2. Safeguarding Human Health Against Plastics and Petrochemicals: A Scientific and Moral Imperative

Sarah Dunlop, Yannick Mulders, Louise Goodes, Hervé Raps, and Philip J. Landrigan

---

Plastics are the signature material of our age. They have supported extraordinary advances in virtually every area of human endeavor, and they have made our daily lives very convenient. However, it is now clear that plastics are neither as safe nor as inexpensive as they seem. Plastics' benefits come at great and increasingly visible costs to human health, the environment and social justice.[1]

Plastics cause disease, disability, and premature death at every stage of their cycle—from extraction of the crude oil, fracked gas, and coal that are their main feedstocks, through transport, manufacture, use, recycling, and on to disposal into the environment as plastic waste. These harms are not equitably distributed. They fall disproportionately on the poor, minorities, and the marginalized. Groups at particularly high risk are fossil fuel extraction workers; chemical and plastic production workers; informal waste and recovery workers; persons living near fracking wells, pipelines, rail lines and compressor stations; people living in "fenceline" communities adjacent to plastic production facilities; Indigenous communities; and people in the Global South. Children and pregnant women are at especially high risk. These groups did not create the plastics crisis. They do not profit from it. They lack the power to address it. Yet they suffer its most severe consequences. They are victims of social and environmental injustice on a planetary scale.

---

[1] Philip J. Landrigan, Hervé Raps, Maureen Cropper, Caroline Bald, Manuel Brunner, Elvia Maya Canonizado, et al., "The Minderoo-Monaco Commission on Plastics and Human Health," *Annals of Global Health* 89, no. 1 (2023): doi.org/10.5334/aogh.4056.

Because plastics harm human health across their life cycle, especially among vulnerable populations, magnify social and environmental injustices, and violate human rights, the global plastics crisis is more than an environmental challenge. Like climate change, air pollution, biodiversity loss, and escalating inequality, the plastics crisis is also a social and ethical challenge.[2] It is another example of humanity's reckless strip-mining of the earth's resources and mortgaging of humanity's future for short-term economic gain.[3]

To examine the global plastics crisis through the dual perspectives of science and ethics and bring moral clarity to the conversation on control of plastics' harms, Boston College convened an international conference, "Joining Science and Theology to End Plastic Pollution, Protect Health, and Advance Social Justice," on October 4–5, 2024.[4] This chapter, based on presentations made by the authors at the conference, summarizes current information on plastics' harms to human health, the environment and the economy, drawing heavily on the findings and conclusions of the Minderoo-Monaco Commission on Plastics and Human Health.[5] Moreover, this chapter notes the disproportionate impacts of these harms on the poor and the vulnerable. It also offers some preliminary thoughts on strategies for joining science with moral theology to create ethically-

---

[2] Francis, *Laudato Si': On Care for Our Common Home* (2015), www.vatican.va/content/francesco/en/encyclicals/documents/papa-francesco_20150524_enciclica-laudato-si.html.

[3] Sarah Whitmee, Andy Haines, Chris Beyrer, Frederick Boltz, Anthony G. Capon, Braulio Ferreira de Souza Dias, et al., "Safeguarding Human Health in the Anthropocene Epoch: Report of the Rockefeller Foundation-Lancet Commission on Planetary Health," *Lancet* 386, no. 10007 (2015): 1973–2028.

[4] Boston College, "Joining Science and Theology to End Plastic Pollution, Protect Health, and Advance Social Justice" (2024), www.bc.edu/content/bc-web/academics/sites/ila/events/Plastic-Pollution-conference.html#tab-about_the_conference.

[5] Landrigan, et al., "The Minderoo-Monaco Commission on Plastics and Human Health."

sound solutions to the plastics crisis and the other great planetary challenges of our age.[6]

Human Health Impacts of Plastic Production

Global Health Impacts

Plastics are complex manufactured chemical materials. They are composed of a carbon-based polymer matrix plus more than sixteen thousand chemical additives.[7] Almost ninety-nine percent of plastic polymers and additives are made from fossil fuels—oil, gas, and coal.[8]

Plastic production is highly energy-intensive, and virtually all of the energy required for plastic manufacture comes from fossil fuel combustion.[9] The resulting greenhouse gas emissions accounted for an estimated four percent of global emissions in 2020.[10] While the production phase of plastic is the main source of greenhouse gas emissions, end-of-life

---

[6] Philip J. Landrigan, Jacqui Remond, Paolo Gomarasca, Thomas C. Chiles, Ella M. Whitman, and Lilian Ferrer, "*Laudato Si'* and the Emerging Contribution of Catholic Research Universities to Planetary Health," *Lancet Planetary Health* 8, no. 3 (2024): e140–e141, doi.org/10.1016/S2542-5196(24)00012-3.

[7] Delilah Lithner, Åke Larsson, and Göran Dave, "Environmental and Health Hazard Ranking and Assessment of Plastic Polymers Based on Chemical Composition," *Science of the Total Environment* 409, no. 18 (2011): 3309–3324.

[8] Center for International Environmental Law (CIEL), "Fueling Plastics: Fossils, Plastics, and Petrochemical Feedstocks," (2017), www.ciel.org/wp-content/uploads/2017/09/Fueling-Plastics-Fossils-Plastics-Petrochemical-Feedstocks.pdf; Almut Reichel, Xenia Trier, Ricardo Fernandez, Ioannis Bakas, and Bastian Zeiger, *Plastics, the Circular Economy and Europe's Environment: A Priority for Action* (European Environment Agency, 2021).

[9] Livia Cabernard, Stephan Pfister, Christopher Oberschelp, and Stefanie Hellweg, "Growing Environmental Footprint of Plastics Driven by Coal Combustion," *Nature Sustainability* 5, no. 2 (2022): 139–148.

[10] International Energy Agency, "Global Energy Review 2021: Assessing the Effects of Economic Recoveries on Global Energy Demand and Co2 Emissions in 2021" (2021), www.iea.org/reports/global-energy-review-2021.

phase emissions associated with plastic waste burning also contribute, accounting for nearly ten percent of total emissions.[11] Today's enormous and ever-increasing production, use and disposal into the environment of virgin plastics (504 Mt [milli] in 2022) and other petrochemicals threatens the safe operating space for humanity.[12] Single-use plastic packaging, especially food packaging, is the largest contributor to plastic waste.

Local Health Impacts

Plastic production creates extensive hazards for human health and the environment, with fossil fuel extraction, plastic production workers, plastic waste pickers, and residents of vulnerable "fenceline" communities living closely adjacent to production facilities suffering the most.[13]

Fossil Fuel Extraction: Particulate Matter Pollution

Extraction of oil, gas, and coal for plastic manufacture produces extensive airborne particulate matter (PM) pollution, which arises from mining, drilling, transport, wells and flaring.[14] Exposure to airborne PM pollution contributes to disease and premature death in workers and nearby fenceline communities. Fine PM can penetrate deep into the lungs, increasing risk in adults for cardiovascular disease, stroke, chronic

---

[11] Jiajia Zheng and Sangwon Suh, "Strategies to Reduce the Global Carbon Footprint of Plastics," *Nature Climate Change* 9, no. 5 (2019): 374–378, doi.org/10.1038/s41558-019-0459-z.

[12] Patricia Villarrubia-Gómez, Bethanie Carney Almroth, Marcus Eriksen, Morten. Ryberg, and Sarah E. Cornell, "Plastics Pollution Exacerbates the Impacts of All Planetary Boundaries," *One Earth* 7, no. 12 (2024): 2119–2138.

[13] Jason D. Rivera and Steve Lerner, "Sacrifice Zones: The Front Lines of Toxic Chemical Exposure in the United States," *Community Development* 52, no. 5 (2021): 630–631.

[14] Dara O'Rourke and Sarah Connolly, "Just Oil? The Distribution of Environmental and Social Impacts of Oil Production and Consumption," *Annual Review of Environment and Resources* 28 (2003): 587–617.

obstructive pulmonary disease, lung cancer and diabetes,[15] as well as dementia,[16] and in infants and children increasing risk for premature birth and low birth weight (which themselves are risk factors for chronic diseases in adult life), stillbirth,[17] impaired lung development and asthma,[18] as well as IQ loss, memory deficits, behavioural dysfunction, reductions in brain volume, and increased risks of attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD).[19] Coal dust inhalation results in further specific health impacts in miners, including pneumoconiosis, silicosis and emphysema[20] and in increasing respiratory infections for exposed nearby communities.[21]

Fossil Fuel Extraction: Ozone Pollution and Other Pollutant Emissions

---

[15] GBD Risk Factors Collaborators, "Global Burden of 87 Risk Factors in 204 Countries and Territories, 1990–2019: A Systematic Analysis for the Global Burden of Disease Study 2019," *Lancet* 396, no. 10258 (2020): 1223–1249.

[16] Eirini Dimakakou, Helinor J. Johnston, George Streftaris, and John W. Cherrie, "Exposure to Environmental and Occupational Particulate Air Pollution as a Potential Contributor to Neurodegeneration and Diabetes: A Systematic Review of Epidemiological Research," *International Journal of Environmental Research and Public Health* 15, no. 8 (2018), doi.org/10.3390/ijerph15081704.

[17] Bruce Bekkar, Susan Pacheco, Rupa Basu, and Nathaniel DeNicola, "Association of Air Pollution and Heat Exposure with Preterm Birth, Low Birth Weight, and Stillbirth in the US: A Systematic Review," *JAMA Netw Open* 3, no. 6 (2020): e208243, doi.org/10.1001/jamanetworkopen.2020.8243.

[18] Molini M. Patel and Rachel L. Miller, "Air Pollution and Childhood Asthma: Recent Advances and Future Directions," *Current Opinion in Pediatrics* 21, no. 2 (2009): 235–242.

[19] Heather E. Volk, Frederica Perera, Joseph M. Braun, et al., "Prenatal Air Pollution Exposure and Neurodevelopment: A Review and Blueprint for a Harmonized Approach Within Echo," *Environmental Research* 196 (2021): 110320, doi.org/10.1016/j.envres.2020.110320.

[20] Long Fan and Shimin M. Liu, "Respirable Nano-Particulate Generations and Their Pathogenesis in Mining Workplaces: A Review," *International Journal of Coal Science & Technology* 8, no. 2 (2021): 179–198.

[21] Juciano Gasparotto and Kátia Da Boit Martinello, "Coal as an Energy Source and Its Impacts on Human Health," *Energy Geoscience* 2, no. 2 (2021): 113–120.

Ground-level ozone is formed in the air surrounding gas and oil extraction sites.[22] It is a respiratory irritant that is especially dangerous for children and the elderly. Exposure can lead to asthma and chronic obstructive pulmonary disease.[23]

Fossil Fuel Extraction: Other Pollutant Emissions

Conventional oil, gas and coal extraction, and unconventional extraction of oil and gas—i.e., fracking—expose "fenceline" communities and workers to multiple hazardous emissions including gases (e.g., methane, carbon monoxide, sulphur dioxide), heavy metals such as mercury, solvents (benzene, xylene, toluene) and other volatile organic compounds (VOCs).[24] A range of health impacts are linked to these exposures. For example, some VOCs can cause damage to the liver, kidneys, and central nervous system,[25] others increase risk of neuropathy and asthma,[26] while

---

[22] Christopher S. Malley, Daven K. Henze, Johan C. I. Kuylenstierna, Harry W. Vallack, Yanko Davila, Susan C. Anenberg, et al., "Updated Global Estimates of Respiratory Mortality in Adults >/=30years of Age Attributable to Long-Term Ozone Exposure," *Environmental Health Perspectives* 125, no. 8 (2017): 087021, doi.org/10.1289/EHP1390.

[23] Theo Colborn, Kim Schultz, Lucille Herrick, and Carol Kwiatkowski, "An Exploratory Study of Air Quality near Natural Gas Operations," *Human and Ecological Risk Assessment* 20, no. 1 (2014): 86–105.

[24] Landrigan, et al., "The Minderoo-Monaco Commission on Plastics and Human Health."

[25] Wen-Tien Tsai, "An Overview of Health Hazards of Volatile Organic Compounds Regulated as Indoor Air Pollutants," *Reviews on Environmental Health* 34, no. 1 (2019): 81–89.

[26] Diane A. Garcia-Gonzales, Seth B. C. Shonkoff, Jake Hays, and Michael Jerrett, "Hazardous Air Pollutants Associated with Upstream Oil and Natural Gas Development: A Critical Synthesis of Current Peer-Reviewed Literature," *Annual Revue of Public Health* 40 (2019): 283–304; Mary D. Willis, Todd A. Jusko, Jill S. Halterman, and Elaine L. Hill, "Unconventional Natural Gas Development and Pediatric Asthma Hospitalizations in Pennsylvania," *Environmental Research* 166 (2018): 402–408.

still others are known carcinogens, such as benzene, 1,3-butadiene and formaldehyde, causing leukemia and lymphoma in adults and children.[27]

Fossil Fuel Extraction: Fracking

Fracking, the extraction of gas and oil from underground shale deposits by hydraulic fracturing, is a chemically intensive process, involving chemicals that are harmful to both reproduction and development.[28] Fracking operations release large quantities of particulates and toxic chemicals to air and water. These pollutants have potential to cause respiratory disease, cardiovascular disease, and cancer, as well as kidney, liver and neurological damage.[29] Epidemiological studies conducted among persons born or living near fracking sites have found health impacts in infants, including preterm birth and reduced birth weight,[30] elevated rates of childhood cancer, especially leukemia, and congenital heart defects.[31]

---

[27] Julia E. Heck, Andrew S. Park, Jiaheng Qiu, Myles Cockburn, and Beate Ritz, "Risk of Leukemia in Relation to Exposure to Ambient Air Toxics in Pregnancy and Early Childhood," *International Journal of Hygiene and Environmental Health* 217, no. 6 (2014): 662–668.

[28] Elise G. Elliott, Adrienne S. Ettinger, Brian P. Leaderer, Michael B. Bracken, and Nicole C. Deziel, "A Systematic Evaluation of Chemicals in Hydraulic-Fracturing Fluids and Wastewater for Reproductive and Developmental Toxicity," *Journal of Exposure Science & Environmental Epidemiology* 27, no. 1 (2017): 90–99.

[29] Lisa M. McKenzie, Roxana Z. Witter, Lee S. Newman, and John L. Adgate, "Human Health Risk Assessment of Air Emissions from Development of Unconventional Natural Gas Resources," *Science of the Total Environment* 424 (2012): 79–87.

[30] Elaine L. Hill and Lala Ma, "Drinking Water, Fracking, and Infant Health," *Journal of Health Economics* 82 (2022), doi.org/10.1016/j.jhealeco.2022.102595.

[31] Lisa M. McKenzie, William Allshouse, and Stephen Daniels, "Congenital Heart Defects and Intensity of Oil and Gas Well Site Activities in Early Pregnancy," *Environment International* 132 (2019), doi.org/10.1016/j.envint.2019.104949; Lisa M. McKenzie, William B. Allshouse, Tim E. Byers, Edward J. Bedrick, Berrin Serdar, and John L. Adgate, "Childhood Hematologic Cancer and Residential Proximity to Oil and Gas Development," *Plos One* 12, no. 2 (2017), doi.org/10.1371/journal.pone.0170423.

Petrochemical Refining, Ethane Cracking and Plastic Production

The large-scale industrial processes that convert fossil carbon into plastic expose workers and "fenceline" communities to multiple airborne pollutants and toxic chemicals including monomers (e.g., vinyl chloride, styrene and 1,3-butadiene), benzene, formaldehyde, toluene, phthalates and bisphenols. These materials are released into air, water and soil within workplaces and in neighboring communities.[32] Exposure to the carcinogens benzene and 1,3-butadiene causes leukemias and lymphomas.[33] Other chemical pollutants associated with plastic production increase risk of lung and breast cancer,[34] anemia, pre-term birth and low birth weight, asthma and other respiratory problems,[35] hypertension, heart disease, stroke, and kidney disease.[36]

Catastrophic Events

Plastic production is associated with extreme exposures that occur during catastrophic failures of the plastic production process, such as fires and

[32] Landrigan, et al., "The Minderoo-Monaco Commission on Plastics and Human Health."
[33] Heck, et al., "Risk of Leukemia in Relation to Exposure to Ambient Air Toxics in Pregnancy and Early Childhood."
[34] Cheng-Kuan Lin, Yu-Tien Hsu, David C. Christiani, Huei-Yang Hung, and Ro-Ting Lin, "Risks and Burden of Lung Cancer Incidence for Residential Petrochemical Industrial Complexes: A Meta-Analysis and Application," *Environment International* 121 (2018): 404–414.
[35] Montse Marquès, José L. Domingo, Martí Nadal, and Marta Schuhmacher, "Health Risks for the Population Living near Petrochemical Industrial Complexes. 2. Adverse Health Outcomes Other than Cancer," *Science of the Total Environment* 730 (2020), doi.org/10.1016/j.scitotenv.2020.139122.
[36] Ogochukwu Chinedum Okoye, Elaine Carnegie, and Luca Mora, "Air Pollution and Chronic Kidney Disease Risk in Oil and Gas- Situated Communities: A Systematic Review and Meta-Analysis," *International Journal of Public Health* 67 (2022): 1604522, doi.org/10.3389/ijph.2022.1604522.

explosions,[37] oil spills, and chemical spills. These events are associated with burns, traumatic injuries, and loss of life, as well as with massive releases of toxic materials to the environment.

Human Health Impacts of Plastic Recycling and Waste Disposal

An estimated 350 million tons of plastic waste are produced globally each year, and an estimated six billion tons, seventy-five percent of all plastic ever made, pollute the planet.[38] This waste causes extensive contamination of the environment, including the ocean,[39] and it threatens the lives of two billion people worldwide with eleven million waste pickers lacking safe workplaces and protective equipment.[40] Strategies for end-of-life waste management of plastic waste include both formal and informal recycling, landfilling, controlled and uncontrolled burning. All of these result in release of hazardous materials to the environment[41] and human exposure.

---

[37] Bluefield Process Safety, "External Plant Fires: What's the Likelihood?" (2017), www.bluefieldsafety.com/2017/09/external-plant-fires-whats-the-likelihood/; Pipeline and Hazardous Materials Safety Administration (PHMSA), and US Department of Transportation, "Pipeline Incident 20 Year Trends" (2022), www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-incident-20-year-trends.

[38] Roland Geyer, Jenna R. Jambeck, and Kara L. Law, "Production, Use, and Fate of All Plastics Ever Made," *Science Advances* 3, no. 7 (2017), doi.org/10.1126/sciadv.1700782.

[39] Richard C. Thompson, Ylva Olsen, Richard P. Mitchell, Anthony Davis, Steven J. Rowland, Anthony W. G. John, et al., "Lost at Sea: Where Is All the Plastic?" *Science* 304, no. 5672 (2004): 838–838.

[40] Costas A. Velis and Ed Cook, "Mismanagement of Plastic Waste Through Open Burning with Emphasis on the Global South: A Systematic Review of Risks to Occupational and Public Health," *Environmental Science & Technology* 55, no. 11 (2021): 7186–7207.

[41] Organisation for Economic Co-operation and Development (OECD), *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options* (OECD Publishing, 2022).

Recycling

Plastic recycling, known variously as chemical recycling, mechanical recycling, enhanced recycling, pyrolysis, and upcycling is highly ineffective. Despite exaggerated claims by the plastic industry about the effectiveness of recycling, less than ten percent of all plastic is recycled globally. Plastic recycling and reuse lags far behind paper, glass, and aluminum recycling. Toxic chemical content and complexity are the major impediments.[42] Different polymers cannot be commingled in making recycled products, and recycled plastics cannot safely be incorporated into materials such as food packaging, clothing, or children's toys because they contain toxic chemicals.[43] For example, black plastic products made from recycled e-waste contain high concentrations of flame retardants including legacy flame retardants.[44]

Landfilling

Landfills containing waste plastic generate airborne gas emissions and cause contamination of ground and surface water by plastic-associated chemicals such as benzene, toluene, ethylbenzene, xylene and naphthalene.[45] Residential proximity to a landfill increases cancer risk.

---

[42] Landrigan, et al., "The Minderoo-Monaco Commission on Plastics and Human Health."
[43] Birgit Geueke, Drake W. Phelps, Lindsey V. Parkinson, and Jane Muncke, "Hazardous Chemicals in Recycled and Reusable Plastic Food Packaging," *Cambridge Prisms: Plastics* 1, no. e7 (2023), doi.org/10.1017/plc.2023.7.
[44] Megan Liu, Sicco H. Brandsma, and Erika Schreder, "From E-Waste to Living Space: Flame Retardants Contaminating Household Items Add to Concern About Plastic Recycling," *Chemosphere* 365 (2024): 143319, doi.org/10.1016/j.chemosphere.2024.143319.
[45] Ayesha Siddiqua, John N. Hahladakis, and Wadha Ahmed K. A. Al-Attiya, "An Overview of the Environmental Pollution and Health Effects Associated with Waste Landfilling and Open Dumping," *Environmental Science and Pollution Research* 29, no. 39 (2022): 58514–58536.

E-Waste

Electronic waste (e-waste), which consists largely of plastics plus thousands of other petrochemicals and metals, results in exposure to a wide range of hazardous materials including flame retardants, plasticizers, bisphenols, dioxins, toxic metals and particulate matter.[46] Additional toxic pollutants are produced when e-waste burns. E-waste's greatest hazards are seen at enormous e-waste disposal sites located in low-income and middle-income countries. Pregnant women and children are severely affected, and health effects include stillbirth, preterm birth, lower birth weight, reduced cognition, loss of IQ points, ADHD and behavioral problems.[47] Further impacts are decreased immune function and changed thyroid function as well as compromised lung function, respiratory symptoms, and asthma. Chronic diseases appearing later in life are also common and include cancer, cardiovascular disease, obesity, and osteoporosis.[48]

Incineration

Uncontrolled burning of plastic waste is a major source of pollution, especially in low- and middle-income countries. It generates airborne particulate matter and a wide range of hazardous chemicals including heavy metals, volatile organic compounds, toxic gases, and dioxins.[49] Health impacts include endocrine disruption, reproductive and

---

[46] Chunmiao M. Jia, Pallab Das, Insup Kim, Yong-Jin Yoon, Chor Yong Tay, and Jong-Min Lee, "Applications, Treatments, and Reuse of Plastics from Electrical and Electronic Equipment," *Journal of Industrial and Engineering Chemistry* 110 (2022): 84–99.

[47] World Health Organization, "Children and Digital Dumpsites" (2021), iris.who.int/handle/10665/341718.

[48] World Health Organization, "Children and Digital Dumpsites."

[49] Okunola A. Alabi, Kehinde I. Ologbonjaye, Oluwaseun Awosolu, and Olufiropo E. Alalade, "Public and Environmental Health Effects of Plastic Wastes Disposal: A Review," *Journal of Toxicology and Risk Assessment* 5, no. 1 (2019), doi.org/10.23937/2572-4061.1510021.

developmental disorders, altered thyroid function, increased risk of cognitive defects, respiratory and cutaneous symptoms, and cancer.[50]

Human Health Impacts from the Use of Plastics Products

Plastic Releases Harmful Chemicals

The more than 16,000 chemicals involved in plastics production include those added intentionally to impart functionality, such as plasticizers, flame retardants, UV light stabilizers, and heat stabilizers, as well as "non-intentionally added substances" (NIAS).[51] More than 4,200 plastic additives are chemicals of concern of which approximately 3,600 are not regulated globally. Moreover, no hazard information is available for over ten thousand plastic additives.[52] NIAS include impurities, contaminants from machinery, as well as degradation and transformation products of the original constituent chemicals. Impacts are also seen from plastic polymers themselves in terms of the constituent chemicals, human exposure and health impacts.[53]

Plastic additives, unreacted monomers, and NIAS are for the most part not chemically bonded to the polymer matrix and can leach out of plastic

---

[50] Landrigan, et al., "The Minderoo-Monaco Commission on Plastics and Human Health."

[51] United Nations Environment Programme (UNEP), and Secretariat of the Basel, Rotterdam, and Stockholm Conventions, "Chemicals in Plastics: A Technical Report" (2023), www.unep.org/resources/report/chemicals-plastics-technical-report; Helene Wiesinger, Zhanyun Y. Wang, and Stefanie Hellweg, "Deep Dive into Plastic Monomers, Additives, and Processing Aids," *Environmental Science & Technology* 55, no. 13 (2021): 9339–9351.

[52] Martin Wagner, Laura Monclús, Hans Peter H. Arp, et al., *State of the Science on Plastic Chemicals: Identifying and Addressing Chemicals and Polymers of Concern* (2024), zenodo.org/records/10701706.

[53] Bhedita J. Seewoo, Enoch V. S. Wong, Yannick R. Mulders, Louise M. Goodes, Ela Eroglu, Manuel Brunner, et al., "Impacts Associated with the Plastic Polymers Polycarbonate, Polystyrene, Polyvinyl Chloride, and Polybutadiene Across Their Life Cycle: A Review," *Heliyon* 10, no. 12 (2024), doi.org/10.1016/j.heliyon.2024.e32912.

products such as drink containers, food containers,[54] and baby food pouches.[55] They contaminate air, food, water, house dust, and the food chain, and they enter the bodies of living organisms, including humans.

Plastic Chemicals Are Ubiquitous in the Human Body

Plastic chemicals are found in seminal fluid,[56] follicular fluid, amniotic fluid, cord blood,[57] meconium,[58] children's and adult's blood and urine,[59] breast milk, and hair,[60] as well as in solid tissues such as liver, brain, breast

---

[54] Lisa Zimmermann, Martin Scheringer, Birgit Geueke, Justin M. Boucher, Lindsey V. Parkinson, Ksenia J. Groh, and Jane Muncke, "Implementing the EU Chemicals Strategy for Sustainability: The Case of Food Contact Chemicals of Concern," *Journal of Hazardous Materials* 437 (2022), doi.org/10.1016/j.jhazmat.2022.129167.

[55] Cheng Tang, Maria Jose Gomez Ramos, Amy Heffernan, Sarit Kaserzon, Cassandra Rauert, Chun-Yin Lin, et al., "Evaluation and Identification of Chemical Migrants Leached from Baby Food Pouch Packaging," *Chemosphere* 340 (2023): 139758, doi.org/10.1016/j.chemosphere.2023.139758.

[56] Elena Sánchez-Resino, Montse Marquès, Daniel Gutiérrez-Martín, Esteban Restrepo-Montes, Maria Angeles Martínez, Albert Salas-Huetos, et al., "Exploring the Occurrence of Organic Contaminants in Human Semen Through an Innovative Lc-Hrms-Based Methodology Suitable for Target and Nontarget Analysis," *Environmental Science & Technology* 57, no. 48 (2023): 19236–19252.

[57] Merve Buke Sahin, Murat Cagan, Anil Yirun, Aylin Balci Ozyurt, Selinay Basak Erdemli Kose, Irem Iyigun, et al., "Bisphenol Derivatives in Cord Blood and Association between Thyroid Hormones and Potential Exposure Sources," *International Journal of Environmental Health Research* 34, no. 8 (2024): 3036–3045.

[58] JiaLin Guo, Min Wu, Xi Gao, JingSi Chen, ShuGuang Li, Bo Chen, and RuiHua Dong, "Meconium Exposure to Phthalates, Sex and Thyroid Hormones, Birth Size, and Pregnancy Outcomes in 251 Mother-Infant Pairs from Shanghai," *International Journal of Environmental Research and Public Health* 17, no. 21 (2020), doi.org/10.3390/ijerph17217711.

[59] Christos Symeonides, Edoardo Aromataris, Yannick Mulders, Janine Dizon, Cindy Stern, Timothy Hugh Barker, et al., "An Umbrella Review of Meta-Analyses Evaluating Associations Between Human Health and Exposure to Major Classes of Plastic-Associated Chemicals," *Annals of Global Health* 90, no. 1 (2024), doi.org/10.5334/aogh.4459.

[60] Zhenwu Tang, Qifei Huang, Jiali Cheng, Yufei Yang, Jun Yang, Wei Guo, et al., "Polybrominated Diphenyl Ethers in Soils, Sediments, and Human Hair in a Plastic

tissue, and adipose tissue. National biomonitoring surveys detect several hundred plastic-associated chemicals in the bodies of virtually all humans of all ages.[61]

Impacts of Plastic Chemicals on Human Health

A large and growing body of evidence indicates that chemicals from plastic products are responsible for disease, disability, and premature death. These harms to health result in very large economic costs, and these impacts fall disproportionately on the poor and the vulnerable. Five classes of plastics chemicals—i.e., the monomer Bisphenol A (BPA), phthalate plasticisers, polychlorinated biphenyl (PCBs) flame retardants, and their polybrominated diphenyl ether (PBDEs) replacements—as well as some perfluoroalkyl and polyfluoroalkyl substances (PFAS) have been especially closely studied. Quantitative analysis encompassing ~1,000 meta-analyses of ~1.5m men, women and children exposed to one or more of these five chemicals and chemical classes shows consistent and statistically significant (95%) evidence for harm to human health.[62]

Health impacts of plastics chemicals in infants include miscarriage, and reduced birthweight, which diminishes children's ability to thrive and increases early mortality. In children, harms include IQ loss, asthma, obesity, insulin resistance (leading to type 2 diabetes) and high blood pressure (leading to cardiovascular disease). Harms in adults include type II diabetes, obesity, cardiovascular disease and cancer.[63] Recent hybrid epidemiological studies have reported that BPA exposure during

---

Waste Recycling Area: A Neglected Heavily Polluted Area," *Environmental Science & Technology* 48, no. 3 (2014): 1508–1516.

[61] US Centers for Disease Control and Prevention, "National Biomonitoring Program," (2024), www.cdc.gov/biomonitoring/index.html.

[62] Symeonides, et al., "An Umbrella Review of Meta-Analyses Evaluating Associations between Human Health and Exposure to Major Classes of Plastic-Associated Chemicals."

[63] Symeonides, et al., "An Umbrella Review of Meta-Analyses Evaluating Associations between Human Health and Exposure to Major Classes of Plastic-Associated Chemicals."

pregnancy acts through genetic and testosterone metabolic pathways to increase risk of autism in boys by over three-fold at age two and over six-fold at age nine.[64] Plastic-associated chemicals have negative impacts also on human reproduction, which include reduced sperm counts, sperm DNA damage, male and female reproductive birth defects, endometriosis, and polycystic ovarian syndrome.

The majority of chemicals in plastics have not been tested for toxicity, and therefore no information is available on their potential harms to human health.[65] Examination of approximately 1500 chemicals commonly used in plastic, comprising bisphenols, plasticisers, flame retardants, some PFAS and polymers, found that fewer than twenty-five percent have been studied in humans.[66] Equally concerning, chemicals identified as being harmful to human health are too often replaced by other chemicals that are also harmful, a process termed "regrettable substitution." Examples include replacement of BPA with its analogues Bisphenol S and Bisphenol F,[67] and replacement of flame-retardant PCBs with PBDEs[68] and organophosphorus flame retardants.[69]

---

[64] Christos Symeonides, Kristina Vacy, Sarah Thomson, Sam Tanner, Hui Kheng Chua, Shilpi Dixit, et al., "Male Autism Spectrum Disorder Is Linked to Brain Aromatase Disruption by Prenatal BPA in Multimodal Investigations and 10HDA Ameliorates the Related Mouse Phenotype," *Nature Communications* 15, no. 1 (2024), doi.org/10.1038/s41467-024-48897-8.

[65] Wagner, et al., *State of the Science on Plastic Chemicals: Identifying and Addressing Chemicals and Polymers of Concern*.

[66] Bhedita J. Seewoo, Louise M. Goodes, Louise Moffin, Yannick R. Mulders, Enoch V. S. Wong, Priyanka Toshniwal, et al., "The Plastic Health Map: A Systematic Evidence Map of Human Health Studies on Plastic-Associated Chemicals," *Environment International* 181 (2023), doi.org/10.1016/j.envint.2023.108225.

[67] Katherine Pelch, Jessica A. Wignall, Alexandra E. Goldstone, Pam K. Ross, Robyn B. Blain, Andrew J. Shapiro, et al., "A Scoping Review of the Health and Toxicological Activity of Bisphenol-a (BPA) Structural Analogues and Functional Alternatives," *Toxicology* 424 (2019), doi.org/10.1016/j.tox.2019.06.006.

[68] Symeonides, et al., "An Umbrella Review of Meta-Analyses Evaluating Associations between Human Health and Exposure to Major Classes of Plastic-Associated Chemicals."

[69] Zohra Chupeau, Nathalie Bonvallot, Fabien Mercier, Barbara Le Bot, Cecile Chevrier, and Philippe Glorennec, "Organophosphorus Flame Retardants: A Global Review of

Another concern is that most epidemiological studies evaluate the health impacts of only one plastic chemical (e.g., BPA) or one class of chemicals (e.g., phthalates) at a time. In reality, however, humans including pregnant women and newborn infants are exposed to mixtures of chemical which often act through similar biological pathways, such as endocrine disruption.[70] Little information is available as to whether these whether chemical mixture interactions are additive, antagonistic, or synergistic.

Plastics Break Down into Chemically Laden Micro- and Nanoplastic Particles

Plastics break down during use and following disposal into the environment into small particles (micro- and nanoplastics [MNPs]).[71] Sources of MNPs include everyday products such as water bottles, teabags, food packaging,[72] synthetic textiles and recycling,[73] as well as landfills and

---

Indoor Contamination and Human Exposure in Europe and Epidemiological Evidence," *International Journal of Environmental Research and Public Health* 17, no. 18 (2020), doi.org/10.3390/ijerph17186713.

[70] Nicolò Caporale, Michelle Leemans, Lina Birgersson, Pierre-Luc Germain, Cristina Cheroni, Gábor Borbély, et al., "From Cohorts to Molecules: Adverse Impacts of Endocrine Disrupting Mixtures," *Science* 375, no. 6582 (2022): 735, doi.org/10.1126/science.abe8244.

[71] Richard C. Thompson, Winnie Courtene-Jones, Julien Boucher, Sabine Pahl, Karen Raubenheimer, and Albert A. Koelmans, "Twenty Years of Microplastic Pollution Research: What Have We Learned?" *Science* 386, no. 6720 (2024), doi.org/10.1126/science.adl2746.

[72] Yang Yu, Nicholas Craig, and Lei Su, "A Hidden Pathway for Human Exposure to Micro- and Nanoplastics—The Mechanical Fragmentation of Plastic Products During Daily Use," *Toxics* 11, no. 9 (2023), doi.org/10.3390/toxics11090774.

[73] Michael J. Stapleton, Ashley J. Ansari, Aziz Ahmed, and Faisal I. Hai, "Evaluating the Generation of Microplastics from an Unlikely Source: The Unintentional Consequence of the Current Plastic Recycling Process," *Science of the Total Environment* 902 (2023), doi.org/10.1016/j.scitotenv.2023.166090; Go Suzuki, Natsuyo Uchida, Kosuke Tanaka, Osamu Higashi, Yusuke Takahashi, Hidetoshi Kuramochi, et al., "Global Discharge of

informal dumpsites.[74] MNPs are disseminated globally in the air, the ocean, fresh water, soil, household dust, food and drink, and they act as sources of human exposure.[75] MNPs leach their constituent chemicals—i.e., plastic additives and NIAS—into the environment and into living organisms, including humans.[76] They act also as vectors of contaminants including heavy metals and pesticides as well as of pathogenic bacteria.[77]

Chemical-laden MNPs Enter the Human Body and May Harm Health

MNPs are increasingly detected in human tissue. Reflecting inhalation and ingestion as major exposure routes, microplastics have been reported

---

Microplastics from Mechanical Recycling of Plastic Waste," *Environmental Pollution* 348 (2024), doi.org/10.1016/j.envpol.2024.123855.

[74] Mosarrat Samiha Kabir, Hong Wang, Stephanie Luster-Teasley, Lifeng Zhang, and Renzun Zhao, "Microplastics in Landfill Leachate: Sources, Detection, Occurrence, and Removal," *Environmental Science and Ecotechnology* 16 (2023), doi.org/10.1016/j.ese.2023.100256; Seewoo, et al., "Impacts Associated with the Plastic Polymers Polycarbonate, Polystyrene, Polyvinyl Chloride, and Polybutadiene across Their Life Cycle: A Review"; Yong Wan, Xin Chen, Qian Liu, Hongjuan Hu, Chenxi Wu, and Qiang Xue, "Informal Landfill Contributes to the Pollution of Microplastics in the Surrounding Environment," *Environmental Pollution* 293 (2022), doi.org/10.1016/j.envpol.2021.118586.

[75] World Health Organization, "Microplastics in Drinking-Water" (2019), www.who.int/publications/i/item/9789241516198; World Health Organization, "Dietary and Inhalation Exposure to Nano- and Microplastic Particles and Potential Implications for Human Health" (2022), www.who.int/publications/i/item/9789240054608.

[76] Yage Li, Chen Liu, Haotian Yang, Wenhui He, Beibei Li, Xinyi Zhu, et al., "Leaching of Chemicals from Microplastics: A Review of Chemical Types, Leaching Mechanisms, and Influencing Factors," *Science of the Total Environment* 906 (2024), doi.org/10.1016/j.scitotenv.2023.167666.

[77] Vasiliki Kinigopoulou, Ioannis Pashalidis, Dimitrios Kalderis, and Ioannis Anastopoulos, "Microplastics as Carriers of Inorganic and Organic Contaminants in the Environment: A Review of Recent Progress," *Journal of Molecular Liquids* 350 (2022), doi.org/10.1016/j.molliq.2022.118580.

in lung and gut,[78] but also in placenta, breast milk, blood, testes and brain.[79] These reports require verification as measurement techniques continue to be refined.

Evidence of human health impacts from MNPs is beginning to emerge. Synthetic textile workers occupationally exposed to high levels of microplastics suffer a wide range of lung diseases, including shortness of breath, cough, respiratory failure, as well as lung and large bowel cancer.[80] Fecal microplastic load is reported to correlate with the severity of inflammatory bowel disease[81] and liver cirrhosis.[82] Patients with MNPs in carotid arterial plaques had a four-fold increased risk of myocardial infarction, stroke, or death from any cause compared to those in whom MNPs were not detected.[83] While measurement techniques have limitations, an increasing body of *in vitro* and animal laboratory studies link MNPs to a wide range of harmful impacts including inflammation

---

[78] Luis Fernando Amato-Lourenço, Regiani Carvalho-Oliveira, Gabriel Ribeiro, Luciana dos Santos Galvao, Romulo Augusto Ando, and Thais Mauad, "Presence of Airborne Microplastics in Human Lung Tissue," *Journal of Hazardous Materials* 416 (2021), doi.org/10.1016/j.jhazmat.2021.126124.

[79] Marthinus Brits, Martin J. M. van Velzen, Feride Öykü Sefiloglu, Lorenzo Scibetta, Quinn Groenewoud, Juan J. Garcia-Vallejo, et al., "Quantitation of Micro and Nanoplastics in Human Blood by Pyrolysis-Gas Chromatography-Mass Spectrometry," *Microplastics and Nanoplastics* 4, no. 1 (2024): 12, doi.org/10.1186/s43591-024-00090-w; Thompson, et al., "Twenty Years of Microplastic Pollution Research: What Have We Learned?"

[80] Joana C. Prata, "Airborne Microplastics: Consequences to Human Health?" *Environmental Pollution* 234 (2018): 115–126.

[81] Zehua H. Yan, Yafei F. Liu, Ting Zhang, Faming M. Zhang, Hongqiang Ren, and Yan Zhang, "Analysis of Microplastics in Human Feces Reveals a Correlation between Fecal Microplastics and Inflammatory Bowel Disease Status," *Environmental Science & Technology* 56, no. 1 (2022): 414–421.

[82] Thomas Horvatits, Matthias Tamminga, Beibei Liu, Marcial Sebode, Antonella Carambia, Lutz Fischer, et al., "Microplastics Detected in Cirrhotic Liver Tissue," *Ebiomedicine* 82 (2022), doi.org/10.1016/j.ebiom.2022.104147.

[83] Raffaele Marfella, Francesco Prattichizzo, Celestino Sardu, Gianluca Fulgenzi, Laura Graciotti, Tatiana Spadoni, et al., "Microplastics and Nanoplastics in Atheromas and Cardiovascular Events," *New England Journal of Medicine* 390, no. 10 (2024): 900–910.

and oxidative stress.[84] In light of this growing evidence, a precautionary regulatory approach is absolutely critical.[85]

Plastic and Social Justice

Plastics' harms to health are not evenly or fairly distributed. In addition to disproportionately harming children, plastics' harms are inequitably distributed amongst adults. Groups especially heavily exposed include people of color, Indigenous populations, fossil fuel extraction workers, chemical and plastic production workers, informal waste and recovery workers, and persons living in "fenceline" communities adjacent to fossil fuel extraction, plastic production, and plastic waste facilities. These groups experience disproportionately high risks of disease, disability, and death caused by plastic as well as experience increased risks of premature birth, low birth weight, asthma, leukemia, cardiovascular disease, chronic obstructive pulmonary disease, and lung cancer.

Economic Impacts of Plastic Production

The disease and premature death caused by plastics result in major economic costs. These health-related losses fall into two categories: health care costs and productivity costs resulting from lost income due to disease, disability, and premature death. The Minderoo-Monaco Commission analysed these health-related costs for the year 2015 and estimated that the health-related costs of plastic production were $592 billion (in PPP dollars) globally.[86] The Commission found additionally that the costs of disease linked to

---

[84] Arifur Rahman, Atanu Sarkar, Om Prakash Yadav, Gopal Achari, and Jaroslav Slobodnik, "Potential Human Health Risks Due to Environmental Exposure to Nano-and Microplastics and Knowledge Gaps: A Scoping Review," *Science of the Total Environment* 757 (2021), doi.org/10.1016/j.scitotenv.2020.143872.

[85] Thompson, et al., "Twenty Years of Microplastic Pollution Research: What Have We Learned?"

[86] Landrigan, et al., "The Minderoo-Monaco Commission on Plastics and Human Health."

three plastic chemicals were $675 billion in the USA alone: diethyl hexyl ortho-phthalate (DEHP) plasticiser for all-cause mortality, PBDEs flame retardants for IQ point loss in children, and BPA for heart-attack and stroke.[87] The total annual health-related economic losses related to plastic in 2015 were thus $1.2 trillion.[88]

A more recent study examining the health-related costs associated with the same three plastic-associated chemicals but for a much larger population—i.e., thirty-eight countries amounting to one third of the world's population—put these estimates even higher at around $1.5 trillion.[89] Another study on the same chemical classes estimated that disease and associated costs were equivalent to 1.22% of the US gross domestic product.[90] Estimated health costs of PFAS exposure in the US were approximately $22 billion in 2018.[91]

The Minderoo-Monaco Commission noted that these economic estimates substantially undercount the full costs of disease and death caused by plastics, since they are based on only a subset of the exposed global population, cover only a fraction of the chemicals known to be used in plastic, and are limited to those health outcomes that to date have been recognized and quantified. Moreover, they consider the consequences of exposures to only one chemical at a time, while in reality humans are simultaneously exposed to multiple chemicals[92] and the possibly

[87] Landrigan, et al., "The Minderoo-Monaco Commission on Plastics and Human Health."
[88] Landrigan, et al., "The Minderoo-Monaco Commission on Plastics and Human Health."
[89] Maureen Cropper, Sarah Dunlop, Hudson Hinshaw, Philip Landrigan, Yongjoon Park, and Christos Symeonides, "The Benefits of Removing Toxic Chemicals from Plastics," *Proceedings of the National Academy of Sciences of the United States of America* 121, no. 52 (2024), doi.org/10.1073/pnas.2412714121.
[90] Leonardo Trasande, Roopa Krithivasan, Kevin Park, Vladislav Obsekov, and Michael Belliveau, "Chemicals Used in Plastic Materials: An Estimate of the Attributable Disease Burden and Costs in the United States," *Journal of the Endocrine Society* 8, no. 2 (2024), doi.org/10.1210/jendso/bvad163.
[91] Trasande, et al., "Chemicals Used in Plastic Materials."
[92] Aolin L. Wang, Dimitri Panagopoulos Abrahamsson, Ting Jiang, Miaomiao Wang, Rachel Morello-Frosch, June-Soo Park, et al., "Suspect Screening, Prioritization, and

synergistic health effects of these multiple, simultaneous exposures have not yet been examined.

Hence, the health-related costs of plastics are largely externalized by the plastic production industry and imposed on governments, taxpayers, and individual citizens.

Polymer Production is Heavily Subsidised

Governments in many countries provide major subsidies and tax breaks for fossil fuel feedstock extraction, energy generation, and polymerisation. Global estimates of the magnitude of these subsidies are $43 billion in 2024 rising to $78 billion by 2050.[93] Saudi Arabia accounted for the majority at $38 billion in 2024 and $64 billion in 2050. Modelling suggests that removing subsidies for plastic production would increase consumer prices only minimally (bottled water: 0.75%; bottled soft drink: 0.17%; clothing: 0.16%; flooring 1.53%; agriculture 3.16%).[94]

The human health costs resulting from exposures to plastic-associated chemicals are much larger than the subsidies provided by governments to plastic producers. This creates an ethical imbalance in which plastic producers and fossil fuel corporations are rewarded economically for creating harms to health that fall disproportionately on the poorest and most vulnerable members of societies.

Confirmation of Environmental Chemicals in Maternal-Newborn Pairs from San Francisco," *Environmental Science & Technology* 55, no. 8 (2021): 5037–5049.

[93] Eunomia and Quaker United Nations Office (QUNO), "Plastic Money: Turning Off the Subsidies Tap. Phase 2 Report," (2024), eunomia.eco/wp-content/uploads/2024/11/Plastic-Production-Subsidies-Modelling-Phase-2-report-v1.0.pdf.

[94] Eunomia and Quaker United Nations Office (QUNO), "Plastic Money."

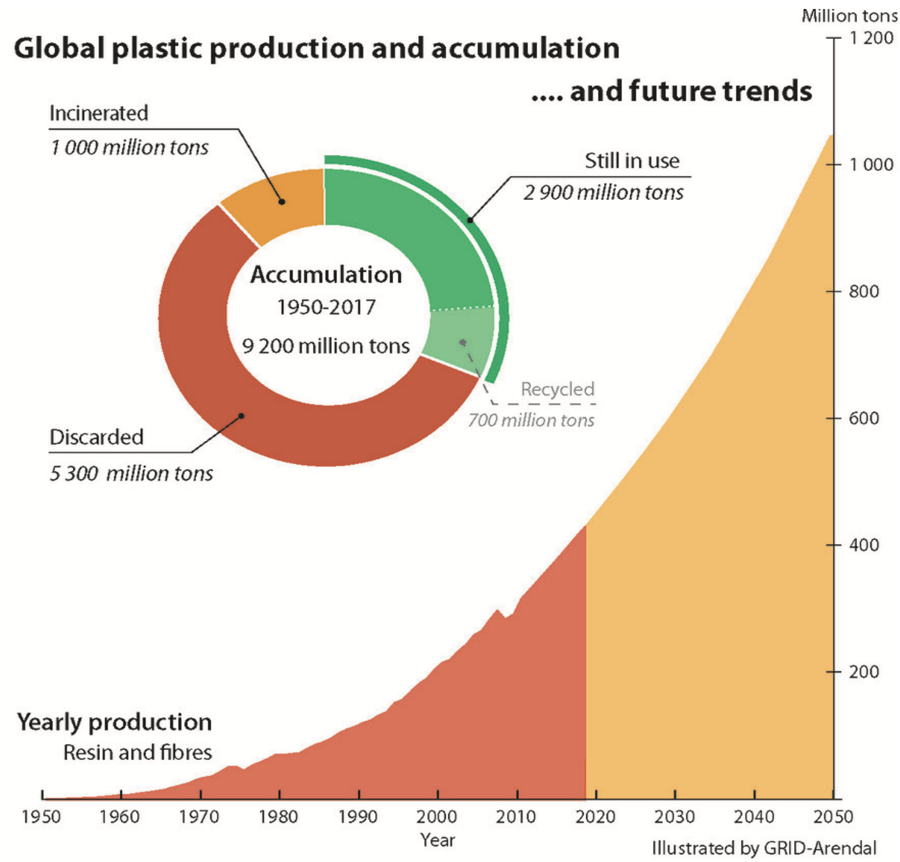
Plastic Production Is Increasing Exponentially

Relentless increases in production are the main driver of plastics' worsening harms to human health and the global environment. Global plastic output has grown over 200-fold; from two million tons in 1950 to more than 450 million tons today. It is projected to double again by 2040 and treble by 2060 (Figure 1). Single-use plastic accounts for thirty-five to forty percent of current production, is the most rapidly growing fraction of plastic manufacture, and contributes disproportionately to plastic waste.[95] As plastic production continues to grow, so does plastic pollution with a strong log-log linear relationship between the two.[96]

---

[95] Organisation for Economic Co-operation and Development (OECD), *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options*; Organisation for Economic Co-operation and Development (OECD), *Global Plastics Outlook: Policy Scenarios to 2060* (OECD Publishing, 2022).

[96] Win Cowger, Kathryn A. Willis, Sybil Bullock, Katie Conlon, Jorge Emmanuel, Lis M. Erdle, et al., "Global Producer Responsibility for Plastic Pollution," *Science Advances* 10, no. 17 (2024), doi.org/10.1126/sciadv.adj8275; Paul Stegmann, Vassilis Daioglou, Marc Londo, Detlef P. P. van Vuuren, and Martin Junginger, "Plastic Futures and Their CO₂ Emissions," *Nature* 612, no. 7939 (2022): 272–276.



UNEP (2021). From Pollution to Solution: A global assessment of marine litter and plastic pollution. Nairobi.

Figure 1.

Solutions

Technical Solutions

To address the global plastics crisis and reduce plastics' harms to human health and the environment, nations and states have begun to pass laws and implement policies.

Since 2008, Rwanda has banned the manufacture, import, and use of plastic bags.[97] In February 2020, Rwanda launched an awareness campaign for ending single use plastics such as disposable dishes, plastic bottles, straws, coffee stirrers, and disposable cutlery. This was followed by a legal ban on single-use plastics in 2019. These laws are supported by strict enforcement and severe penalties. They have resulted in nationwide reduction in plastic pollution.

California legislation enacted in 2022 (SB 54) will require plastic producers to pay $500 million a year for ten years starting in 2027 for environmental mitigation and to address harms caused by plastics to disadvantaged, low-income, and rural communities.[98] California also passed legislation (SB 1137) to protect the health of California's "fenceline" communities by creating a minimum health and safety distance of 3,200 feet between sensitive receptors (such as a residences, schools, childcare facilities, playgrounds, hospitals, and nursing homes) and oil and gas production wells.[99]

To bring these actions to global scale, the UN Environment Assembly adopted a historic resolution on March 2, 2022, to develop a global plastics treaty. The stated goal of this treaty is to reduce plastic pollution, including ocean pollution and microplastics, across the entire plastic life cycle. Treaty negotiations are on a fast track. To date, an Intergovernmental Negotiating Committee (INC) has met five times with a sixth meeting scheduled for 2025. A plastics treaty that prioritizes protection of human health will contain two key provisions—a cap on production of new plastics and strict regulation of plastic-associated chemicals. More than one

---

[97] Janvier Hakuzimana, "Break Free from Plastics: Environmental Perspectives and Evidence from Rwanda," *Environment & Ecosystem Science* 5, no. 1 (2021): 27–36.

[98] California Legislative Information, "Senate Bill No. 54 Solid Waste: Reporting, Packaging, and Plastic Food Service Ware" (2022), leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220SB54.

[99] California Legislative Information, "Senate Bill No. 1137 Oil and Gas: Operations: Location Restrictions: Notice of Intention: Health Protection Zone: Sensitive Receptors" (2022), leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220SB1137.

hundred nations, the High Ambition Coalition, support these provisions in the treaty negotiations. However, the plastics and petrochemical industries as well as major petrostates, led by Saudi Arabia and Russia, oppose these provisions. Negotiations will continue in 2025.

Sustainable Solutions

Technical and legal solutions to planetary problems such as the Global Plastics Treaty are important, necessary, and frequently effective, as seen in the sharp declines in chlorofluorocarbon manufacture that resulted from the Montreal Protocol,[100] reductions in air pollution following passage of national clean air laws,[101] and global bans on the manufacture of persistent organic pollutants under the Stockholm Convention.[102] All of these solutions have, however, been reactive. They have been developed only after recognition of a threat. None has looked beyond the problem at hand. None offers protection against hazards yet to come.

Sustainable protection against current and future dangers will require solutions that extend beyond specific threats. Such solutions go beyond one-off technical and legal solutions and address the underlying political, economic, and ethical causes of plastic pollution, climate change, and other components of the current planetary crisis. Likewise, assessment of the impacts of these deeper solutions will require metrics that go beyond

---

[100] Ashley Woodcock, "Hydrofluorocarbons, Climate, and Health: Moving the Montreal Protocol Beyond Ozone-Layer Recovery," *New England Journal of Medicine* 388, no. 26 (2023): 2404–2406.

[101] Jason Price, Sahil Gulati, Jacob Lehr, and Stefani Penn, "The Benefits and Costs of U.S. Air Pollution Regulations" (2020), https://www.nrdc.org/sites/default/files/iec-benefits-costs-us-air-pollution-regulations-report.pdf.

[102] Heidelore Fiedler, Roland Kallenborn, Jacob de Boer, and Leiv K. Sydnes, "The Stockholm Convention: A Tool for the Global Regulation of Persistent Organic Pollutants," *Chemistry International* 41, no. 2 (2019): 4–11.

gross domestic product (GDP) and explicitly value human and natural capital.[103]

In his 2015 encyclical letter *Laudato Si': On Care for Our Common Home*, the late Pope Francis (1936–2025) examines the current planetary crises, offers insights into their root causes, and suggests strategies for planetary restoration and regeneration. With the integration of science and theology, Francis breaks through the stereotype, dating to the time of Galileo Galilei (1564–1642), that there is an inherent conflict between science and religion, and he opens the way for new solutions based on both faith and reason. Drawing on science, Francis argues that there is "an urgent need" to reduce greenhouse gas emissions, control pollution, replace fossil fuels, and encourage the development of renewable energy.[104] Drawing on theology, he argues that climate change, pollution, and biodiversity loss are not only environmental problems, but also moral injustices—affronts to human dignity.

For Pope Francis, sustainable strategies for healing the planet must be based on both the best science and the most rigorous ethical analysis. These strategies need to be scientifically sound, and they need to be just. He urges humankind to move beyond one-off solutions, to examine the structures and metrics used to manage our economy, and to reimagine how these structures could be redesigned for the benefit of all. He states that every solution to the planetary crisis must incorporate "a preferential option for the poorest"[105] and restore "dignity to the excluded."[106] He terms this approach integral ecology. Integral ecology is a powerfully holistic concept that moves ecologic thinking beyond purely green concerns and puts people in the landscape. It is anchored in Francis' view that the Earth is a

[103] Pushpam Kumar, ed., *Mainstreaming Natural Capital and Ecosystem Services into Development Policy* (Routledge/Taylor & Francis Group, 2019).
[104] Francis, *Laudato Si'*, no. 26.
[105] Francis, *Laudato Si'*, no. 158.
[106] Francis, *Laudato Si'*, no. 139.

shared inheritance, a "common home," whose "fruits are meant to benefit everyone."[107]

Declaration

Acting on the recognition that the plastic crisis has an ethical and a moral dimension, the October 2024 Boston College conference, "Joining Science and Theology to End Plastic Pollution, Protect Health, and Advance Social Justice," issued a Declaration stating that:

> Continuing unchecked increases in plastic production are unethical and immoral.[4] They threaten all life on earth. Those who advocate for unchecked growth in plastics must re-examine their behavior, embrace the reality that the earth is a shared inheritance—a gift from the Creator, and work toward a more equitable and sustainable future. All of us have a shared responsibility to be good stewards of God's creation.[108]

This Declaration was endorsed by Prince Albert II of Monaco and by multiple religious leaders of many faiths, including the Dalai Lama, Patriarch Bartholomew of Constantinople, prominent rabbis, and Christian theologians—Catholic, mainstream Protestant, and evangelical Protestant—as well as women and men of faith who recognize humanity's responsibility to protect our small blue planet and protect all life.

Going forward, it is our hope that negotiations for the UN Global Plastics Treaty will incorporate the best science, consider the moral and ethical dimension of the plastic crisis, and act responsibly in light of those considerations to prioritize the protection of human health.

---

[107] Francis, *Laudato Si'*, no. 93.

[108] The Declaration can be found in Chapter 15 of this volume.

Sarah Dunlop, PhD, is Emerita Professor, University of Western Australia. Her medical research career focused on brain development and recovery following chemical and physical injury to the brain, spinal cord and peripheral nervous system, including randomised controlled trials. She joined Minderoo Foundation in 2020 to establish and lead the Plastics and Human Health Impact Mission. Dr. Dunlop's previous roles include Accorded Status, Royal Perth Hospital; Director, Spinal Cord Injury Network; President, Australian Neuroscience Society; President, Federation of Australasian & Oceanian Neuroscience Societies.

Yannick Mulders received his PhD from the University of Western Australia on research focusing on temperate reef ecology. He joined the Minderoo Foundation in 2021 and is Advisor Researcher in the Plastic and Human Health Impact Mission. He has co-authored multiple major publications such as the Plastic Health Map, the "Minderoo-Monaco Commission on Plastic and Human Health," and the "Plastic and Human Health Umbrella Review." He continues to work on innovative ways of accelerating the synthesis and dissemination of evidence of harm to human health across the entire lifecycle of plastic. His passion for investigating the effects of plastics on human health largely stems from his youth, when he lived in the fenceline community of a large petrochemical refinery.

Louise Goodes is a physiotherapist with extensive clinical research experience. She joined Minderoo in 2020 and is Principal Researcher in the Plastic and Human Health Impact Mission. She coordinates major scientific literature reviews such as the Plastic Health Map examining plastic chemical exposure and human health outcomes. Previous roles include Research Manager of the Western Australian Neurotrauma Research Program and Research Coordinator for the Western Australian arm of three multinational randomised controlled trials on Spinal Cord Injury and Physical Activity; she was also a clinical trial coordinator investigating biological therapies for bladder health in acute spinal cord injury.

Hervé Raps, MD, is the Research Delegate Physician at the Monaco Scientific Center, where he leads the Clinical Research support activity and the "Ocean and Human Health" theme. He is conducting awareness-raising and capacity-building activities on environmental health issues, particularly those related to the oceans, for a range of stakeholders. He has been on the steering committee and among the authors of the Monaco Commission on Ocean Pollution and Human Health and the Minderoo-Monaco Commission on Plastics and Human Health. He is a member of the Steering Committee of the "Espace Éthique PACA Corse" and the Scientific Council of Académie 3 at the Université Côte d'Azur in France.

Philip J. Landrigan, MD, MSc, FAAP, is Director of the Global Public Health and the Common Good program, and Director of the Global Observatory on Planetary Health at Boston College. Internationally, he collaborates with the Centre Scientifique de Monaco. He is a pediatrician, public health physician, and epidemiologist. Author of over seven hundred scientific publications and ten books, in his research he uses the tools of epidemiology to elucidate connections between toxic chemicals and human health, especially the health of infants and children. He is particularly interested in understanding how toxic chemicals injure the developing brains and nervous systems of children and in translating this knowledge into public policy to protect health. In New York City, he worked for many years in the Icahn School of Medicine at Mount Sinai and he was involved in the medical and epidemiologic follow-up of twenty thousand 9/11 rescue workers. From 2015 to 2017, he co-chaired the *Lancet* Commission on Pollution and Health. He is also member of the National Institute of Medicine.