Impact of Air Quality – Including Ozone formation in the Troposphere

Gurubaran Veeravel

Chemical Engineering Department
Lamar University

Enno "Ed" Koehn

Civil Engineering Department
Lamar University

Abstract

Air pollution, which makes the air harmful for human inhalation, is not only due to outdoor polluters like automobiles, industries, etc., but also due to indoor pollutants like asbestos, carbon monoxide, formaldehyde, tobacco smoke, etc. Inadequate ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the facility. Hence, both indoor and outdoor air quality should be monitored and kept clean to ensure the safety and health of society. Outdoor air pollution, which has been a problem for a long time, is still a challenge for researchers. The major sources are identified as ozone, smog, particulate matter, nitrogen oxides, sulfur dioxide, toxic chemicals, carbon monoxide, acid rain, lead and carbon dioxide.

Ozone is the main component of the air pollution known as smog. Ozone is formed in the troposphere, by the action of sunlight on carbon-based chemicals known as hydrocarbons, acting in combination with a group of air pollutants called oxides of nitrogen. In the greenhouse effect, certain gases in the atmosphere trap heat in the troposphere. The amount of heat trapped in the troposphere depends on the concentrations of greenhouse gases and how long they stay in the atmosphere. The most common greenhouse gases are Ozone (O_3), H_2O, CO_2, CH_4, N_2O, and CFC's.

Ozone levels typically rise during the May through September period when higher temperatures and the increased amount of sunlight combine with the stagnant atmospheric conditions that are associated with ozone air pollution episodes.

Proceedings of the 2004 ASEE Gulf-Southwest Annual Conference
Texas Tech University

The harmful health effects of ozone present in the troposphere such as aggravating asthma, emphysema, bronchitis, and impairing the body immune systems, are presented. The chemical reaction in which ozone is formed and the reason why the formation of ozone is more pronounced in summers is also investigated. Suggestions to develop a healthy indoor and outdoor environment are presented.

Introduction

The quantity and severity of health problems caused by the poor quality of air has increased over the last ten years. This is attributed to many factors. Today, people spend a significant amount of time indoors. Apart from outdoor air quality which has been a concern for many years, the indoor quality has also grown dangerously noxious. To lower energy costs, buildings are often sealed to prevent infiltration of outside air, and the amount of fresh air added to buildings via ventilation systems has been significantly decreased. To lower material and construction costs, as well as to provide for less maintenance, products are sometimes used that emit toxic and irritating vapors. As a result, employees may experience headaches, nausea, sinus congestion, dizziness, and several other physical problems both at home and at work[1].

Outdoor air pollution can be hazardous to human health. When people breathe dirty air, pollutants may come into direct contact with their lungs. On days when air pollution is bad, both deaths and hospital admissions increase. So consistent is the association between dirty air and health problems, that some epidemiological studies blame air pollution for the premature deaths of more than 50,000 individuals every year from heart disease, lung cancer, pneumonia, asthma, stroke, and bronchitis, among other diseases. Possible health effects of air pollutants that are toxic to human health include: cancer; birth defects; damage to the brain, nervous system or respiratory tract; and even, in rare instances, death Air pollution also threatens plants, animals, and the natural environment. Common air pollutants can also damage property, dirtying buildings and corroding monuments and statues. And the haze produced by air pollution reduces visibility, affecting a number of activities, including airplane transportation, astronomical investigations by observatories, and tourism at national parks such as the Grand Canyon and Big Bend National Park. According to the Occupational Safety and Health Administration (OSHA) and the EPA, many individuals are breathing air that's making them sick or uncomfortable[2, 3].

Indoor Pollutants and their sources

Researchers have determined that the following pollutants and their respective sources are significant in causing air pollution[4].

1. Asbestos: Heating System Insulation, Acoustic Insulation, Ceiling Tiles, and Floor Tiles.

2. Carbon Monoxide: Garages, Motor Vehicles, Loading Docks, Gas Appliances and Gas Broilers, and Tobacco Smoke.

3. Formaldehyde: Glues, Partitions, Carpeting, Paneling, Drapery, Fabric, and Particleboard Furniture.

4. Microorganisms: Humidifiers, Air Conditioners, Dehumidifiers, Washrooms, Ventilation Pipes and Ducts, Leaky Roofs, Locations of Water Leaks and High Relative Humidity (>60%)

5. Tobacco Smoke: Cigarettes, Cigars, and Pipes.

6. Volatile Organic Compounds: Felt-tip Markers and Pens, Cleaning Compounds, Paint, Copy Machines, Solvents, Office Furnishings and Carpeting, Glues, and Pesticides.

7. Ozone: Copy Machines, and Ozone-Generating Air Purifiers

Sources of indoor air problems in offices

Three major reasons for poor indoor air quality in office buildings are the following:

- The presence of indoor air pollution sources.
- Poorly designed, maintained, or operated ventilation systems.
- Uses of the building that were unanticipated or poorly planned for when the building was designed or renovated.

The most important factor influencing indoor air quality is the presence of pollutant sources. Common sources of office pollutants include the following:

- Environmental tobacco smoke (ETS).
- Asbestos from insulation and fire-retardant building supplies.
- Formaldehyde from pressed wood products.
- Other organics from building materials, carpeting, and similar office furnishings.
- Cleaning materials and related activities.
- Restroom air fresheners.
- Paints and adhesives.
- Copying machines, photography, and print shops.
- Biological contaminants from dirty ventilation systems or water damaged walls, ceilings, and carpets.
- Pesticides generated by pest management practices.

Among the various pollutants, molds may be most common. In fact molds grow everywhere, wherever they can find humidity.

Molds:

Molds are the most typical form of fungus found on earth. They have been found growing in private homes, office buildings, schools, automobiles, and other locations where organic matter and water are left unattended. Molds produce tiny spores to reproduce[5, 6]. Mold spores waft through the indoor and outdoor air continually. When mold spores land on a damp spot indoors, they may begin growing and digesting whatever they are growing on in order to survive. There are molds that can grow on wood, paper, carpet, and foods. Molds are the cause of a variety of health effects in humans ranging from minor allergic reactions, increased asthma, and producing brain damage.

Basic mold cleanup:

The key to mold control is moisture control. It is important to dry water damaged areas and items within 24-48 hours to prevent mold growth. If mold is a problem, clean up the mold and get rid of the excess water or moisture. Fix leaky plumbing or other sources of water. Wash mold off hard surfaces with detergent and water, and dry completely. Absorbent materials (such as ceiling tiles & carpet) that become moldy may have to be replaced.

Health Effects of Indoor Air Pollution

A Building-Related Illness (BRI) may be caused by a biological contaminant, fungus, bacteria, or a toxic gas or vapor[7,8]. Here, people develop clinically demonstrable illnesses, such as Legionnaires' disease or radon poisoning. When they leave the building, they don't get better. In contrast, SBS (Sick Building Syndrome) is defined by the symptoms of the occupants rather than by success at linking their complaints to specific pathogenic or toxic compounds.

Individuals may complain of one or more of the following symptoms: dry or burning mucous membranes in the nose, eyes, and throat, sneezing, stuffy or runny nose, fatigue or lethargy, headache, dizziness, nausea, irritability, and forgetfulness. In addition, poor lighting, noise, vibration, thermal discomfort, and psychological stress may also cause, or contribute to, these symptoms. Microorganisms, such as bacteria, fungi, and viruses are known to cause some serious illnesses, such as Legionnaire's disease, humidifier fever, Pontiac fever, and hypersensitivity pneumonitis. Most of the forgoing diseases can be treated, although some can pose serious risks to individuals with other health conditions or toxic sensitivities.

There is no single manner in which these health problems appear. In some cases, problems begin soon after workers enter their offices and diminish soon after workers leave (typically called sick building syndrome). At other times, symptoms continue until the illness is treated (typically called building-related illnesses). Sometimes there are outbreaks of illness among many workers in a single building; in other cases, health symptoms show up in only certain employees.

Action needed for indoor air quality

A smoke-free building reduces the need for recirculation, requires less cleaning, reduces maintenance of air handling equipment, and lowers heating-ventilation-air-conditioning (HV AC) operating costs. The elements of a smoke-free workplace policy are as follows[7]:

- Management is involved and supportive.
- A smoke-free policy is issued.
- Smoking is prohibited except in designated smoking areas, and
- There is separate, dedicated ventilation for the smoking area.

There are numerous actions that can be taken to monitor and improve air quality that aren't very expensive. One inexpensive option is to purchase a carbon dioxide meter. Too much carbon dioxide in the air is a tip-off that the air is foul. Once CO2 gets beyond a certain level, people start to complain of discomfort. Another suggestion is to keep the building clean with identifiable problems lower than 50 percent. It has been found that, most complaints are triggered by thermal discomfort. However the following actions are recommended:

- Name an indoor air quality manager who knows the building well and who is responsible for maintaining a checklist of things that need to be done,
- Give the manager responsibility for walking through the building regularly looking for potential problems,
- Go after existing problems that you know about first, such as trucks idling at loading docks near ventilation ducts,
- Be mindful of events like remodeling, painting, pest control and renovations that introduce new elements into the environment and can trigger symptoms, and
- Maintain good communications with building occupants,

Out door air quality

Air pollution has many different aspects[8]. Whether the pollution is likely to cause environmental or health effects depend on the concentration of pollutants and the amount of time an individual is exposed to them. For example, smog is a visible haze made up of thousands of constituents, the most abundant, but not necessarily the most toxic, of which is ozone. Ozone -- made up of three oxygen atoms -- is produced when volatile organic compounds (VOCs) and nitrogen oxides released from natural and human sources combine in the presence of sunlight.

In addition, nitrogen oxides result from the burning of fossil fuels, such as coal, natural gas, gasoline, and oil. At present, automobiles are the main source of nitrogen oxide emissions in urban areas. Nitrogen oxides, at elevated concentrations, can damage the respiratory system. They can also be a key ingredient in the formation of both ozone and acid rain. Nitric oxide and nitrogen dioxide are together known as NO_x and often pronounced “nox.”

The efficiency of ozone formation rises and then falls as the ratio of nitrogen oxides (NO_x) to volatile organic compounds (VOCs) increases[9]. Therefore, NO_x emissions result in less efficient ozone production. The following have been found to contribute to air pollution:

1. Sulfur dioxide is released when sulfur-containing fuels, such as coal and oil, are burned. Common sources of sulfur dioxide emissions are electric utilities and certain industrial processes, such as copper smelting. Sulfur dioxide at elevated concentrations can cause respiratory problems and also affects plant and crop production. It also can be a contributing component of acid rain.

2. Toxic chemicals, which include VOCs such as benzene, toluene and 1,1,1 trichloroethane, when inhaled in elevated concentrations over time, can cause birth defects, cancer, and various other health problems. Sources of toxic emission include industrial processes, such as refineries and chemical manufacturers, and small businesses, such as print shops and dry cleaners. VOCs also contribute directly to the formation of ozone, another air pollutant.

3. Carbon monoxide (CO) is formed when fuel does not burn completely. Cars and trucks, as well as power plants, are the main contributors. Carbon monoxide interferes with the blood's ability to transport oxygen to cells and tissues. Exposure to elevated levels of carbon monoxide can cause drowsiness, headaches, and sometimes death.

4. Acid rain forms when the sulfur dioxide, nitrogen oxides, and carbon dioxide emitted from fossil-fuel-burning industrial plants and other combustion processes combine with rain, fog, or snow in the atmosphere. Over time, with conducive geologic conditions, acid rain can increase the acidities of lakes, streams, and soils, disturbing or destroying local environments. Wind can carry pollutants far away from where they originated, creating problems in other states or countries.

5. Lead is a heavy metal that persists in the environment for decades. The former use of leaded gasoline, which is no longer commercially available in most of the United States, the manufacture of lead-based paint, and lead-acid battery reclamation operations are sources of lead in the air. Emissions from metal smelters are another source. Exposure to lead at high levels and over time can cause brain and other nervous system damage, particularly in children. Excess exposure to lead can also harm wildlife and is known to cause cancer in animals.

6. Carbon dioxide, a compound naturally found in the atmosphere, is produced by humans and animals and utilized by plants in the photosynthesis process. Carbon dioxide is also produced, however, by electric utilities, cars, petroleum refineries, the burning of wood, and many other sources. The elevated presence of carbon dioxide, as well as other gases such as methane and nitrous oxide, is believed to influence global climate change by preventing heat from escaping out of the atmosphere in a phenomenon known as global warming.

7. Particulate Matter

It is a complex mixture of solid and liquid particles suspended in atmosphere. PM10 is coarse particulate matter 10 microns or less in diameter (approx. one-seventh the width of a

human hair). PM2.5 is fine particulate matter 2.5 microns or less in diameter. The elderly, children, asthmatics, and adults with preexisting heart or lung disease are most at risk of suffering effects of particulate matter. Sources of PM10 include: street sand, road dust, grinding operations, and agricultural operations. Sources of PM2.5 include: motor vehicles, power plants, wood burning, and industrial processes.

National Ambient air quality standards

The U.S. Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards (NAAQS) for six air pollutants: ozone, lead, carbon monoxide, sulfur dioxide, nitrogen dioxide, and particulate matter[10]. The standards were established to protect the public from exposure to harmful amounts of pollutants. When the pollutant levels in an area have caused a violation of a particular standard, the area is classified as "nonattainment" for that pollutant. This may be due to the following:

- Ground-level ozone (smog),
- Particulate matter (PM),
- Lead,
- Nitrogen dioxide,
- Sulfur dioxide, and
- Carbon monoxide

Ozone

Ozone is of two types namely Good Ozone and Bad Ozone, depending on the layer of atmosphere in which it is present. To understand this fully, it is essential to understand these layers and their characteristics.

Structure of earth's atmosphere

A blanket of air, which is called the atmosphere, surrounds the Earth[11]. It reaches over 560 kilometers (348 miles) from the surface, so we are only able to see what occurs fairly close to the ground. The troposphere starts at the Earth's surface and extends 8 to 14.5 kilometers high (5 to 9 miles). The stratosphere begins above the troposphere and extends to 50 kilometers (31 miles). Compared to the troposphere, this part of the atmosphere is dry and less dense

Major contributors to ozone

The average concentration of ozone in the atmosphere is about 300 parts per billion by volume (ppbv) that is, there are about 3 molecules of ozone for every ten million-air molecules[12]. Most of it (~90%) is contained in the stratosphere about 15 - 30 km above the Earth's surface where it is present at levels of several parts per million by volume (ppmv).

The ozone found in the stratosphere is known as good ozone[13]. It is formed naturally and is produced and destroyed at a constant pace when outside influences are not taken into account.

In this layer, ozone is formed when an O_2 molecule is split apart due to the vibrations caused by ultraviolet radiation from the sun. The individual oxygen atoms then combine with other O_2 molecules to form O_3. The destruction of ozone happens when an individual atom of oxygen combines with the unstable O_3 molecule which is then split into two separate O_2 molecules and the process starts over. This layer of ozone helps protect the earth in two ways. First it creates a very thin protective layer around the Earth that absorbs harmful ultraviolet radiation and prevents it from reaching the Earth's surface. The ozone layer plays a vital role in our lives. Without ozone in this layer of the atmosphere life on Earth would not be possible. The second role ozone plays is the creation of the stratosphere in which the temperature rises as you increase in height. (In the **stratosphere**, the absorption of ultraviolet radiation causes the temperature to increase with altitude. In a **temperature inversion**, the normal situation of air cooling with altitude is reversed and air warms with altitude[14].) This process also regulates the weather patterns in the troposphere.

Unfortunately, the rate of destruction has been increased by the presence of harmful ozone destroying products from fire extinguishers, coolants, foaming agents, solvents, and aerosol propellants created from chlorofluorocarbons (CFC), carbon tetrachloride, bromides, methalchloroform, and halons. With the increasing destruction of the ozone layer more and more harmful ultraviolet light will be allowed down to the Earth's surface. The increasing levels of harmful ultraviolet light at the surface can cause more sun burns, eye problems such as cataracts, decreased immune systems, and impacts on the growth of both land and water plants.

The foregoing set of reactions continues back and forth establishing a steady state of oxygen and ozone concentrations[15]. A steady state is defined as a dynamic balance of reactions in which there is no overall change in concentration of any of the compounds involved in the reactions. This steady state reaction sequence removes harmful ultraviolet radiation before it reaches the Earth.

$$O_2 + sunlight \longrightarrow O + O \quad (Reaction\ 1)$$
$$O + O_2 \longrightarrow O_3 \quad (Reaction\ 2)$$
$$O_3 + Sunlight \longrightarrow O_2 + O \quad (Reaction\ 3)$$

In the lower atmosphere (troposphere 0-8km), ozone is formed in a different set of chemical reactions involving hydrocarbons and nitrogen-containing gases (reactions 4-8)[16]. Here the sources are**:** Motor Vehicles, Power Plants, Factories, Consumer and Commercial Products, Fuel Combustion Processes

$$O + O_3 \longrightarrow O_2 + O_2 \quad (Reaction\ 4)$$
$$NO2 + Sunlight \longrightarrow NO + O \quad (Reaction\ 5)$$
$$O + O_2 \longrightarrow O_3 \quad (Reaction\ 6)$$
$$NO + O_3 \longrightarrow NO_2 + O_2 \quad (Reaction\ 7)$$
$$NOx + VOC + Sunlight \longrightarrow O3\ (and\ other\ products) \quad (Reaction\ 8)$$

Changes in ozone concentration in the atmosphere affect ultra violet (UV) radiation[17].
The UV portion of the solar spectrum is generally divided into three regions:

- UV-A (315-400 nm) (essentially unaffected by ozone absorption),
- UV-B (280-315 nm) (strongly affected by variations in ozone), and
- UV-C (< 280 nm) (almost entirely absorbed before it reaches the surface).

If the ozone layer in the stratosphere gets depleted because of pollutants, it is described as an ozone hole. Thus when an ozone hole is formed UV-C, which is responsible for formation of large amount of ozone in the troposphere, enters this layer. Therefore a hole in the ozone not only allows harmful Ultra violet rays but also produces Bad Ozone.

Fluctuation of ozone with climate changes

Weather plays a key role in ozone formation. The highest ozone levels are usually recorded when temperatures approach the high 80s and 90s and when the wind is stagnant or light[18]. Since solar radiation is strongest over the tropics, most of the global ozone is formed in this region[19]. However, the sun in the tropics does not only drive ozone formation, but also the rise of tropospheric air to higher altitudes. There ozone is transported towards the poles and accumulates in the cold sub Polar Regions with low photochemical depletion. The values at the poles themselves are lower, in particular in winter, when no ozone can be formed during the polar night. Therefore, the highest ozone values are observed over the Polar Regions, as long as the system is not disturbed by the ozone hole.

Health Effects

When inhaled at harmful levels, ozone can[20]:

- Pose health problems for children, asthmatics, the elderly and even healthy adults,
- Cause acute respiratory problems,
- Aggravate asthma, emphysema and bronchitis,
- Lead to hospital admissions and emergency room visits, and
- Impair the body's immune system defenses.

Environmental Effects

The environmental effects of ozone may:

- Reduce agricultural yields for many economically important crops,
- Reduces visibility in many parts of the U.S,
- Causes soiling and damage to materials, and
- Adversely affects forests, plant life and ecosystems.

Suggestions and Recommendations

- Indoor pollutants such as asbestos, formaldehyde, micro-organism, especially molds, carbon monoxide, etc., should be identified in offices, buildings, homes, etc., and should be eliminated,

- Indoor air quality should be maintained at permissible quality by providing proper ventilation and building usage. For example, the same building should not be used for offices that have different functions such as a software developing firm and a highly polluting firm. If such a situation arises, separate air conditioning systems should be provided for both areas,
- Indoor Air quality monitoring devices should be made cheaper and easy to install in buildings and homes like fire alarms. Homes that are sealed for air conditioning should have devices to monitor increase of VOC's, molds, etc.,
- Industries and companies not complying with the EPA's emission regulations should be punished severely by federal law. The plant should be required to shut down and operations not resumed until it is proven that the standard is met.
- Public should be made aware of what kind of air quality they are breathing outdoor and especially, indoor in their home. Individuals living in heavily industrial places like Houston, Beaumont, Dallas, etc., should be aware of precautions to be undertaken and should avoid contributing additional ozone forming pollutants.
- To reduce Ground-level "Bad" Ozone:
    1. Keep your automobile well tuned and maintained,
    2. Carpool, use mass transit, walk, bicycle, and/or reduce driving, especially on hot summer days,
    3. Be careful not to spill gasoline when filling up your car or gasoline powered lawn and garden equipment,
    4. During the summer, fill your gas tank during the cooler evening hours,
    5. Make sure your car's tires are properly inflated and your wheels are aligned,
    6. Seal containers of household cleaners, workshop chemicals and solvents, and garden chemicals to prevent volatile organic chemicals from evaporating into the air also dispose containers properly.
- To maintain High-Altitude "Good" Ozone:
    1. Make sure that technicians working on your car air conditioner, home air conditioner, or refrigerator are certified by an EPA approved program to recover the refrigerant (this is required by law),
    2. Have your car and home air conditioner units and refrigerator checked for leaks,
    3. When possible, repair leaky air conditioning units before refilling them,
    4. Contact local authorities to properly dispose of refrigeration or air conditioning equipment,
    5. Protect yourself against sunburn,
    6. Minimize sun exposure during midday hours (10 a.m. to 4 p.m.),
    7. Wear sunglasses, a hat with brim, and protective clothing with a tight weave, and
    8. Use a broad spectrum sunscreen with a sun protection factor (SPF) of at least 15 and better yet, 30.

Conclusion

Air quality both indoors and outdoors is becoming a severe problem. As discussed, indoors, the pollutants must be identified and sources eradicated from buildings. Here ventilation systems should be properly maintained in order to prevent harmful effects.

Outdoor air pollutants should be identified and sharply reduced before they reach the atmosphere. Ozone production in the troposphere can be prevented as it is largely produced by reaction of exhaust gases like NO_x and VOCs from chemical industries and automobiles. It is hoped that, in the future, the public will demand that the air pollution problem be reduced and brought under control.

References

1. Quade R. Stahl, Ph.D., SORM RMTSA vol. III, Section Two, Chapter 7 "Occupational Health Program – Indoor Air Quality"

2. http://phaseoneesa.com/mold%20air%20sampling%20fungi%20testing%20toxic%20iaq.htm

3. Robert J.Grossman, October 2000, HR magazine "Out with the Bad Air"

4. RMTSA vol. III, Section Two, Chapter 7

5. Sandra Mc Neel and R. Kreutzer, "Fungi & Indoor Air Quality" *Health & Environment Diges* Vol 10, No. 2, (May/June 1996), 9-12. Posted online at: http://www.dhs.cahwnet.gov/org/ps/deodc/ehib/EHIB2/topics/fungi_indoor.html.

6. Pamela J. Davis, March 2001 CRB Note. Vol. 8, No. 1 ISBN: 1-58703-133-7 "Molds, Toxic Molds, and Indoor Air Quality

7. Robert J.Grossman, October 2000, HR magazine "Out with the Bad Air"

8. http://www.texasep.org/html/air/air_1nfa_poll.html

9. http://earthobservatory.nasa.gov/Library/ChemistrySunlight/chemistry_sunlight3.html

10. Texas Natural Reserves Conservation commission, "Air Quality Issues in Texas" (http://www.tnrcc.state.tx.us/oprd/sips/sip101.pdf)

11. http://www.atmosphere.mpg.de/enid/m2.html

12. http://earthobservatory.nasa.gov/Library/ChemistrySunlight/chemistry_sunlight3.html

13. Wendy M Thomson 2003 "Ozone in the Earth's atmosphere" (http://www.physics.isu.edu/weather/kmdbbd/paper.PDF)

14. Alan Strahler, Boston University and Arthur Strahler, Columbia University, WILEY Publications, 2003 "Physical Geography"

http://www.wiley.com/college/strahler/sc/strach3.html

15. http://www.science.uwaterloo.ca/~cchieh/cact/applychem/ozone.html

16. EPA, The Clean Air Act Amendments: A Guide for Small Businesses [September 1992 –(Ref: 8.1-8.8)

17. http://www.cmdl.noaa.gov/ozone.html

18. http://www.raqc.org/LG%20Communicators/print%20article.doc

19. http://www.atmosphere.mpg.de/enid/m2.html

20. http://www.texasep.org/html/air/air_1nfa_poll.html

ENNO "ED" KOEHN
Enno "Ed" Koehn is a professor of Civil Engineering at Lamar University, Beaumont, TX. Professor Koehn has served as the principal investigator for several research and development projects dealing with the various aspects of construction and has experience in the design, scheduling, and estimating of facilities. In addition, he has authored/co-authored approximately 200 papers and presentations in engineering education and the general areas of civil and construction engineering. Dr.Koehn is a member of ASEE, AACE International, ASCE, NSPE, Chi Epsilon, Tau Beta Pi, and Sigma Xi and is registered Professional Engineer and Surveyor.

GURUBARAN VEERAVEL
Gurubaran Veeravel has been awarded a M.E in Chemical Engineering, Lamar University, Beaumont, TX. He has served as Research Assistant for a period of one year in the project "Nano composite catalyst for PEM fuel cell" and as Teaching Assistant for the Department of Chemistry. In addition he has served as a Process Engineer with AGIL Polymers, India.