Unraveling the Links Between Plastic Exposure and Chronic Disease Risk

Tanya L. Alderete, PhD
Associate Professor
Johns Hopkins University
Department of Environmental Health and Engineering
Bloomberg School of Public Health

CU-CSU Summit
Chronic Disease Frontiers: Colorado Approach to Causes and Treatment
August 13, 2025

JOHNS HOPKINS
BLOOMBERG SCHOOL
of PUBLIC HEALTH

Plastics: What Are They and Why Do They Matter?

Polymer Chains

Long chains of repeating **molecules** that make up plastics.

Additives

Chemicals mixed in to enhance flexibility, strength, or longevity.

Over Time, Plastics Break Down into Smaller Fragments

Plastic Items Shed Tiny Fragments:
Microplastics (<5 mm) and
Nanoplastics (<1,000 nm)

Particles pollute the environment and contaminate water, air, and food.

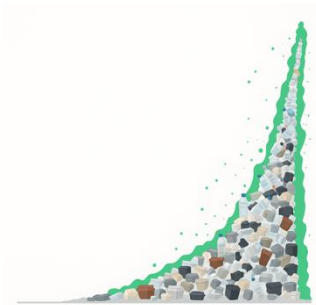
Yee et al. (2021), Nanomaterials; Cai et al. (2023), Microorganisms

Plastic Production is on the Rise

Humans Have Made
8.3 Billion
Tons of Plastics

25,000 X
Empire State Building
(331,000 metric Tons)

Rapid Rise of Plastics Production
(Dates Back to 1950)



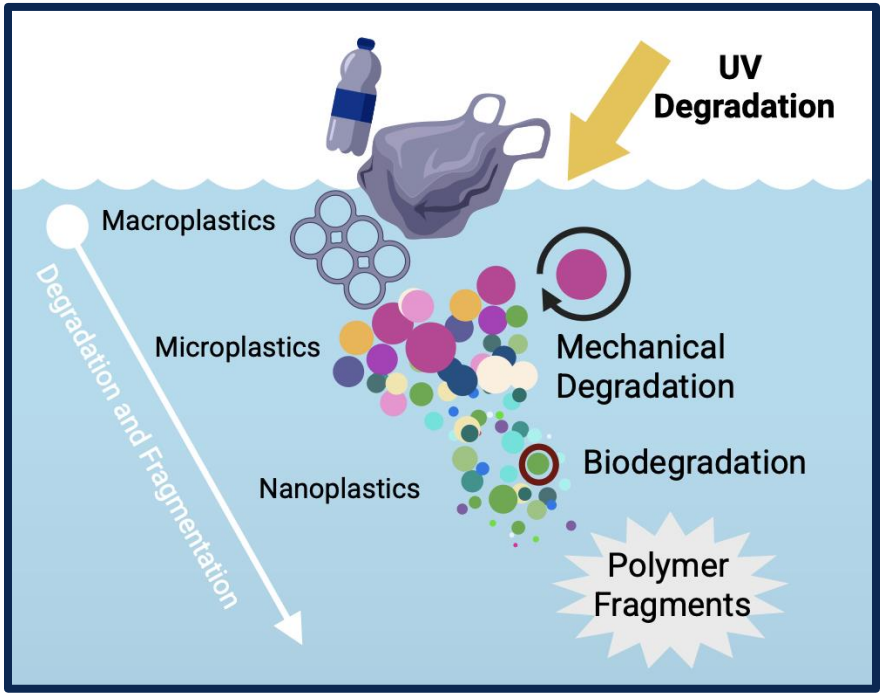
TRIPLE Plastic Production by 2060

>16,000 chemicals used to make plastics
4,200 are chemicals of concern

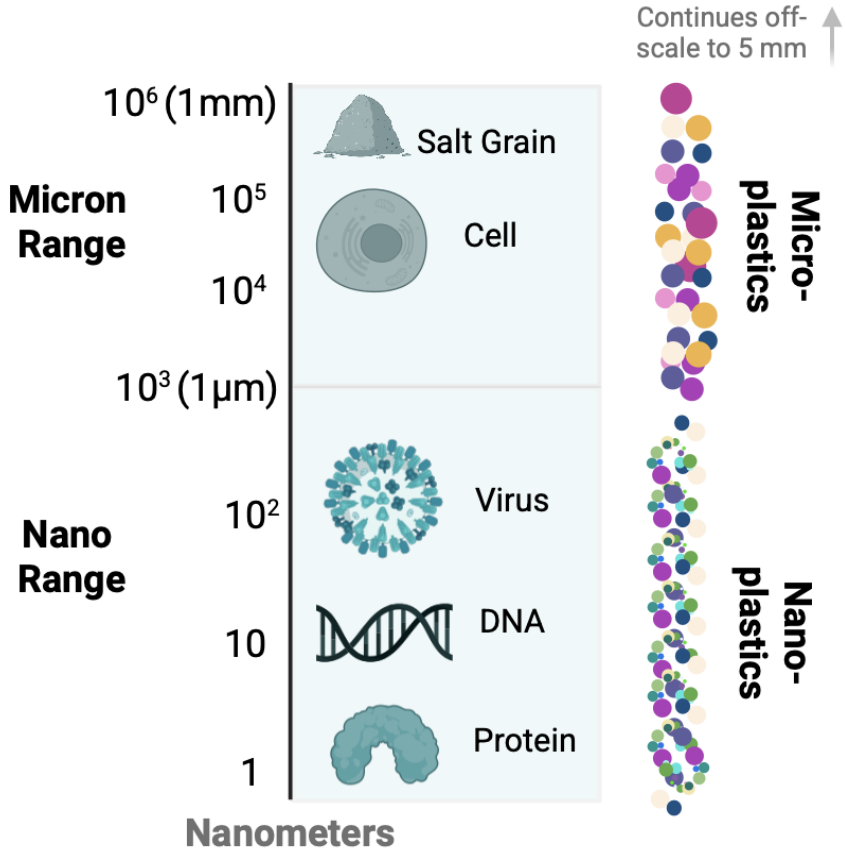
Plastics are multipollutant vectors, combining the physical hazards of particulates with a mixture of endocrine-disrupting and pro-inflammatory chemicals.

Humans Have Produced Enough Plastic To Build 25,000 Empire State Buildings; Plastic waste: Here's what it could look like by 2060

Plastics Never Stop Being Plastics – They Get Smaller and Smaller

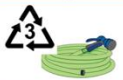


Pfohl et al. (2022), Environmental Science & Technology



Fragments in the nano range are super small & easily taken into human body

7 Most Common Types of Polymers in Production and Their Uses

Polymer Type[a]	Resin identification code[a]	Product Examples[a]	% of Plastics Production by Polymer Type[b]
Polyethylene terephthalate (PET/PETE)		Water/juice/soft drink bottles, ovenable/microwaveable food trays, carryout food containers, shampoo bottles, carpet, films, synthetic clothing (polyester)	26.7% (*in combination with PP*)
High density polyethylene (HDPE)		Toys, reusable water bottles, food storage containers, cereal box liners, wire/cable covering, outdoor signage	12.3%
Polyvinyl chloride (PVC)		Packaging (clam shells, shrink wrap) rigid pipes, flooring, building siding, wire insulation, garden hoses, gutters, medical products	10%
Low density polyethylene (LDPE)		Plastic film/baggies (dry cleaning, newspapers, garbage bags), single-use bags, juice boxes, wire insulation, container lids, toys, shrink wrap, beverage cup liners	17.5%
Polypropylene (PP)		Carpet, rope, luggage, marine equipment, appliances, straws, medical components, plastic caps/lids, carpeting	26.7% (*in combination with PET*)
Polystyrene (PS)		Car parts, appliances, TVs/computers, medical lab equipment, carryout food containers (Styrofoam™), yogurt containers, cups/plates/utensils, packing peanuts, egg cartons	6.3%
Other (e.g., polycarbonate [PC]; polylactic acid [bioplastic PLA]; poly methyl acrylate [PMA]; polyamide [PA]; polyvinyl alcohol [PVA])		Safety shields/glasses, toys, oven-baking bags, 3/5 gallon reusable water jugs, ketchup bottles, custom packing, synthetic clothing (nylon and acrylic), detergent pods, resins/paints, automotive, safety glass	27.2%

Given their widespread use these polymers have been the focus of many studies:

- ***Polyethylene (PET)***
- ***Polypropylene (PP)***
- ***Polycarbonate (PC)***

Microplastics Occurrence, Health Effects, and Mitigation, An Evidence Review for the California State Legislature

Human Exposure to Plastics and Adverse Health Effects

Sources

Everyday Plastic Products
(Food packaging, clothing, & personal care & household products)

Children's
(Products, toys, clothing, furniture)

Occupational
(Exposure at various stages of the plastic chain)

Exposure Pathways (examples)

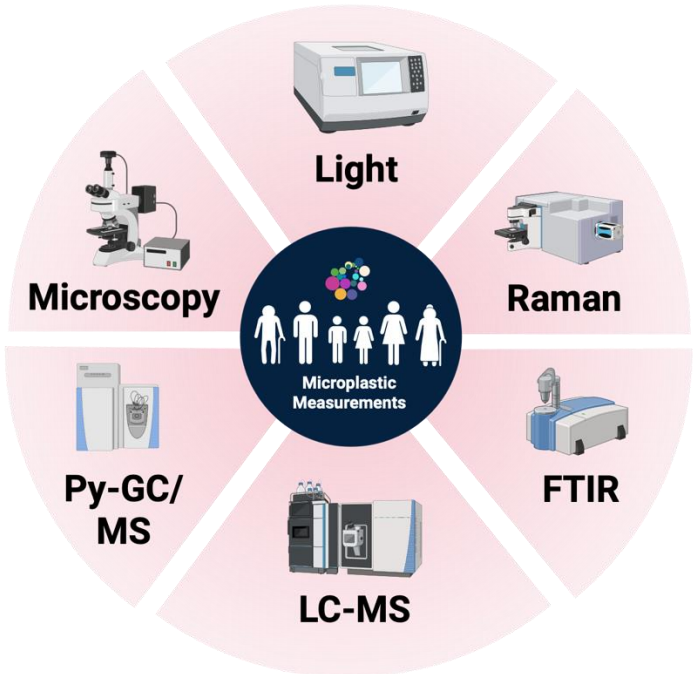
- Ingestion of Contaminated Food, Water, Dust
- Inhalation of Contaminated Air
- Dermal Contact

Adverse Health Effects (examples)

- Systemic Inflammation
- Vascular & Organ Damage
- Neurotoxicity & Cellular Damage
- Endocrine Disruption
- Carcinogenic Effects

United Nations Environment Programme and Secretariat of the Basel, Rotterdam and Stockholm Conventions (2023)

Methods for Measuring Micro- and Nano-Plastics (MNPs)



Physical Properties	Chemical Properties	Size of Particles
✓	✗	1 µm–5 mm
✓	✗	20–50 µm
✓	✓	1–100 µm
✓	✓	>10–20 µm
✗	✓	Chemicals
✗	✓	All Sizes

Microscopy
Particle size, counts, morphology

Light Microscopy
Smaller size, counts, morphology

Raman Spectroscopy
Spectral intensity, size, counts

FTIR Spectroscopy
Spectral peaks, polymer ID

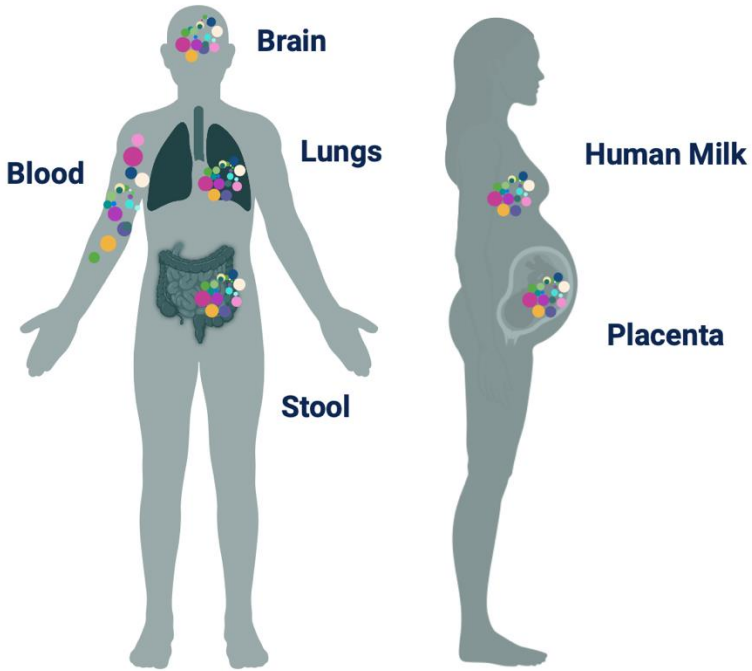
LC-MS
Quantifies plastics and additives via chemical depolymerization

Py (Pyrolysis)-GC/MS
Quantifies polymers and additives via thermal breakdown

Detecting MNPs requires a combination of techniques, each with its own strengths and limitations depending on particle size, sample matrix, and information needed (physical vs. chemical properties).

Shao et al. (2025), Annual Review of Pharmacology and Toxicology

Exposure Isn't Just Environmental, It's Internal: Plastics in Human Samples



Average concentration of 1.6 µg/ml
(e.g., PE, polymers of styrene)

Placenta (in all portions)
(Size range: 5 to 10 µm)

Human milk (20.2 particles/g)
(e.g., PE, PP, polyvinyl chloride)

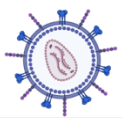
14x higher in infant vs adult stool
(Dietary PET/day)

PE: polyethylene; PP: polypropylene; PET: polyethylene terephthalate

Roslan et al. (2024), J Glob Health

Urgent need to better understand what these exposures mean for health—especially in vulnerable populations like pregnant people and infants

Chemical and Physical Effects of Micro- and Nano-Plastics

Mechanism	Source	Health Impacts
Leaching of Additives		Endocrine, immune, neurotoxic, carcinogenic effects
Physical Particle Effects		Inflammation, ROS, cell damage, barrier disruption
Systemic Circulation		Accumulation in blood, liver, kidney, brain, placenta, stool
Developmental Exposures		Fetal exposure, reproductive toxicity
Vector for Co-Pollutants		Enhanced exposure to environmental toxicants
Microbiome Alterations		Alterations to gut bacterial composition & function

Proposed mechanisms based on emerging toxicological and experimental evidence. Human data are still limited.

The Gut Microbiome may be Particularly Vulnerable to MNP Exposure

The gut is the primary entry point for plastics, which can trigger key disruptions

- Lower Gut Bacterial Diversity
- Higher Abundance of Pathogenic Bacteria
- Lower Mucus Secretion
- Reduced Gut Barrier Function
- Intestinal Inflammation

Covello et al. (2024), Current Issues In Molecular Biology

Summary of Human Studies: Plastics and the Gut Microbiome

Proinflammatory / Pathogenic

↑ *Proteobacteria (phylum),*
↑ *Porphyromonas*, ↑ *Escherichia,*
↑ *Shigella*, ↑ *Fusobacterium*, ↑ *Dorea,*
↑ *Ruminococcus torques group*, ↑ *Clostridium,*
↑ *Streptococcus*, ↑ *Troponema*, ↑ *Collinsella,*

SCFA Producers (Mixed)

↑/↓ B*acteroides*, ↓ *Parabacteroides*, , ↓ Alistipes,
↑/↓ *Faecalibacterium*,↓ *Bifidobacterium,*
↑/↓ C*oprococcus*, ↑ *Agathobacter*,↓ B*utyricicoccus*,↓
Prevotella, ↓ *Pelomonas,*
↓ *Lachnospiraceae_NK4A136_group*, ↓ *Allisonella*

Figure summarizes general trends across studies: Zhang et al. (2022), Frontiers in Public Health; Nugrahapraja et al. (2022), Environments; Liu et al. (2022), Ecotoxicology and Public Health; Jimenez-Arroyo et al. (2023), Science of the Total Environment ; Ke et al. (2023), EbioMedicine; Hong et al. (2024), Journal of Hazardous Materials

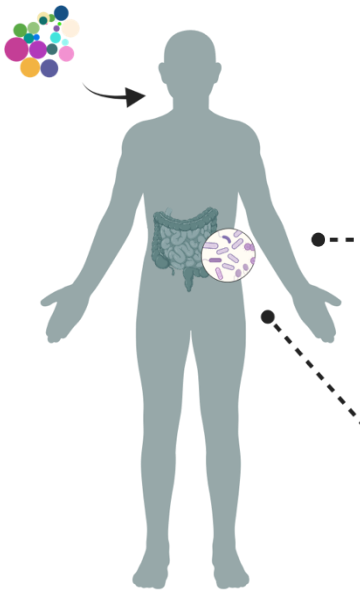
Plastics in Adult Stool are Associated with the Gut Microbiome

22 healthy participants (20–50 years old) from 2 study populations:
Kenjeran, Surabaya, Indonesia (9 male and 2 female) and Pacet, Mojokerto, Indonesia (5 male and 6 female)

Stool Measures

Gut Microbiome
Taxa Abundance
Gene Abundance

Plastics
Raman spectroscopy
HDPE (high-density polyethylene)
PP (polypropylene)
PS (polystyrene)



Gene Abundance Analysis

Detection of genes encoding plastic-degrading enzymes

pbsA	*styC*
cutA	*feaB*
alkA	polyurethenase
alkB	*nylA*
cut1	*phaZ*
esterase	PHB

Gut Microbiome Analysis

MPs associated with gut bacteria

↑ HDPE	↓ *Bacteroides*
↑ PP	↑ *Roseburia, Prevotellamassilia, Clostridium*
↑ PS	↓ *Roseburia, Clostridium*

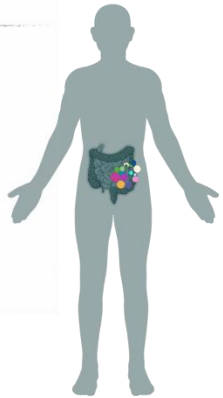
Nugrahapraja et al. (2022), Environments

Pilot Study: Stool Plastics and the Gut Microbiome

Enrolled n	78
Age (years)	23.2 SD: 2.2
BMI	25.0 SD: 6.1
Hispanic (self ID)	23.1%
Sex (self ID)	56.4% F / M 43.6%

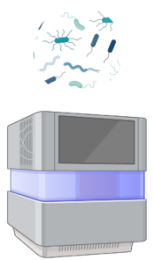
HYPHY

Young Adults
Denver, CO



Stool Sample Assays

Py-GC/MS



Metagenomics

Coming September 2025

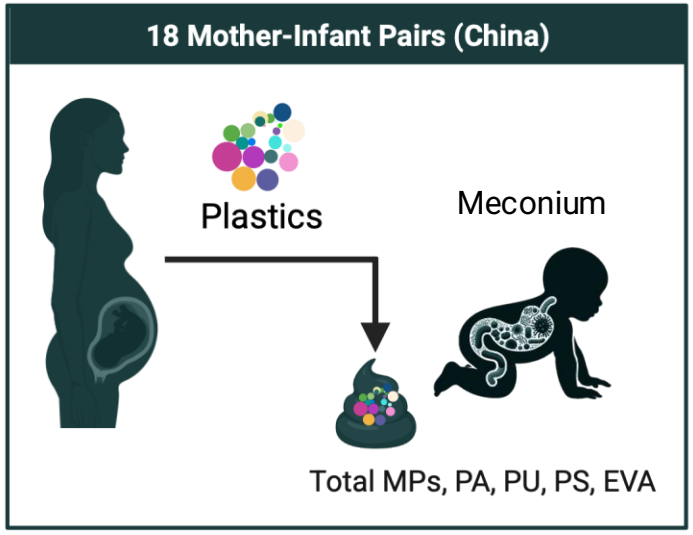
Tanya Alderete, PhD
Johns Hopkins

Doug Walker, PhD
Emory University

Environmental **H**ealth Effects on **Y**our **Phy**siology (2019-2022)

How might plastic exposure during pregnancy, infancy, and early childhood impact health?

Plastics in Newborn Stool are Associated with Gut Bacteria



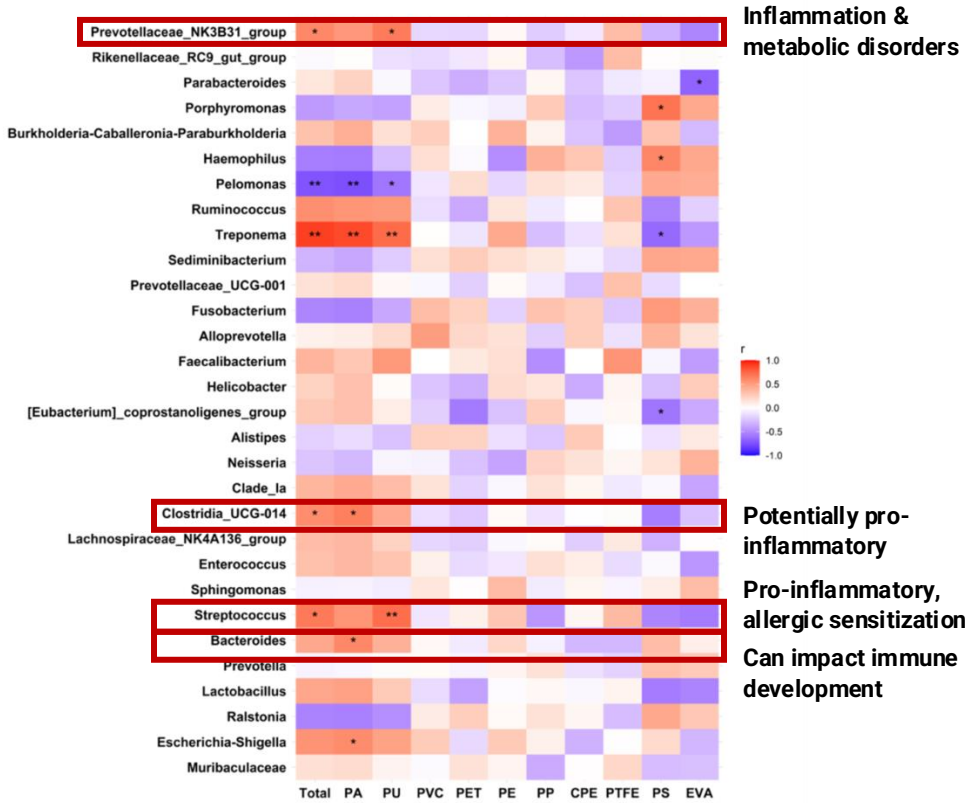
Plastics

PA, polyamide; PU, polyurethane; PE, polyethylene; PET, polyethyleneterephthalate; PP, polypropylene; PVC, poly(vinyl chloride); POM, polyoxymethylene; EVA, ethylene vinyl acetate copolymer; PTFE,polytetrafluoroethylene; CPE, chlorinated polyethylene; PC, polycarbonate; PS, polystyrene; PMMA, polymethylmethacrylate; PLA, poly(lacticacid).

Suggestive of in utero exposures

Liu et al. (2022), Ecotoxicology and Public Health

Correlations between microplastics in the meconium and microbiota genera. * P < 0.05, ** P < 0.01

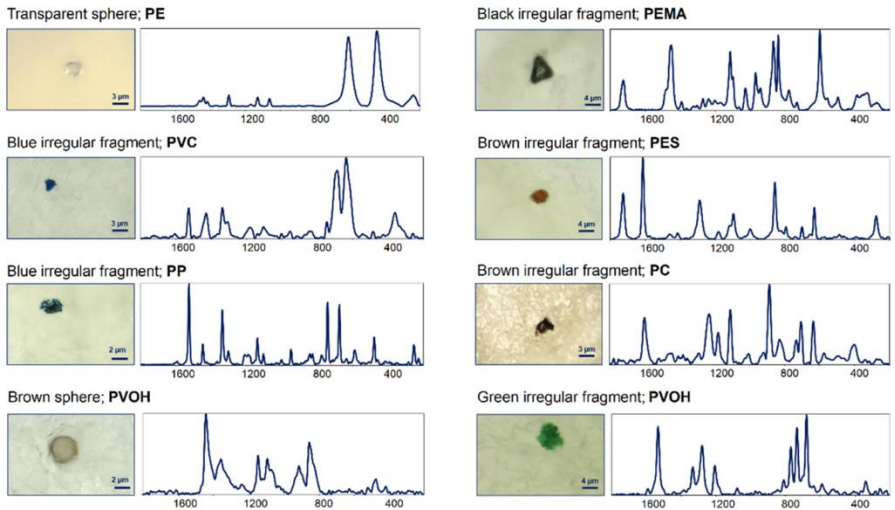


Beyond the *In Utero* Period: Plastics in Human Milk are Another Source of Early Life Exposure

Samples: Human milk 1 week after delivery (Italy, n=34); **Method:** Raman Microspectroscopy

Plastics in **76% of samples** (size range: 2 to 12 µm):

Most abundant plastics being composed of polyethylene (PE), polyvinyl chloride (PVC), and polypropylene (PP)



Ragusa et al. (2022), Polymers

Microphotographs and Raman spectra (wavenumbers, cm^{-1}) of some selected microplastics found in breastmilk samples. PE: polyethylene; PVC: polyvinyl chloride; PP: polypropylene; PVOH: polyvinyl alcohol; PEVA: poly(ethylene-co-vinyl acetate); PEMA: poly(ethyl methacrylate); PES: polyester, and PC: polycarbonate.

While I have largely focused on plastics in the context of the gut microbiome, it's also critical to ask:

Where else do these particles go, and what are their implications for human health?

The Plastics Health Burden: Disease, Death, and Economic Costs

This month, *The Lancet* published its first "Countdown on Health and Plastics"

HEALTH POLICY · Online first, August 03, 2025

The *Lancet* Countdown on health and plastics

Prof Philip J Landrigan, MD [a,h] · Prof Sarah Dunlop, PhD [c,d] · Marina Treskova, PhD [f,g] · Hervé Raps, MD [h] · Christos Symeonides, MB ChB [d,e] · Jane Muncke, PhD [i] · et al. Show more

WORLD

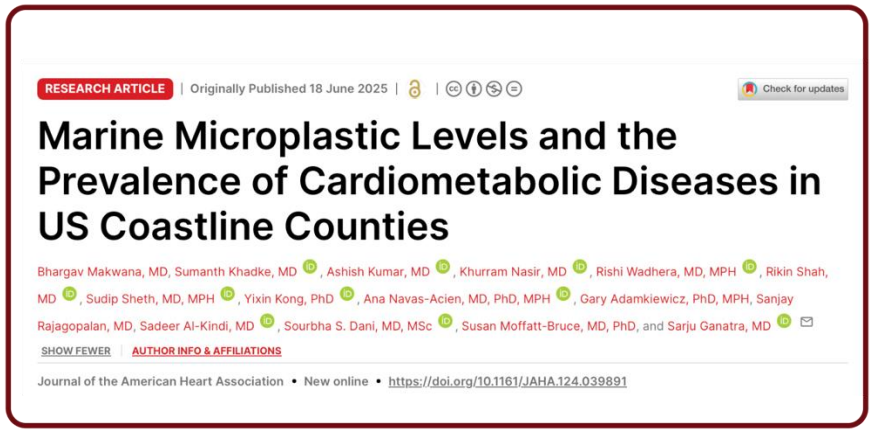
CBS NEWS

Plastic causing "disease and death from infancy to old age" that costs $1.5 trillion a year, report warns

Updated on: August 4, 2025 / 8:50 AM EDT / CBS/AFP

https://doi.org/10.1073/pnas.2412714121

Microplastics are Associated with Higher Chronic Disease Prevalence



RESEARCH ARTICLE | Originally Published 18 June 2025 | Check for updates

Marine Microplastic Levels and the Prevalence of Cardiometabolic Diseases in US Coastline Counties

Bhargav Makwana, MD, Sumanth Khadke, MD, Ashish Kumar, MD, Khurram Nasir, MD, Rishi Wadhera, MD, MPH, Rikin Shah, MD, Sudip Sheth, MD, MPH, Yixin Kong, PhD, Ana Navas-Acien, MD, PhD, MPH, Gary Adamkiewicz, PhD, MPH, Sanjay Rajagopalan, MD, Sadeer Al-Kindi, MD, Sourbha S. Dani, MD, MSc, Susan Moffatt-Bruce, MD, PhD, and Sarju Ganatra, MD

SHOW FEWER | AUTHOR INFO & AFFILIATIONS

Journal of the American Heart Association • New online • https://doi.org/10.1161/JAHA.124.039891

- **152 US coastline counties** located within 200 meters of large bodies of water
- **Microplastic** data (National Centers for Environmental Information's marine microplastics geodatabase)
- **Socioeconomic and environmental factors** (e.g., income, employment, social vulnerability, air pollution)

*Counties exposed to **high microplastic** concentrations in nearby ocean waters had significantly **higher prevalence** of:*

- ***Type 2 diabetes (+18%)***
- ***Coronary Artery Disease (+7%)***
- ***Stroke (+9%)***

Analyses adjusted for age, sex, physician access, and social/environmental vulnerabilities).
Low (0–0.005 pieces/m^3), medium (0.005–1 pieces/m^3), high (1–10 pieces/m^3), and very high (≥10 pieces/m^3).

How can Plastics Contribute to Disease?
They Don't Just Pass Through Us, They Accumulate in Organs

Brief Communication | Open access | Published: 03 February 2025

Bioaccumulation of microplastics in decedent human brains

Alexander J. Nihart, Marcus A. Garcia, Eliane El Hayek, Rui Liu, Marian Olewine, Josiah D. Kingston, Eliseo F. Castillo, Rama R. Gullapalli, Tamara Howard, Barry Bleske, Justin Scott, Jorge Gonzalez-Estrella, Jessica M. Gross, Michael Spilde, Natalie L. Adolphi, Daniel F. Gallego, Heather S. Jarrell, Gabrielle Dvorscak, Maria E. Zuluaga-Ruiz, Andrew B. West & Matthew J. Campen

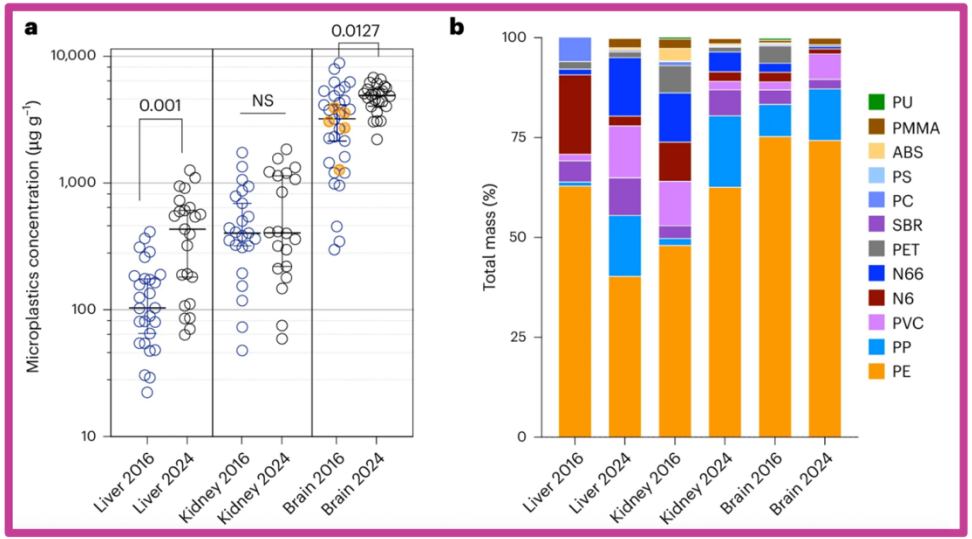
Samples: Liver, Kidney, Brain (Frontal Cortex)

Collected 2016 and 2024
(8-year Gap)

Methods: Py-GC/MS, attenuated total reflectance–Fourier transform infrared spectroscopy and electron microscopy with energy-dispersive spectroscopy

Significant Presence of Plastics in All Organs

Plastics Increasing in Brain and Liver



a, Microplastic concentrations in liver, kidney and brain (n = 20–28 separate participants for each timepoint). Data on a $\log_{10}$ scale, with bar representing group median value and 95%CI. Orange = samples analyzed independently at Oklahoma State University. Brain MNP concentrations were higher than liver and kidney ($P < 0.0001$). **b**, Distribution of 12 different polymers suggests greater accumulation of PE in brain relative to liver or kidney. *Polyethylene (PE).

Plastics in Dementia Cases Appear in Brain Vascular Wall and Immune Cells

Brief Communication | Open access | Published: 03 February 2025

Bioaccumulation of microplastics in decedent human brains

Alexander J. Nihart, Marcus A. Garcia, Eliane El Hayek, Rui Liu, Marian Olewine, Josiah D. Kingston, Eliseo F. Castillo, Rama R. Gullapalli, Tamara Howard, Barry Bleske, Justin Scott, Jorge Gonzalez-Estrella, Jessica M. Gross, Michael Spilde, Natalie L. Adolphi, Daniel F. Gallego, Heather S. Jarrell, Gabrielle Dvorscak, Maria E. Zuluaga-Ruiz, Andrew B. West & Matthew J. Campen

(polarization wave microscopy)

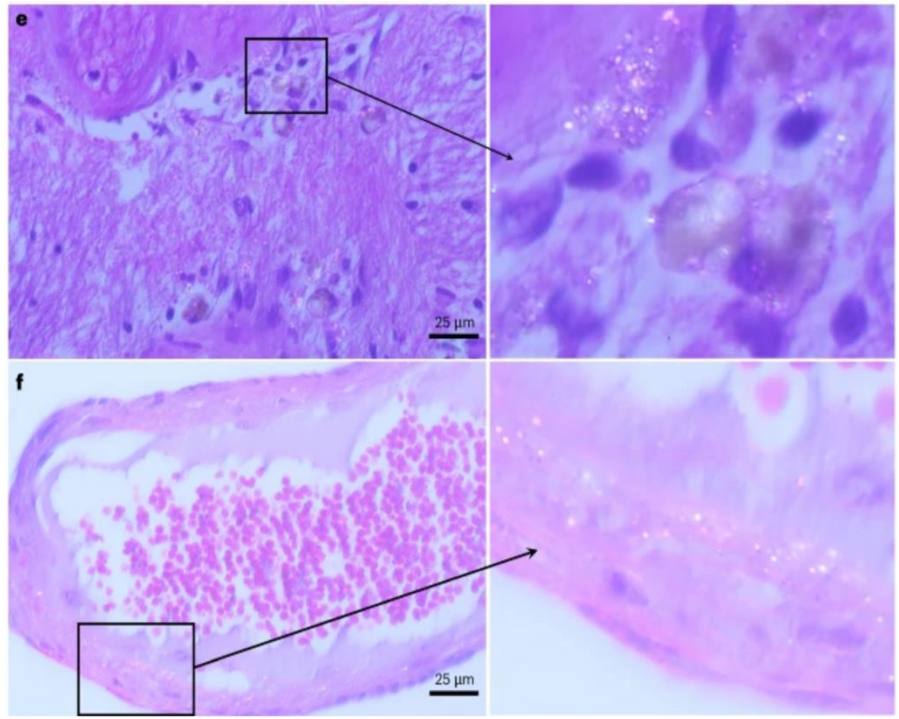
The Human Brain May Contain as Much as a Spoon's Worth of Microplastics, New Research Suggests

~7 grams

The amount of microplastics in the human brain appears to be increasing over time: Concentrations rose by roughly 50 percent between 2016 and 2024, according to a new study

Sarah Kuta - Daily Correspondent
February 4, 2025

Smithsonian *magazine*



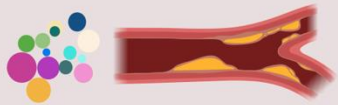
In dementia samples, many refractile inclusions were prominent in regions with inflammatory cells and along the vascular wall

*Does not establish causation – but **raises important questions** about whether **accumulation of plastics in sensitive tissues like the brain** could contribute to neuroinflammation or neurodegenerative processes*

Microplastics in the Cardiovascular System: Human Evidence & Mechanisms

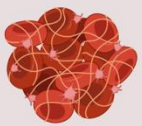
Microplastics Detected in Human Cardiovascular Tissues

Carotid Plaques



Associated with myocardial infarction, stroke, and all-cause mortality

Thrombi



Heart

Plastics may be Contributing to Disease Processes (Mechanistic Insights)

Mechanism Identified in Animal & In Vitro Studies

Autophagy

Senescence

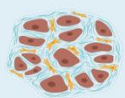
Oxidative Stress

Endothelial Dysfunction

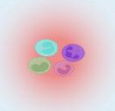
Apoptosis

Platelet Aggregation

Fibrosis



Inflammation



Adapted From: Prattichizzo et al. (2024), European Health Journal

Microplastics in Arterial Plaques Predict Cardiovascular Events

ORIGINAL ARTICLE

Microplastics and Nanoplastics in Atheromas and Cardiovascular Events

Authors: Raffaele Marfella, M.D., Ph.D. , Francesco Prattichizzo, Ph.D., Celestino Sardu, M.D., Ph.D., Gianluca Fulgenzi, Ph.D., Laura Graciotti, Ph.D., Tatiana Spadoni, Ph.D., Nunzia D'Onofrio, Ph.D., +35 , and Giuseppe Paolisso, M.D. Author Info & Affiliations

Published March 6, 2024 | N Engl J Med 2024;390:900-910 | DOI: 10.1056/NEJMoa2309822 | VOL. 390 NO. 10

Prospective, multicenter, observational study involving patients undergoing carotid endarterectomy for asymptomatic carotid artery disease

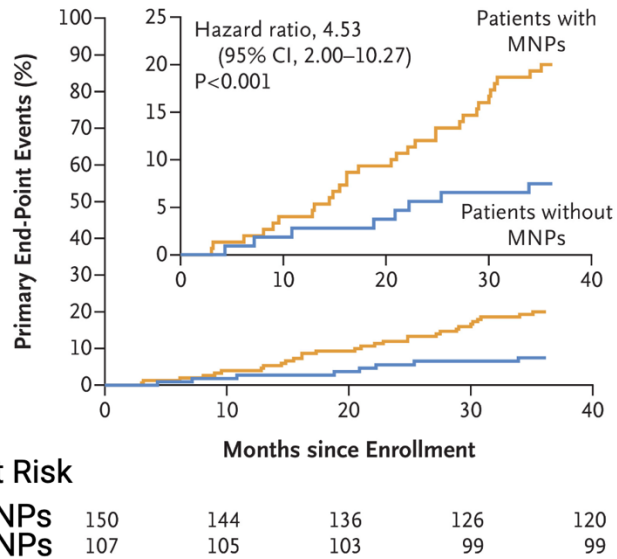
Total N = 257
Mean follow-up: 2.8 years

Carotid Artery Plaque
Polyethylene (58%)
Polyvinyl Chloride (12%)

Py-GC/MS & Electron Microscopy

4.5x
Higher Risk
of Cardiovascular Events
4.53 (95% CI: 2.00–10.27)
MI, Stroke, Death (any cause)

MNPs in plaque predict higher incidence of events over time



Summary

- **Plastics have been detected in a range of human samples —** including, but not limited to, blood, placenta, milk, and stool **— indicating widespread exposure**
    - Can trigger **oxidative stress, inflammation,** and **alternations to the gut microbiome**, potentially contributing to chronic disease risk
- **Plastics have been associated with**:
    - **Type 2 diabetes**
    - **Dementia**
    - **Cardiovascular effects** (e.g., endothelial dysfunction, platelet aggregation)
- **Urgent need** for ***large prospective*** and tightly controlled studies focused on **MNPs and how they may contribute to chronic disease** risk

What Can we Do About Plastics?
UN Plastics Treaty: Aiming to End Plastic Pollution

🌐 **175 countries** agreed to develop a legally binding treaty addressing **plastic pollution across its full life cycle**. ***Goal: Finalize treaty by end of 2025***

📅 Key Meetings

- **2022**: Rules set; early divide on national vs global obligations
- **2023**: Began talks; led to "zero draft"
- **2023**: Continued drafting and revisions
- **2024**: Focus on impacts; upstream measures weakened
- **2024**: Record participation; no consensus on production caps

Global Plastic Laws

https://www.globalplasticlaws.org/un-global-plastics-treaty

Industry pressure has diluted treaty ambition and contributed to ongoing gridlock, with negotiators deadlocked over binding production limits as industry-backed coalitions push for voluntary approaches.

Acknowledgements

JHU
- Ellie Holzhausen, PhD
- Devendra Paudel, PhD
- Haonan Li, PhD
- Kate Marquess, PhD
- Nathan Young, MS
- Nicole Brown
- Adrianna Luger

Emory
- Donghai Liang, PhD
- Douglas Walker, PhD
- Dean Jones, PhD
- Jeremy Sarnat, ScD
- Howard Chang, PhD

UNC
- Daisy Brumit

Funding Sources

NIEHS K99/R00 ES027853 (PI), HEI Rosenblith New Investigator (PI), NIEHS R01 ES035035 (PI), NIMHD P50 MD017344 (mPI Project 1), NIMHD R01 ES035056-03 (mPI), NIEHS R01 ES029944 (Co-I), NHGRI U01 HG013288 (Co-I) , 2022 USC EH-Pilot Grant (mPI), ECHO DAC, CU Boulder Seed Grant (PI, HYPHY)

National Institute of Environmental Health Sciences

National Institute on Minority Health and Health Disparities

Contact Information

taldere1@jhu.edu

@tanya_alderete

Presentation created in BioRender