Application of Noise Control in Environmental Engineering Education

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ABSTRACT

Noise control is both a factor in the health and safety of those in the workplace and in the annoyance and interference of the quality of life at home. This falls squarely in the realm of the Environmental Engineering Profession. Noise, its effects and control, is an important element of a few Graduate Environmental Engineering Programs, but it does not have a role in most undergraduate programs. One objective of this paper is to demonstrate that noise is an issue needing to be addressed in Environmental Engineering Programs and to suggest that making it a requirement at the undergraduate level has merit. Several models including the program at Cal Poly, San Luis Obispo will be discussed.

The authors will also share some spreadsheets that undergraduate students have developed in class.

INTRODUCTION: The Case For Noise Control in Environmental Engineering

The engineering profession creatively applies the best science and technology toward solving problems of humanity. Environmental Engineering as a specific branch of the profession has matured over the last thirty years and contains elements of more established disciplines including Civil, Chemical and Mechanical Engineering.

Today the American Academy of Environmental Engineers takes the lead in developing specific criteria for the accreditation of Environmental Engineering Programs at Universities in the United States. The Academy is dedicated to excellence in the practice of environmental engineering to ensure the public health, safety, and welfare to enable humankind to co-exist in harmony with nature. This sets the stage to consider noise control as a component of Environmental Engineering education.

Noise control is both a factor in the health and safety of those in the workplace and in the annoyance and interference of the quality of life at home. This falls squarely in the realm of the
Environmental Engineering Profession. The subject is covered in the Environmental Professional Engineering Registration Examination.

Noise, its effects and control, is an important element of a few Graduate Environmental Engineering Programs, but it does not have a role in most undergraduate programs. The objective of this paper is to demonstrate that noise is an issue needing to be addressed in Environmental Engineering Programs and to suggest that making it a requirement at the undergraduate level has merit. Several models including the program at Cal Poly, San Luis Obispo will be discussed.

The authors will also share some spreadsheets that undergraduate students have developed in class. It is hoped they will be useful to the reader in course development or in exploring the subject in more detail. Of course they are offered without warranty.

**Noise -- an Environmental Problem**

Noise is a problem that affects people in both industry and at home. Noise induced hearing loss adversely changes the lives of many today. This loss results in a significant decrease in the quality of life and has economic consequences. Such loss is often preventable in part by the Environmental Engineer. Noise is also annoying and can disrupt everyday life in the home. More and more public agencies are answering the public's request for noise control in cases such as new light rail systems, highways, airports and concert pavilions. Sleep disturbance due to aircraft overflights or backup bells from construction equipment operating throughout the night has the public demanding noise walls, sound insulation, or other types of mitigation. With the requirement of Environmental Impact Reports for any new or expanded project, the states are listening and designing such mitigation. Therefore, engineers should be trained in acoustics early on in their education for both health related, as well as, disruptive noise issues.

Noise was an issue addressed in the Clean Air Act in 1970. Although EPA no longer has a leadership role in noise control other Federal Agencies are involved including the Federal Aviation Administration, Federal Highway Administration, Federal Transit Administration, Department of Defense and Occupational Safety and Health Administration.

The Noise Control Engineering Journal celebrating its 15th year recently cited this paradox: while our technological capabilities to measure, evaluate, and control noise have expanded dramatically, our political will to address environmental issues such as noise has weakened.

Although there have been gains with aircraft and diesel trucks much of our manufacturing industry remains as noisy as ever, with workers relatively unprotected. The goal of hearing conservation is to preserve and maintain hearing. Hearing conservation should be a lifelong concern of the environmental engineer.

Noise requires informed application of basic principles. While the European Union can mandate noise planning across member nations, most noise control in the US at present is local. Although there is no broad planning framework, there is still a mandate in the US for quieter Environments.
The problem is not new...
The science of sound had its origin in the study of music and vibrating strings by Pathagorus
during the sixth century B.C.\(^4\) Hearing loss was probably known in biblical times. It was
recognized in the Napoleonic Wars. It was considered to be a major problem in the shipyards of
Glasgow in 1890.\(^5\) The advent of the industrial revolution changed noise-induced hearing loss
from an infrequent occupational condition to an epidemic.\(^5\)

The first specific reference to the study of noise by the National Physical Laboratory in the UK
occurred in a 1928 report, but only that this kind of work was not going on because of lack of
resources. In the 1950’s, it was known that boilermakers became deaf and it was an accepted part
of the price of putting food on the table. It took additional changes in the 1960’s to recognize that
good health in the workplace is not only a privilege but it is a right. The Unions have helped in
this progress.\(^6\)

ACADEMIC TRAINING

One must recognize that the study of noise touches many disciplines. It is truly an
interdisciplinary subject. It is beyond the scope of the paper to review all the academic programs
dealing with noise control. Originally the authors were going to examine how Environmental
Engineering Programs are dealing with the subject. Because of a void in the published literature,
the goal was modified to look at several programs as models that could be used in Environmental
Engineering.

Noise Control in Graduate Curriculum

Many excellent Graduate Programs are available in the U.S. and worldwide. The Acoustical
Society of America lists 35 Universities that have Graduate Programs in Noise Control in the
U.S. and 105 faculty worldwide.\(^7\)

UNIVERSITY OF CENTRAL FLORIDA (UCF)

Environmental Engineering at UCF clearly states the discipline covers areas such as air and noise
pollution, solid waste, potable water and wastewater. Two courses are offered at the graduate
level emphasizing noise control. One involves outdoor noise control and the other transportation
systems. Only Civil and Environmental Engineering Students take the classes.\(^8\)

Most of the established graduate programs in noise control are in Mechanical Engineering or
Physics Departments. The program at Penn State and the University of Mississippi are examples.

PENN STATE

The Acoustics program at Penn State is one of the largest in the nation awarding the M.S. in
Mechanical Engineering and Ph.D. degree in Acoustics. It started in 1965 under an initiative of
Dr. John Johnson offering courses in underwater acoustics and sonar engineering. At the same
time it established an interdisciplinary Graduate Program in acoustics. Today the program is
centered on acoustics, which is a subject that touches many diverse disciplines and allows many
options for a professional career.
There are a number of departments in the college of engineering that contribute to the program. Outside the college of engineering Mathematics, Meteorology, Geosciences, Physics, Speech Communication and Communication Disorders participate.

Penn State also offers an acoustic program on the Web. Through Penn State’s World Campus, a four course Noise Control Engineering Program is taught via CD-ROMs and interaction with professors and other students through the Internet. The program is aimed toward working professionals with an undergraduate degree in engineering, math or a related science field. After two years, the certificate achieved prepares the students for the Institute of Noise Control’s Board Certified Exam. Courtney Burroughs is the lead faculty member for this program. Students from all fields of noise control engineering (such as industrial noise, muffler design, architectural acoustics and transportation noise) take this program.

UNIVERSITY OF MISSISSIPPI
The program in noise control at the University of Mississippi extends back to the 1970’s. The main players include Drs. Jim Chambers, Henry Bass, Richard Raspet, Lee Bolen, Gordon Baird, Jack Seiner and Ken Gilbert along with a host of students. Their work has included the effects of propagation on Sonic Booms to help determine their annoyance and thereby acceptability. They have also performed pioneering work on determining the influence of ground effects on propagation. Researchers also examined the influence of molecular effects on sound absorption. Other work includes analyzing the influence of turbulent scattering and irregular topography.

U.M. has produced numerous graduates in the field of outdoor sound propagation which includes noise mitigation and all of their scientists have joint appointments with either the physics department or the Mechanical engineering department.

Noise Control in Undergraduate Curriculum

The American Academy of Environmental Engineering (AAEE) believes Environmental Engineering training should provide the foundation to work in any aspect of environmental protection. The major areas include air pollution control, industrial hygiene, radiation protection, hazardous waste management, toxic materials control, water supply, wastewater management, storm water management, solid waste disposal, public health, and land management. And, within each of these major categories are many sub-specialties. Noise Control is often considered a sub-specialty of air pollution, industrial hygiene and public health.

The AAEE states that "entry into (Environmental Engineering) requires a B.S. degree in engineering --- probably civil, chemical, mechanical or environmental." There are several ways noise control could be introduced into the undergraduate environmental engineering curriculum.

Traditionally Universities offering graduate courses in Noise Control have let interested undergraduates take one or two courses in acoustics or noise control in their senior year. This is true at the University of Central Florida. Universities could offer specific courses in noise control at the undergraduate level. Cal Poly requires all Environmental Engineering students to take one course in Noise Control. Several Mechanical Engineering Departments offer a Noise Control
elective series. Finally, issues of noise could be presented in the introductory course in Environmental Engineering. This is done at the junior level at the University of Central Florida.

A recent survey of the web sites of all 19 undergraduate environmental engineering programs listed on the Air & Waste Management Association’s web page\textsuperscript{10} showed that only Cal Poly had a required course in Noise Control. In fact, noise was not even mentioned in the course descriptions of the introductory courses in environmental engineering at any of these institutions. The authors recognize this may be misleading since many of the best introductory books on environmental engineering do have chapters in noise and noise control. When asked, some faculty involved with teaching these introductory courses indicated Noise is briefly covered.

In an effort to indicate how Noise can be effectively introduced into the Environmental Engineering Curriculum at the undergraduate level, the authors describe the program at Cal Poly. In addition, the undergraduate noise programs in Mechanical Engineering at Purdue and Penn State are discussed. They provide different models for consideration.

**Objective: Noise in the Undergraduate Curriculum**

- Provide motivation and background so students can work effectively in noise and vibration control.

**CAL POLY**

Cal Poly has offered an undergraduate program in Environmental Engineering since 1968. The curriculum at Cal Poly includes the control of air and water pollution, industrial hygiene, noise and vibration control, and solid and hazardous waste management. The program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology. The noise program at Cal Poly dates back to a course in noise and vibration control taught in the college of engineering by Norman Sharp in 1945. Sharp’s background was in Physics and Air Conditioning and Refrigeration. His two-quarter course built on the basic coverage of sound in Physics. It covered in detail the material in the ASHRAE Guide. For example, subjects included the propagation of sound indoors and out, the engineering design guidelines for acceptability such as the NC curves and the control of noise with silencers and vibration isolation. In 1968, the undergraduate Environmental Engineering program was formed. One of the authors (Cota) was asked to teach the class which became one of the key courses in the curriculum.

Beranek’s classic ‘Noise Reduction’\textsuperscript{11} served as the first text. Publications in the ASHRAE Guide, the ASHRAE Journal and the Acoustical Society of America and later Sound and Vibrations provided case studies to discuss in class an on which to develop homework and exams.

In the early 1970s a set of notes were developed that became the text. It was edited from original contributions, and many preprints from the published literature, which were kindly made available through the permission of the respective authors and publishers. In addition old exam problems were placed at the back of the book and served as homework.\textsuperscript{12}
In the late 1970's books by Yeagers\textsuperscript{13}, Irvin\textsuperscript{14} and Lord\textsuperscript{15} were published and were used as class texts.

In an effort to improve the course and give the students more hands on experience, it was decided to convert a 3-unit lecture course to a 2-unit lecture 1 unit lab format and a 3-hour laboratory. The lecture is held twice a week for 1 hour and the lab is held once a week for three hours.

The objectives of the current class included:

1. Introduce students to the sources of noise and the noise issues environmental engineers face.

2. Cover topics such as:
   - measurement of sound
   - the mechanism of hearing
   - the threshold of hearing
   - damage risk criteria
   - masking
   - propagation of sound outdoors
   - propagation of sound indoors in large and small rooms
   - various comfort criteria such as the loudness, Loudness Level, Speech Interference Level, and the NC curves
   - concepts of noise control including TL, noise reduction and insertion loss of barriers
   - the design of silencers in fluid systems; vibration isolation and damping

Table 1 outlines topics covered in the required course in Noise Control.

3. Require students to review the literature and develop models and evaluate current models.

4. Demonstrate how to organize and carry out field studies and analyze the results and prepare reports.

5. Require the use of spreadsheets in engineering analysis. Some examples of spreadsheets developed by individual students over the years appear in the Appendix A.

The laboratory portion of this class is outlined in Table 2. This laboratory created a much more valuable and interesting class for the students.

In addition to the lecture-lab course described above students have other opportunities to explore the subject. Summer work and intern experience is available. Students can assist faculty in projects and consulting. Cal Poly also requires a senior project (undergraduate thesis) which provides motivation for students to become experienced in a particular field. For senior projects relating to noise, students have developed or worked with models of highway and airport noise, silencer design and various industrial noise problems.
Related courses are sometimes available in other departments at Cal Poly. For example, acoustics is taught in Physics, room acoustics is addressed in Architecture and vibrations is covered in Mechanical Engineering.

Students graduating from the Cal Poly program have worked in noise consulting firms, worked as the plant environmental engineer and in industry where industrial noise was an issue, and worked as an environmental safety and health engineer.

**PURDUE**

The noise control engineering program at Purdue is included within the curriculum of the School of Mechanical Engineering. Related programs exist in acoustics, audiology, and electo-acoustics. The noise control program evolved from a research program in the early 1970’s. At the undergraduate level two courses are offered in the senior year to develop the skills needed by a noise control engineer based on the fundamentals that all mechanical engineering students have. In addition, students may take graduate course work which is open to them and includes a research component.

Students graduating from these programs with a background in noise and vibration control are good entry level employees in the industrial noise laboratories and as specialists for design functions within a company.

Dr. R. J. Bernhard points out that engineers are now often part of a design team rather than specialists. More engineers and industrial employees are involved with noise control problems and would benefit by appropriate training.¹⁶

**PENN STATE**

The Mechanical Engineering Department at Penn State allows senior to select a technical option in Noise Control consisting of courses in vibrations, noise control and acoustics.

**RUTGERS UNIVERSITY**

Another part of the evolution of Noise in environmental programs at the undergraduate level is the work of Ray Manganelli at Rutgers. He helped establish the Rutgers Noise Technical Assistance Center in 1965. Today it is the only remaining Center originally contracted with EPA’s Office of Noise Abatement and Control. All other regional centers closed in the early 1980’s on ONAC’s closure. Eric Zwerling operates the center and offers an undergraduate course in Occupational and Community Noise to students in the environmental science program.

There may be reluctance to deal with the subject of noise control in Environmental Engineering Programs at some Universities. This may be due to lack of time, the fact the faculty have not had experience with the subject or it is perceived to be of little importance to the student. The authors believe that Noise is an extremely important environmental problem and merits coverage in all environmental engineering programs. Unless the course that contains the material is required few students pursue the subject.
One of the authors originally graduated from Cal Poly, San Luis Obispo with a BS in Environmental Engineering. When applying for an entry-level job in the noise and vibration field, this author was the only candidate with any introductory noise experience. In fact, the company simply looked for entry-level engineers who they could train in acoustics since they so rarely found any applicants with noise experience. Undergraduate Environmental Engineering programs must provide noise control courses because companies need this expertise.

The programs at Cal Poly, Purdue, Penn State, Rutgers and the University of Central Florida provide different models of introducing Noise related issues to undergraduate students. These could be introduced into any environmental engineering program. Summarizing, ways to introduce Noise Control in undergraduate Environmental Engineering include:

- PART OF REQUIRED CLASS
- REQUIRED CLASS
- OPTIONAL TECHNICAL SPECIALITY
- OPTIONAL ABILITY TO TAKE ONE OR TWO GRADUATE LEVEL CLASSES

CONCLUSION

It is clear that the technological developments in the late 1990’s will not only change the nature of the sources under investigation but also continue to influence the techniques applied in research on noise and its effects on the work on the realization of primary standards. Over many years an undergraduate course in Noise Control has remained in place to provide all Environmental Engineering Undergraduates experience with this important Environmental Problem. We find that most engineers and many environmental engineers have no experience with this problem and the engineering remedies. We find that noise issues are increasingly important and the profession must serve the public and industry in this area. Noise problems involve economics, public health, and environmental health and safety.

RECOMMENDATIONS

AT LEAST ONE REQUIRED CLASS IN NOISE AT UNDERGRADUATE LEVEL

- Offer internships and summer work
  - students hired by consulting firms
  - summer work—survey, hearing conservation, field study
- Senior Projects, Thesis, Special Projects
  - as an extension of summer work
ACKNOWLEDGMENTS

The authors wish to acknowledge the work of J.D. Brigance, Eric Covington, Kimberly Gonzalez, David Harrington, Tim Lee, Tracie Mustain, Courtney Palco and Russ Vierra who worked on the spreadsheets listed in the Appendix. These spreadsheets are available on request by e-mail from Dr. Hal Cota (hcota@calpoly.edu). It is hoped they can be useful in teaching the subject.

REFERENCES CITED


Table 1. Noise Control Course Outline

definitions
measurement of sound
comfort criteria - loudness, loudness level, PSIL, NC, NCB, NR
threshold of hearing
damage risk criteria- TTS, NIPTS
hearing conservation
propagation of sound outdoors
room acoustics
community noise
transportation
noise control:
absorption
barriers- Transmission Loss, Noise Reduction and Insertion Loss
masking
silencers
hearing protection
vibration isolation
damping
case studies
HVAC systems
<table>
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<th><strong>Table 2. Noise Control Laboratory Course Content</strong></th>
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<td>Spectrum analysis with an octave band analyzer</td>
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<td>Measuring the effect of distance on sound levels outdoors</td>
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<td>Measuring Community Noise Levels</td>
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<tr>
<td>Hearing Conservation and Audiometric Testing</td>
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<td>Measuring the transmission loss of walls between rooms</td>
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<td>Measuring the reverberation time</td>
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<td>Transportation Noise using the FHWA model and field data</td>
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APPENDIX

Spreadsheet Programs

- Calculating Sound Levels, Sound Pressure Levels and Spectrum Levels
  AWTLEVELS.XLS, BACKGRND.XLS, SPECANAL.XLS

- Hearing Thresholds
  ARTHS.XLS

- Noise Induced Threshold Shift
  NIPTS.XLS

- Calculating Ldn and CNEL’s
  COMUNITY.XLS, ANNOYLDN.XLS

- Transmission Loss of Composite Walls
  NR_TL.XLS

- NC curves
  NC.XLS, PNC.XLS

- Loudness and Loudness Levels
  SONEPHON.XLS, LOUD.XLS

- Insertion Loss of Barriers
  BARRIER1.XLS, BARRIER2.XLS