Master of Science in Sustainability Science

Course Title: Air Pollution and Measuring Environmental Burden of Disease

3 Credits

Instructors:

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Class Hours:	Tuesdays, 6:10 pm – 8:00 pm
Instructor Office Hours:	Tuesdays, 8:10 pm – 9:00 pm or by appointment
TA Office Hours:	TBD

Response Policy: Students can expect a response within 2 days. Email is our preferred mode of communication.

Course Overview

In this course, we will first provide a global perspective on the current status of environmental problems and the leading environmental contributors to the burden of diseases. We will then introduce how air pollutants are produced, transported, and what are their environmental fates. We will cover how air pollutants are measured and monitored, including government monitoring networks, NASA remote sensing techniques, and research tools for fixed site monitoring (indoor and outdoor) and personal level monitoring. Students will be able to learn basic concepts about the toxicity and target organs of different pollutants, both of which are important for understanding dose-response and health outcomes. Building on knowledge of exposure and toxicity, we will then introduce risk assessment, including the Global Burden of Disease (GBD) associated with air pollution. Students will specifically learn how to use software tools for calculating burdens such as BenMAP. Their usage in evaluating sustainability as well as their limitations will be introduced.

Each weekly class will be divided into lecture portion and hands on data activity and/or discussion portion. Students will have a chance to join discussion about environmental regulation, policies, and other efforts to mitigate ecological impact and burden of disease caused by environmental exposures in both industrialized and developing nations. In-class step-by-step instruction will be provided to help students learn how to find and download available online data from EPA, NASA, and WHO, etc. and how to do risk assessment, and GBD calculations based on these data.

The course will provide students with the methods and tools to understand, monitor, and analyze current environmental health threats in air, and explore strategies for policy interventions for lowering exposure to air pollutants over time given complex challenges. Students will leave the course with a stronger sense of the power, and limitations, of environmental data and better equipped to evaluate and communicate the effectiveness of new interventions. After completing the course, students will be able to more confidently apply core scientific concepts to evaluate and address public health challenges posed by contaminants, such as airborne fine particulate ($PM_{2.5}$). In addition, the course will provide the students skills in searching, downloading, and analyzing various online datasets from reliable sources and an introduction into research design for investigating environmental issues. These useful skills could position students well in their future careers.

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This course is designed to meet the degree requirements for either the Area 2 (Methods of Earth Observation and Measurement) or Area 4 (of Scientific Tools for Responding to Sustainability Challenges) requirement for the M.S. in Sustainability Science Program.

Learning Objectives

Students will be expected to gain a quantitative understanding of the main physical and chemical processes that lead to contamination of air, based on the presented case-studies and the data they download from reliable resources (e.g., WHO), as well as the ability to conduct back-of-the-envelope calculations and design a sampling campaign to identify the impact of a suspected source and/or simple health studies to gauge the new situations they may encounter in their career. Specific learning outcomes include:

L1. Define tools and methods used to measure pollutant levels, characterize exposure, and assess risks.
L2. Analyze scientific data to quantify environmental burdens on human health.
L3. Use online data to quantify air hazards in real-world environments
L4. Use environmental data to evaluate existing and new policies for improving public health.

Readings (some of them will be uploaded to Courseworks)

- AirQ+ introduction: http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/airq-software-tool-for-health-risk-assessment-of-air-pollution
- Ali Z, Bhaskar SB. Basic statistical tools in research and data analysis. Indian Journal of Anaesthesia 2016; 60:662-9.
- Babatola SS. Global burden of diseases attributable to air pollution. *J Public Health Afr*. 2018;9(3):813. Published 2018 Dec 21. doi:10.4081/jphia.2018.813
- Bell, et al.: Prenatal exposure to fine particulate matter and birth weight: variations by particulate constituents and sources. *Epidemiology (Cambridge, Mass.)* 21(6): 884-891 (2010)
- BenMAP introduction: https://www.epa.gov/benmap
- Berner, Elizabeth Kay, and Robert A. Berner. Global environment: water, air, and geochemical cycles. 2nd Ed., Princeton University Press, 2012.
- Chillrud, S.N, D. Epstein, J. Ross, S. Ramstrom, D. Pederson, J.D. Spengler, and P. L. Kinney. 2004a. Elevated airborne exposures to manganese, chromium and iron of teenagers from steel dust and New York City's subway system. *Environ. Sci. Tech.*, 38:732-737. PMCID: PMC3142791
- Chillrud, SN, RF Bopp, HJ Simpson, J Ross, EL Shuster, DA Chaky, DC Walsh, CC Choy, LR Tolley and A. Yarme, Twentieth century metal fluxes into Central Park Lake, New York City, Environ. Sci. Technol. 33, 657-662, 1999.
- Cohen AJ, Brauer M, Burnett R, Anderson HR, et al., Forouzanfar MH. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. Lancet 2017; 389:1907-18.
- Cohen et al., 2014, Sustainability Metrics White Paper Series (3 in total), Columbia University Academi Commons, https://doi.org/10.7916/D8RN36RW.
- Duncan BN, et al. Satellite data of atmospheric pollution for U.S. air quality applications: Examples of applications, summary of data end-user resources, answers to FAQs, and common mistakes to avoid. Atmospheric Environment. 2014;94:647-62.
- Fullman, et al., Measuring progress and projecting attainment on the basis of past trends of the health-related Sustainable Development Goals in 188 countries: an analysis from the Global Burden of Disease Study 2016. The Lancet. 390(10100): p. 1423-1459.

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- Giordano MR, Malings C, Pandis SN, Presto AA, McNeill FV, Westervelt DM, Beekmann M, Subramanian R. 2021. From low-cost sensors to high-quality data: A summary of challenges and best practices for effectively calibrating low-cost particulate matter mass sensors . Journal of Aerosol Science 158 (2021) 105833
- Kampa, M. and Castanas, E., Human health effects of air pollution. Environmental Pollution, 2008. 151(2): p. 362-367.
- Lanphear BP, Hornung R, Khoury J, Yolton K, Baghurst P, Bellinger DC, Canfield RL, Dietrich KN, Bornschein R, Greene T, Rothenberg SJ, Needleman HL, Schnaas L, Wasserman G, Graziano J, Roberts R. Low-level environmental lead exposure and children's intellectual function: an international pooled analysis. Environ Health Perspect. 113, 894-899 (2005).
- Lim, Stephen S., 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 380.9859 (2012): 2224-2260.
- Mehaffy J, Miller-Lionberg D, Volckens J. 2020.   Effects of aerosol type and simulated aging on performance of low-cost PM sensors. Journal of Aerosol Science 150 (2020) 105654
- Murray, C.J.L., A.Y. Aravkin, P. Zheng, C. Abbafati, K.M. Abbas, M. Abbasi-Kangevari et al.: Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *The Lancet* 396(10258): 1223-1249 (2020).
- Naghavi, et al.., Global, regional, and national age-sex specific mortality for 264 causes of death, 1980-2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet, 2017. 390(10100): p. 1151-1210.
- Peel, JL and Smith, KR. "Mind the Gap." Environmental Health Perspectives. 2010; 118 (12): 1643-1645.
- Rodes, C. E., Chillrud, S. N., Haskell, W. L., Intille, S. S., Albinali, F., Rosenberger, M., 2012. Predicting Adult Pulmonary Ventilation Volume and Wearing Compliance by On-Board Accelerometry During Personal Level Exposure Assessments, Atmospheric Environment, 57: 126-137. PMCID: PMC3779692
- Smith CM, Chillrud SN, Jack DW, Kinney P, Yang Q, Layton AM. Laboratory Validation of Hexoskin Biometric Shirt at Rest, Submaximal Exercise, and Maximal Exercise While Riding a Stationary Bicycle. J Occup Environ Med. 2019 Apr;61(4):e104-e111. doi:
- Smith KR, et al; HAP CRA Risk Expert Group. Millions dead: how do we know and what does it mean? Methods used in the comparative risk assessment of household air pollution. Annu Rev Public Health. 2014;35:185-206. doi: 10.1146/annurev-publhealth-032013-182356. PMID: 24641558.
- Theis, T. and Klein-Banai, C., Problem-Solving, Metrics, and Tools for Sustainability. Sustainability: A Comprehensive Foundation', U of I Open Source Textbook Initiative, 2012: p. 423-488
- United Nations Environment Programme (2017) Towards a Pollution-Free Planet Background Report. United Nations Environment Programme, Nairobi, Kenya
- https://www.who.int/data/gho/data/indicators/indicator-details/GHO/ambient-and-household-air-pollution-attributable-death-rate-(per-100-000-population-age-standardized)
- Wilson, Richard, and John D. Spengler, eds. Particles in our air: concentrations and health effects. Harvard University Press, 1996.
- Wu, et al., Smoke plume optical properties and transport observed by a multi-wavelength lidar, sunphotometer and satellite. Atmos. Env., 2012, 63, 32-42.
- Yan, B.;Abrajano, T.A.;Bopp, R.F.;Chaky, D.A.;Benedict, L.;Chillrud, S.N., (2005) Molecular tracers of saturated and polycyclic aromatic hydrocarbon inputs into central park lake, new york city Environmental Science & Technology, 39(18), 7012-7019. PMCID: PMC3142882.
- Zou Y, Clark JD, May AA. 2021. A systematic investigation on the effects of temperature and relative humidity on the performance of eight low-cost particle sensors and devices. Journal of Aerosol Science 152 (2021) 10571

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Resources

Columbia University Library
Columbia's extensive library system ranks in the top five academic libraries in the nation, with many of its services and resources available online: http://library.columbia.edu/.

SPS Academic Resources
The Office of Student Affairs provides students with academic counseling and support services such as online tutoring and career coaching: http://sps.columbia.edu/student-life-and-alumni-relations/academic-resources.

Air monitors. Several air monitors that collect data in real-time will be available for student use, including black carbon monitors (https://aethlabs.com/microaeth), particulate monitors for personal (RTI microPEMs (*https://www.rti.org/sites/default/files/brochures/rti_micropem.pdf*) , Airbeams (Aircasting.org)) or for fixed site indoor or outdoor use (PurpleAir.org) and smart watch, etc.

Course Requirements (Assignments)

Four home assignments on global environmental status, exposure, and risk assessment, and GBD (L1, L2, L3, L4)

> The homework will gauge to which extent students are able to apply the material presented in class and the additional readings. The quizzes will each consist of several short problems requiring students to analyze and interpret data sets related to but not identical to the case-studies covered in class.

Mid-term quiz covering the global environmental status, toxicity and exposure parts (L1, L2, L3, L4)

> The take-home mid-term quiz will require students to apply the knowledge and tools learned in the class to comprehensively evaluate environment status, analyze human exposure and assess risk of air pollution in different rural and urban settings.

Final Group Project: analysis of air pollution and/or global burden of disease associated in a specific area (L1, L2, L3, L4)

> Environmental Measurements: Students will select their topics, including characterizing the personal exposures of pollutants for transport modes or different restaurant types in NYC, assessing risk for different countries, calculating burden of disease for countries with different development levels, conducting a research design in environment health, etc. The group will be formed based on selected topics and individual interests. Starting on the third lecture, example topics will be suggested in the class. On week 10, details about the topics, requirement, and approach for designing the study, collecting data, and data analysis will be discussed. The presentations will be given on Weeks 15 and 16. The presentation from each group will last about 20 minutes, followed by a 15 to 20 mins of discussion. The final report will be about 15-20 pages in length with double line spacing, and should include introduction, method, results, and discussion parts. The final report will be due May 8th.

Participation (L1, L2)

Class participation: students will come to class with readings completed and ready to participate in classroom discussions.

Evaluation/Grading

Take-home problem sets: four sets (40%, 10% each)

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Problem sets will be scored on a scale of 0-100.
Problem sets will be graded by the quality of the answers, including whether knowledge learned from class and readings are used correctly, clearness of the answers, etc.

Mid-term quiz (20%)
The quiz will be scored on a scale of 0-100.
The quiz will be graded by the quality of the answers, including whether knowledge learned from class and readings are used correctly, clearness of the answers, etc.

Final Group Project: Environmental Measurements (30%)
The final group presentation and report will be scored combined on a scale of 0-100.
Presentation will be graded based on a list of criteria, including whether the problem of hypothesis is clearly stated, the study design, methods are data analysis are explained, and whether the results and interpretation can be followed, as well as whether, the student(s) display knowledge during question and answering session. Each group member must have a defined role, including each student must have contributed in the final group presentation. Final report will be graded on the depth of their understanding, the merit of the writing, etc.

Participation (10%).
Participation in class discussions will count towards 10% of final grade. Students are expected to attend class and contribute at least one substantive comment every other week. Substantive comments include answering questions, defending your point of view, and/or challenging the point of view of others when appropriate.

The final grade will be calculated as described below:

FINAL GRADING SCALE

Grade	Percentage
A+	98–100 %
A	93–97.9 %
A-	90–92.9 %
B+	87–89.9 %
B	83–86.9 %
B-	80–82.9 %
C+	77–79.9 %
C	73–76.9 %
C-	70–72.9 %
D	60–69.9 %
F	59.9% and below

ASSIGNMENTS	% Weight
Homework 1, 2, 3, 4	40 (each 10%)
Week 10 Take Home	20
Group Project	30
Participation	10

Course Policies

Participation and Attendance

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You are expected to complete all assigned readings, attend all class sessions, and engage with others in online discussions. Your participation will require that you answer questions, defend your point of view, and challenge the point of view of others. If you need to miss a class for any reason, please discuss the absence with the instructors in advance.

Late work
There will be no credit granted to any written assignment that is not submitted on the due date noted in the course syllabus without advance notice and permission from the instructor.

Citation & Submission
All written assignments must use [citation format], cite sources, and be submitted to the course website (not via email).

School Policies

Copyright Policy
Please note—Due to copyright restrictions, online access to this material is limited to instructors and students currently registered for this course. Please be advised that by clicking the link to the electronic materials in this course, you have read and accept the following:

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted materials. Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement.

Academic Integrity
Columbia University expects its students to act with honesty and propriety at all times and to respect the rights of others. It is fundamental University policy that academic dishonesty in any guise or personal conduct of any sort that disrupts the life of the University or denigrates or endangers members of the University community is unacceptable and will be dealt with severely. It is essential to the academic integrity and vitality of this community that individuals do their own work and properly acknowledge the circumstances, ideas, sources, and assistance upon which that work is based. Academic honesty in class assignments and exams is expected of all students at all times.

SPS holds each member of its community responsible for understanding and abiding by the SPS Academic Integrity and Community Standards posted at http://sps.columbia.edu/student-life-and-alumni-relations/academic-integrity-and-community-standards. You are required to read these standards within the first few days of class. Ignorance of the School's policy concerning academic dishonesty shall not be a defense in any disciplinary proceedings.

Accessibility
Columbia is committed to providing equal access to qualified students with documented disabilities. A student's disability status and reasonable accommodations are individually determined based upon disability documentation and related information gathered through the intake process. For more information regarding this service, please visit the University's Health Services website: http://health.columbia.edu/services/ods/support.

Course Schedule/Course Calendar

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Date	Topics and Activities	Readings	Assignments
Week 1 01/18/22	**Overview of global environmental status (welcome to anthropocene)** Brief introduction of the course 1. Current status of environmental pollution, including a comparison of pre- and post-industrialization 2. Legacy and emerging contaminants (endocrine disruptors) 3. Brief introduction of temporal and country specific trends in environmental causes for Global Burden of Diseases 4. In-class activity: visit GBD website	Murray et al., *Lancet* 2020; 396: 1135–59 Chillrud et al., *ES&T,* 1999. Yan et al., *ES&T*, 2005 United Nations Environment Programme (2017) Towards a Pollution-Free Planet Background Report. United Nations Environment Programme, Nairobi, Kenya	
Week 2 01/25/22	**Source, Transport, and Fate of Air Pollutants (BY)** 1. Air circulation and mixing 2. EPA "criteria" air pollutants 3. Natural and anthropogenic sources of airborne particles, physics and chemistry of particle formation, 4. Transport of air pollutants 5. Chemical reactions during transport (primary and secondary pollutants) 6. In-class activity: downloading air pollutant data from AirNow	Wilson, Richard, and John D. Spengler, eds. *Particles in our air: concentrations and health effects*. Harvard University Press, 1996. Phalen, et al., *Introduction to Air Pollution Science: A Public Health Perspective* by. Jones & Bartlett Learning, 2013. Poschl, U., *Atmospheric aerosols: Composition, transformation, climate and health effects*, 2005. 44(46): p. 7520-7540	HW 1 (covering wk 1 to 4) out
Week 3 02/01/22	**Research Design for air Pollution (SNC)** 1. Various needs for investigating air pollution 2. Types of air pollution studies 3. Case study: Community-Based Participatory Research Pilot- assessing Nightime Diesel and Noise Emissions from Woodbine Rail Yard (Spring Valley) a. In-class activity: design an air pollution study to distinguish local vs regional sources, affected area, and/or personal exposure of children	Journal News, May 20, 24, July 10	
Week 4 02/08/22	**Air Pollution Measurement and Monitoring (SNC)** 2. Federal AQ Networks: AirNow Network, IMPROVE a. Air Quality index	EPA, Air Quality Index A Guide to Air Quality and Your Health, 2014 Smith & Peel, Mind the gap, EHP 2010	HW 1 due

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	3. New York City Community Air Survey (NYCCAS) 4. In-class activity: Low Cost Sensors: Fixed Site a. TEACH study to highlight study design options	Visiting the following websites: https://airnow.gov/index.cfm?action=airnow.main http://vista.cira.colostate.edu/Improve https://www1.nyc.gov/site/doh/data/data-publications/air-quality-nyc-community-air-survey.page Giordano et al 2021 Zou et al 2021 Tryner et al 2020	

Week 5
 	
02/15/22
	Characterizing exposure (SNC)
	
	1. Exposure pathway
	2. Factors affecting indoor pollutant level
	3. Factors affecting personal exposure and dose
	4. The development of smart samplers
	5. In-class activity:
	  a. Class training on how to use devices that can be taken home for projects
	    i. microAeth BC
	    ii. UPAS PM2.5
	    iii. CO/CO2
	    iv. Ultra Fine Particle Monitor
	    v. GPS logging
		Zartarian, et al., Basic Concepts and Definitions of Exposure and Dose, in book Exposure Analysis (pdf file will be provided)
		
		1) google book Chapters 1 and 2 of
		
		Exposure Analysis. 2006 Edited by Ott WR, Steinemann AC, and Wallace LA
		
		Rabionovitch et al. 2005; J Allergy Clin Immun;
		Chillrud et al. 2004,
		Kinney et al. 2001
		Chillrud et al 2005	

Week 6 02/22/22	**Introduction of Global Burden of Disease (BY)** 1. GBD history and assumptions 2. GBD 3.		HW 2 out
Week 7: 03/01/22	**Guest lecture, Prof. Allan Just from Icahn School of Medicine at Mount Sinai: The usage of satellite remote sensing data to measure air pollutants for health studies:** 1. Remote sensing approach to measuring aerosol optical depth (AOD) and ambient temperature 2. Method to estimated $PM_{2.5}$ based on AOD 3. Linking pollutant data with health 1. In-class activity: Download NASA AOD-derived $PM_{2.5}$ data and compare them with EPA AirNow data	Duncan, et al., Atmospheric Environment. 2014; 94:647-62.	

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	Project research ideas		
Week 8 03/08/22	**Introduction of EPA BenMAP** 1. Introduction of EPA BenMAP (Pete Maliloff) 2. Continue the discussion of research ideas	EPA BenMap installation Self-paced BenMAP training	HW 2 due HW 3 out
03/15/22	Spring break		
Week 9 03/22/22	**Using BenMao in foreign countries** 1. BenMap function selection 2. Download health function from GBD website 3. Use PM2.5 from BenMAP website 4. Use PM2.5 data from WUSTL 3. In-class activity: Introducing population data into BenMap	Kan, et al., 2009	
Week 10 03/29/22	**Guest Lecture: Prof. Kioumourtzoglou Exposure and Health Effects of Mixtures of Air Pollutants** 1. Introduction of matrix 2. Health outcomes of matrix 3. In-class activity: Discussion of how EBD estimates on HAP have changed over time.	**Bell, M.L., K. Belanger, K. Ebisu, J.F. Gent, H.J. Lee, P. Koutrakis et al.:** Prenatal exposure to fine particulate matter and birth weight: variations by particulate constituents and sources. *Epidemiology (Cambridge, Mass.)* 21(6): 884-891 (2010 Discussion on Smith et al 2014	HM 3 due Home Quiz out
Week 11 04/05/22	**Research design for Environmental Health (SNC)** 1. Different needs of Envir. Health (EH) investigation 2. Types of EH studies 3. Types of EH study design 4. In-class activity: design an EH research project on cardiovascular indicators of men living in area cooking with biomass fuels in poorly vented stoves.	Morgenstern, H. and Thomas, D., Principles of *study design in Environmental Epidemiology*. Environmental Health Perspectives, 1993. 101: p. 23-38. WHO, Health Research Methodology: A Guide for Training in Research Methods Second Edition, 2001 (Optional)	

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Week 12 04/12/22	**Source Apportionment and Risk Assessment of Environmental Pollutants (BY)** ~~2.~~1. Source Apportionment Methods ~~3.~~2. Dose-Response ~~4.~~3. Risk assessment procedure and tools ~~5.~~4. Limitation of current methods ~~6.~~5. In-class activity: download PMF model	EPA, Risk Assessment for Toxic Air Pollutants: A Citizen's Guide WHO, Health Risk Assessment of Air Pollution: General Principle, 2016 Wu, et al.,. *Atmos. Env.,* 2012, *63*, 32-42.	Hand in Group project ideas for approval Quiz due HW 4 out
Week 13 02/19/22	**Toxicity of air pollutants (BY)** 1. Internal dose 2. Particle deposition and clearance in the respiratory system 3. Toxicity of metals and organic pollutants 4. Acute and chronic effects	Stanek, et al., *Air Pollution Toxicology.* Toxicological Sciences, 2011. 120(suppl_1): p. S8-S27 Kampa, M. and Castanas, E., *Human health effects of air pollution.* Environmental Pollution, 2008. 151(2): p. 362-367. Bell's paper Rodes et al 2012 Smith et al 2019	
Week 14 04/26/22	**Use of environmental burden of disease in Sustainability Science (BY+SNC)** 1. Major sustainability metrics 2. Difference between environmental analysis and sustainability analysis Case study: Hydraulic fracturing in PA 3. The use of burden of disease in consideration of the sustainable development 4. In-class activity: Assessing risk of wildfire smoke plume CA Campfire vs long range transport for NYC residents	Cohen et al., 2014, Sustainability Metrics White Paper Series (3 in total), Columbia University, https://doi.org/10.7916/D8RN36RW. Theis, T. and Klein-Banai, C., *Problem-Solving, Metrics, and Tools for Sustainability.* Sustainability: A Comprehensive Foundation', University of Illinoi Open Source Textbook Initiative, 2012: p. 423-488 Fullman, et al., The Lancet. 2016, 390(10100): p. 1423-1459	HM4 due
Week 15 05/03/22	**Course Summary** **Draft Project Discussions**		

Week 16	**Group Project Presentations**		Group Final Report Due on May 13th, 2022
05/10/22			