COLUMBIA UNIVERSITY
School of Professional Studies

Master of Science in Sustainability Science

SUSC PS5140 Plastic Pollution and Sustainable Solutions

3 Credits

Instructors:	Beizhan Yan, Lamont Associate Research Professor in the Lamont-Doherty Earth Observatory, yanbz@ldeo.columbia.edu
Class Hours:	TBD
Office Hours:	TBD
TA Office Hours:	TBD
Response Policy:	Students can expect a response within 2 days. Email is our preferred mode of communication.

Course Overview
This course aims to equip students with the knowledge and tools necessary to understand and address plastic pollution from a multidisciplinary perspective, encouraging innovative and sustainable solutions. The course offers a comprehensive global perspective on the current state of plastic pollution, its primary causes, and the sustainable solutions being explored worldwide. The curriculum is divided into four main areas: 1) **Formation and Environmental Behavior** - We will explore how plastic pollution is generated and how it behaves in various environmental settings; 2) **Ecological and Health Impacts** - Students will learn about the effects of plastic pollution on ecosystems and human health, including the toxicity and potential targets of microplastics and nanoplastics; 3) **Sustainable Solutions** - The focus will be on the life cycle of plastics, emphasizing sustainable practices and technologies aimed at reducing plastic waste and pollution; 4) **Policy and Regulation** - We will analyze existing policies and regulations, assessing their effectiveness and limitations in combating plastic pollution. We will also review the status of the International Plastic Treaty spearheaded by the United Nations Environment Programme, discussing its strengths and limitations. Additionally, students will gain foundational knowledge in methodologies for measuring plastic pollution, laboratory procedures, and the evaluation of the toxicological impacts of microplastics and nanoplastics on various organisms.

Each weekly class will be divided into a lecture portion, hands-on data activity, and/or discussion portion. Students will have a chance to join discussions about environmental regulations, policies, and other efforts to mitigate the ecological impact and health outcomes caused by environmental exposures in both industrialized and developing nations. The class will also discuss the disproportionate burden of plastic pollution in marginalized communities. In-class, step-by-step instruction will be provided to help students learn how to find and download available online data from credible websites and how to conduct risk assessments and health impact analyses based on these data.

The course will provide students with the methods and tools to understand, monitor, and analyze current environmental threats from plastic pollution through various exposure pathways and explore strategies for policy interventions for lowering exposure over time given complex challenges. After completing the course, students will be able to more confidently apply core scientific concepts to evaluate challenges posed by plastic pollution and search for suitable solutions, covering aspects ranging from policy initiatives at various governmental levels to the latest scientific research and innovative environmental technologies. 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 plastic environmental issues. These useful skills could position students well in their future careers.

This course is designed to the Area of Scientific Tools for Responding to Sustainability Challenges requirement for the M.S. in Sustainability Science Program.

Master of Science in Sustainability Science

Learning Objectives

Students will be expected to gain an in-depth understanding of the sources, environmental behavior, and ecological and health impacts of plastic pollution, as well as solutions including policy interventions and novel techniques. Specific learning outcomes include:

L1. Comprehensively understand plastic pollution and its impact, taking into account the full plastic life cycle
L2. Identify and utilize tools and methods, including online data mining, for assessing plastic pollution and its impact on ecosystems and human health.
L3. Apply knowledge of sustainable solutions and life cycle analysis learned in this and other classes to reduce the plastic pollution footprint.
L4. Evaluate and critique policies and regulations aimed at reducing plastic pollution and improving environmental health.

Readings (most of them will be uploaded to Courseworks)

1 Stöfen-O'Brien, A. The Prospects of an International Treaty on Plastic Pollution. *The International Journal of Marine and Coastal Law* **37**, 727-740, doi:https://doi.org/10.1163/15718085-bja10108 (2022).
2 UNEP. From Pollution to Solution: A Global Assessment of Marine Litter and Plastic Pollution. (Nairobi, 2021).
3 UNEP. From solution to solution: a global assessment of marine litter and plastic pollution (UN Environment Nairobi, Kenya, 2022).
4 Qian, N. *et al.* Rapid single-particle chemical imaging of nanoplastics by SRS microscopy. *Proceedings of the National Academy of Sciences* **121**, e2300582121, doi:doi:10.1073/pnas.2300582121 (2024).
5 Geyer, R. *et al.* Quantity and fate of synthetic microfiber emissions from apparel washing in California and strategies for their reduction. *Environmental Pollution* **298**, 118835, doi:https://doi.org/10.1016/j.envpol.2022.118835 (2022).
6 Geyer, R., Jambeck, J. R. & Law, K. L. Production, use, and fate of all plastics ever made. *Science Advances* **3**, e1700782, doi:10.1126/sciadv.1700782 (2017).
7 Jambeck, J. R. *et al.* Plastic waste inputs from land into the ocean. *Science* **347**, 768, doi:10.1126/science.1260352 (2015).
8 Jenner, L. C. *et al.* Detection of microplastics in human lung tissue using μFTIR spectroscopy. *Sci Total Environ* **831**, 154907, doi:10.1016/j.scitotenv.2022.154907 (2022).
9 Li, H. *et al.* Expanding plastics recycling technologies: chemical aspects, technology status and challenges. *Green Chemistry* **24**, 8899-9002 (2022).
10 Boucher, J. & Friot, D. *Primary microplastics in the oceans: a global evaluation of sources*. Vol. 10 (Iucn Gland, Switzerland, 2017).
11 Fulgencio-Medrano, L. *et al.* Oil production by pyrolysis of real plastic waste. *Polymers* **14**, 553 (2022).
12 Nielsen, T. D., Hasselbalch, J., Holmberg, K. & Stripple, J. Politics and the plastic crisis: A review throughout the plastic life cycle. *Wiley Interdisciplinary Reviews: Energy and Environment* **9**, e360 (2020).
13 Simon, N. *et al.* A binding global agreement to address the life cycle of plastics. *Science* **373**, 43-47 (2021).
14 Nikiema, J. & Asiedu, Z. A review of the cost and effectiveness of solutions to address plastic pollution. *Environmental Science and Pollution Research* **29**, 24547-24573 (2022).
15 Moshood, T. D. *et al.* Sustainability of biodegradable plastics: new problem or solution to solve the global plastic pollution? *Current Research in Green and Sustainable Chemistry* **5**, 100273 (2022).
16 Marfella, R. *et al.* Microplastics and Nanoplastics in Atheromas and Cardiovascular Events. *New England Journal of Medicine* **390**, 900-910, doi:doi:10.1056/NEJMoa2309822 (2024).
17 Magadini, D. L. *et al.* Assessing the sorption of pharmaceuticals to microplastics through in-situ experiments in New York City waterways. *Science of the Total Environment* **729**, doi:10.1016/j.scitotenv.2020.138766 (2020).

18 Rochman, C. M., Hoh, E., Hentschel, B. T. & Kaye, S. Long-Term Field Measurement of Sorption of Organic Contaminants to Five Types of Plastic Pellets: Implications for Plastic Marine Debris. *Environmental Science & Technology* **47**, 1646-1654, doi:10.1021/es303700s (2013).
19 Aves, A. R. *et al.* First evidence of microplastics in Antarctic snow. *The Cryosphere* **16**, 2127-2145, doi:10.5194/tc-16-2127-2022 (2022).
20 Mitrano, D. Nanoplastic should be better understood. *Nature nanotechnology* **14**, 299, doi:10.1038/s41565-019-0437-7 (2019).
21 Bourtsalas, A. C., Yepes, I. M. & Tian, Y. U.S. plastic waste exports: A state-by-state analysis pre- and post-China import ban. *Journal of Environmental Management* **344**, 118604, doi:https://doi.org/10.1016/j.jenvman.2023.118604 (2023).
22 Yu, Z. Y., Jiang, L. & Yin, D. Q. Behavior toxicity to Caenorhabditis elegans transferred to the progeny after exposure to sulfamethoxazole at environmentally relevant concentrations. Journal of Environmental Sciences 23, 294-300, doi:10.1016/s1001-0742(10)60436-6 (2011).
23 Cole, M. et al. Microplastic ingestion by zooplankton. Environ Sci Technol 47, 6646-6655, doi:10.1021/es400663f (2013).
24 Kannan, K. & Vimalkumar, K. A Review of Human Exposure to Microplastics and Insights Into Microplastics as Obesogens. Frontiers in Endocrinology 12, doi:10.3389/fendo.2021.724989 (2021).
25 World Health Organization. Dietary and inhalation exposure to nano-and microplastic particles and potential implications for human health. Report No. 924005460X, (2022).
26 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
27 Idumah, C. I. & Nwuzor, I. C. Novel trends in plastic waste management. SN Applied Sciences 1, 1-14 (2019).
28 Siddiqui, J. & Pandey, G. A review of plastic waste management strategies. Int. Res. J. Environ. Sci 2, 84 (2013)
29 Amobonye, A., Bhagwat, P., Raveendran, S., Singh, S. & Pillai, S. Environmental impacts of microplastics and nanoplastics: a current overview. Frontiers in Microbiology 12, 768297 (2021).
30 Sana, S. S., Dogiparthi, L. K., Gangadhar, L., Chakravorty, A. & Abhishek, N. Effects of microplastics and nanoplastics on marine environment and human health. Environmental Science and Pollution Research 27, 44743-44756 (2020).
31 Cary, C. M. et al. Single inhalation exposure to polyamide micro and nanoplastic particles impairs vascular dilation without generating pulmonary inflammation in virgin female Sprague Dawley rats. Part Fibre Toxicol 20, 16, doi:10.1186/s12989-023-00525-x (2023).
32 Fournier, S. B. et al. Nanopolystyrene translocation and fetal deposition after acute lung exposure during late-stage pregnancy. Particle and Fibre Toxicology 17, 55, doi:10.1186/s12989-020-00385-9 (2020).

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.

Course Requirements (Assignments)

Four home assignments on global environmental status, exposure, and ecological and health impacts, and policy (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.

Home quiz covering the global environmental status, exposure, and ecological parts (L1 & L2)

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

Final Group Project: (L1, L2, L3, L4)

Students will select their topics, including those covered in the class. 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, requirements, 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 15 to 20 minutes of discussion. The final report will be about 15-20 pages in length with double line spacing and should include an introduction, method, results, and discussion parts. The final report will be due one week after the presentation.

Participation (L1, L2, L3, L4)

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)
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.

Home quiz (15%)
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, the clearness of the answers, etc.

Final Group Project (35%)
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 hypothesis is clearly stated, the study design, methods are data analysis are well 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 to the final group presentation. The 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 9 Take Home	15
Group Project	35
Participation	10

Course Policies

Participation and Attendance
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:

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

Date	**Topics and Activities**	**Readings**	**Assignments**
Week 1	**Overview of Global Plastic Pollution (Welcome to anthropocene)** 1. Brief introduction to the course 2. Current status of plastic pollution 3. In-class activity: visiting several major websites e.g., the MacArthur Foundation, Global Plastic Solutions	Geyer, et al., 2017 Jambeck, et al., 2015 Nielsen, et al., 2017 Aves et al., 2021	HW 1 out
Week 2	**Unintended and Intended Plastic Wastes** 1. Introduction to plastic waste by intended (signal-use and packaging materials) and unintended activities (e.g., wear and tear) 2. Solid waste management 3. Dumping plastic waste on the Global South 4. In-class activity: Role-playing on policy development. Divide students into groups, assigning each a role:	Idumah et al., 2019 Siddiqui et al., 2013 Bourtsalas et al., 2023	

	government officials, environmental NGOs, plastic manufacturers, community leaders, and waste management companies.		
Week 3:	**Environmental Behavior of Plastic Wastes** 1. Weathering 2. Transport and fate of plastics 3. Macroplastics, microplastics, and nanoplastics 4. In-class activity: Microscope observation of weathered plastics.	Qian, *et al., 2024* Magadini, et al., 2022 Rochman et al., 2013	HW1 due HW2 out
Week 4	**Ecological Impacts** 1. Impact on terrestrial and freshwater ecosystems 2. Impact on marine ecosystems 3. Microplastics and nanoplastics: ecological penetration 4. In-class activity: International Pellet Watch	Magadini, et al., 2022 Rochman, et al., 2013 Amobonye, et al., 2021 Sana, et al., 2020	
Week 5	**Toxicity of Microplastic and Nanoplastics** 1. Penetration 1st and 2nd biological barriers 2. Leaching of plastic additives 3. Nanotoxicity 4. Animal experiments 5. In-class activity: introducing EPA toxicity tool	Jenner et al., 2022 Cole, et al, 2013 Yu, et al., 2013 Mitrano et al., 2021	HW2 due
Week 6	**Exposure Pathways** 1. Inhalation 2. Ingestion 3. In-class activity: scientific tools used to characterize exposure	Jenner et al., 2022 Kannan, et al., 2021 WHO, 2022	Hand in Group project ideas for approval HW3 out
Week 7	**Health Outcomes (Guest lecturer Prof. Phoebe Stapleton from Rutgers)** 1. Immune responses 2. Placenta and other 2nd biological barriers 3. Oxidative stress and inflammation 4. Diseases 5. Review of materials covered (~20 mins)	Jenner et al., 2022 Marfella, et al., 2023 Cary, et al., 2023 Fournier, et al., 2020	
	Spring break		

Week 9	**Solution 1: Reduction in Usage and Replacement** 1. Four Rs: Reduce, Reuse, Recycle, and Recover 2. Approaches of reduction and reuse 3. Bioplastics 4. Pros and cons of bioplastics 5. In-class activity: Q/A for Midterm Quiz	Li, et al., 2022 Nielsen, et al., 2017 Nikiema, et al., 2021 Moshood, et al., 2022	HW3 due Home Quiz out
Week 10	**Solution 2: Recycle and Recover** 1. Recycling approach 2. Combustion of plastics for energy 3. Pyrolysis to oil 4. In-class activity: Discuss NYC solid waste management	Fulgencio-Medrano et al., 2022 Li, et al., 2022 Nikiema, et al., 2021	
Week 11	**Solution 3: Sustainable Solutions** 1. Extended producer responsibility 2. Major criteria of sustainable solutions 3. Case studies, including Dr. Yan's laundry study 4. In-class activity: shedding rate of various textiles	Cohen et al., 2014, Theis, et al., 2012	
Week 12	**Life Cycle Analysis of Plastics** **(Guest lecture by Dr. Thanos Boursalas)** **1.** Current models **2.** Major findings **3.** In-class activity: Open accessed models	Bourtsalas, 2023 Nielsen, et al., 2017 Simon, et al., 2021	Quiz Due HW4 out
Week 13	**UNEP Plastic Treaty (Guest Lecture from Prof. Professor Cymie Payne at Rutgers Law School)** 1. Contents of the treaty 2. Strengths and limitations 3. Resources provided for developing countries 4. In-class activity: Ranking countries' plastic pollution level and their approaches to control **Proposal presentations of group projects** Students present group project proposals to class (~ 30 mins)	Stöfen-O'Brien, 2022 UNEP, 2021 UNEP, 2022 Simon, 2021	
Week 14	**Environmental Justice of plastic pollution** **(co-lecture with Ms. Antoinette Wannebo)** 1. Global map of open landfills 2. Income vs. distances to pollution sites 3. Plastic usage impacted by income 4. In-class activity: The life of Indonesia plastic collectors	https://globalplasticwatch.org/map Bourtsalas, et al., 2023	HW4 due
Week 15	**Course Summary**		

	Draft project discussions		
Week 16	**Group Project Presentations**		