ENVE 576: Indoor Air Pollution — Fall 2017

Illinois Institute of Technology — 3 credit hours
Department of Civil, Architectural, and Environmental Engineering

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Course Unique Number(s)
ENVE 576 Section 01: 17688 (graduate); ENVE 576 Section 02: 17689 (graduate online)

Classroom and Meeting Time
John T. Rettaliata Engineering Center Room 241
Tuesdays, 5:00 PM – 7:40 PM

Course Website(s)
Syllabus/lectures: http://built-envi.com/courses/enve-576-indoor-air-pollution-fall-2017/
Blog: http://IITindoorair.wordpress.com

Prerequisites
None, but familiarity with differential equations is recommended.

Instructor
Brent Stephens, Ph.D., Associate Professor, Architectural Engineering
Office: Alumni Memorial Hall Room 212, Phone: (312) 567-3356
Email: brent@iit.edu | Website: www.built-envi.com

Office Hours
Office hours are by appointment only. Please email me to schedule an appointment.

Course Catalog Description
Indoor air pollution sources, indoor pollutant levels, monitoring instruments and designs; indoor pollution control strategies: source control, control equipment and ventilation; energy conservation and indoor air pollution; exposure studies and population time budgets; effects of indoor air population; risk analysis; models for predicting source emission rates and their impact on indoor air environments.

Course Objectives
To introduce students to important concepts of indoor airborne pollutants, including their physical and chemical properties, emission sources, and removal mechanisms. By taking this course students will be able to:

1. Describe particle-phase, gas-phase, and biological pollutants found in indoor environments and their impact on human health
2. Model indoor pollutant emission, transport, and control
3. Manipulate and perform calculations with aerosol distributions and gas-phase compounds
4. Analyze indoor pollutant control technologies and determine their effectiveness
5. Read and critically analyze articles in the technical literature on indoor air pollution
6. Prepare and review written and oral technical communication

Textbook
There is no required textbook for this course. We will rely on peer-reviewed literature and handouts from reference texts for the majority of our topics. Reference texts include the following:

- Hinds, W. C., *Aerosol technology: Properties, behavior, and measurement of airborne particles*, Wiley (1999).
- Morawska, L. and Salthammer, T., *Indoor environment: airborne particles and settled dust*, Wiley-VCH (2003).
- Salthammer, T. and Uhde, E., *Organic Indoor Air Pollutants: occurrence, measurement, evaluation*, Wiley-VCH (2009).
- Seinfeld, J. H. and Pandis, S. N., *Atmospheric chemistry and physics: from air pollution to climate change*, Wiley (2006).
- Spengler, J., McCarthy, J., and Samet, J. *Indoor air quality handbook*, McGraw-Hill Professional (2001).

Homework Assignments
There will be 4 homework (HW) assignments during the course that will involve a combination of hand calculations, development of spreadsheets, and learning the basics of some software packages typically used in the field. Some general rules for homework assignments are as follows:

- HW assignments will be posted online on Blackboard (BB) and will typically be due one week after they are assigned
- Either electronic PDF copies of HW or hardcopies are acceptable. If submitting electronically, your file should be in PDF format and the filename should be in the format of **hw1_lastname_firstname.pdf**
- Hardcopy HW assignments should be neatly printed
- Multiple page submissions of any hardcopies must have all pages stapled together
- Students enrolled in the online course can submit HW via email to the instructor or via Blackboard (BB). Handwritten HW must be scanned and converted to PDF by online students. Multiple pages must be converted to a single PDF for submission

Blog Posts
Each student will be required to write 3 blog posts throughout the duration of the course on topics related to indoor air quality, indoor exposures, indoor environmental health, and any other topics closely related to the course. You will be provided with a username for the course blog, which is available at the following URL: http://iitindoorair.wordpress.com. You will be expected to login and publish posts on the dates that they are due (refer to the most current course schedule for due dates). The blog posts will be on the topic of your choice and should be at least 500 words in order to fully explain your ideas on a subject, typically with at least one or two helpful figures and/or tables. Examples of good posts include reviews of recently published peer-reviewed research articles, highlights of IAQ topics in the popular media, overviews of new or old IAQ standards, and many others. Each blog post will be worth 50 points, with 50% of your grade coming from relevance and completeness of your post and the other 50% coming from your writing technique and grammar.

Late Homework Policy
Homework is due at the beginning of class on the day that it is due. Do not work on HW during the lecture. Late HW will receive a 5-point deduction for every day that it is late, excluding weekends. For example, a HW due on a Tuesday turned in the following Tuesday will have its grade reduced by 50%.

Exams
One take-home exam will be given. Students will have one week to complete the exam and return to Dr. Stephens. A final exam is not scheduled for this course.

Project
There will be one major research project in this course instead of a final exam. It is a research project where students research an indoor air pollution topic. Students will develop a technical research report describing their motivation, literature review, methods, and results, and will summarize their research with a classroom presentation at the end of the semester. Graduate students are expected to perform a more detailed analysis and format their report as a more formal research article/conference paper. Students will complete a final report and give a final presentation at the end of the semester.

Grading
Course grades will be determined by the total number of points accumulated through HW assignments, project(s), and exam(s). The total number of points available in each category is listed in the table below. The percentage of total points required for various letter grades is also given below.

Grading	HW	Blog posts	Exam	Final project	Total
All students	300	150	300	400	1150

Grading scale	A	B	C	D	F
All students	90% and up	80.0-89.9%	70.0-79.9%	60.0-69.9%	<60.0%

Personal Problems
If you have illness or personal problems that will affect your performance during the course of the semester, please let me know as soon as possible. "After the fact" provides little protection unless there are extreme circumstances. Contact me by phone or e-mail at any time.

Students with Disabilities
Reasonable accommodations will be made for students with documented disabilities. In order to receive accommodations, students must obtain a letter of accommodation from the Center for Disability Resources. The Center for Disability Resources (CDR) is located in 3424 S. State St., Room 1C3-2 (on the first floor), telephone (312) 567-5744 or email: disabilities@iit.edu.

Academic Honesty
It is your responsibility to be familiar with IIT's Code of Academic Honesty. The Code of Academic Honesty can be found online:
http://www.iit.edu/student_affairs/handbook/information_and_regulations/code_of_academic_honesty.shtml

You must submit your own work for homework. You are encouraged to discuss and even work with other students on homework (unless explicitly told otherwise), but material that is submitted must be your own work. For group project assignments, each group is to submit their own work. For a first violation of the IIT Code of Academic Honesty for a homework or project, the homework will receive a grade of zero for all involved students and the students will be reported to the Designated Dean for Academic Discipline (DDAD). For a first violation of the Code of Academic Honesty for a major project or an examination, the student will receive a failing grade for the course and the student will be reported to the DDAD. For a second violation, the student will receive also failing grade for the course and be reported to the DDAD.

Course Topics and Tentative Schedule

Week	Date	Lecture Topics	Reading*	Assignment:
1	Aug 22	Introduction to topic/field • Indoor and outdoor atmospheres • Fundamental air principles	1–5	
2	Aug 29	Reactor models • Steady-state and dynamic • Ventilation and air exchange rates Human exposure patterns • Inhalation and intake fractions	6–8	
3	Sep 5	Overview of indoor pollutants/constituents • Particulate matter • Gas-phase compounds ⇒ Organic and inorganic • Biological	9	Blog #1 due
4	Sep 12	Gaseous pollutants • Sources and emissions models	10–13	HW #1 due
5	Sep 19	Gaseous pollutants and indoor chemistry • Adsorption/desorption • Reactive surface deposition • Homogenous chemistry • Reaction byproduct formation	14–18	
6	Sep 26	Indoor aerosols • Single particle dynamics • Particle size distributions • Respiratory deposition	19–21	HW #2 due
7	Oct 3	Indoor aerosols • Indoor particle sources • Deposition and resuspension • Penetration/infiltration	22–27	HW #3 due
8	Oct 10	Indoor aerosols • Filtration and air cleaners	28–31	
9	Oct 17	SVOCs and aerosol chemistry IAQ measurement techniques	32–35	HW #4 due
10	Oct 24	Health effects and epidemiology	36–39	Blog #2 due
11	Oct 31	Indoor microbiology	40–43	Take-home exam assigned
12	Nov 7	Airborne infectious disease transmission	44–46	Take-home exam due
13	Nov 14	IAQ in developing countries Applications • Standards and manufacturer ratings • Modeling software	47–49 50–53	
14	Nov 21	***No class – work on your projects***		
15	Nov 28	Final presentations in class		Final presentations
Final	Dec 5	No final exam		Final project report due Blog #3 due

*Suggested readings are listed on the following page. These readings are not required unless stated otherwise.

Suggested Readings:

(1) Mitchell, C. S.; Zhang, J.; Sigsgaard, T.; Jantunen, M.; Lioy, P. J.; Samson, R.; Karol, M. H. Current State of the Science: Health Effects and Indoor Environmental Quality. *Environ Health Perspect* **2007**, *115* (6), 958–964.

(2) Nazaroff, W. W.; Weschler, C. J.; Corsi, R. L. Indoor air chemistry and physics. *Atmospheric Environment* **2003**, *37* (39–40), 5451–5453.

(3) Ott, W. R.; Roberts, J. W. Everyday exposure to toxic pollutants. *Sci. Am* **1998**, *278* (2), 86–91.

(4) Jones, A. Indoor air quality and health. *Atmospheric Environment* **1999**, *33* (28), 4535–4564.

(5) Sundell, J. On the history of indoor air quality and health. *Indoor Air* **2004**, *14 Suppl 7*, 51–58.

(6) Bennett, D. H.; McKone, T. E.; Evans, J. S.; Nazaroff, W. W.; Margni, M. D.; Jolliet, O.; Smith, K. R. Defining intake fraction. *Environ. Sci. Technol.* **2002**, *36* (9), 207A–211A.

(7) Murray, D. M.; Burmaster, D. E. Residential air exchange rates in the United States: empirical and estimated parametric distributions by season and climatic region. *Risk Analysis* **1995**, *15* (4), 459–465.

(8) Klepeis, N. E.; Nelson, W. C.; Ott, W. R.; Robinson, J. P.; Tsang, A. M.; Switzer, P.; Behar, J. V.; Hern, S. C.; Engelmann, W. H. The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. *J Expo Anal Environ Epidemiol* **2001**, *11* (3), 231–252.

(9) Weschler, C. J. Changes in indoor pollutants since the 1950s. *Atmospheric Environment* **2009**, *43* (1), 153–169.

(10) Meininghaus, R.; Gunnarsen, L.; Knudsen, H. N. Diffusion and sorption of volatile organic compounds in building materials: Impact on indoor air quality. *Environmental Science & Technology* **2000**, *34* (15), 3101–3108.

(11) Guo, Z. Review of indoor emission source models. Part 1. Overview. *Environ. Pollut.* **2002**, *120* (3), 533–549.

(12) Sparks, L. E.; Tichenor, B. A.; Chang, J.; Guo, Z. Gas-phase mass transfer model for predicting volatile organic compound (VOC) emission rates from indoor pollutant sources. *Indoor Air* **1996**, *6* (1), 31–40.

(13) Hodgson, A. T.; Rudd, A. F.; Beal, D.; Chandra, S. Volatile organic compound concentrations and emission rates in new manufactured and site-built houses. *Indoor Air* **2000**, *10* (3), 178–192.

(14) Cano-Ruiz, J. A.; Kong, D.; Balas, R. B.; Nazaroff, W. W. Removal of reactive gases at indoor surfaces: Combining mass transport and surface kinetics. *Atmospheric Environment. Part A. General Topics* **1993**, *27* (13), 2039–2050.

(15) Weschler, C. J. Ozone in indoor environments: concentration and chemistry. *Indoor Air* **2000**, *10* (4), 269–288.

(16) Waring, M. S.; Wells, J. R.; Siegel, J. A. Secondary organic aerosol formation from ozone reactions with single terpenoids and terpenoid mixtures. *Atmospheric Environment* **2011**, *45* (25), 4235–4242.

(17) Gall, E. T.; Corsi, R. L.; Siegel, J. A. Impact of Physical Properties on Ozone Removal by Several Porous Materials. *Environmental Science & Technology* **2014**, *48* (7), 3682–3690.

(18) Waring, M. S. Secondary organic aerosol in residences: predicting its fraction of fine particle mass and determinants of formation strength. *Indoor Air* **2014**, *24*, 376–389.

(19) Hinds, W. C. Chapter 3: Uniform Particle Motion. In *Aerosol Technology*; Wiley, 1999.

(20) Hinds, W. C. Chapter 11: Respiratory Deposition. In *Aerosol Technology*; Wiley, 1999.

(21) Seinfeld, J. H.; Pandis, S. N. Chapter 8: Properties of the Atmospheric Aerosol. In *Atmospheric Chemistry and Physics*; Wiley, 2006.

(22) Stephens, B.; Siegel, J. A. Penetration of ambient submicron particles into single-family residences and associations with building characteristics. *Indoor Air* **2012**, *22* (6), 501–513.

(23) Thatcher, T. L.; Lunden, M. M.; Revzan, K. L.; Sextro, R. G.; Brown, N. J. A concentration rebound method for measuring particle penetration and deposition in the indoor environment. *Aerosol Sci. Technol.* **2003**, *37* (11), 847–864.

(24) Rim, D.; Wallace, L.; Persily, A. Infiltration of outdoor ultrafine particles into a test house. *Environ. Sci. Technol.* **2010**, *44* (15), 5908–5913.
(25) Nazaroff, W. W. Indoor particle dynamics. *Indoor Air* **2004**, *14* (s7), 175–183.
(26) Wallace, L. Indoor sources of ultrafine and accumulation mode particles: size distributions, size-resolved concentrations, and source strengths. *Aerosol Science & Technology* **2006**, *40* (5), 348–360.
(27) Chen, C.; Zhao, B. Review of relationship between indoor and outdoor particles: I/O ratio, infiltration factor and penetration factor. *Atmos. Environ.* **2011**, *45* (2), 275–288.
(28) Hinds, W. C. Chapter 9: Filtration. In *Aerosol Technology*; Wiley, 1999.
(29) Stephens, B.; Siegel, J. A. Comparison of test methods for determining the particle removal efficiency of filters in residential and light-commercial central HVAC systems. *Aerosol Science and Technology* **2012**, *46* (5), 504–513.
(30) US EPA. *Evaluation of in-room particulate matter air filtration devices*; EPA/600/R-08/012; United States Environmental Protection Agency, 2008.
(31) Azimi, P.; Zhao, D.; Stephens, B. Estimates of HVAC filtration efficiency for fine and ultrafine particles of outdoor origin. *Atmospheric Environment* **2014**, *98*, 337–346.
(32) Weschler, C. J.; Nazaroff, W. W. Semivolatile organic compounds in indoor environments. *Atmospheric Environment* **2008**, *42* (40), 9018–9040.
(33) Hodas, N.; Turpin, B. J. Shifts in the Gas-Particle Partitioning of Ambient Organics with Transport into the Indoor Environment. *Aerosol Science and Technology* **2013**, 131207050823004.
(34) Johnson, A. M.; Waring, M. S.; DeCarlo, P. F. Real-time transformation of outdoor aerosol components upon transport indoors measured with aerosol mass spectrometry. *Indoor Air* **2016**.
(35) Wallace, L. A.; Wheeler, A. J.; Kearney, J.; Van Ryswyk, K.; You, H.; Kulka, R. H.; Rasmussen, P. E.; Brook, J. R.; Xu, X. Validation of continuous particle monitors for personal, indoor, and outdoor exposures. *J Expos Sci Environ Epidemiol* **2010**, *21* (1), 49–64.
(36) Logue, J. M.; Price, P. N.; Sherman, M. H.; Singer, B. C. A method to estimate the chronic health impact of air pollutants in U.S. residences. *Environmental Health Perspectives* **2012**, *120* (2), 216–222.
(37) Chen, C.; Zhao, B.; Weschler, C. J. Indoor exposure to "outdoor PM10." *Epidemiology* **2012**, *23* (6), 870–878.
(38) Chen, C.; Zhao, B.; Weschler, C. J. Assessing the Influence of Indoor Exposure to "Outdoor Ozone" on the Relationship between Ozone and Short-term Mortality in U.S. Communities. *Environ. Health Perspect.* **2011**.
(39) Ji, W.; Zhao, B. Estimating mortality derived from indoor exposure to particles of outdoor origin. *PLOS ONE* **2015**, *10* (4), e0124238.
(40) Qian, J.; Hospodsky, D.; Yamamoto, N.; Nazaroff, W. W.; Peccia, J. Size-resolved emission rates of airborne bacteria and fungi in an occupied classroom. *Indoor Air* **2012**, *22* (4), 339–351.
(41) Hospodsky, D.; Qian, J.; Nazaroff, W. W.; Yamamoto, N.; Bibby, K.; Rismani-Yazdi, H.; Peccia, J. Human occupancy as a source of indoor airborne bacteria. *PLoS ONE* **2012**, *7* (4), e34867.
(42) Konya, T.; Scott, J. A. Recent Advances in the Microbiology of the Built Environment. *Current Sustainable/Renewable Energy Reports* **2014**, *1* (2), 35–42.
(43) Stephens, B. What Have We Learned about the Microbiomes of Indoor Environments? *mSystems* **2016**, *1* (4), e00083-16.
(44) Azimi, P.; Stephens, B. HVAC filtration for controlling infectious airborne disease transmission in indoor environments: Predicting risk reductions and operational costs. *Building and Environment* **2013**, *70*, 150–160.
(45) Sze To, G. N.; Chao, C. Y. H. Review and comparison between the Wells-Riley and dose-response approaches to risk assessment of infectious respiratory diseases. *Indoor Air* **2010**, *20* (1), 2–16.
(46) Nicas, M.; Nazaroff, W. W.; Hubbard, A. Toward understanding the risk of secondary airborne infection: emission of respirable pathogens. *J Occup Environ Hyg* **2005**, *2* (3), 143–154.

(47) Bruce, N.; Perez-Padilla, R.; Albalak, R. Indoor air pollution in developing countries: a major environmental and public health challenge. *Bull World Health Organ* **2000**, *78* (9), 1078–1092.
(48) Lopez, A. D.; Mathers, C. D.; Ezzati, M.; Jamison, D. T.; Murray, C. J. Global and regional burden of disease and risk factors, 2001: systematic analysis of population health data. *The Lancet* **2006**, *367* (9524), 1747–1757.
(49) Lim, S. S.; Vos, T.; Flaxman, A. D.; Danaei, G.; Shibuya, K.; Adair-Rohani, H.; Amann, M.; Anderson, H. R.; Andrews, K. G.; Aryee, M.; et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet* **2012**, *380* (9859), 2224–2260.
(50) ASHRAE. Standard 52.2: Method of testing general ventilation air-cleaning devices for removal efficiency by particle size. American Society of Heating, Refrigerating and Air-Conditioning Engineers 2007.
(51) ASHRAE. Standard 62.2: Ventilation and acceptable indoor air quality in low-rise residential buildings. American Society of Heating, Refrigerating and Air-Conditioning Engineers 2016.
(52) ASHRAE. Standard 62.1: Ventilation for acceptable indoor air quality. American Society of Heating, Refrigerating and Air-Conditioning Engineers 2010.
(53) Walton, G. N.; Dols, W. S. *CONTAM*; National Institutes of Standards and Technology, 2008.