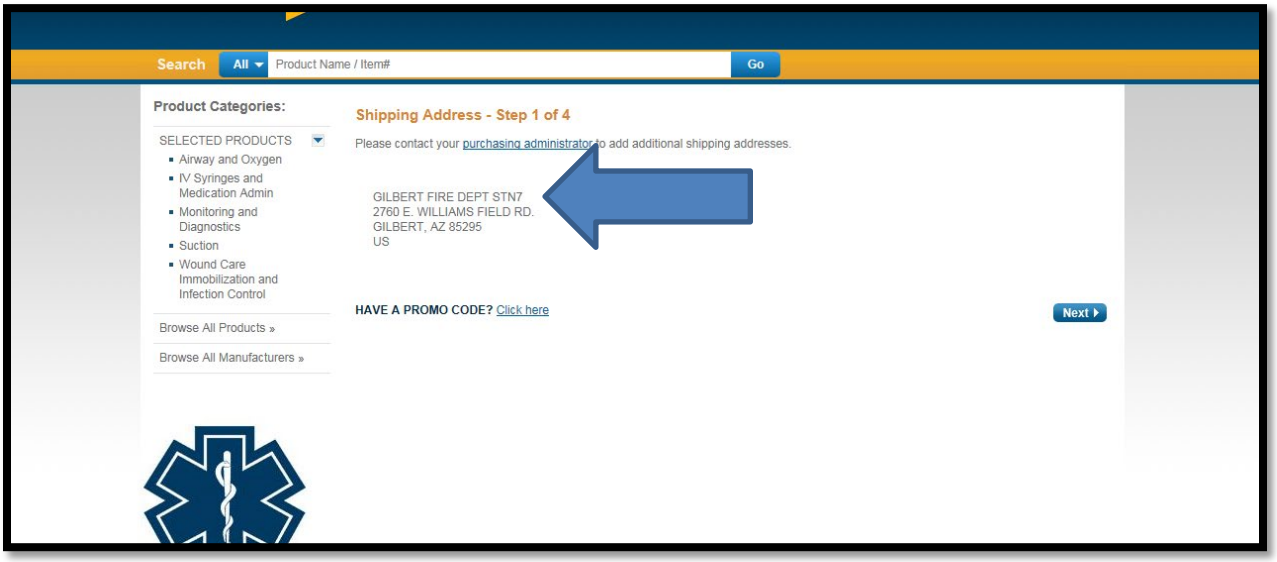
Make a note of your station number in the PO Number/Order Reference” and “Notes to Customer Service” box, leave payment type as NET 30, and hit “Next”.



Check your order for accuracy and select “Checkout”.



Make sure the station number is correct and click “Next”



Bound Tree

December 3, 2025

City of Farmington Hills
Department of Central Services

Dear Michelle Aranowski:

Bound Tree Medical knows that Healthcare is ever changing, and the pre-hospital setting is transforming faster than ever before. Patients are presenting more challenging clinical cases while continual budget compression leaves you to do more with less. The increased pressure to track supplies, manage your fleet and provide staffing makes managing your service more difficult than ever. Our goal is to help you meet all your supply and clinical support needs while driving efficiencies and helping to stretch your resources further.

Controlling product cost is a very important piece of our proposed solution, but we also recognize that
time is money. Our proposed solution includes, but is not limited to the following:

- Bound Tree Medical has industry-leading pricing and contract teams to ensure The City of Farmington Hills Cooperative receive products at highly competitive prices. This, combined with our buying power, helps to keep your cost of goods low.
- Exceptional manufacturing partner relationships that allow us to receive all-customer, and customer-specific rebated pricing which will further reduce your product costs.
- High quality, private label products, at lower costs through our extensive, and ever-expanding Curaplex line.
- Best-in-class customer service, from the ground up.
- Bound Tree is offering at The City of Farmington Hills Cooperative valuable inventory and asset management solutions to increase operational efficiency and accuracy, reduce liability and positive impact on your bottom line at little to no cost. We have partnered with industry-leading technology companies to offer you solutions that will enable you to streamline your ordering process and better manage your inventory. These are outlined below.

During a 1 on 1 meeting ED Draper will review the needs of your business to determine which of be below combinations of inventory management technology would bring the most value into your organization. Once the combination has been reviewed, he will be able to provide that solution at little to no cost.

Operative 10 Asset Management
Operative 10 inventory management solution is designed specifically for the EMS industry. Inventory management eliminates user error while adding accountability. By replacing manual paper processes, Operative lQ's inventory management tool provides tracking of medical supply expiration dates and lot numbers, station inventory and vehicle inventory.

Bound Tree Medical
5000 Bradenton Avenue
Dublin, OH 43017
www.boundtree.com

With Operative IQ, asset management, controlled substance tracking and fleet maintenance are all controlled and connected through one system. Asset management empowers you to know the location and history of your asset maintenance, store documents online, generate reports and quickly check assets out and verify their location. Controlled substance tracking enables you to replace your current paper logs with a more secure system. It provides the needed capability to track your narcotic boxes, expiration dates, lot numbers, and easily create reports on the possession and movement of controlled substances. Fleet maintenance connects your frontline crew with your fleet manager by tracking and scheduling vehicle repairs and routine maintenance based on crew member inspections. Crew members can report mileage, fuel costs, damage and vehicle service requests. Inspections completed using the Operative IQ check sheet make it easy to generate reports that keep vehicles in service while understanding their cost per mile.

Operative 10 is directly integrated with Bound Tree Medical's Order Management System which allows for easy and accurate ordering. Operative 10 will build your order form/PO as items are moved from the upstairs storage area to the binning/kitting room. When the order for PO is authorized and sent through.

UCaplt Controlled Access Medical Supply Dispensing

Maintaining and ordering pharmaceutical items can be a major supply room and regulatory concern. Bound Tree Medical offers the UCapIt Controlled Access Medical Supply Dispensing solution to successfully mitigate the challenge. This system helps monitor and track accountability for access to controlled substances, narcotics, pharmaceuticals, and durable assets and helps ensure that items with expiration dates are used in a timely manner. Usage reports, restock lists and other inventory reports can be generated for integration into billing/tracking software. Annual savings using the UCapIt dispenser have been realized up to 30% related to shrink, expiration management and overhead. The UCapit software integrates seamlessly with Operative IQ.

Both Operative IQ and UCapIt dispensing solutions are rapidly becoming/have become industry standards in controlling inventory and managing assets. Bound Tree Medical has many customers nationally that use these products, both singularly and in tandem. Bound Tree Medical is the sole source for UCapIt dispensing solutions.

Controlled Substance Ordering System

The Controlled Substances Ordering System (CSOS) was developed by the DEA for the electronic transmission of Class II controlled substances orders. Bound Tree offers this solution and it is the only allowance for electronic ordering of Class II controlled substances. CSOS allows for a significant reduction in the number of ordering errors, faster transaction times and lower costs due to order accuracy and decreased paperwork.

William Waite

Michigan, Account Manager

810.588.3424

William.waite@boundtree.com

Heather Legg

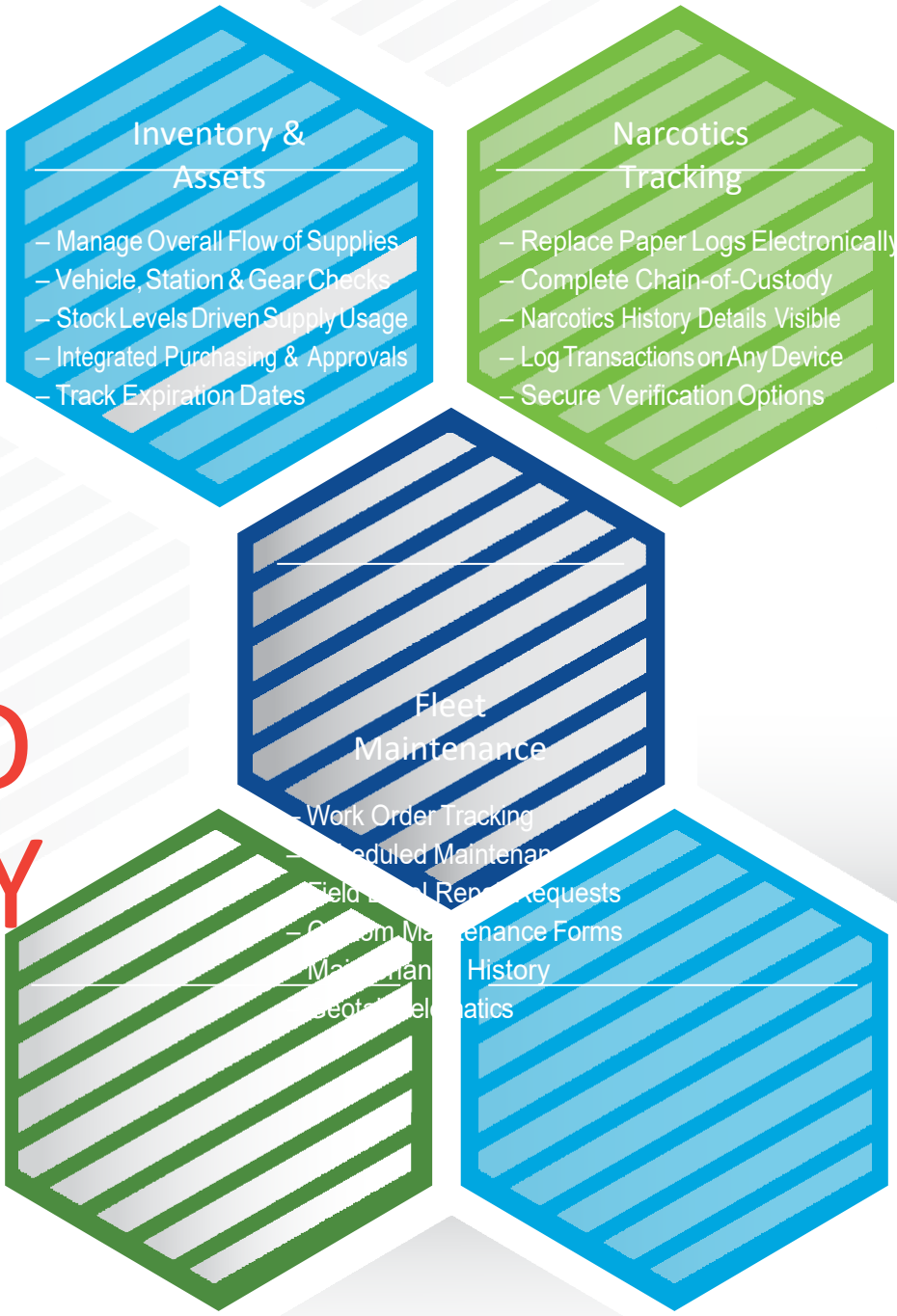
Pricing Analyst, Bids & Contracts

800.533.0523 x5179

heather.legg@boundtree.com

OPERATIVE IQ

DESIG NED AROUND THE WAY YOU WORK



Operations Management in the Palm of Your Hands

Operative IQ goes beyond standard warehouse management software by continuing to track inventory and equipment in the field providing you with complete visibility across a distributed supply chain. This unique cloud-based solution seamlessly connects field personnel to management through our Check Sheet application and Back Office.

Designed for First Response and Public Safety professionals, Operative IQ understands your daily demands and provides you with streamlined processes to help you get more done in less time. Your crew uses our Electronic Check Sheet to conduct rig checks, equipment & gear inspections, inventory counts, report issues and much more from any smartphone, tablet or computer. Electronically track and report on Inventory & Assets, Fleet Maintenance and Narcotics Transactions in real-time from any device.

Join the thousands of professionals managing their day-to-day operations with Operative IQ and find immediate cost savings with minimal investment in a trusted, innovative, platform designed to meet your demands.

EMS Technology Solutions, LLC / 3771 Tramore Pointe Pkwy, SW, Austell, GA 30106
www.operativeiq.com / info@operativeiq.com / USA: 877-217-3707 / Canada: 647-694-0150



Hear from Operative IQ Users:

"Our original, annual EMS supply budget used to be $250,000. Operative IQ has dropped it to $190,000 per year. The savings we've seen have allowed us to reduce our operating budget as it pertains to both EMS and fire."

– Tim Sweat, Assistant Chief and CFO, Clayton County Fire and Emergency Services

"Within 9 months we were able to reduce our inventory overhead by 65%, and then an additional 10% by integrating multiple suppliers to help reduce cost since the beginning of 2017. We used to over order supplies but with Operative IQ we can closely monitor usage and minimize the loss of outdated items to order the ideal stock levels without fear of running out."

– Chris Venters, Russell County EMS

"I've got much, much better accountability across the board, I know where my controlled substances are all the time. So that's huge."

– Michael Baker, Tulsa Fire Department (On Narcotics Tracking)

"We found many companies that wanted to sell us a product, but none of them could compare to Operative IQ. The customer service and dedication that Operative IQ provides is second to none. We found no other companies with the willingness to adapt to what our needs were."

– Mark Hopper, Pike Township Fire Department

"Operative IQ accelerated everything we were doing. Our audits don't take any time at all; within 90 seconds, you've got [access to] all documentation that was done and the reporting can show all the details you need.

The best thing is that you can track a vial from birth to grave, and it's all electronic! Within seconds, I can see an audit log of any unique substance. [I can see] where it's been, who performed the transaction the person that administered, the person that issued the narcotic, and the person that received it. Everything is captured."

– Michael Potts, Logistics Manager, Medstar Mobile Healthcare

"Honestly, I think if I were to compare Operative IQ to some of the other software we use around here, it's is probably one of the more user-friendly. I definitely think it's a great software. I think it leans toward fire service and lines up well with it. We do like it, and we do appreciate the support and [onsite training] that came out to us."

– Josh Mandolini, Fire Captain, Big Bear Fire Department

UCapIt
Controlled Medical Supply Dispensing

Controlled Access Pharmaceutical Dispensers



24/7 Controlled Access
True Inventory Visibility
Real Time Reporting

A unique solution to today's challenge of controlling access, tracking inventory and dispensing of products according to access protocol.

Your Solution to a Growing Problem



- **Do you know what your on hand inventory is today? Do you know where it's located?**
- **Can you identify the people that have access to your medical supplies or pharmacy?**
- **If you had an internal shortage problem would you be able to track why?**
- **Are you able to ensure that only the people with proper credentials have access to controlled substances? Does your system meet the DEA requirements for narcotic controlled storage and reporting?**
- **Are you able to track lot numbers and expiration dates automatically? Are you able to see where expiring product is located in order to ensure it gets used and not wasted?**
- **How do you know when its time to re-order? Do you know what your par levels should be or your item turn over rate?**
- **How do you audit and provide reporting on your medical and pharmaceutical supplies today?**

The Controlled Access Pharmacy or CAP allows EMS, Pharmaceutical, Veterinary and other medical professionals the ability to restock their units 24/7 and have real-time usage and inventory tracking. The CAP can check multiple forms of ID and will prompt for station or dispatch specific data. All withdrawals are cataloged, time stamped and regulated by tech clearance/training level.

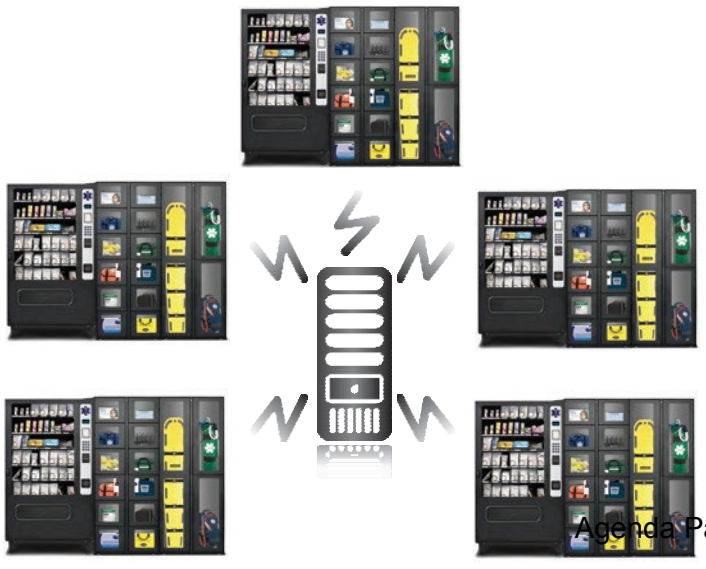
The CAP aggregates all dispensing history and alerts for low stock position, expiring product and creates a pick list for restocking. It will generate individual call reports based on products restocked. This information can be printed or exported to your Accounts Payable/Receivable or EPC Software.

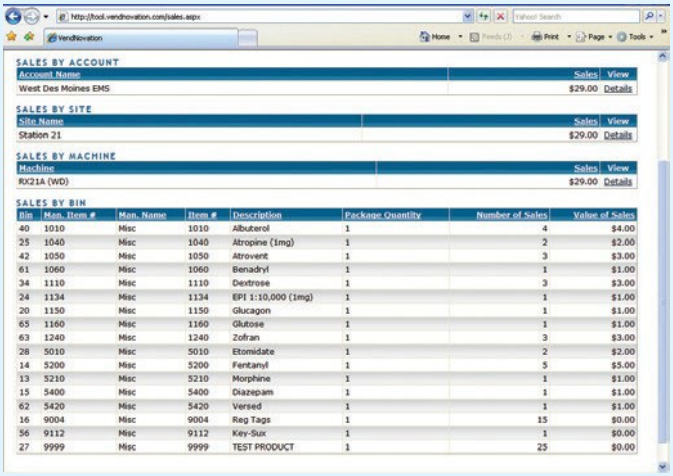
Revolutionary Inventory and Tracking System

The Controlled Access Pharmaceutical Dispenser uses the latest inventory and tracking technology for instant recording, reporting and tracking of supplies.

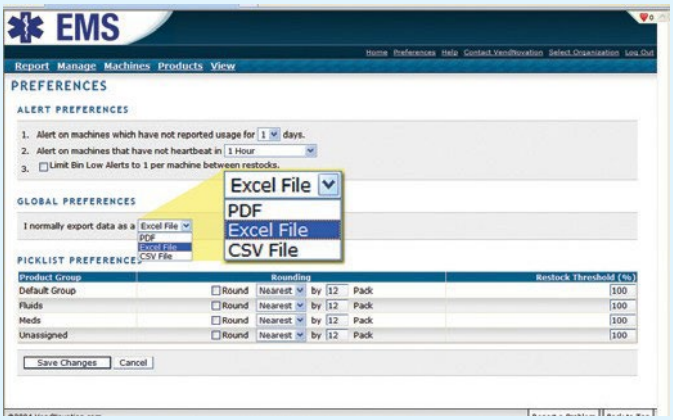
- Authorized professionals can use existing identification methods and can include a combination of:
  - Pin number
  - Proximity card reader
  - Bar code ID scanner
  - Biometric (fingerprint) reader
- Dispensing data is available online 24/7 and accessible through a secure login
- Usage reports, re-stock lists, inventory position and many other management reports can be generated and printed online or can be exported to your desktop for manipulation or import into your billing/ tracking or EPC software
- Dynamic checklists for ambulances, supply cabinets and other equipment
- Alerts can be sent to key personnel via e-mail to warn of low stock positions, expiring product, loss of Internet connection, power loss and more
- The CAP can be configured to control the temperature in a zone to maintain a constant level if necessary
- Cloud hosted software enables the CAP to track the inventory in your stock room or in your vehicles so that the complete chain of products can be tracked for reordering and expiration status

All Data is encrypted and sent via internet to secure cloud based server.

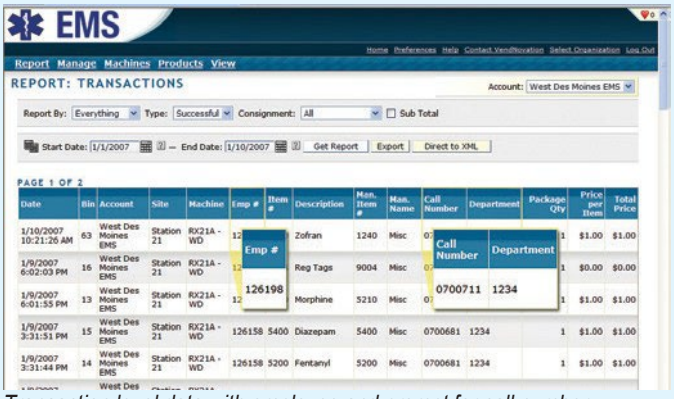




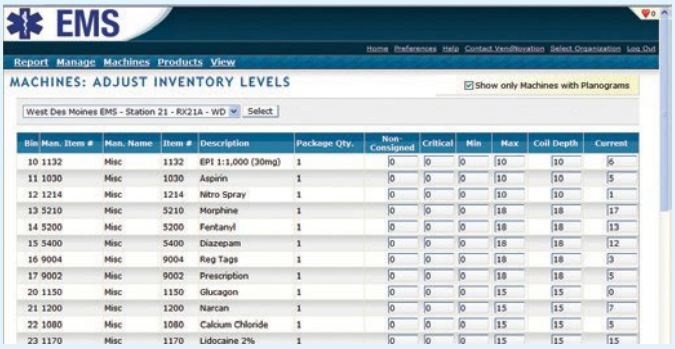
Aggregate dispensing usage by user defined time period.



Export data to PDF, Excel, CSV comma delimited files for imports to billing software or other uses.



Transaction level data with employee and prompt for call number and department.



Easy to maintain machine inventory Par levels & products.

Our controlled access pharmaceutical dispensers allow service providers to increase productivity and reduce downtime by spreading out your single point of storage to your point of use. These dispensers provide secure machine-based management of consumable and returnable supplies.

INTELLIGENT CONTROL SYSTEM

State-of-the-art control system allows secure web based interface for 24/7 real-time reporting of transactions.

DURABLE SHELVES

Configurable to almost any package size in the field with no need for tools.

Full selection (5-3/4"W)
3/4 selection (4-5/16"W)
Single selection (2-7/8"W)

ELECTRONIC DISPLAY

Communicates all dispensing and programming data to technicians and managers.



STANDARD LED LIGHTING

High visibility and high efficiency LED lighting option for dimly lighted locations.

STANDARD SECONDARY PORT

For static instruction or secondary input modules.

MULTIPLE INTERFACES AVAILABLE

- Pin number
- Proximity card reader
- Bar code ID scanner
- Biometric (fingerprint) reader

EXTRA LARGE DELIVERY PORT

Even large packages are accessible through the extra large delivery port.

RETURN PORT

For reusing dispensing bags or accepting expired product.

DURABLE CABINET AND DOOR CONSTRUCTION

Uniquely designed and constructed from 20 gauge steel, UCaplt Dispensers feature fully welded seams and internal bracing for long term reliable service.

Our CAP 3 controlled access pharmaceutical dispenser allows stock and access of supplies in a small areas. A slim cabinet of under 30" lets this unit fit in tight hallways and alcoves while providing all the features and benefits of our larger units.

INTELLIGENT CONTROL SYSTEM

State-of-the-art control system allows secure web based interface for 24/7 real-time reporting of transactions.

DURABLE SHELVES

Configurable to almost any package size in the field with no need for tools.

Full selection (5-3/4"W)
3/4 selection (4-5/16"W)
Single selection (2-7/8"W)

ELECTRONIC DISPLAY

Communicates all dispensing and programming data to technicians and managers.



STANDARD LED LIGHTING

High visibility and high efficiency LED lighting option for dimly lighted locations.

STANDARD SECONDARY PORT

For static instruction or secondary input modules.

MULTIPLE INTERFACES AVAILABLE

- Pin number
- Proximity card reader
- Bar code ID scanner
- Biometric (fingerprint) reader

EXTRA LARGE DELIVERY PORT

Even large packages are accessible through the extra large delivery port.

RETURN PORT

For reusing dispensing bags or accepting expired product.

DURABLE CABINET AND DOOR CONSTRUCTION

Uniquely designed and constructed from 20 gauge steel, UCapIt Dispensers feature fully welded seams and internal bracing for long term reliable service.

SMALL CABINET

Only 29.3" wide allows for locating in tight locations.

This fully refrigerated dispenser supports compliance with regulatory standards and ensure products maintain freshness and usability, saving you thousands of dollars annually in replacement costs due to spoilage or improper storage of products.

REFRIGERATED PRODUCT AREA

Settable refrigeration for keeping products within mandated storage temperatures and maintaining product life.

DURABLE SHELVES

Configurable to almost any package size in the field with no need for tools.

Full selection (5-3/4"W)
3/4 selection (4-5/16"W)
Single selection (2-7/8"W)

INTELLIGENT CONTROL SYSTEM

State-of-the-art control system allows secure web based interface for 24/7 real-time reporting of transactions.



ELECTRONIC DISPLAY

Communicates all dispensing and programming data to technicians and managers.

STANDARD LED LIGHTING

High visibility and high efficiency LED lighting option for dimly lighted locations.

MULTIPLE INTERFACES AVAILABLE

- Pin number
- Proximity card reader
- Bar code ID scanner
- Biometric (fingerprint) reader

EXTRA LARGE DELIVERY PORT

Even large packages are accessible through the extra large delivery port.

STANDARD SECONDARY PORT

For secondary input modules.

DURABLE CABINET AND DOOR CONSTRUCTION

Uniquely designed and constructed from 20 gauge steel, UCaplt Dispensers feature fully welded seams and internal bracing for long term reliable service.

This fully refrigerated space saving dispenser supports compliance with regulatory standards and ensure products maintain freshness and usability, saving you thousands of dollars annually in replacement costs due to spoilage or improper storage of products.

REFRIGERATED PRODUCT AREA

Settable refrigeration for keeping products within mandated storage temperatures and maintaining product life.

DURABLE SHELVES

Configurable to almost any package size in the field with no need for tools.

Full selection (5-3/4"W)
3/4 selection (4-5/16"W)
Single selection (2-7/8"W)

STANDARD LED LIGHTING

High visibility and high efficiency LED lighting option for dimly lighted locations.

EXTRA LARGE DELIVERY PORT

Even large packages are accessible through the extra large delivery port.

DURABLE CABINET AND DOOR CONSTRUCTION

Uniquely designed and constructed from 20 gauge steel, UCaplt Dispensers feature fully welded seams and internal bracing for long term reliable service.



INTELLIGENT CONTROL SYSTEM

State-of-the-art control system allows secure web based interface for 24/7 real-time reporting of transactions.

ELECTRONIC DISPLAY

Communicates all dispensing and programming data to technicians and managers.

MULTIPLE INTERFACES AVAILABLE

- Pin number
- Proximity card reader
- Bar code ID scanner
- Biometric (fingerprint) reader

STANDARD SECONDARY PORT

For secondary input modules.



Shown with 43 select configuration.



Shown with 27 select configuration.

	CAP 5	CAP 3
Selections	43 Standard; Configurable up to 60 Items	25 Standard; Configurable up to 36 Items
Capacity	664 Items, Capacity varies with tray configurations.	412 Items, Capacity varies with tray configurations.
Communication	Web based	
Electrical Requirements	115 VAC/60Hz, 1.2 AMPS; 230 VAC/50Hz, 0.6 AMPS	
Height	72"(183 cm)	
Width	41" (104 cm)	29.3" (74.4 cm)
Depth	35.2" (89.4 cm)	34.75" (88.3 cm)
Shipping Weight	628 lbs.	445 lbs.
Standard Features	Bar Code or Mag Stripe Reader; iVend® Delivery Sensor System; Parrot Door (Enable reuse of protective bags); LED Lighting	
Colors	Black Standard (Custom colors available at extra charge)	
Options	Optional Point of Interface (Prox, RFID, Card Reader, Mag Stripe, Biometric, Bar Code); High Security Lexan Window Cover; Temperature Controlled Model (Inquire for Specs.); Thermostat; Personalized logo on your web reporting site	



Shown with 43 select configuration.



Shown with 43 select configuration.

	CAP 5 Refrigerated	CAP 3 Refrigerated
Selections	43 Standard; Configurable up to 60 Items	25 Standard; Configurable up to 36 Items
Capacity	664 Items, Capacity varies with tray configurations.	412 Items, Capacity varies with tray configurations.
Communication	Web based	
Electrical Requirements	115 VAC/60Hz, 9.5 AMPS; With Heated Glass: 115 VAC/60Hz, 10.5 AMPS; 230 VAC/50Hz, 5.2 AMPS	115 VAC/60Hz, 7.0 AMPS; With Heated Glass: 115 VAC/60Hz, 8.0 AMPS; 230 VAC/50Hz, 3.5 AMPS; With Heated Glass Active: 115 VAC/60Hz, 4.0 AMPS
Refrigeration	Super 1/3 HP, R-134a or R-513a Closed System	
Height	72"(183 cm)	
Width	41" (104 cm)	29.5" (75 cm)
Depth	38" (97 cm)	
Shipping Weight	838 lbs.	665 lbs.
Standard Features	Bar Code or Mag Stripe Reader; iVend® Delivery Sensor System; Parrot Door (Enable reuse of protective bags); LED Lighting	
Colors	Black Standard (Custom colors available at extra charge)	
Options	Optional Point of Interface (Prox, RFID, Card Reader, Mag Stripe, Biometric, Bar Code); High Security Lexan Window Cover	

Supply Locker

Supply Lockers provide secure accountability for reusable assets and consumable products, ensuring your team has exactly what they need, when and where they need it 24/7. Single and multiple item dispense, check-in/check-out, loan periods, and asset management, are all possible with UCapIt Supply Lockers.

LED LIGHTING

High visibility and high efficiency LED lighting spotlights products.

SOLID AND WINDOW DOOR OPTIONS

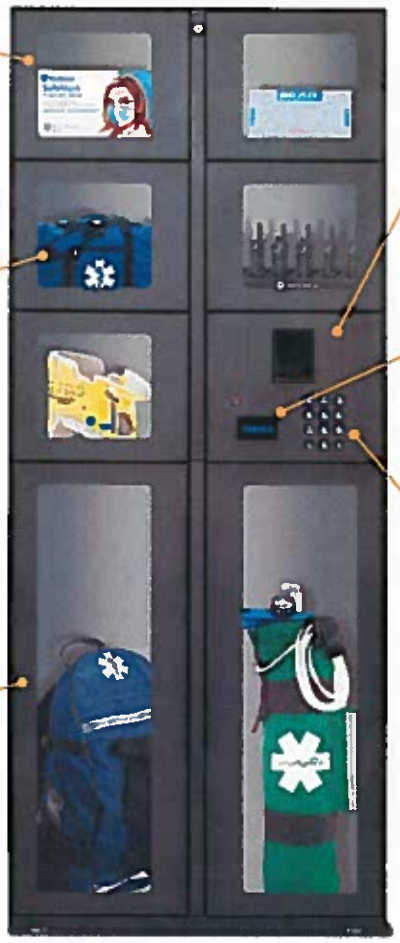
Acrylic window version for immediate identification of available it



Solid door version for higher security.

DURABLE CABINET AND DOOR CONSTRUCTION

Uniquely designed and constructed from 20 gauge steel, lockers feature fully welded seams and internal bracing for long term reliable service.



INTELLIGENT CONTROL SYSTEM

State-of-the-art control system allows secure web based interface for 24/7 real-time transactions and reporting.

ELECTRONIC DISPLAY

Communicates all dispensing and programming data to technicians and managers.

MULTIPLE INTERFACES AVAILABLE

- Pin number
- Proximity card reader
- Bar code ID scanner
- Magnetic strip reader

VERSATILE COMPARTMENTS

Sized for a wide variety of products.
Opening: 10-3/4"H x 11"W
Depth: 22-15/16"D

OPTIONAL POWER AND CAT5E CONNECTED*

Charge devices and connect to your LAN for updating and remote servicing. *11 Door Controller and 6 Door Satellite Lockers Only.





Supply Locker Controllers



7 Door Locker Controller					
Compartments	7 individual				
Compartments Sizes	Opening: (5) 10-15/16"W x 10-23/32"H, (2) 10-15/16"W x 34-23/32"H Depth: 22-15/16"D				
Electrical Requirements	Domestic: 115 VAC/60Hz, 1.2 AMPS International: 230 VAC/50Hz, 0.6 AMPS				
Height	73-5/16"(186.2 cm)	**Width**	30-1/8" (76.5 cm)	**Depth**	24-3/8" (62 cm)
Shipping Weight	327 lbs.				
Standard Features	Keypad Interface; LED Lighting				
Colors	Black Standard (Custom colors available at extra charge)				



16 Door Locker Controller					
Compartments	16 individual				
Compartments Sizes	Opening: (6) 10-15/16" W x 10-23/32"H, (10) 10-15/16"W x 4-23/32"H Depth: 22-15/16"D				
Electrical Requirements	Domestic: 115 VAC/60Hz, 1.2 AMPS International: 230 VAC/50Hz, 0.6 AMPS				
Height	73-5/16"(186.2 cm)	**Width**	30-1/8" (76.5 cm)	**Depth**	24-3/8" (62 cm)
Shipping Weight	327 lbs.				
Standard Features	Keypad Interface; LED Lighting				
Colors	Black Standard (Custom colors available at extra charge)				

Supply Locker Satellites



CAP 3 Door Locker					
Compartments	3 individual				
Compartments Sizes	Opening: (1) 10-15/16"W x 70-23/32"H, (2) 10-15/16"W x 34-23/32"H Depth: 22-15/16"D				
Electrical Requirements	Domestic: 115 VAC/60Hz, 1.2 AMPS International: 230 VAC/50Hz, 0.6 AMPS				
Height	73-5/16"(186.2 cm)	**Width**	30-1/8" (76.5 cm)	**Depth**	24-3/8" (62 cm)
Shipping Weight	327 lbs.				
Standard Features	CAP 5 or CAP 3 dispenser connection; LED Lighting				
Colors	Black Standard (Custom colors available at extra charge)				



4 Door Locker Satellite					
Compartments	4 individual				
Compartments Sizes	Opening: (4) 10-15/16"W x 34-23/32"H Depth: 22-15/16"D				
Electrical Requirements	Domestic: 115 VAC/60Hz, 1.2 AMPS International: 230 VAC/50Hz, 0.6 AMPS				
Height	73-5/16"(186.2 cm)	**Width**	30-1/8" (76.5 cm)	**Depth**	24-3/8" (62 cm)
Shipping Weight	327 lbs.				
Standard Features	CAP 5 or CAP 3 dispenser connection; LED Lighting				
Colors	Black Standard (Custom colors available at extra charge)				



6 Door Locker Satellite (Powered)					
Compartments	6 individual				
Compartments Sizes	Opening: (6) 10-15/16" W x 22-23/32"H Depth: 22-15/16"D				
Electrical Requirements	Domestic: 115 VAC/60Hz, 1.2 AMPS International: 230 VAC/50Hz, 0.6 AMPS				
Height	73-5/16"(186.2 cm)	**Width**	30-1/8" (76.5 cm)	**Depth**	24-3/8" (62 cm)
Shipping Weight	327 lbs.				
Standard Features	CAP 5 or CAP 3 dispenser connection; LED Lighting; Power outlets (1) per compartment				
Colors	Black Standard (Custom colors available at extra charge)				



8 Door Locker Satellite					
Compartments	8 individual				
Compartments Sizes	Opening: (6) 10-15/16” W x 10-23/32”H , (2) 10-15/16”W x 34-23/32”H Depth: 22-15/16”D				
Electrical Requirements	Domestic: 115 VAC/60Hz, 1.2 AMPS International: 230 VAC/50Hz, 0.6 AMPS				
Height	73-5/16”(186.2cm)	**Width**	30-1/8” (76.5 cm)	**Depth**	24-3/8” (62 cm)
Shipping Weight	327 lbs.				
Standard Features	CAP 5 or CAP 3 dispenser connection; LED Lighting				
Colors	Black Standard (Custom colors available at extra charge)				



12 Door Locker Satellite					
Compartments	12 individual				
Compartments Sizes	Opening: (12) 10-15/16” W x 10-23/32”H, Depth: 22-15/16”D				
Electrical Requirements	Domestic: 115 VAC/60Hz, 1.2 AMPS International: 230 VAC/50Hz, 0.6 AMPS				
Height	73-5/16”(186.2 cm)	**Width**	30-1/8” (76.5 cm)	**Depth**	24-3/8” (62 cm)
Shipping Weight	327 lbs.				
Standard Features	CAP 5 or CAP 3 dispenser connection; LED Lighting				
Optional Features	120 Volt Power and CAT5 Ethernet connections in each compartment.				
Colors	Black Standard (Custom colors available at extra charge)				



18 Door Locker Satellite					
Compartments	18 individual				
Compartments Sizes	Opening: (6) 10-15/16” W x 10-23/32”H, (12) 10-15/16”W x 4-23/32”H Depth: 22-15/16”D				
Electrical Requirements	Domestic: 115 VAC/60Hz, 1.2 AMPS International: 230 VAC/50Hz, 0.6 AMPS				
Height	73-5/16”(186.2 cm)	**Width**	30-1/8” (76.5 cm)	**Depth**	24-3/8” (62 cm)
Shipping Weight	327 lbs.				
Standard Features	CAP 5 or CAP 3 dispenser connection; LED Lighting				
Colors	Black Standard (Custom colors available at extra charge)				

SAFEMEDS Secure Storage Box

SAFEMEDS high security lock box system capable of mounting in ambulances and other areas where drugs need to be tracked or distributed. Capable of dual validation and two form factor identification using your PIN and PROX Card, Bar Code, Magnetic Strip or Biometrics reader ID system.



SAFEMEDS Secure Storage Box					
Compartment Size	Opening: 10”H x 11.2”W; Interior: 10”H x 9.8”W (Min. to door latch); Depth: 9.1”D				
Electrical Requirements	Domestic: 120 VAC/60Hz, 1.5 AMPS International: 230 VAC/50Hz, 0.75 AMPS Current Draw: 0.25 Amp				
Height	11.2”(28 cm)	**Width**	13.03” (34 cm)	**Depth**	13.88” (36 cm)
Shipping Weight	35 lbs.				
Standard Features	CAT5E Connection, Override Key, Bottom Mounting				
Options	PROX Card Reader, Bar Code, Magnetic Strip or Biometric Reader, Cellular Connection				









WE MAKE SURE OUR CUSTOMERS ARE SATISFIED





"We can now audit our usage and remotely poll stations in order to determine restocking needs! We are in compliance with the DEA regulations regarding narcotics and can pinpoint the location of all supplies from the pharmacy storeroom to the truck."
Rob Dehnert - NREMT-P Specialist - West Des Moines EMS, West Des Moines, IA

"The report tells me what I need to know, how many are expiring, where they are located and the name of the medication. I really like that I can run the report for 90 or more days because I order replacement medications 3-4 months in advance, plus my regular stock... so I know I won't run out. Now instead of having to do a count by hand at the end of the month or so I check them in when I receive them and simply run the reports I need."
Beth Hines - Captain - Onlow City EMS, Jacksonville NC

"We will pay for the machine in 2 1/2 years just based off of direct drug costs alone. That doesn't take into account man-hours spent doing inventory."
Shawn Treloar - EMS Battalion Chief - Sanford Fire Department, Sanford, FL

UNMATCHED RELIABILITY AND DURABILITY

Built in the USA, Intelligent Dispensing Solutions equipment incorporates over three quarters of a century worth of dispensing technology in a rugged and dependable enclosure.

Every IDS product is engineered for easy maintenance and high reliability. From the raw materials to final product, the commitment to quality sets the tone for the entire manufacturing effort.

Using the latest techniques including state-of-the-art computer controlled machinery and the highest construction standards, parts are stamped and formed, refined and assembled. Then every machine is checked and rechecked for optimum performance levels before entering service.



From raw materials, through assembly and final quality checks, CAP dispensing equipment is prepared for a long life of dependable service.



Manufactured in the Heartland, Des Moines Iowa.

UCapIt Controlled Medical Supply Dispensing

IDS Intelligent Dispensing Solutions

Bound Tree

Contact Your BoundTree Account Manager For more information:

800.533.0523

8040 University Boulevard, Des Moines, Iowa 50325
www.intelligentdispensingsolutions.com



BOUND TREE MEDICAL EMERGENCY
DISASTER SUPPORT PROGRAM

If your agency is in need of emergency medical supplies and equipment, the Bound Tree Medical Emergency Disaster Support Program is here to help. This program enables you to call our Disaster Support Hotline 24 hours a day to report major incidents and identify medical supply needs. Once reported, Bound Tree Medical personnel will take immediate measures to assist in relief efforts.

GET HELP IN THREE SIMPLE STEPS

1. Report a major Incident.
2. Call the Bound Tree Medical DiH5tor $upporl HoUlno,
3. Receive emergency medical $Upplie5,

Bound Tree Medical is the only national, EMS focused supplier in the country. We have a proven track record of supplying vital customer needs in situations from hurricanes, tornadoes and floods to MCI's. Our national presence and multiple regional warehouses stocked with products specifically for emergency preparedness make us the clear choice when every minute counts. To learn more about the Bound Tree Medical Emergency Disaster Support Program, contact Customer Service.

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800.8s3.o9s3



Need to report a major incident? Need help locating critical emergency medical supply needs? Simply call the toll-free Disaster Support Hotline at **800.863.0953.**

Partners in EMS





In-Service Training

Our EMS-experienced Account Managers can provide quality in-service training and support to you and your department. Since they live in your area, they understand state and local requirements and protocols.



Advanced Online Tools

From free online continuing education courses at www.BoundTreeUniversity.com to elaborate online ordering tools at www.boundtree.com, we are focused on the most cutting edge technology that will streamline your day-to-day operations.



24-Hour Disaster Support

Our Emergency Disaster Support Program can provide relief efforts to agencies that require immediate deployment of emergency medical supplies. To activate the program, call 800-863-0953 and identify your needs.



Grants Support

Safety and patient care should never be compromised because of inadequate budgets. Our experienced grant writers can help you find funding opportunities for equipment, training, personnel and vehicles at www.boundtreegrants.com.



Passion and Perspective

At the heart of Bound Tree Medical is a team of employees who are passionate about EMS and the communities they serve. We have the experience required to meet your needs.

Bound Tree Medical is a specialty distributor of emergency medical equipment, supplies, pharmaceuticals and product expertise for fire departments, military, government institutions and other EMS organizations that provide pre-hospital, emergency care. We support our customers with our team of EMS-experienced product specialists, customer service representatives and local account managers, backed by strong vendors and a national distribution network.

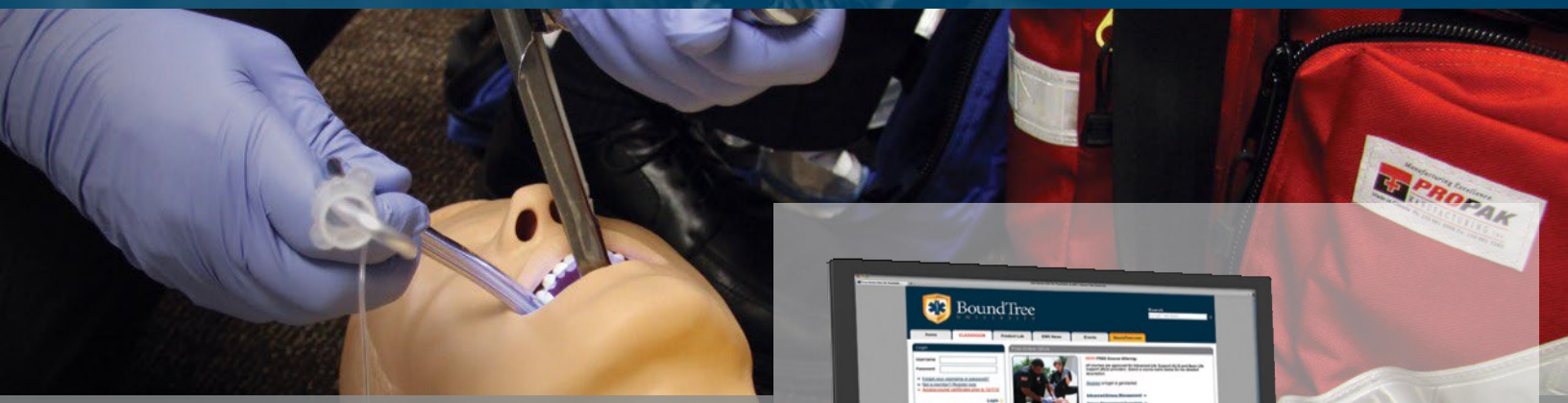
From everyday disposable items to extensive capital equipment, we offer thousands of quality products from leading manufacturers to help our customers save lives. Our cutting-edge distribution model and five nationwide distribution centers allow us to provide prompt and accurate delivery anywhere in the United States. We are passionate about EMS and have developed specialty programs to demonstrate our dedication, including scholarships, grants support and disaster support. We strive to truly understand the needs and demands of EMS providers and deliver the products and services that address those needs.

Bound Tree

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FREE CEUs

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Current Course Offering:

Acute MI and STEMI »

Asthma »

Evidence-based Guidelines for EMS Providers »

Safe Transport of the Pediatric Patient »

Pediatric Shortness of Breath »

Capnography for Respiratory Distress »

Emergency Operations EMS1 »

Anaphylaxis »

CHF vs. COPD »

Sepsis »

Bound Tree University is dedicated to the continuing education of EMTs and Paramedics. All online courses are FREE and fully accredited by the Continuing Education Coordinating Board for Emergency Medical Services (CECBEMS). Each course is worth 1.5 credit hours and they are approved for both Advanced Life Support (ALS) and Basic Life Support (BLS) providers.

BoundTree UNIVERSITY

In partnership with Bound Tree and EMS1.com

EMERGENCY MEDICAL SUPPLIES AND EQUIPMENT

Section B - Discount Proposal

CORE LIST PROPOSAL FORM

Items listed are by the specified by manufacturer. ***The line below each specified item is available for entering generic or approved equivalent items*** . **Please note - it is acceptable to bid both the specified item and/or a generic or approved equivalent**. The SMEMS COOPERATIVE retains the sole right to determine whether an item is equivalent .The SMEMS COOPERATIVE also retains the right to request a sample of any item on the list for comparison purposes. Where no Manufacturer is listed please bid to the line item specification and make sure to give both a Manufacturer name & vendor part #.

Definitions –

Component Price=Price per smallest measured item (example one 4x4, one splint, one ounce of cleaner

Unit Price=Price per Item # listed

Unit Pack=Description of item # listed (example below Box of 30)

Case price-Price of standard shipped case

Case Pack=Description of standard shipped case (example below Case of 900)

Line #	Item Category	Subcategory (if applicable)	Mfg.	Description	Part #	Component Price	Unit price	Unit Pack	Case Price	Case Pack
N/A	***SAMPLE***	***SAMPLE SUB***	***CONMED***	***ADULAT DIAPHORETIC***	***123456***	***$0.18***	***$ 5.25***	***BOX-30***	***$157.50***	***CASE-900***
1	Airway		INTERSURGICAL, INC.	i-gel Plus O2 Resus Pack, MED Adult, incl size 4 i-gel O2, for Pts 50-90kg	8804030	$25.00	$ 25.00	6/bx		
2										
3	Airway		INTERSURGICAL, INC.	i-gel Plus O2 Resus Pack, LG Adult, incl size 5 i-gel O2, for Pts 90 plus kg	8805030	$25.00	$ 25.00	6/bx		
4										
5	Airway		INTERSURGICAL, INC.	I-GEL SUPRAGLOTTIC AIRWAY FOR NEONATES (SIZE 1) 5-11 LBS (2-5 KG)	8201000	$15.64	$ 15.64		$ 156.40	10/cs
6										
7	Airway		INTERSURGICAL, INC.	I-GEL SUPRAGLOTTIC AIRWAY FOR INFANTS (SIZE 1.5) 11-25 LBS (5-12 KG)	8215000	$15.64	$ 15.64		$ 156.40	10/cs
8										
9	Airway		INTERSURGICAL, INC.	I-GEL SUPRAGLOTTIC AIRWAY FOR SMALL PEDIATRICS (SIZE 2) 22-55 LBS (10-25 KG)	8202000	$15.64	$ 15.64		$ 156.40	10/cs
10										
11	Airway		INTERSURGICAL, INC.	I-GEL SUPRAGLOTTIC AIRWAY FOR LG PEDIATRICS (SIZE 2.5) 55-77 LBS (25-35 KG)	8225000	$15.64	$ 15.64		$ 156.40	10/cs
12										
13	Airway		AIRLIFE	Air-Q sp3G Size 3.0 Intubating Laryngeal Airway, Self-Pressurizing with Gastric Access	60305	$17.50	$ 17.50		$ 175.00	10/cs
14										
15	Airway		AIRLIFE	Air-Q sp3G Size 4.0 Intubating Laryngeal Airway, Self-Pressurizing with Gastric Access	60405	$17.50	$ 17.50		$ 175.00	10/cs
16										
17	Airway		AIRLIFE	Air-Q sp3G Size 5.0 Intubating Laryngeal Airway, Self-Pressurizing with Gastric Access	60505	$17.50	$ 17.50		$ 175.00	10/cs
18										
19	Airway		CURAPLEX BY BOUND TRE	Air-Q sp3G Kit SIZE 3 with Connector, ET Tube Holder, and Lube Jelly	670274-KIT	$23.00	$ 23.00			
20										
21	Airway		CURAPLEX BY BOUND TRE	Air-Q sp3G Kit SIZE 4 with Connector, ET Tube Holder, and Lube Jelly	670275-KIT	$23.00	$ 23.00			
22										
23	Airway		CURAPLEX BY BOUND TRE	Air-Q sp3G Kit SIZE 5 with Connector, ET Tube Holder, and Lube Jelly	670276-KIT	$23.00	$ 23.00			
24										
25	Airway		AMBU INC.	King LTS-D Supraglottic Airway Kit Size 3 Yellow	KLTSD433	$32.25	$ 32.25		$ 161.25	5/cs
26										
27	Airway		AMBU INC.	King LTS-D Supraglottic Airway Kit Size 4 Red	KLTSD434	$32.25	$ 32.25		$ 161.25	5/cs
28										
29	Airway		AMBU INC.	King LTS-D Supraglottic Airway Kit Size 5 Purple	KLTSD435	$32.25	$ 32.25		$ 161.25	5/cs
30										
31	Airway		UE MEDICAL DEVICES INC	UE Scope VL460 Monitor, Case, and Charger	460-1200	$1,682.69	$ 1,682.69			
32										
33	Airway		UE MEDICAL DEVICES INC	Single Use Blade Size D0 for UESCOPE 2 (VL460)	010-3201	$43.00	$ 43.00			
34										
35	Airway		UE MEDICAL DEVICES INC	Single-Use Blade MD1	010-3211	$43.00	$ 43.00			
36										
37	Airway		UE MEDICAL DEVICES INC	Single Use Blade Size D1 for UESCOPE 2 (VL460)	010-3210	$43.00	$ 43.00			
38										
39	Airway		UE MEDICAL DEVICES INC	Single Use Blade Size D2 for UESCOPE 2 (VL460)	010-3220	$43.00	$ 43.00			
40										
41	Airway		UE MEDICAL DEVICES INC	Single Use Blade Size D3 for UESCOPE 2 (VL460)	010-3230	$43.00	$ 43.00			

42											
43	Airway		UE MEDICAL DEVICES INC	Single Use Blade Size D4 for UESCOPE 2 (VL460)	010-3240	$43.00	$	43.00			
44											
45	Airway		UE MEDICAL DEVICES INC	MAC 3 Non Hyper Angulated Blade	010-3236	$43.00	$	43.00			
46											
47	Airway		UE MEDICAL DEVICES INC	MAC 4 Non Hyper Angulated Blade	010-3246	$43.00	$	43.00			
48											
49	Airway		UE MEDICAL DEVICES INC	Single-Use Channeled Blade J3	010-3293	$43.00	$	43.00			
50											
51	Airway		UE MEDICAL DEVICES INC	UE Intubation Stylet, P1 (Pediatric)	131-1102	$40.45	$	40.45			
52											
53	Airway		UE MEDICAL DEVICES INC	UE Intubation Stylet, P2 (Adult)	131-1101	$28.90	$	28.90			
54											
55	Airway		CURAPLEX BY BOUND TRE	OneScope Pro Video Laryngoscope	1726785	$1,899.99	$	1,899.99			
56											
57	Airway		CURAPLEX BY BOUND TRE	OneScope Pro - Neonatal Size 1 Blade	3010001	$14.99	$	14.99			
58											
59	Airway		CURAPLEX BY BOUND TRE	OneScope Pro - Pediatric Size 2 Blade	3020001	$14.99	$	14.99			
60											
61	Airway		CURAPLEX BY BOUND TRE	OneScope Pro - Angulated Adult Size 3 Blade	3031001	$14.99	$	14.99			
62											
63	Airway		CURAPLEX BY BOUND TRE	OneScope Pro - Angulated Adult Size 4 Blade	3041001	$14.99	$	14.99			
64											
65	Airway		CURAPLEX BY BOUND TRE	OneScope Pro - Direct Adult Mac 3 Blade	3034001	$14.99	$	14.99			
66											
67	Airway		CURAPLEX BY BOUND TRE	OneScope Pro - Direct Adult Mac 4 Blade	3044001	$14.99	$	14.99			
68											
69	Airway		CURAPLEX BY BOUND TRE	OneScope Pro Disposable Rigid Stylet	1004	$7.50	$	7.50			
70											
71	Airway		TRI-ANIM HEALTH SERVIC	Laryngoscope Blade, Greenline, Mac 1, Fiber Optic, Disposable, Stainless Steel	5-5332-01	$3.75	$	3.75	20/bx		
72											
73	Airway		TRI-ANIM HEALTH SERVIC	Laryngoscope Blade, Greenline, Mac 2, Fiber Optic, Disposable, Stainless Steel	5-5332-02	$3.75	$	3.75	20/bx		
74											
75	Airway		TRI-ANIM HEALTH SERVIC	Laryngoscope Blade, Greenline, Mac 3, Fiber Optic, Disposable, Stainless Steel	5-5332-03	$3.75	$	3.75	20/bx		
76											
77	Airway		TRI-ANIM HEALTH SERVIC	Laryngoscope Blade, Greenline, Mac 4, Fiber Optic, Disposable, Stainless Steel	5-5332-04	$3.75	$	3.75	20/bx		
78											
79	Airway		TRI-ANIM HEALTH SERVIC	Laryngoscope Blade, Greenline, Miller 0, Fiber Optic, Disposable, Stainless Steel	5-5333-00	$3.75	$	3.75	20/bx		
80											
81	Airway		TRI-ANIM HEALTH SERVIC	Laryngoscope Blade, Greenline, Miller 1, Fiber Optic, Disposable, Stainless Steel	5-5333-01	$3.75	$	3.75	20/bx		
82											
83	Airway		TRI-ANIM HEALTH SERVIC	Laryngoscope Blade, Greenline, Miller 2, Fiber Optic, Disposable, Stainless Steel	5-5333-02	$3.75	$	3.75	20/bx		
84											
85	Airway		TRI-ANIM HEALTH SERVIC	Laryngoscope Blade, Greenline, Miller 3, Fiber Optic, Disposable, Stainless Steel	5-5333-03	$3.75	$	3.75	20/bx		
86											
87	Airway		TRI-ANIM HEALTH SERVIC	Laryngoscope Blade, Greenline, Miller 4, Fiber Optic, Disposable, Stainless Steel	5-5333-04	$3.75	$	3.75	20/bx		
88											
89	Airway		TRI-ANIM HEALTH SERVIC	Laryngoscope Handle, GreenLine, Medium, Fiber Optic, Chrome Plated Brass	5-0236-09	$5.68	$	5.68	20/bx		
90											
91	Airway		TRI-ANIM HEALTH SERVIC	Laryngoscope Handle, GreenLine, Petite, Fiber Optic, Chrome Plated Brass	5-0236-10	$5.68	$	5.68	20/bx		
92											
93	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube with Stylette, 2.5mm, Cuffed	2113-10225	$2.29	$	2.29	10/bx	$ 229.00	10bx/cs
94											
95	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube with Stylette, 3.0mm, Cuffed	2113-10230	$2.29	$	2.29	10/bx	$ 229.00	10bx/cs
96											

97	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube with Stylette, 3.5mm, Cuffed	2113-10235	$2.29	$ 2.29	10/bx	$ 229.00	10bx/cs
98										
99	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube with Stylette, 4.0mm, Cuffed	2113-10240	$2.29	$ 2.29	10/bx	$ 229.00	10bx/cs
100										
101	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube with Stylette, 4.5mm, Cuffed	2113-10245	$2.29	$ 2.29	10/bx	$ 229.00	10bx/cs
102										
103	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube with Stylette, 5.0mm, Cuffed	2113-10250	$2.29	$ 2.29	10/bx	$ 229.00	10bx/cs
104										
105	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube with Stylette, 5.5mm, Cuffed	2113-10255	$2.29	$ 2.29	10/bx	$ 229.00	10bx/cs
106										
107	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube with Stylette, 6.0mm, Cuffed	2113-10260	$2.29	$ 2.29	10/bx	$ 229.00	10bx/cs
108										
109	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube with Stylette, 6.5mm, Cuffed	2113-10265	$2.29	$ 2.29	10/bx	$ 229.00	10bx/cs
110										
111	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube with Stylette, 7.0mm, Cuffed	2113-10270	$2.29	$ 2.29	10/bx	$ 229.00	10bx/cs
112										
113	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube with Stylette, 7.5mm, Cuffed	2113-10275	$2.29	$ 2.29	10/bx	$ 229.00	10bx/cs
114										
115	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube with Stylette, 8.0mm, Cuffed	2113-10280	$2.29	$ 2.29	10/bx	$ 229.00	10bx/cs
116										
117	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube with Stylette, 8.5mm, Cuffed	2113-10285	$2.29	$ 2.29	10/bx	$ 229.00	10bx/cs
118										
119	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube with Stylette, 9.0mm, Cuffed	2113-10290	$2.29	$ 2.29	10/bx	$ 229.00	10bx/cs
120										
121	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube with Stylette, 10.0mm, Cuffed	2113-10200	$2.29	$ 2.29	10/bx	$ 229.00	10bx/cs
122										
123	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube, 3.0mm, Cuffed, w/o Stylette	2113-20230	$1.21	$ 1.21	10/bx	$ 121.00	10bx/cs
124										
125	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube, 3.5mm, Cuffed, w/o Stylette	2113-20235	$1.21	$ 1.21	10/bx	$ 121.00	10bx/cs
126										
127	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube, 4.0mm, Cuffed, w/o Stylette	2113-20240	$1.21	$ 1.21	10/bx	$ 121.00	10bx/cs
128										
129	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube, 4.5mm, Cuffed, w/o Stylette	2113-20245	$1.21	$ 1.21	10/bx	$ 121.00	10bx/cs
130										
131	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube, 5.0mm, Cuffed, w/o Stylette	2113-20250	$1.21	$ 1.21	10/bx	$ 121.00	10bx/cs
132										
133	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube, 5.5mm, Cuffed, w/o Stylette	2113-20255	$1.21	$ 1.21	10/bx	$ 121.00	10bx/cs
134										
135	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube, 6.0mm, Cuffed, w/o Stylette	2113-20260	$1.21	$ 1.21	10/bx	$ 121.00	10bx/cs
136										
137	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube, 6.5mm, Cuffed, w/o Stylette	2113-20265	$1.21	$ 1.21	10/bx	$ 121.00	10bx/cs
138										
139	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube, 7.0mm, Cuffed, w/o Stylette	2113-20270	$1.21	$ 1.21	10/bx	$ 121.00	10bx/cs
140										
141	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube, 7.5mm, Cuffed, w/o Stylette	2113-20275	$1.21	$ 1.21	10/bx	$ 121.00	10bx/cs
142										
143	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube, 8.0mm, Cuffed, w/o Stylette	2113-20280	$1.21	$ 1.21	10/bx	$ 121.00	10bx/cs
144										
145	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube, 8.5mm, Cuffed, w/o Stylette	2113-20285	$1.21	$ 1.21	10/bx	$ 121.00	10bx/cs
146										
147	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube, 9.0mm, Cuffed, w/o Stylette	2113-20290	$1.21	$ 1.21	10/bx	$ 121.00	10bx/cs
148										
149	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube, 9.5mm, Cuffed, w/o Stylette	2113-20295	$1.21	$ 1.21	10/bx	$ 121.00	10bx/cs
150										
151	Airway		CURAPLEX BY BOUND TRE	Select Endotracheal Tube, 10.0mm, Cuffed, w/o Stylette	2113-20200	$1.21	$ 1.21	10/bx	$ 121.00	10bx/cs

152											
153	Airway		LAERDAL MEDICAL CORP	Endotracheal Tube Holder, Thomas Select, Adult, for ET/SGA Tubes 6.5mm ID to 42mm OD	600-42500	$4.25	$	4.25		$	106.25	25/cs
154											
155	Airway		LAERDAL MEDICAL CORP	Endotracheal Tube Holder, Thomas, Pediatric/Child, for ET/SGA Tubes 4.3mm ID to 15.8mm OD	600-20000	$3.40	$	3.40				
156											
157	Airway		LAERDAL MEDICAL CORP	Endotracheal Tube Holder, Thomas, Adult, for ET/SGA Tubes 6.5mm ID to 21mm OD	600-10000	$3.40	$	3.40				
158											
159	Airway		PULMODYNE	Control-Cric, including Cric-knife, Cric-key, Square Obturator, Extension tube, Wedge	313-4567	$173.85	$	173.85				
160											
161	Airway		PARENT PRODUCTION	Control-Cric System Capno Kit	670155-KIT	$172.94	$	172.94				
162											
163	Airway		TELEFLEX LLC	TRACHEOTOMY DEVICE ADULT 4.0MM QUICKTRACH	120900040	$145.12	$	145.12				
164											
165	Airway		TELEFLEX LLC	TRACHEOTOMY DEVICE CHILD 2.0MM QUICKTRACH	120900020	$145.12	$	145.12				
166											
167	Airway		PULMODYNE	GO-PAP with BiTrac ED with Neb - Adult Medium	313-4602N	$48.67	$	48.67				
168											
169	Airway		PULMODYNE	GO-PAP with BiTrac ED with Neb- Adult Large	313-4603N	$48.67	$	48.67				
170											
171	Airway		PULMODYNE	GO-PAP with BiTrac ED - Adult Medium	313-4602	$48.50	$	48.50				
172											
173	Airway		PULMODYNE	GO-PAP with BiTrac ED- Adult Large	313-4603	$48.50	$	48.50				
174											
175	Airway		PULMODYNE	Go-Pap CPAP Kit , Sm Adult Bitrac Mask, Standard Head Harness. Nebulizer Canister	313-4601N	$49.80	$	49.80		$	498.00	10/cs
176											
177	Airway		PULMODYNE	O2 MAX BiTrac ED Mask, w/ Neb, Adult LG, w/3-SET Valve, Ohmeda Connector, Fixed Flow	313-7555XN-1	$54.40	$	54.40		$	544.00	10/cs
178											
179	Airway		PULMODYNE	O2 MAX BiTrac ED Mask, w/ Neb, Adult MED, w/3-SET Valve, Ohmeda Connector, Fixed Flow	313-7556XN-1	$54.40	$	54.40		$	544.00	10/cs
180											
181	Airway		PULMODYNE	O2 MAX BiTrac ED Mask, w/ Neb, Adult LG, w/5-SET Valve, Ohmeda Connector, Fixed Flow	313-7554XN-1	$54.16	$	54.16		$	541.60	10/cs
182											
183	Airway		PULMODYNE	O2 MAX BiTrac ED Mask, w/ Neb, Adult MED, w/5-SET Valve, Ohmeda Connector, Fixed Flow	313-7557XN-1	$54.17	$	54.17		$	541.70	10/cs
184											
185	Airway		MERCURY MEDICAL	CPAP System, Flow-Safe II EZ, w/Integral Neb, Child Mask w/Port	1057320	$64.55	$	64.55	5/bx			
186											
187	Airway		MERCURY MEDICAL	CPAP System, Flow-Safe II EZ, w/Integral Neb, LG Adult Mask w/Port	1057318	$64.55	$	64.55				
188											
189	Airway		MERCURY MEDICAL	CPAP System, Flow-Safe II EZ, w/Integral Neb, SM Adult Mask w/Port	1057319	$64.55	$	64.55				
190											
191	Airway		MERCURY MEDICAL	CPAP System, Flow-Safe II, w/Child Mask	1057211	$50.78	$	50.78	5/bx			
192											
193	Airway		MERCURY MEDICAL	CPAP System, Flow-Safe II, w/SM Adult Mask	1057210	$50.78	$	50.78	5/bx			
194											
195	Airway		MERCURY MEDICAL	CPAP System, Flow-Safe II, w/LG Adult Mask	1057209	$50.78	$	50.78	5/bx			
196											
197	Airway		CURAPLEX BY BOUND TRE	Oxygen Regulator, All-Brass, 2 DISS, 1 Barb, CGA870	EMSREG8725-B2D-BTM	$63.44	$	63.44				
198											
199	Airway		MEDSOURCE INTERNATIO	Oxygen Nasal Cannula, Adult, Conventional, Clear, Non-Flared Prongs, 7 ft tubing	24003	$0.45	$	0.45		$	22.50	50/cs
200											
201	Airway		CURAPLEX BY BOUND TRE	Oxygen Nasal Cannula, Adult, Conventional, Clear, Flared Prongs, 7 ft tubing	24004	$0.45	$	0.45		$	22.50	50/cs
202											
203	Airway		CURAPLEX BY BOUND TRE	Oxygen Nasal Cannula, Adult, Conventional, Green, 7 ft Tubing	30050	$0.45	$	0.45		$	22.50	50/cs
204											
205	Airway		CURAPLEX BY BOUND TRE	Oxygen Nasal Cannula, Pediatric, Conventional, Green, 7 ft Tubing	30056	$0.64	$	0.64		$	32.00	50/cs
206											

207	Airway		MEDLINE INDUSTRIES, IN	CANNULA INFANT 1828	HUD1828	$1.67	$	1.67		$	83.50	50/cs
208												
209	Airway		CURAPLEX BY BOUND TRE	Oxygen Mask, Adult, Elongated, Partial NRB w/Vent, Reservoir Bag, 7 ft Tubing	30051	$1.15	$	1.15		$	57.50	50/cs
210												
211	Airway		CURAPLEX BY BOUND TRE	Oxygen Mask, Adult, Elongated, High Conc, Partial NRB, Metal Noseclip, Reservoir Bag	25059	$1.18	$	1.18		$	59.00	50/cs
212												
213	Airway		CURAPLEX BY BOUND TRE	Oxygen Mask, Adult, Elongated, High Conc, Total NRB w/o Vent, Reservoir Bag, Tubing	25060	$1.14	$	1.14		$	57.00	50/cs
214												
215	Airway		CURAPLEX BY BOUND TRE	Oxygen Mask, Adult, Elongated, Total NRB w/o Vent, Reservoir Bag, 7 ft Tubing	30052	$1.15	$	1.15		$	57.50	50/cs
216												
217	Airway		CURAPLEX BY BOUND TRE	Oxygen Mask, Elongated, Pediatric, Partial NRB w/Vent, Reservoir Bag, 7 ft Tubing	30053	$1.11	$	1.11		$	55.50	50/cs
218												
219	Airway		CURAPLEX BY BOUND TRE	Oxygen Mask, Infant, Elongated, Total NRB w/o Vent, Reservoir Bag, 7 ft Tubing	30058	$1.14	$	1.14		$	57.00	50/cs
220												
221	Airway		AMBU INC.	BVM, SPUR II, ADULT W/ MED ADULT MASK, INDIVIDUALLY BAGGED	520211000	$9.60	$	9.60		$	115.20	12/cs
222												
223	Airway		AMBU INC.	BVM, SPUR II, Pedi w/Neonate/Infant/Toddler Masks, Bag Reservoir, Medi Port, Boxed	530214000B	$14.78	$	14.78		$	177.36	12/cs
224												
225	Airway		AMBU INC.	BVM, SPUR II, PEDIATRIC, EXP FILTER, MANOMETER, Neonate, Infant, Toddler Mask and BVM/Set	530614017	$18.29	$	18.29		$	109.74	6/cs
226												
227	Airway		AMBU INC.	BVM, SPUR II, ADULT W/ MEDIUM ADULT MASK, INDIVIDUALLY BOXED	520211000B	$9.60	$	9.60		$	115.20	12/cs
228												
229	Airway		AMBU INC.	BVM, SPUR II, Pediatric w/Toddler Mask, Individually Boxed	530213000B	$10.78	$	10.78		$	129.36	12/cs
230												
231	Airway		AMBU INC.	BVM, SPUR II, Infant w/Neonate Mask	540211000	$9.60	$	9.60		$	115.20	12/cs
232												
233	Airway		INTERSURGICAL, INC.	VT Select BVM - Adult Mask	7159094	$17.10	$	17.10		$	136.80	8/cs
234												
235	Airway		INTERSURGICAL, INC.	VT Select BVM with Manometer, PEEP Valve, Filter - Adult Mask	7159090	$22.04	$	22.04		$	176.32	8/cs
236												
237	Airway		CURAPLEX BY BOUND TRE	BVM, Adult, Mask Size 5, Universal Connector, 7FT O2 Tubing	2442-BVM1500	$7.25	$	7.25		$	72.50	10/cs
238												
239	Airway		CURAPLEX BY BOUND TRE	BVM, Small Adult/Pediatric, Mask Size 4, Universal Connector, 7FT O2 Tubing	2442-BVM1000	$7.25	$	7.25		$	72.50	10/cs
240												
241	Airway		CURAPLEX BY BOUND TRE	BVM, Child, Mask Size 3, Universal Connector, 7FT O2 Tubing, Pop-Off Valve	2442-BVM550	$8.25	$	8.25		$	82.50	10/cs
242												
243	Airway		CURAPLEX BY BOUND TRE	BVM, Infant, Mask Size 2, Universal Connector, 7FT O2 Tubing, Pop-Off Valve	2442-BVM300	$8.25	$	8.25		$	82.50	10/cs
244												
245	Airway		CURAPLEX BY BOUND TRE	Select Sm Ad/Ped BVM Manometer PEEP Bacterial Filter	2442-BVMPSA	$14.99	$	14.99		$	149.90	10/cs
246												
247	Airway		CURAPLEX BY BOUND TRE	Select Child BVM, Manometer, Bacterial Filter, Child, Neonate, Infant Masks	2442-BVMCIN	$14.99	$	14.99		$	149.90	10/cs
248												
249	Airway		CURAPLEX BY BOUND TRE	Nasopharyngeal airway NP, 12 Fr, adjustable flange, disposable, sterile	1-5072-12	$2.19	$	2.19	10/bx			
250												
251	Airway		CURAPLEX BY BOUND TRE	Nasopharyngeal airway NP, 14 Fr, adjustable flange, disposable, sterile	1-5072-14	$2.19	$	2.19	10/bx			
252												
253	Airway		CURAPLEX BY BOUND TRE	Nasopharyngeal airway NP, 16 Fr, adjustable flange, disposable, sterile	1-5072-16	$2.19	$	2.19	10/bx			
254												
255	Airway		CURAPLEX BY BOUND TRE	Nasopharyngeal airway NP, 18 Fr, adjustable flange, disposable, sterile	1-5072-18	$2.19	$	2.19	10/bx			
256												
257	Airway		CURAPLEX BY BOUND TRE	Nasopharyngeal airway NP, 20 Fr, adjustable flange, disposable, sterile	1-5072-20	$2.19	$	2.19	10/bx			
258												
259	Airway		CURAPLEX BY BOUND TRE	Nasopharyngeal airway NP, 22 Fr, adjustable flange, disposable, sterile	1-5072-22	$2.19	$	2.19	10/bx			
260												
261	Airway		CURAPLEX BY BOUND TRE	Nasopharyngeal airway NP, 24 Fr, adjustable flange, disposable, sterile	1-5072-24	$2.19	$	2.19	10/bx			

262											
263	Airway		CURAPLEX BY BOUND TRE	Nasopharyngeal airway NP, 26 Fr, adjustable flange, disposable, sterile	1-5072-26	$2.19	$ 2.19	10/bx		
264											
265	Airway		CURAPLEX BY BOUND TRE	Nasopharyngeal airway NP, 28 Fr, adjustable flange, disposable, sterile	1-5072-28	$2.19	$ 2.19	10/bx		
266											
267	Airway		CURAPLEX BY BOUND TRE	Nasopharyngeal airway NP, 30 Fr, adjustable flange, disposable, sterile	1-5072-30	$2.19	$ 2.19	10/bx		
268											
269	Airway		CURAPLEX BY BOUND TRE	Nasopharyngeal airway NP, 32 Fr, adjustable flange, disposable, sterile	1-5072-32	$2.19	$ 2.19	10/bx		
270											
271	Airway		CURAPLEX BY BOUND TRE	Nasopharyngeal airway NP, 34 Fr, adjustable flange, disposable, sterile	1-5072-34	$2.19	$ 2.19	10/bx		
272											
273	Airway		CURAPLEX BY BOUND TRE	Nasopharyngeal airway NP, 36 Fr, adjustable flange, disposable, sterile	1-5072-36	$2.19	$ 2.19	10/bx		
274											
275	Airway		CURAPLEX BY BOUND TRE	Berman airway, 40 mm, size 00, newborn, pink, disposable, individually packaged	1-1508-40	$0.25	$ 0.25	50/bg	$ 20.00	80bg/cs
276											
277	Airway		CURAPLEX BY BOUND TRE	Berman airway, 50 mm, size 0, infant, blue, disposable, individually packaged	1-1508-50	$0.25	$ 0.25	50/bg	$ 20.00	80bg/cs
278											
279	Airway		CURAPLEX BY BOUND TRE	Berman airway, 60 mm, size 1, small child, black, disposable, individually packaged	1-1508-60	$0.25	$ 0.25	50/bg	$ 20.00	80bg/cs
280											
281	Airway		CURAPLEX BY BOUND TRE	Berman airway, 70 mm, size 2, child, white, disposable, individually packaged	1-1508-70	$0.25	$ 0.25	50/bg	$ 20.00	80bg/cs
282											
283	Airway		CURAPLEX BY BOUND TRE	Berman airway, 80 mm, size 3, small adult, green, disposable, individually packaged	1-1508-80	$0.25	$ 0.25	50/bg	$ 20.00	80bg/cs
284											
285	Airway		CURAPLEX BY BOUND TRE	Berman airway, 90 mm, size 4, medium adult, yellow, disposable, individually packaged	1-1508-90	$0.25	$ 0.25	50/bg	$ 20.00	80bg/cs
286											
287	Airway		CURAPLEX BY BOUND TRE	Berman airway, 100 mm, size 5, large adult, red, disposable, individually packaged	1-1508-100	$0.25	$ 0.25	50/bg	$ 20.00	80bg/cs
288											
289	Airway		CURAPLEX BY BOUND TRE	Berman airway, 110 mm, size 6, x-large adult, orange, disposable, individually packaged	1-1508-110	$0.25	$ 0.25	50/bg	$ 20.00	80bg/cs
290											
291	Airway		CURAPLEX BY BOUND TRE	Suction Catheter, 6 Fr, coiled, w/whistle tip and thumb control port, sterile, disp, LF	MS-SC06	$0.25	$ 0.25		$ 12.50	50/cs
292											
293	Airway		CURAPLEX BY BOUND TRE	Suction Catheter, 8 Fr, coiled, w/whistle tip and thumb control port, sterile, disp, LF	MS-SC08	$0.25	$ 0.25		$ 12.50	50/cs
294											
295	Airway		CURAPLEX BY BOUND TRE	Suction Catheter, 10 Fr, coiled, w/whistle tip and thumb control port, sterile, disp, LF	MS-SC10	$0.25	$ 0.25		$ 12.50	50/cs
296											
297	Airway		CURAPLEX BY BOUND TRE	Suction catheter, 12 Fr, coiled, w/whistle tip and thumb control port, sterile, disp, LF	MS-SC12	$0.25	$ 0.25		$ 12.50	50/cs
298											
299	Airway		CURAPLEX BY BOUND TRE	Suction Catheter, 14 Fr, coiled, w/whistle tip and thumb control port, sterile, disp, LF	MS-SC14	$0.25	$ 0.25		$ 12.50	50/cs
300											
301	Airway		CURAPLEX BY BOUND TRE	Suction catheter, 16 Fr, coiled, w/ whistle tip and thumb control port, sterile, disp, LF	MS-SC16	$0.25	$ 0.25		$ 12.50	50/cs
302											
303	Airway		CURAPLEX BY BOUND TRE	Suction catheter, 18 Fr, coiled, w/whistle tip and thumb control port, sterile, disp, LF	MS-SC18	$0.25	$ 0.25		$ 12.50	50/cs
304											
305	AIRWAY		CURAPLEX BY BOUND TRE	Berman airway set, 8 sizes per set, 40, 50, 60, 70, 80, 90, 100 and 110 mm airway	792-1-1508-00EA	$2.50	$ 2.50			
306											
307	AIRWAY		CURAPLEX BY BOUND TRE	Nebulizer	301-200EA	$1.00	$ 1.00		$ 50.00	50/cs
308											
309	AIRWAY		EMI	Bite Block	0003	$0.85	$ 0.85	10/pk		
310											
311	AIRWAY		AIRLIFE	SM. Laryngoscope Bulb	303676	$3.42	$ 3.42	10/bx		
312											
313	AIRWAY		AIRLIFE	LG. Laryngoscope Bulb	308257	$3.40	$ 3.40	10/bx		
314											
315	AIRWAY		ASPEN SURGICAL PRODU	Scalpel	372610	$2.50	$ 2.50		$ 250.00	100/cs
316											

317	AIRWAY		CURAPLEX BY BOUND TRE	Pocket Mask	36045	$3.99	$ 3.99				
318											
319	AIRWAY		NORTH AMERICAN RESCU	Spear (Pneumothorax Emergency Air Release)	2160-00051	$30.45	$ 30.45				
320											
321	AIRWAY		SURGICAL DESIGN, INC	Peds Magill Forceps	0128	$3.49	$ 3.49				
322											
323	AIRWAY		LAERDAL MEDICAL CORP	ET Holders - Adult	020500	$3.40	$ 3.40				
324											
325	AIRWAY		LAERDAL MEDICAL CORP	ET Holders - Peds	020400	$3.40	$ 3.40				
326											
327	AIRWAY		PULMODYNE	Large CPAP Mask	313-7030EA	$23.65	$ 23.65		$ 236.50	10/cs	
328											
329	AIRWAY		MEDTRONIC (COVIDIEN)	Colorimetric CO2 Detector PEDS	530025	$9.56	$ 9.56	6/bx	$ 229.44	4bx/cs	
330											
331	AIRWAY		MEDTRONIC (COVIDIEN)	Colorimetric CO2 Detector Adult	530024	$9.56	$ 9.56	6/bx	$ 229.44	4bx/cs	
332											
333	AIRWAY		ALLIED MEDICAL LLC	Autovent Tubing	539090	$16.44	$ 16.44		$ 164.40	10/cs	
334											
335	AIRWAY		CURAPLEX BY BOUND TRE	Suction Canister 1200cc	2212-11200	$3.29	$ 3.29		$ 157.92	48/cs	
336											
337	AIRWAY		CURAPLEX BY BOUND TRE	Suction Canister 800cc	2212-10800	$3.02	$ 3.02		$ 302.00	100/cs	
338											
339	AIRWAY		BUSSE HOSPITAL DISPOS	Bulb Syringe	590031	$1.16	$ 1.16		$ 58.00	50/cs	
340											
341	AIRWAY		CURAPLEX BY BOUND TRE	One-Way Valve	L820300	$9.99	$ 9.99				
342											
343	AIRWAY		PULMODYNE	Small CPAP Mask	313-7028EA	$23.94	$ 23.94		$ 239.40	10/cs	
344											
345	AIRWAY		CURAPLEX BY BOUND TRE	Stick Stylet 14 fr	12998	$1.01	$ 1.01	20/bx	$ 202.00	10bx/cs	
346											
347	AIRWAY		CURAPLEX BY BOUND TRE	Stick Stylet 6 fr	12996	$1.01	$ 1.01	20/bx	$ 202.00	10bx/cs	
348											
349	AIRWAY		CURAPLEX BY BOUND TRE	Lubrication Jelly Packet	1340-27000	$0.05	$ 7.50	144/bx	$ 90.00	12bx/cs	
350											
351	AIRWAY		ZULCO INTERNATIONAL	Adult Magill Forceps	61435	$3.78	$ 3.78	12/bx			
352											
353	AIRWAY		AIRLIFE	Bougie	2120-21282	$6.00	$ 6.00	10/pk			
354											
355	AIRWAY		CURAPLEX BY BOUND TRE	ETCO2	8600-01298	$6.30	$ 63.00				
356											
357	AIRWAY		MEDSOURCE INTERNATIO	Infant NC	410336	$1.48	$ 1.48		$ 74.00	50/cs	
358											
359	AIRWAY		CURAPLEX BY BOUND TRE	O2 Regulator	14288	$63.44	$ 63.44				
360											
361	AIRWAY		CURAPLEX BY BOUND TRE	Nasal ETCO2	301-5707F-SE	$6.49	$ 6.49		$ 162.25	25/cs	
362											
363	AIRWAY		CURAPLEX BY BOUND TRE	Hepa Filter	301-439EA	$2.26	$ 2.26		$ 113.00	50/cs	
364											
365	AIRWAY		CURAPLEX BY BOUND TRE	Portable Pulse Oximeter	2711-30310	$19.99	$ 19.99				
366											
367	Equipment		CURAPLEX BY BOUND TRE	Penlights, Rainbow, colors subject to change based on availability	211	$3.96	$ 3.96	6/pk	$ 237.60	60pk/cs	
368											
369	Equipment		CURAPLEX BY BOUND TRE	Trauma Shears	2811-05524	$0.85	$ 0.85		$ 170.00	200/cs	
370											
371	Equipment		CURAPLEX BY BOUND TRE	Pediatric BP Cuff	36011	$8.49	$ 8.49		$ 424.50	50/cs	

372											
373	Equipment		CURAPLEX BY BOUND TRE	Adult BP Cuff	36012	$8.49	$	8.49		$	424.50	50/cs
374											
375	Equipment		CURAPLEX BY BOUND TRE	Adult Large BP Cuff	36013	$9.49	$	9.49		$	474.50	50/cs
376											
377	Equipment		CURAPLEX BY BOUND TRE	Stethoscope	36020	$8.50	$	8.50		$	425.00	50/cs
378											
379	Equipment		MED PLUS SERVICES USA	Wall Mounted Sharps Bracket	298519	$14.29	$	14.29		$	714.50	5/cs
380											
381	Equipment		CURAPLEX BY BOUND TRE	Backboard Strap	16683	$2.39	$	2.39		$	239.00	100/cs
382											
383	Equipment		ASSOCIATED BAG COMPA	Brown Paper Bags	4310-30635	$0.10	$	50.85	500/pk			
384											
385	Equipment		MEDSOURCE INTERNATIO	Stretcher Straps	533-MS-ST393	$9.36	$	9.36				
386											
387	Equipment		STRYKER	Lucas Cups	4510-04776	$50.66	$	607.98	12/pk			
388											
389	Equipment		CURAPLEX BY BOUND TRE	KED	15329	$54.96	$	54.96				
390											
391	Equipment		CURAPLEX BY BOUND TRE	Infant BP Cuff	36010	$9.49	$	9.49		$	474.50	50/cs
392											
393	Equipment		MACO INTERNATIONAL	Ring Cutter	400010	$7.93	$	7.93				
394											
395	Equipment		EMI	Seatbelt Cutters	K4026	$5.10	$	5.10				
396											
397	General First Aid		CURAPLEX BY BOUND TRE	Rapid Heat Instant Hot Pack, 10.5 in x 5.5in	2054	$0.60	$	0.60		$	14.40	24/cs
398											
399	General First Aid		DYNAREX CORPORATION	HOT COMPRESS 5 IN X 9	4516	$0.61	$	14.63		$	351.12	24/cs
400											
401	General First Aid		DYNAREX CORPORATION	Ice pack, Rapid Cold, Convenient Slide Off Clip, Instant Cold 6EA/BX 4BX/CS	2000	$0.63	$	0.63		$	15.12	24/cs
402											
403	General First Aid		CURAPLEX BY BOUND TRE	COLD PACK INSTANT 5.5 IN X 10 IN 24/CS RAPID COLD	2004	$0.45	$	0.45		$	10.80	24/cs
404											
405											
406	General First Aid		CURAPLEX BY BOUND TRE	Emesis Bag, 1000cc, White, Cardboard Rim w/ Hand Protection	1071-10210	$0.79	$	19.85	25/pk	$	198.50	10pk/cs
407											
408	General First Aid		NORTH AMERICAN RESCU	Arterial Tourniquet	1880-23315	$26.43	$	26.43				
409											
410	General First Aid		BAXTER HEALTHCARE-DM	Sterile water 250 cc	607112	$3.54	$	3.54		$	84.96	24/cs
411											
412	General First Aid		DICK MEDICAL SUPPLY	Padded, Short Board	660012	$2.90	$	2.90				
413											
414	General First Aid		DICK MEDICAL SUPPLY	Padded, Medium Board	660013	$4.91	$	4.91		$	368.25	75/cs
415											
416	General First Aid		DICK MEDICAL SUPPLY	Padded, Long Board	660014	$6.63	$	6.63		$	331.50	50/cs
417											
418	General First Aid		DICK MEDICAL SUPPLY	Head Blocks (Set of 2)	3141-50402	$6.63	$	6.63				
419											
420	General First Aid		TACTICAL MEDICAL SOLU	Blast Bandage	660235	$6.99	$	6.99				
421											
422	General First Aid		SAM MEDICAL	SAM Splint (Arm)	770-1410EA	$8.35	$	8.35		$	200.40	24/cs
423											
424	General First Aid		SAM MEDICAL	Sam Splint (Wrist)	3014-00515	$2.89	$	2.89		$	173.40	60/cs
425											
426	General First Aid		SAM MEDICAL	Sam Splint (Wide Leg)	3014-12104	$7.62	$	7.62		$	457.20	60/cs

427											
428	General First Aid		CURAPLEX BY BOUND TRE	3" Kling	1121-36559	$0.11	$	1.35	12rl/bg	$ 10.80	8bg/cs
429											
430	General First Aid		CURAPLEX BY BOUND TRE	Trauma Dressing	16353	$1.00	$	1.00		$ 50.00	50/cs
431											
432	General First Aid		CURAPLEX BY BOUND TRE	Burn Sheet	30061MS	$2.32	$	2.32		$ 116.00	50/cs
433											
434	General First Aid		CURAPLEX BY BOUND TRE	Emergency Blanket	16570	$3.25	$	3.25		$ 78.00	24/cs
435											
436	General First Aid		DYNAREX CORPORATION	Blue "Chux" Pad	1073-09853	$0.15	$	30.85		$ 6,170.00	200/cs
437											
438	General First Aid		DYNAREX CORPORATION	Razor	540047	$0.44	$	0.44		$ 110.00	250/cs
439											
440	General First Aid		CURAPLEX BY BOUND TRE	Bandaids	1122-14960	$0.01	$	1.43	100/bx	$ 85.80	60bx/cs
441											
442	General First Aid		CURAPLEX BY BOUND TRE	6" Ace Wrap	1121-36553	$0.88	$	8.75	10pk/bx	$ 43.75	5bx/cs
443											
444	General First Aid		CURAPLEX BY BOUND TRE	Surgipad 5 x 9	1212-12110	$0.17	$	4.28	25/bx	$ 68.48	16bx/cs
445											
446	General First Aid		CURAPLEX BY BOUND TRE	Sterile 4 x 4	1212-12113	$0.09	$	4.31	50/bx	$ 51.72	12bx/cs
447											
448	General First Aid		TIDI PRODUCTS, LLC	Soft Restraints	2532	$7.87	$	7.87	1/pr		
449											
450	General First Aid		CURAPLEX BY BOUND TRE	Pen Light	32762	$0.66	$	3.96	6/pk	$ 237.60	60pk/cs
451											
452	General First Aid		CAMBRIDGE SENSORS US	Glucose Paste	664389	$3.40	$	10.19	3/bx		
453											
454	General First Aid		CURAPLEX BY BOUND TRE	Triangular Bandage	1124-32400	$0.41	$	4.91	12/pk	$ 98.20	20pk/cs
455											
456	General First Aid		NORTH AMERICAN RESCU	Emergency Trauma Dressing	G1288	$7.28	$	7.28			
457											
458	General First Aid		NORTH AMERICAN RESCU	Nar Compressed Gauze	1121-30052	$2.52	$	2.52			
459											
460	General First Aid		CURAPLEX BY BOUND TRE	Cohesive Bandage	1121-36571	$0.41	$	14.71	36/bx	$ 88.26	6bx/cs
461											
462	General First Aid		NORTH AMERICAN RESCU	Chest Seal	NAR10-0037	$7.30	$	14.60	2/pk		
463											
464	Infection Control		ANSELL HEALTHCARE PR	Gloves, Cobalt, SM, Nitrile, Exam, Powder Free, Blue, 4.0 mil palm	N191	$0.08	$	7.99	100/bx	$ 79.90	10bx/cs
465											
466	Infection Control		ANSELL HEALTHCARE PR	Gloves, Cobalt, MED, Nitrile, Exam, Powder Free, Blue, 4.0 mil palm	N192	$0.08	$	7.99	100/bx	$ 79.90	10bx/cs
467											
468	Infection Control		ANSELL HEALTHCARE PR	Gloves, Cobalt, LG, Nitrile, Exam, Powder Free, Blue, 4.0 mil palm	N193	$0.08	$	7.99	100/bx	$ 79.90	10bx/cs
469											
470	Infection Control		ANSELL HEALTHCARE PR	Gloves, Cobalt, XL, Nitrile, Exam, Powder Free, Blue, 4.0 mil palm	N194	$0.08	$	7.99	100/bx	$ 79.90	10bx/cs
471											
472	Infection Control		ANSELL HEALTHCARE PR	Gloves, Supreno EC, XS, Nitrile, Powder Free, Textured, High Risk, Extended Cuff	SEC-375-XS	$0.18	$	9.05	50/bx	$ 90.50	10bx/cs
473											
474	Infection Control		ANSELL HEALTHCARE PR	Gloves, Supreno EC, SM, Nitrile, Powder Free, Textured, High Risk, Extended Cuff	SEC-375-S	$0.18	$	9.05	50/bx	$ 90.50	10bx/cs
475											
476	Infection Control		ANSELL HEALTHCARE PR	Gloves, Supreno EC, MED, Nitrile, Powder Free, Textured, High Risk, Extended Cuff	SEC-375-M	$0.18	$	9.05	50/bx	$ 90.50	10bx/cs
477											
478	Infection Control		ANSELL HEALTHCARE PR	Gloves, Supreno EC, LG, Nitrile, Powder Free, Textured, High Risk, Extended Cuff	SEC-375-L	$0.18	$	9.05	50/bx	$ 90.50	10bx/cs
479											
480	Infection Control		ANSELL HEALTHCARE PR	Gloves, Supreno EC, XL, Nitrile, Powder Free, Textured, High Risk, Extended Cuff	SEC-375-XL	$0.18	$	9.05	50/bx	$ 90.50	10bx/cs
481											

482	Infection Control		ANSELL HEALTHCARE PR	Gloves, Supreno EC, 2XL, Nitrile, Powder Free, Textured, High Risk, Extended Cuff	SEC-375-XXL	$0.18	$ 9.05	50/bx	$ 90.50	10bx/cs
483										
484	Infection Control		ANSELL HEALTHCARE PR	Gloves, Supreno EC, 3XL, Nitrile, Powder Free, Textured, High Risk, Extended Cuff	SEC-375-XXXL	$0.23	$ 9.05	40/bx	$ 90.50	10bx/cs
485										
486	Infection Control		ANSELL HEALTHCARE PR	Gloves, Supreno SE, SM, Nitrile, Powder Free, Standard Textured Exam	SU-690-S	$0.10	$ 10.40	100/bx	$ 104.00	10bx/cs
487										
488	Infection Control		ANSELL HEALTHCARE PR	Gloves, Supreno SE, MED, Nitrile, Powder Free, Standard Textured Exam	SU-690-M	$0.10	$ 10.40	100/bx	$ 104.00	10bx/cs
489										
490	Infection Control		ANSELL HEALTHCARE PR	Gloves, Supreno SE, LG, Nitrile, Powder Free, Standard Textured Exam	SU-690-L	$0.10	$ 10.40	100/bx	$ 104.00	10bx/cs
491										
492	Infection Control		ANSELL HEALTHCARE PR	Gloves, Supreno SE, XL, Nitrile, Powder Free, Standard Textured Exam	SU-690-XL	$0.10	$ 10.40	100/bx	$ 104.00	10bx/cs
493										
494	Infection Control		ANSELL HEALTHCARE PR	Gloves, Supreno SE, 2XL, Nitrile, Powder Free, Standard Textured Exam	SU-690-2XL	$0.10	$ 10.40	100/bx	$ 104.00	10bx/cs
495										
496	Infection Control		ANSELL HEALTHCARE PR	Gloves, MidKnight, XS, Black, Nitrile, Powder Free	MK-296-XS	$0.10	$ 9.90	100/bx	$ 99.00	10bx/cs
497										
498	Infection Control		ANSELL HEALTHCARE PR	Gloves, MidKnight, SM, Black, Nitrile, Powder Free	MK-296-S	$0.10	$ 9.90	100/bx	$ 99.00	10bx/cs
499										
500	Infection Control		ANSELL HEALTHCARE PR	Gloves, MidKnight, MED, Black, Nitrile, Powder Free	MK-296-M	$0.10	$ 9.90	100/bx	$ 99.00	10bx/cs
501										
502	Infection Control		ANSELL HEALTHCARE PR	Gloves, MidKnight, LG, Black, Nitrile, Powder Free	MK-296-L	$0.10	$ 9.90	100/bx	$ 99.00	10bx/cs
503										
504	Infection Control		ANSELL HEALTHCARE PR	Gloves, MidKnight, XL, Black, Nitrile, Powder Free	MK-296-XL	$0.10	$ 9.90	100/bx	$ 99.00	10bx/cs
505										
506	Infection Control		ANSELL HEALTHCARE PR	Gloves, MidKnight, 2XL, Black, Nitrile, Powder Free	MK-296-XXL	$0.10	$ 9.90	100/bx	$ 99.00	10bx/cs
507										
508	Infection Control		ANSELL HEALTHCARE PR	Gloves, MidKnight Touch 93-732, XS, Nitrile, Black, Powder Free, 9.5in	93732060	$0.07	$ 6.59	100/bx	$ 65.90	10bx/cs
509										
510	Infection Control		ANSELL HEALTHCARE PR	Gloves, MidKnight Touch 93-732, SM, Nitrile, Black, Powder Free, 9.5in	93732070	$0.07	$ 6.59	100/bx	$ 65.90	10bx/cs
511										
512	Infection Control		ANSELL HEALTHCARE PR	Gloves, MidKnight Touch 93-732, MED, Nitrile, Black, Powder Free, 9.5in	93732080	$0.07	$ 6.59	100/bx	$ 65.90	10bx/cs
513										
514	Infection Control		ANSELL HEALTHCARE PR	Gloves, MidKnight Touch 93-732, LG, Nitrile, Black, Powder Free, 9.5in	93732090	$0.07	$ 6.59	100/bx	$ 65.90	10bx/cs
515										
516	Infection Control		ANSELL HEALTHCARE PR	Gloves, MidKnight Touch 93-732, XL, Nitrile, Black, Powder Free, 9.5in	93732100	$0.07	$ 6.59	100/bx	$ 65.90	10bx/cs
517										
518	Infection Control		ANSELL HEALTHCARE PR	Gloves, MidKnight Touch 93-732, 2XL, Nitrile, Black, Powder Free, 9.5in	93732110	$0.07	$ 6.59	90/bx	$ 65.90	10bx/cs
519										
520	Infection Control		ANSELL HEALTHCARE PR	Gloves, Ultrasense EC, XS, Latex Free, Powder Free	USE-880-XS	$0.11	$ 11.39	100/bx	$ 113.90	10bx/cs
521										
522	Infection Control		ANSELL HEALTHCARE PR	Gloves, Ultrasense EC, SM, Latex Free, Powder Free	USE-880-S	$0.11	$ 11.39	100/bx	$ 113.90	10bx/cs
523										
524	Infection Control		ANSELL HEALTHCARE PR	Gloves, Ultrasense EC, MED, Latex Free, Powder Free	USE-880-M	$0.11	$ 11.39	100/bx	$ 113.90	10bx/cs
525										
526	Infection Control		ANSELL HEALTHCARE PR	Gloves, Ultrasense EC, LG, Latex Free, Powder Free	USE-880-L	$0.11	$ 11.39	100/bx	$ 113.90	10bx/cs
527										
528	Infection Control		ANSELL HEALTHCARE PR	Gloves, Ultrasense EC, XL, Latex Free, Powder Free	USE-880-XL	$0.11	$ 11.39	100/bx	$ 113.90	10bx/cs
529										
530	Infection Control		ANSELL HEALTHCARE PR	Gloves, Ultrasense EC, 2XL, Latex Free, Powder Free	USE-880-XXL	$0.11	$ 11.39	100/bx	$ 113.90	10bx/cs
531										
532	Infection Control		ANSELL HEALTHCARE PR	Gloves, UltraSense, XS, Nitrile, Powder Free	US-220-XS	$0.08	$ 7.59	100/bx	$ 75.90	10bx/cs
533										
534	Infection Control		ANSELL HEALTHCARE PR	Gloves, UltraSense, SM, Nitrile, Powder Free	US-220-S	$0.08	$ 7.59	100/bx	$ 75.90	10bx/cs
535										
536	Infection Control		ANSELL HEALTHCARE PR	Gloves, UltraSense, MED, Nitrile, Powder Free	US-220-M	$0.08	$ 7.59	100/bx	$ 75.90	10bx/cs

537											
538	Infection Control		ANSELL HEALTHCARE PR	Gloves, UltraSense, LG, Nitrile, Powder Free	US-220-L	$0.08	$ 7.59	100/bx	$ 75.90	10bx/cs	
539											
540	Infection Control		ANSELL HEALTHCARE PR	Gloves, UltraSense, XL, Nitrile, Powder Free	US-220-XL	$0.07	$ 7.44	100/bx	$ 74.40	10bx/cs	
541											
542	Infection Control		O&M HALYARD, INC.	Gloves, BLACK-FIRE, XS, Powder-Free, Nitrile, Exam	44755	$0.13	$ 19.93	150/bx	$ 199.30	10bx/cs	
543											
544	Infection Control		O&M HALYARD, INC.	Gloves, BLACK-FIRE, SM, Powder-Free, Nitrile, Exam	44756	$0.13	$ 19.93	150/bx	$ 199.30	10bx/cs	
545											
546	Infection Control		O&M HALYARD, INC.	Gloves, BLACK-FIRE, MED, Powder-Free, Nitrile, Exam	44757	$0.13	$ 19.93	150/bx	$ 199.30	10bx/cs	
547											
548	Infection Control		O&M HALYARD, INC.	Gloves, BLACK-FIRE, LG, Powder-Free, Nitrile, Exam	44758	$0.13	$ 19.93	150/bx	$ 199.30	10bx/cs	
549											
550	Infection Control		O&M HALYARD, INC.	Gloves, BLACK-FIRE, XL, Powder-Free, Nitrile, Exam	44759	$0.14	$ 19.93	140/bx	$ 199.30	10bx/cs	
551											
552	Infection Control		O&M HALYARD, INC.	Gloves, KC500 Purple Nitrile, XS, Latex Free, Powder Free, 9.5 in Cuff	55080	$0.20	$ 9.88	50/bx	$ 98.80	10bx/cs	
553											
554	Infection Control		O&M HALYARD, INC.	Gloves, KC500 Purple Nitrile, SM, Latex Free, Powder Free, 9.5 in Cuff	55081	$0.20	$ 9.88	50/bx	$ 98.80	10bx/cs	
555											
556	Infection Control		O&M HALYARD, INC.	Gloves, KC500 Purple Nitrile, MED, Latex Free, Powder Free, 9.5 in Cuff	55082	$0.20	$ 9.88	50/bx	$ 98.80	10bx/cs	
557											
558	Infection Control		O&M HALYARD, INC.	Gloves, KC500 Purple Nitrile, LG, Latex Free, Powder Free, 9.5 in Cuff	55083	$0.20	$ 9.88	50/bx	$ 98.80	10bx/cs	
559											
560	Infection Control		O&M HALYARD, INC.	Gloves, KC500 Purple Nitrile, XL, Latex Free, Powder Free, 9.5 in Cuff	55084	$0.20	$ 9.88	50/bx	$ 98.80	10bx/cs	
561											
562	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip VL Gloves,SM	1012-44883	$0.04	$ 8.39	200/bx	$ 83.90	10bx/cs	
563											
564	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip VL Gloves, MED	1012-44884	$0.04	$ 8.39	200/bx	$ 83.90	10bx/cs	
565											
566	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip VL Gloves, LG	1012-44885	$0.04	$ 8.39	200/bx	$ 83.90	10bx/cs	
567											
568	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip VL Gloves, XL	1012-44886	$0.04	$ 8.39	180/bx	$ 83.90	10bx/cs	
569											
570	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip TE Gloves, SM, Black Nitrile, Powder Free	1012-47133	$0.07	$ 6.50	100/bx	$ 65.00	10bx/cs	
571											
572	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip TE Gloves, MED, Black Nitrile, Powder Free	1012-47134	$0.07	$ 6.50	100/bx	$ 65.00	10bx/cs	
573											
574	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip TE Gloves, LG, Black Nitrile, Powder Free	1012-47135	$0.07	$ 6.50	100/bx	$ 65.00	10bx/cs	
575											
576	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip TE Gloves, XL, Black Nitrile, PF	1012-47136	$0.07	$ 6.50	90/bx	$ 65.00	10bx/cs	
577											
578	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip SE Gloves, SM, Blue Nitrile, Powder Free	1012-47123	$0.07	$ 7.00	100/bx	$ 70.00	10bx/cs	
579											
580	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip SE Gloves, MED, Blue Nitrile, Powder Free	1012-47124	$0.07	$ 7.00	100/bx	$ 70.00	10bx/cs	
581											
582	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip SE Gloves, LG, Blue Nitrile, Powder Free	1012-47125	$0.07	$ 7.00	100/bx	$ 70.00	10bx/cs	
583											
584	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip SE Gloves, XL, Blue Nitrile, Powder Free	1012-47126	$0.08	$ 7.00	90/bx	$ 70.00	10bx/cs	
585											
586	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip HV Gloves, XS, Orange Nitrile	1015-47150	$0.07	$ 6.80	100/bx	$ 68.00	10bx/cs	
587											
588	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip HV Gloves, SM, Orange Nitrile	1015-47151	$0.07	$ 6.80	100/bx	$ 68.00	10bx/cs	
589											
590	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip HV Gloves, MED, Orange Nitrile	1015-47152	$0.07	$ 6.80	100/bx	$ 68.00	10bx/cs	
591											

592	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip HV Gloves, LG, Orange Nitrile	1015-47153	$0.07	$ 6.80	100/bx	$ 68.00	10bx/cs
593										
594	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip HV Gloves, XL, Orange Nitrile	1015-47154	$0.07	$ 6.80	100/bx	$ 68.00	10bx/cs
595										
596	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip HV Gloves, 2XL, Orange Nitrile	1015-47155	$0.09	$ 6.80	80/bx	$ 68.00	10bx/cs
597										
598	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip EP X2 Gloves, SM, White Ext/Green Int, PF Nitrile Exam	1015-47143	$0.16	$ 15.99	100/bx	$ 159.90	10bx/cs
599										
600	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip EP X2 Gloves, MED, White Ext/Green Int, PF Nitrile Exam	1015-47144	$0.16	$ 15.99	100/bx	$ 159.90	10bx/cs
601										
602	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip EP X2 Gloves, LG, White Ext/Green Int, PF Nitrile Exam	1015-47145	$0.16	$ 15.99	100/bx	$ 159.90	10bx/cs
603										
604	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip EP X2 Gloves, XL, White Ext/Green Int, PF Nitrile Exam	1015-47146	$0.16	$ 15.99	100/bx	$ 159.90	10bx/cs
605										
606	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip EP X2 Gloves, 2XL, White Ext/Green Int, PF Nitrile Exam	1015-47147	$0.16	$ 15.99	100/bx	$ 159.90	10bx/cs
607										
608	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip EC Exam Gloves, Blue, Small	1015-47161	$0.08	$ 7.50	100/bx	$ 75.00	10bx/cs
609										
610	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip EC Exam Gloves, Blue, Medium	1015-47162	$0.08	$ 7.50	100/bx	$ 75.00	10bx/cs
611										
612	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip EC Exam Gloves, Blue, Large	1015-47163	$0.08	$ 7.50	100/bx	$ 75.00	10bx/cs
613										
614	Infection Control		CURAPLEX BY BOUND TRE	TritonGrip EC Exam Gloves, Blue, X-Large	1015-47164	$0.08	$ 7.50	100/bx	$ 75.00	10bx/cs
615										
616	Infection Control		ECOLAB INC	Foam Hand Cleaner	1063-72915	$8.40	$ 8.40		$ 100.80	12/cs
617										
618	Infection Control		BECTON DICKINSON	Squad Sharps Container	295488	$4.02	$ 4.02		$ 96.48	24/cs
619										
620	Infection Control		MAMMOTH MEDICAL, INC	Wall Mounted Sharps Container	298507SA	$5.39	$ 5.39		$ 107.80	20/cs
621										
622	Infection Control		O&M HALYARD, INC.	Mask w/ Shield	29080	$0.98	$ 24.51	25/bx	$ 98.04	4bx/cs
623										
624	Infection Control		CURAPLEX BY BOUND TRE	N95 Mask	670245-KIT	$29.56	$ 29.56			
625										
626	Infection Control		MEDSOURCE INTERNATIO	Spit Sock	MS-44400	$0.84	$ 0.84			
627										
628	Infection Control		ANSELL HEALTHCARE PRO	Safety Glasses	660274	$2.42	$ 2.42	1/pr	$ 29.04	12pr/cs
629										
630	Infection Control		PDI	Super-Sani Cloth	1061-17517	$0.04	$ 6.63	160/tb	$ 79.56	12tb/cs
631										
632	Infection Control		MAMMOTH MEDICAL, INC	Small Sharps Container	298303	$4.75	$ 4.75		$ 95.00	20/cs
633										
634	Infection Control		MEDEGEN MEDICAL PROI	Small Bio-Hazard Bags	520-RD650	$0.10	$ 19.46		$ 3,892.00	200/cs
635										
636	Infection Control		MEDLINE INDUSTRIES, IN	Wash Basin	1072-80347	$0.73	$ 0.73		$ 36.50	50/cs
637										
638	Infection Control		SAFETEC OF AMERICA, IN	P.A.W.S. Wipes	2034400	$0.07	$ 6.57	100/bx	$ 65.70	10bx/cs
639										
640	Infection Control		WELCH ALLYN, INC.	Thermometer Probe Covers	2733-53175	$0.04	$ 9.69	250/bx	$ 290.70	30bx/cs
641										
642	Infection Control		CURAPLEX BY BOUND TRE	Wall Mounted Emesis Bags	1071-10202	$0.53	$ 13.13	25/pk	$ 78.78	6pk/cs
643										
644	Infection Control		ANSELL HEALTHCARE PRO	Tyvek Suits	TY127SLG	$7.50	$ 7.50		$ 187.50	25/cs
645										
646	Infection Control		MEDLINE INDUSTRIES, IN	Exam Gowns	X2320	$0.66	$ 0.66			

647											
648	Infection Control		O&M HALYARD, INC.	Surgical Masks	1031-91422	$0.16	$ 8.20	50/bx	$ 82.00	10bx/cs
649											
650	Infection Control		O&M HALYARD, INC.	Booties	290540	$0.18	$ 0.18			
651											
652	IV / Drug Admin		CURAPLEX BY BOUND TRE	IV Start Kit (Tegaderm, Alcohol, No Flush)	540-1358-A	$1.25	$ 1.25			
653											
654	IV / Drug Admin		CURAPLEX BY BOUND TRE	IV Start Kit (Tegaderm, Alcohol, No Flush, Towel)	670062-KIT	$1.29	$ 1.29			
655											
656	IV / Drug Admin		CURAPLEX BY BOUND TRE	IV Start Kit (Tegaderm, Alcohol, Flush)	670064-KIT	$2.70	$ 2.70			
657											
658	IV / Drug Admin		BECTON DICKINSON (BAR	BD IO Powered Driver w/ Charger	D001001	$700.00	$ 700.00			
659											
660	IV / Drug Admin		BECTON DICKINSON (BAR	BD IO 15mm Needle Kit w/ Stabilizer and Extension Set	D015151NK	$130.00	$ 130.00		$ 780.00	6/cs
661											
662	IV / Drug Admin		BECTON DICKINSON (BAR	BD IO 25mm Needle Kit w/ Stabilizer and Extension Set	D015251NK	$130.00	$ 130.00		$ 780.00	6/cs
663											
664	IV / Drug Admin		BECTON DICKINSON (BAR	BD IO 35mm Needle Kit w/ Stabilizer and Extension Set	D015351NK	$130.00	$ 130.00		$ 780.00	6/cs
665											
666	IV / Drug Admin		BECTON DICKINSON (BAR	BD IO 45mm Needle Kit w/ Stabilizer and Extension Set	D015451NK	$130.00	$ 130.00		$ 780.00	6/cs
667											
668	IV / Drug Admin		BECTON DICKINSON (BAR	BD IO 55mm Needle Kit w/ Stabilizer and Extension Set	D015551NK	$130.00	$ 130.00		$ 780.00	6/cs
669											
670	IV / Drug Admin		BECTON DICKINSON (BAR	IO DRILL CARRYING CASE	D001005	$70.00	$ 70.00			
671											
672	IV / Drug Admin		CURAPLEX BY BOUND TRE	IV Admin Set, 10 Drp, 83in, Pre-Prcd Y-Site, SrLk Ndle-Free Y Ste, Rotat Male LL	108306	$1.25	$ 1.25		$ 62.50	50/cs
673											
674	IV / Drug Admin		CURAPLEX BY BOUND TRE	IV Admin Set, 60Drp, 83in,PP Y-Site, Sure-Lok Ndle-Free Y-Site, Rotat Male LL	608306	$1.25	$ 1.25		$ 62.50	50/cs
675											
676	IV / Drug Admin		CURAPLEX BY BOUND TRE	Extension Set, 8 in, Removable Sure-Lok, NeedleFree Connect, Rotating Male LL	AE3108	$100.00	$ 100.00		$ 5,000.00	50/cs
677											
678	IV / Drug Admin		CURAPLEX BY BOUND TRE	Pressure Infuser	350310	$8.06	$ 8.06	5/bx	$ 40.30	5bx/cs
679											
680	IV / Drug Admin		B. BRAUN MEDICAL INC.	3-Way Stopcock	1811-03456	$0.72	$ 0.72		$ 72.00	100/cs
681											
682	IV / Drug Admin		CURAPLEX BY BOUND TRE	14 ga. Catheter	602594	$1.35	$ 1.35	50/bx	$ 270.00	4bx/cs
683											
684	IV / Drug Admin		CURAPLEX BY BOUND TRE	16 ga. Catheter	602586	$1.35	$ 1.35	50/bx	$ 270.00	4bx/cs
685											
686	IV / Drug Admin		CURAPLEX BY BOUND TRE	18 ga. Catheter	602560	$1.35	$ 1.35	50/bx	$ 270.00	4bx/cs
687											
688	IV / Drug Admin		CURAPLEX BY BOUND TRE	20 ga. Catheter	602535	$1.35	$ 1.35	50/bx	$ 270.00	4bx/cs
689											
690	IV / Drug Admin		CURAPLEX BY BOUND TRE	22 ga. Catheter	602519	$1.35	$ 1.35	50/bx	$ 270.00	4bx/cs
691											
692	IV / Drug Admin		CURAPLEX BY BOUND TRE	24 ga. Catheter	602500	$1.35	$ 1.35	50/bx	$ 270.00	4bx/cs
693											
694	IV / Drug Admin		DYNAREX CORPORATION	Betadine Prep	609153	$0.05	$ 4.99	100/bx	$ 49.90	10bx/cs
695											
696	IV / Drug Admin		CURAPLEX BY BOUND TRE	Alcohol Prep	1330-85300	$0.01	$ 2.50	200/bx	$ 50.00	20bx/cs
697											
698	IV / Drug Admin		CURAPLEX BY BOUND TRE	Tegaderm Dressing	661469MS	$0.16	$ 15.78	100/bx	$ 63.12	4bx/cs
699											
700	IV / Drug Admin		MAMMOTH MEDICAL, INC	18 ga. Hypodermic Needle	1641-42018	$0.09	$ 0.09	100/bx	$ 180.00	20bx/cs
701											

702	IV / Drug Admin		MAMMOTH MEDICAL, INC	20 ga. Hypodermic Needle	11317	$0.09	$ 0.09	100/bx	$ 180.00	20bx/cs
703										
704	IV / Drug Admin		MAMMOTH MEDICAL, INC	23 ga. Hypodermic Needle	620408	$0.08	$ 8.20	100/bx	$ 164.00	20bx/cs
705										
706	IV / Drug Admin		MAMMOTH MEDICAL, INC	25 ga. Hypodermic Needle	30-26406BX	$0.08	$ 8.20	100/bx	$ 164.00	20bx/cs
707										
708	IV / Drug Admin		MAMMOTH MEDICAL, INC	27 ga. Hypodermic Needle	11309	$0.11	$ 0.11	100/bx	$ 220.00	20bx/cs
709										
710	IV / Drug Admin		MAMMOTH MEDICAL, INC	1 cc Syringe	620048	$0.17	$ 17.38	100/bx	$ 173.80	10bx/cs
711										
712	IV / Drug Admin		B. BRAUN MEDICAL INC.	3 cc syringe	1633-30303	$0.07	$ 0.07	100/bx	$ 168.00	24bx/cs
713										
714	IV / Drug Admin		B. BRAUN MEDICAL INC.	5 cc syringe	1633-05305	$0.10	$ 0.10	100/bx	$ 200.00	20bx/cs
715										
716	IV / Drug Admin		B. BRAUN MEDICAL INC.	10 cc Syringe	1633-10010	$0.12	$ 0.12	100/bx	$ 144.00	12bx/cs
717										
718	IV / Drug Admin		B. BRAUN MEDICAL INC.	20 cc Syringe	1633-20720	$0.29	$ 0.29	100/bx	$ 232.00	8bx/cs
719										
720	IV / Drug Admin		B. BRAUN MEDICAL INC.	30 cc Syringe	1633-30430	$0.46	$ 0.46	100/bx	$ 276.00	6bx/cs
721										
722	IV / Drug Admin		MAMMOTH MEDICAL, INC	25G Butterfly Needle	30-27708BX	$0.54	$ 0.54		$ 270.00	500/cs
723										
724	IV / Drug Admin		MAMMOTH MEDICAL, INC	23G Butterfly Needle	30-27706BX	$0.76	$ 38.04	50/bx	$ 380.40	10bx/cs
725										
726	IV / Drug Admin		DYNAREX CORPORATION	1" Clear Tape	1110-08402	$0.60	$ 7.15	12/bx	$ 85.80	12bx/cs
727										
728	IV / Drug Admin		CURAPLEX BY BOUND TRE	2" Cloth Tape	1110-14008	$1.67	$ 9.99	6/bx	$ 119.88	12bx/cs
729										
730	IV / Drug Admin		CURAPLEX BY BOUND TRE	Tourniquet	1841-14000	$0.08	$ 19.88	250/bg	$ 39.76	2bg/cs
731										
732	Monitoring		MASIMO	Pediatric Pulse Oximeter	2712-51418	$15.24	$ 15.24			
733										
734	Monitoring		DYNAREX CORPORATION	Acetone Wipes	279-1501BX	$0.06	$ 5.82	100/bx	$ 58.20	10bx/cs
735										
736	Monitoring		CURAPLEX BY BOUND TRE	EKG Paper 108mm	2745-10108	$2.49	$ 2.49	1/rl	$ 149.40	60rl/ct
737										
738	Monitoring		STRYKER	PAPER EKG 100MM LP11, LP12, LP15, LP35 2RL/BX LifePak	11240-000032	$13.10	$ 13.10	2rl/bx	$ 26.20	
739										
740	Monitoring		CURAPLEX BY BOUND TRE	ZOLL X-Series Paper, 80mm, Red Grid, 6/bx	8000-000876-01	$2.49	$ 2.49		$ 186.75	75rl/cs
741										
742	Monitoring		CURAPLEX BY BOUND TRE	Select Defib Pads, Physio Adult/Child Combo, Leads Out Direct Connect	6600208H	$20.73	$ 20.73		$ 207.30	10pr/cs
743										
744	Monitoring		CURAPLEX BY BOUND TRE	Select Multi-Function Defib Pads, Physio-Control Pediatric/Infant	6600201H	$21.79	$ 21.79		$ 217.90	10pr/cs
745										
746	Monitoring		CURAPLEX BY BOUND TRE	Select Multi-Function Defib Pads, Physio-Control Adult/Child	6600205H	$19.95	$ 19.95		$ 199.50	10pr/cs
747										
748	Monitoring		CURAPLEX BY BOUND TRE	Select Defib Pads, Zoll Adult/Child Combo, Leads Out Direct Connect	6600209H	$23.72	$ 23.72		$ 237.20	10pr/cs
749										
750	Monitoring		CURAPLEX BY BOUND TRE	Select Multi-Function Defib Pads, Zoll Pediatric/Infant	6600202H	$21.47	$ 21.47		$ 214.70	10pr/cs
751										
752	Monitoring		CURAPLEX BY BOUND TRE	Select Multi-Function Defib Pads, Zoll Adult/Child	6600206H	$20.51	$ 20.51		$ 205.10	10pr/cs
753										
754	Monitoring		LINKS MEDICAL PRODUCT	Fora GD20 Blood Glucose Meter, Black, Free w/Purchase of Strips *Approved for Multi-patient Use*	GD20FM01-BLK	$8.54	$ 8.54			
755										
756	Monitoring		LINKS MEDICAL PRODUCT	Fora GD20 Test Strips CLIA MODERATE 50/ bottle *Approved for Multipatient Use (one bottle per box)	GD20FS50	$0.18	$ 9.00	50/bx		

757											
758	Monitoring		LINKS MEDICAL PRODUCT	SOLUTION CONTROL BLOOD GLUCOSEHI/LO FORA GD20 2/BX	GD20FCS01	$4.50	$ 9.00	1/bx		
759											
760	Monitoring		ARKRAY USA, INC.	*SEE NOTES* Blood Glucose Meter, Assure Prism Multi*Approved for Multipatient Use*	530001	$6.10	$ 6.10			
761											
762	Monitoring		ARKRAY USA, INC.	Blood Glucose Test Strips, Assure Prism Multi CLIA WAIVED 50/bt 1bt/box *Approved for Multi pt Use*	530050	$0.20	$ 10.00	50/bx		
763											
764	Monitoring		ARKRAY USA, INC.	Control Solution, Assure Prism Multi, L1 and L2, 1 bottle of EA/BX	530006	$10.00	$ 10.00			
765											
766	Monitoring		CURAPLEX BY BOUND TRE	Assure Prism Orange Kit BASIC, incl Meter, Orange Case, 2 Bt Test Strips	670161-KIT	$24.00	$ 24.00			
767											
768	Monitoring		AMBU INC.	Electrodes, BlueSensor SP, Medium Size, Pediatric/Adult, Foam	SP-00-S/50	$0.24	$ 12.00	50/pk	$ 24.00	2bx/cs	
769											
770	Monitoring		AMBU INC.	Electrodes, BlueSensor SP, Medium Size, Pediatric/Adult	R-00-S-25	$0.30	$ 7.50	25/pk	$ 300.00	40pk/cs	
771											
772	Monitoring		AMBU INC.	Electrodes, BlueSensor R, Adult, Foam	SP-00-S/10	$0.26	$ 2.55	10/pk	$ 510.00	200pk/cs	
773											
774	Monitoring		AMBU INC.	Electrodes, BlueSensor R, Adult, Foam	R-00-S/10	$0.30	$ 2.95	10/pk, 50pk/bx	$ 5.90	2bx/cs	
775											
776	Monitoring		CURAPLEX BY BOUND TRE	Foam Electrode, Wet Gel 50mm x 48mm	2741-50487	$0.09	$ 5.25	60/pk, 15pk/bx	$ 31.50	6bx/cs	
777											
778	Monitoring		CURAPLEX BY BOUND TRE	Foam Electrode, Wet Gel 50mm x 48mm	2741-50486	$0.13	$ 0.75	6/pk, 100pk/bx	$ 4.50	6bx/cs	
779											
780	Monitoring		CURAPLEX BY BOUND TRE	Foam Electrode, wet gel 50mm x 48mm	2741-50485	$0.11	$ 1.12	10/pk, 80pk/bx	$ 6.72	6bx/cs	
781											
782	Monitoring		CURAPLEX BY BOUND TRE	Foam Electrode, Wet Gel 50mm x 48mm	2741-50484	$0.14	$ 0.55	4/pk, 150pk/bx	$ 3.30	6bx/cs	
783											
784	Monitoring		MAMMOTH MEDICAL, INC	ELECTRODES, MEDI-TRACE SERIES 530, ADULT	31013926	$0.16	$ 4.75	30/pk	$ 95.00	20pk/cs	
785											
786	Monitoring		MAMMOTH MEDICAL, INC	ECG electrode, Medi-Trace 230, adult, foam, teardrop shape, cond. adhesive hydrogel	31078135	$0.21	$ 6.24	30/pk	$ 124.80	20pk/cs	
787											
788	Monitoring		STRYKER	DEFIB/PACING/ECG PADS PEDI W/ QUIK-COMBO CONNECTOR FOR LP15, LP12, LP10, LP5	11996-000093	$40.83	$ 40.83	1/pr			
789											
790	Monitoring		STRYKER	DEFIB/PACING/ ECG PADS ADULT W/QUIK-COMBO CONNECTOR 2FT LEAD, LP12, LP15	11996-000091	$32.79	$ 32.79	10pr/bx	$ 163.95	5bx/cs	
791											
792	Monitoring		STRYKER	Defib/Pacing/ECG Pads, EDGE RTS, w/QUIK-COMBO Connector, Radiotransparent, Lifepak 12, 15, 20, 1/pr	11996-000090	$40.83	$ 40.83				
793											
794	Monitoring		ZOLL MEDICAL CORPORA	Zoll CPR Stat Padz, HVP Multi-Function CPR Electrodes, for Zoll M, E, X, R Series, AED Plus/Pro 1/PR	8900-0400	$88.21	$ 88.21				
795											
796	Monitoring		ZOLL MEDICAL CORPORA	STAT PADZ II PEDIATRIC FOR ZOLL AED PLUS, AED PRO, M Series, R Series and E Series	8900-0810-01	$141.32	$ 141.32				
797											
798	Monitoring		ZOLL MEDICAL CORPORA	STAT PADZ II ADULT FOR ZOLL AED PLUS X Series, AED PRO, M Series, R Series and E Series	8900-0802-01	$47.66	$ 47.66				
799											
800	Monitoring		ZOLL MEDICAL CORPORA	Zoll Stat Padz, Multi-Function Defibrillation Pads, works with Zoll M Series and Zoll X	8900-4003	$47.96	$ 47.96				
801											
802	Monitoring		CURAPLEX BY BOUND TRE	Microstream Advance, Adlt, Oral/Nasal, Non-Intubated, w/ Female O2 Connector, Short Term Use, 6.5ft	MVAO100U	$6.49	$ 6.49		$ 162.25	25/cs	
803											
804	Monitoring		CURAPLEX BY BOUND TRE	Microstream Advance, Ped, Oral/Nasal, Non-Intubated, w/ No O2 Delivery, Short Term Use, 6.5ft	MVP	$6.76	$ 6.76		$ 169.00	25/cs	
805											
806	Monitoring		MEDTRONIC (COVIDIEN)	Microstream Advance, Inf & Neo, Nasal Cannula, Non-Intubated w/o O2 Delivery, Short Term Use, 6.5ft	MVIN	$9.95	$ 9.95				
807											
808	Monitoring		CURAPLEX BY BOUND TRE	Microstream Advance, Adlt & Ped, Intubated Filter Line, Short Term Use, 6.5ft	MVAI100U	$6.34	$ 6.34		$ 158.50	25/cs	
809											
810	Monitoring		AMBU INC.	CO2 Detector, Ambu, Adult, 12ea/cs	000172712	$9.24	$ 9.24		$ 110.88	12/cs	
811											

812	Monitoring		AMBU INC.	CO2 Detector, Ambu, Pediatric 12/cs	000172713	$9.24	$ 110.93		$ 1,331.16	12/cs
813										
814	OB		CURAPLEX BY BOUND TR	OB Kit	4440010-B	$9.85	$ 9.85			
815										
816	PT Handling		CURAPLEX BY BOUND TR	MegaMover Transport Unit, 40 in x 80 in, Non-woven/Poly, White/Black, 14 Handles	51926	$14.99	$ 14.99		$ 149.90	10/cs
817										
818	PT Handling		CURAPLEX BY BOUND TR	MegaMover Transport Chair, 35 in x 35 in, Nonwoven/Poly, White/Yellow	56307	$11.25	$ 11.25		$ 112.50	10/cs
819										
820	PT Handling		AMBU INC.	Extrication Collar, Ambu Mini Perfit ACE, Pediatric, Adjustable 12 Settings	000281106	$4.50	$ 4.50		$ 135.00	30/cs
821										
822	PT Handling		AMBU INC.	Extrication Collar, Ambu Perfit ACE, Adult, Adjustable 16 Settings	000281000	$4.50	$ 4.50		$ 135.00	30/cs
823										
824	PT Handling		CURAPLEX BY BOUND TR	Extrication Collar, Mini, Single-use, Adjustable, 6 Settings	472004000	$4.00	$ 4.00		$ 120.00	30/cs
825										
826	PT Handling		CURAPLEX BY BOUND TR	Extrication Collar, Adult, Single-use, Adjustable, 8 Settings	472003000	$4.00	$ 4.00		$ 120.00	30/cs
827										
828	PT Handling		CURAPLEX BY BOUND TR	Cot Sheet, Fitted, Taylor G-Force, Blue, 36 in x 90 in, Fluid Resistant	90-GFRC3690	$2.50	$ 75.00		$ 2,250.00	30/cs
829										
830	PT Handling		CURAPLEX BY BOUND TR	Cot Sheet, Fitted, 30 in x 84 in, Resistant, Blue	90-BSS3084	$1.30	$ 65.00		$ 3,250.00	50/cs
831										
832	PT Handling		CURAPLEX BY BOUND TR	Mattress Cover, SnugFit, Expandable, Blue, Nonwoven	72930	$1.30	$ 65.00		$ 3,250.00	50/cs
833										
834	PT Handling		CURAPLEX BY BOUND TR	EMS STANDARD SHEET SNUGFIT 30 IN X 84 IN	44547	$1.20	$ 60.00		$ 3,000.00	50/cs
835										
836	PT Handling		CURAPLEX BY BOUND TR	Flat Sheet, 40 in x 90 in, Tissue/Poly, White/Blue	52166	$0.73	$ 36.54		$ 1,827.00	50/cs
837										
838	PT Handling		CURAPLEX BY BOUND TR	SPACE RESCUE BLANKET MYLAR FOIL 84 X 52	3537	0.49	$ 0.49		$ 98.00	200/cs

MANUFACTURER LIST PRICE DISCOUNT BY CATEGORY

For Evaluation Purposes this section will be based on the discounts submitted by the Vendor below. Please submit a percentage (%) discount from Manufacturer's List Price (MLP) for non-core items. Vendors must submit the following:

A. Catalogs w/Manufacturers current price List (Vendor Catalog or link to website are both acceptable where list prices are shown)
B. Percent of Discount per MLP

Failure to submit the information will be considered non-responsive and will result in vendor disqualification.

CATEGORY	%OFF MANUFACTURER'S LIST PRICE	NAMES OF MANUFACTURER'S REPRESENTED
Bandages & Dressings Adhesive Bandages, Gauze Products, Self-Adhesive Bandages, Elastic Bandages Surgical Tape, IV Dressings, Trauma & Specialty Bandages Hemostatic Agents, Burn Care, Heat Packs, Cold Packs and Emergency Obstetric Supplies	40%	Please see attachment.
Infection Control Latex Gloves, Latex Free Gloves, Glove Accessories, Respirators & Facemasks, Respirator Fit Test Kits, Protective Eyewear, Ear Plugs, Antimicrobial Hand Wipes, Hand Soaps, Sanitizers & Lotions, Sharps Safety Under pads, Surface Disinfectants, High-Level Disinfectants, Personal Protection, Biohazard Spill Kits & Supplies and Biohazard Waste Bags	40%	Please see attachment.
IV & Pharmaceuticals Needle-Free Solution Sets, Needle-Free Extension Sets, Needle-Free IV Sets, Specialty IV Systems, Standard IV Sets, IV Accessories, IV Preparation, IV Dressings, IV Catheters, Needles & Syringes, Blood Collection, Solutions, Irrigation, Emergency Medications and Bone Injection Guns	37%	Please see attachment.
Diagnostic Equipment Pulse Oximeter, Blood Pressure Cuffs, Stethoscopes, Thermometers, Penlights, EKG Electrodes, Defib Supplies, Magil Forceps & Flashlights	35%	Please see attachment.
Immobilization & Extrication Backboards, Backboard straps, Cervical Collars, Head Immobilizers, Mast Pants, Tractions splints, Disposable and reusable Splints, Basket stretchers & Scoop Stretchers	40%	Please see attachment.
Patient Transport Equipment	30%	Please see attachment.

CATEGORY	%OFF MANUFACTURER'S LIST PRICE	NAMES OF MANUFACTURER'S REPRESENTED
Cot Accessories, patient Restraints, Cot Blankets, Cot Sheets, Stair Chairs, soft stretchers, clipboards, triage vests & triage supplies	30%	Please see attachment.
Equipment Bags & Cases i.e. Oxygen bags, stocked oxygen kits, trauma bags, airway bags, ALS bags, drug bags & boxes, first call in bags, rescue packs, fanny packs & rescue bags	35%	Please see attachment.
Medical Education & Training AED trainers, CPR manikins, intubation trainers, Defib manikins, EKG simulators, IV training arms, ALS training manikins, Choking Manikins & Rescue Randy	32%	Please see attachment.
Airway Management Endotracheal Tubes, Stylettes, Endotracheal Tube, Holders, Oral Airways, Nasal Airways, Difficult Airways Double Lumen Airways, Laryngeal Masks, Airway Detectors, Airway Accessories, Laryngoscope, Blades, Hand Powered Suction Units, Suction Catheters, Suction, Canisters, Disposable Suction Supplies and Specialized Tubing	37%	Please see attachment.
Breathing & Respiratory Equip. Disposable Resuscitators (BVM's), CPR First Response Supplies, Valves / Adapters, Connectors, Regulators, Flowmeters, Oxygen Cylinders, Oxygen, Delivery Supplies, Nebulizers and CPAP Ventilation	35%	Please see attachment.
Disaster Preparedness Coveralls, ear protection, fit test kits, gloves, head protection, oxygen manifolds, respiration masks & hoods, traffic control & triage	37%	Please see attachment.
Tools & Personal Items Field guides, forceps, scalpels, holsters, shears & scissors, penlights, ring cutters, hammers, seat belt cutters & window punches	40%	Please see attachment.

A. Please visit www.boundtree.com for current vendor catalog and pricing

MANUFACTURER LIST PRICE REMAINING LINE DISCOUNT

For Evaluation Purposes this section will be based on the discounts submitted by the Vendor below. Please submit a percentage (%) discount from Manufacturer's List Price (MLP) for your remaining line of products:

A. Catalogs w/Manufacturers current price List (Vendor Catalog or link to website are both acceptable where list prices are shown)
B. Percent of Discount per MLP

Failure to submit the information will be considered non-responsive and will result in vendor disqualification.

ITEM	%OFF MANUFACTURER'S LIST PRICE
REMAINING LINE DISCOUNT(S) NOT LISTED ABOVE	40%

Bound Tree

To Whom It May Concern:

In response to your Bid #rfp-fh-25-25-2525, Bound Tree Medical is pleased to offer specific categories off the prices from the current Bound Tree Medical Emergency Medical Product Catalog. These items are also available for reference on our website, www.boundtree.com.

Product Categories 35% Off		**Product Categories 40% Off**
Diagnostic Equipment		Bandages
Equipment Bags & Cases		Infection Control
Breathing & Respiratory Equipment		Immobilization & Extrication
		Tools & Personal Items
Product Categories 32% Off		Remaining Items Not Listed Above
Medical Education & Training		
		Product Categories 37% Off
Product Categories 30% Off		IV & Pharmaceuticals
Patient Transport Equipment		Airway Management
		Disaster Preparedness

We are pleased to provide you with a competitive bid for the emergency medical supplies and equipment that you are seeking. Please contact our Bids and Contracts Department at 800-533-0523 with any questions. Thank you.

Sincerely,

Heather Legg

Heather Legg
Pricing Analyst
Bound Tree Medical, LLC

Bound Tree Medical
5000 Bradenton Avenue
Dublin, OH 43017
www.boundtree.com

AUTHORIZATION OF PROPOSAL

PAYMENT METHOD

Does your company accept MasterCard (or other credit card) for payment as well? _X_ YES _____ NO

If yes, please state any applicable discounts or additional fees associated for this method of payment.

N/A

Please select company's preferred payment method:

____ Check – minimally 60 days from receipt of order

_X_ ACH – 45 days from receipt of invoice

____ Credit Card – 20 days from receipt of invoice

ACKNOWLEDGEMENT OF OFFICIAL DOCUMENTS

I Rob Meriweather, certify that I have read section 3 (Official Documents) of the invitation to bid and that the bid proposal documents contained herein were obtained directly from the City of Farmington Hills Purchasing Office or MITN website, www.mitn.info and is an official copy of the authorized version.

SIGNATURE OF AUTHORIZED COMPANY REPRESENTATIVE_____

FORMAL AUTHORIZATION

The undersigned herein submits this proposal and agrees to enter into an agreement with the City of Farmington Hills on behalf of the aforementioned entities, SMEMS COOPERATIVE and MITN Purchasing Cooperative in accordance with the Contract documents. In submitting this completed and signed proposal, it is understood that the right is reserved by the City of Farmington Hills to reject any or all bids and to make such award that, in the opinion of the City Council, is in the best interest of the City of Farmington Hills.

Signature _____ **Company** Bound Tree Medical, LLC

Printed Rob Meriweather **Address** 5000 Bradenton Ave.

Title President, EP **City/State/Zip** Dublin, OH 43017

Date 12/02/2025 **Phone** 800-533-0523 **Fax** 877-311-2437

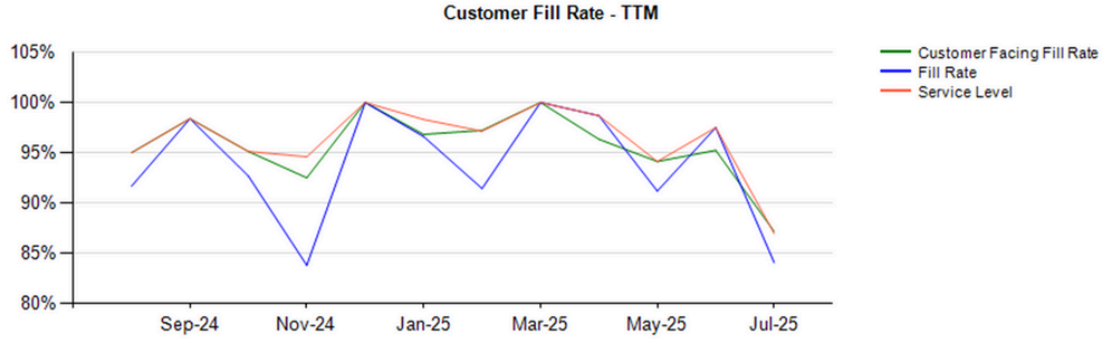
Contact Person Heather Legg **Cell phone** 614-760-5179

Email submitbids@boundtree.com **website** www.boundtree.com

FEIN: 31-1739487

Examples of our Customer Scorecard highlighting our fill rate performance out of all warehouses, including backordered items

	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Total
Total Lines	60	62	41	40	28	63	36	24	82	34	42	70	582
Stock on Demand - Filled	0	0	0	2	1	3	1	2	4	0	1	1	15
Stock on Demand - Backordered	0	0	0	1	0	1	0	0	2	0	1	0	5
Stocked Item - Filled from Primary WH	55	61	38	31	27	57	32	22	75	31	39	58	526
Stocked Item - Filled from Secondary WH	2	0	1	4	0	1	2	0	0	1	0	2	13
Stocked Item - Backordered	3	1	2	2	0	1	1	0	1	2	1	9	23
Total Backorder Lines	3	1	2	3	0	2	1	0	3	2	2	9	28
Fill Rate	91.67 %	98.39 %	92.68 %	83.78 %	100.00 %	96.61 %	91.43 %	100.00 %	98.68 %	91.18 %	97.50 %	84.06 %	93.59 %
Service Level	95.00 %	98.39 %	95.12 %	94.60 %	100.00 %	98.31 %	97.14 %	100.00 %	98.68 %	94.12 %	97.50 %	86.96 %	95.91 %
% BO Lines to Total Lines	5.00 %	1.61 %	4.88 %	7.50 %	0.00 %	3.18 %	2.78 %	0.00 %	3.66 %	5.88 %	4.76 %	12.86 %	4.81 %
Customer Facing Fill Rate	95.00 %	98.39 %	95.12 %	92.50 %	100.00 %	96.83 %	97.22 %	100.00 %	96.34 %	94.12 %	95.24 %	87.14 %	95.19 %



Examples of a cost savings opportunity with Curaplex

Item	UOM	Description	Qty	Price	Ext.Price
1015-70702	2000/CS	Gloves, KC300 Sterling, MED, Nitrile, Exam, Pow der Free, 9.5 in 200/bx 10bx/cs	15	$ 265.10	$ 3,976.50
1012-47124	1000/CS	Curaplex TritonGrip SE Gloves, MED, Blue Nitrile, Pow der Free 100/bx 10bx/cs	30	$ 71.90	$ 2,157.00
				Savings w ith MED Curaplex Gloves	**$ 1,819.50**
1015-70803	2000/CS	Gloves, KC300 Sterling, LG, Nitrile, Exam, Pow der Free, 9.5 in 200/bx 10bx/cs	19	$ 265.10	$ 5,036.90
1012-47125	1000/CS	Curaplex TritonGrip SE Gloves, LG, Blue Nitrile, Pow der Free 100/bx 10bx/cs	38	$ 71.90	$ 2,732.20
				Savings w ith LARGE Curaplex Gloves	**$ 2,304.70**

Item Number	Item Description	Price	Sub Item Number	Sub Item Description	Sub Price	Price Difference
22850	ELECTRODES MEDI-TRACE 850 RADIOLUCENT FOAM 50/PK 20PK/CS	$167.76	2741-50487	Curaplex Foam Electrode, Wet Gel 50mm x 48mm 60/pk 15pk/bx 6bx/cs	$90.58	$77.18
1714-83092	Ext Set, 8 in, Needleless, Clamp, MedSource Connector, Luer Lock Connector 100/cs	$128.66	1714-31081	Curaplex 8" Exten Set, RmvbleSure-Lok, NeedleFree Connect, Rotating Male LL 1/EA 50EA/CS	$59.50	$69.16
1712-83163	IV Admin Set, 60 Drop, 83 in, Needle-free Y-site, Rotary Luer Lock, Clamp 50/cs	$77.42	1712-60830	Curaplex IV Admin Set, 60Drp, 83in,PP Y-Site,Sure-Lok Ndle-Free Y-Site, Rotat Male LL 1	$75.00	$2.42
541310	DEFIB PADS MEDTRONIC QUIK-COMBO (2ea=1pk) 10PK/CS	$31.66	16384	Curaplex Select Multi-Function Defib Pads, Physio-Control Adult/Child >10KG/22LBS 10pr/cs	$17.95	$13.71
533-MS-BP200EA	Blood pressure unit BP, large adult, black, nylon adjustable cuff, metal valve, case, LF 50ea/cs	$8.99	36013	Curaplex Manual Blood Pressure Cuff , LG Adult, with Case 50ea/cs	$7.47	$1.52
533-MS-BP100EA	Blood pressure unit BP, adult, black, nylon adjustable cuff, metal inflation valve, case, LF 50ea/cs	$8.09	36012	Curaplex Manual Blood Pressure Cuff, Adult, with Case 50ea/cs	$7.53	$0.56
236086	DEFIB/PACING/ ECG PADS ADULT W/QUIK-COMBO CONNECTOR 2FT LEAD, LP12, LP15 1/PR 10PR/BX 5BX/CS	$25.30	16384	Curaplex Select Multi-Function Defib Pads, Physio-Control Adult/Child >10KG/22LBS 10pr/cs	$17.95	$7.35
232023	EKG PAPER 100MM FOR LP11, LP12 AND LP15 18RL/CS LifePak	$5.60	2745-10108	Curaplex ECG Chart Paper, Thermal,108mm,Red Grid, for Physio-Control LP11, LP12 , LP15 1/RL 60RL/CT	$1.39	$4.21
1712-83110	IV Admin Set, 10 Drop, 83 in, Needle Free Y site, 1 Luer Connector 50ea/cs	$1.54	1712-10830	Curaplex IV Admin Set, 10 Drp, 83in, Pre-Prcd Y-Site, SrLk Ndle-Free Y Ste, Rotat Male LL 50EA/C	$1.09	$0.45
10847	Pillow Case, Disp., Graham 47256, 21 in x 30 in, tissue/poly, white 100ea/cs	$33.00	3271-44125	Curaplex Disposable Pillow Case, 22x30 inches Tissue/Poly, White 100/CS	$18.00	$15.00

Gary Proctor, MA, Paramedic IC
Director

Sean Bowers, BA, Paramedic IC
Deputy Director

2872 Hansen Road
West Branch, MI 48661
Phone: 989-345-4503

November 13, 2025

City of Farmington Hills
Purchasing Department
31555 W. 11 Mile Rd
Farmington Hills, MI 48336-1103

RE: Southeast Michigan EMS Supply Purchasing Consortium/MITN Contract

Board of Directors,

With the upcoming review and bid process for the above referenced EMS supply contract I am writing to express my support for Bound Tree Medical. Having served as the EMS Captain for the West Bloomfield Fire Department for 10 years and voting member of the Board of Directors for this contract, and in my current position as the Director of the Ogemaw County EMS Authority, I am intimately familiar with this contract and the history of it.

Over the years this contract has been served by many different suppliers. Some of these suppliers have been strong partners, others that started out strong and then over time lost sight of the customer service aspect and needs of the departments participating. I can say without hesitation that Bound Tree and their entire staff have by far provided the highest level of service to this contract that I can recall.

Because of this dedication to the contract and the departments throughout our great state and region that participate in the consortium I would like to offer my highest recommendation to continue this contract with Bound Tree.

Kindest Regards,

Gerard F. Proctor, MA, Paramedic IC
Director
Ogemaw County EMS Authority

Cc: Dan O'Brian