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The Plastics Treaty and Its Importance for Global Health

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Disclosures

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- Scientific Advisory Roles: Beautycounter, IS-Global, Footprint, Food Packaging Forum, Ahimsa

Summary

Many plastic additives are known to interfere with hormone functioning and are, by definition, endocrine disrupting chemicals.

There is clear and extensive evidence of the human health impacts of many chemicals in common plastics.

The health and economic impacts of the use of chemicals in plastic materials can be profound and life threatening.

We need a global plastics treaty that:

- Reduces plastic production
- Recognizes hazards posed by recycling and use of bioplastics
- Uses hazard rather than risk to evaluate and remove endocrine disrupting chemicals from plastic
- Expands biomonitoring globally
- Establishes an independent scientific body to evaluate hazards of endocrine disrupting chemicals

“Better living through chemistry”

- 2 million tons produced each year in 1950s
- Today: 400 million tons produced each year
- Growing demand from emerging economies

Of the virgin plastics produced globally in 2020, 52% produced in Asia (32% in China), followed by North America (19%), Europe (17%), the Middle East and Africa (7%), and Latin America (4%)

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The Plastics Crisis

- Ecosystem effects
- Climate change
- Chemicals and human health

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Ecosystem effects

- 22 million tons of plastic waste enter the environment annually

- 9% of all plastic used to date has been recycled

Fates for unrecycled plastic:

- Controlled and uncontrolled landfills
- Burning (more on this when we address human health)
- Export

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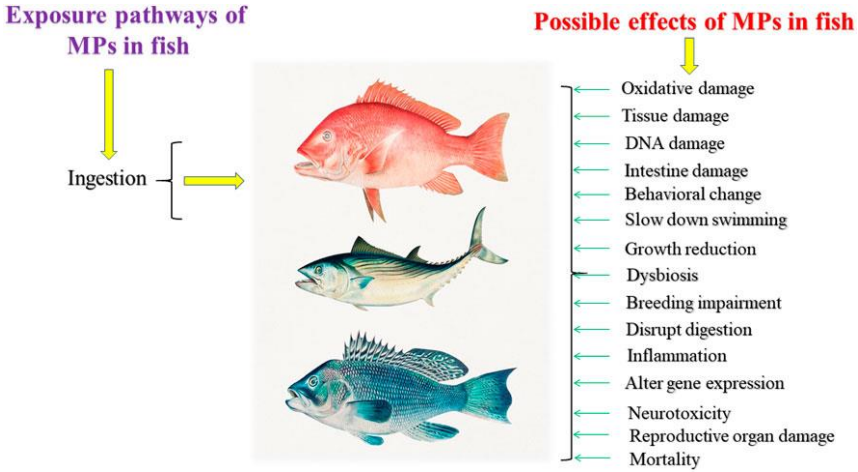
Visible and micro-plastics in wildlife



Bhuyan Front. Environ. Sci., 16 March 2022 | https://doi.org/10.3389/fenvs.2022.827289

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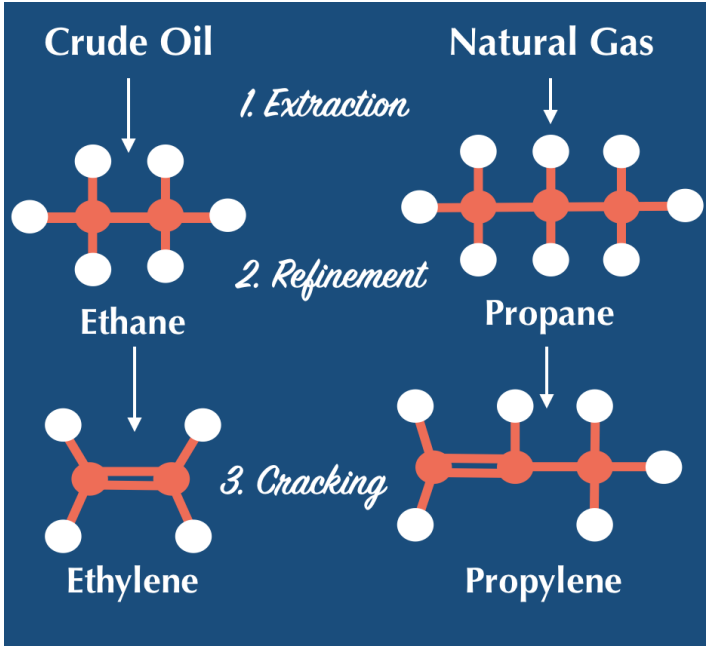
Plastics come from fossil fuels

- Nearly all plastics are made from fossil fuel feed stocks
- Polyethylene plastics are produced by cracking ethane, which is readily separated from natural gas.
- In fact, multinational fossil companies are pivoting from making fuels to plastic
  - Sinopec (+36% growth in plastic production between 2020-2025),
  - ExxonMobil (+35%)
  - PetroChina (+38%)
  - Russian-owned SIBUR (+240%),
  - Oman Oil Refineries and Petroleum (+269%)
  - Indian HPLC-Mittal (+343%)



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Accidents as other downstream consequences of plastic use

- East Palestine, Ohio
- Vinyl chloride burned widely (five rail cars worth)
- Newly released data shows soil contains dioxin levels hundreds of times greater than cancer risk threshold set by US Environmental Protection Agency

Climate change

- In 2030, emissions from plastic production could be equivalent to emissions from 295 coal-fired power plants.

- Microplastics in the ocean also reduce the planet’s capacity to sequester carbon dioxide

What are endocrine disrupting chemicals?

- Endocrine disrupting chemicals (EDCs) interfere with hormonal signaling systems
- We now know of >1,000 synthetic chemicals that can disrupt hormonal functions and thereby contribute to disease and disability
  - Mimic, block, or modulate the synthesis, release, transport, metabolism, binding, or elimination of natural hormones
  - Brain, pituitary, gonads, thyroid, and other components of the endocrine system

	Representative EDCs
Pharmaceuticals	Trenbolone acetate, ethinylestradiol, dexamethasone, levonorgestrel, rosiglitazone
Cosmetics, personal care products	DBP, benzophenones, parabens, triclosan, DEET
Pesticides, herbicides, fungicides	Chlorpyrifos, glyphosate, pyraclostrobin, DDT, atrazine
Industrial chemicals	BPA, PCBs, triphenyl phosphate, PBDEs
Metals	Lead, cadmium, mercury, arsenic
Synthetic and naturally occurring hormones	Progesterone, testosterone, cortisol, oestrone

Representative EDCs from diverse functional use categories. EDC=endocrine-disrupting chemical. DBP=dibutyl phthalate. DEET=N,N-diethyl-m-toluamide. DDT=dichlorodiphenyltrichloroethane. BPA=bisphenol A. PCB=polychlorinated biphenyl. PBDE=polybrominated diphenyl ether.

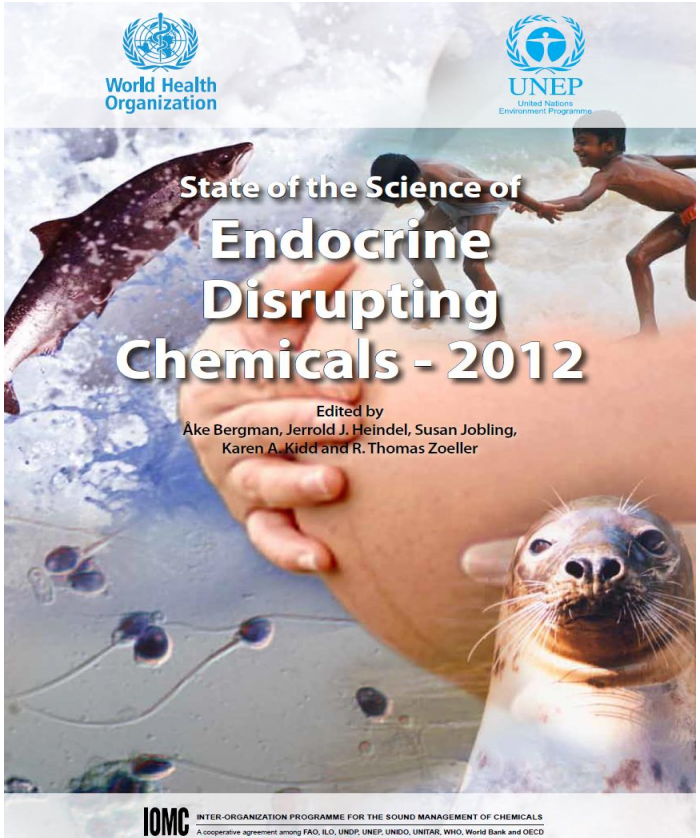
Table 1: **List of representative EDCs in use**

Endocrine-Disrupting Chemicals: An Endocrine Society Scientific Statement

Evanthia Diamanti-Kandarakis, Jean-Pierre Bourguignon, Linda C. Giudice, Russ Hauser, Gail S. Prins, Ana M. Soto, R. Thomas Zoeller, and Andrea C. Gore

Endocrine Section of First Department of Medicine (E.D.-K.), Laiko Hospital, Medical School University of Athens, 11527 Athens, Greece; Department of Pediatrics (J.-P.B.), Centre Hospitalier Universitaire de Liege, 4000 Liege, Belgium; Department of Obstetrics, Gynecology, and Reproductive Sciences (L.C.G.), University of California San Francisco, San Francisco, California 94131; Department of Environmental Health (R.H.), Harvard School of Public Health, Boston, Massachusetts 02115; Department of Urology (G.S.P.), University of Illinois at Chicago, Chicago, Illinois 60612; Department of Anatomy and Cell Biology (A.M.S.), Tufts University School of Medicine, Boston, Massachusetts 02111; Biology Department (R.T.Z.), University of Massachusetts, Amherst, Massachusetts 01003; and Division of Pharmacology and Toxicology (A.C.G.), The University of Texas at Austin, Austin, Texas 78712

There is growing interest in the possible health threat posed by endocrine-disrupting chemicals (EDCs), which are substances in our environment, food, and consumer products that interfere with hormone biosynthesis, metabolism, or action resulting in a deviation from normal homeostatic control or reproduction. In this first Scientific Statement of The Endocrine Society, we present the evidence that endocrine disruptors have effects on male and female reproduction, breast development and cancer, prostate cancer, neuroendocrinology, thyroid, metabolism and obesity, and cardiovascular endocrinology. Results from animal models, human clinical observations, and epidemiological studies converge to implicate EDCs as a significant concern to public health. The mechanisms of EDCs involve divergent pathways including (but not limited to) estrogenic, antiandrogenic, thyroid, peroxisome proliferator-activated receptor γ, retinoid, and actions through other nuclear receptors; steroidogenic enzymes; neurotransmitter receptors and systems; and many other pathways that are highly conserved in wildlife and humans, and which can be modeled in laboratory *in vitro* and *in vivo* models. Furthermore, EDCs represent a broad class of molecules such as organochlorinated pesticides and industrial chemicals, plastics and plasticizers, fuels, and many other chemicals that are present in the environment or are in widespread use. We make a number of recommendations to increase understanding of effects of EDCs, including enhancing increased basic and clinical research, invoking the precautionary principle, and advocating involvement of individual and scientific society stakeholders in communicating and implementing changes in public policy and awareness. (***Endocrine Reviews*** **30: 293–342, 2009)**



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Response to WHO/UNEP Report

WHO/UNEP report (2012) “welcomed” by all participant countries at 2015 Strategic Alliance for International Chemicals Management

EDC-2: The Endocrine Society’s Second Scientific Statement on Endocrine-Disrupting Chemicals

A. C. Gore, V. A. Chappell, S. E. Fenton, J. A. Flaws, A. Nadal, G. S. Prins, J. Toppari, and R. T. Zoeller

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The Endocrine Society’s first Scientific Statement in 2009 provided a wake-up call to the scientific community about how environmental endocrine-disrupting chemicals (EDCs) affect health and disease. Five years later, a substantially larger body of literature has solidified our understanding of plausible mechanisms underlying EDC actions and how exposures in animals and humans—especially during development—may lay the foundations for disease later in life. At this point in history, we have much stronger knowledge about how EDCs alter gene-environment interactions via physiological, cellular, molecular, and epigenetic changes, thereby producing effects in exposed individuals as well as their descendants. Causal links between exposure and manifestation of disease are substantiated by experimental animal models and are consistent with correlative epidemiological data in humans. There are several caveats because differences in how experimental animal work is conducted can lead to difficulties in drawing broad conclusions, and we must continue to be cautious about inferring causality in humans. In this second Scientific Statement, we reviewed the literature on a subset of topics for which the translational evidence is strongest: 1) obesity and diabetes; 2) female reproduction; 3) male reproduction; 4) hormone-sensitive cancers in females; 5) prostate; 6) thyroid; and 7) neurodevelopment and neuroendocrine systems. Our inclusion criteria for studies were those conducted predominantly in the past 5 years deemed to be of high quality based on appropriate negative and positive control groups or populations, adequate sample size and experimental design, and mammalian animal studies with exposure levels in a range that was relevant to humans. We also focused on studies using the developmental origins of health and disease model. No report was excluded based on a positive or negative effect of the EDC exposure. The bulk of the results across the board strengthen the evidence for endocrine health-related actions of EDCs. Based on this much more complete understanding of the endocrine principles by which EDCs act, including nonmonotonic dose-responses, low-dose effects, and developmental vulnerability, these findings can be much better translated to human health. Armed with this information, researchers, physicians, and other healthcare providers can guide regulators and policymakers as they make responsible decisions. (*Endocrine Reviews* 36: 0000–0000, 2015)

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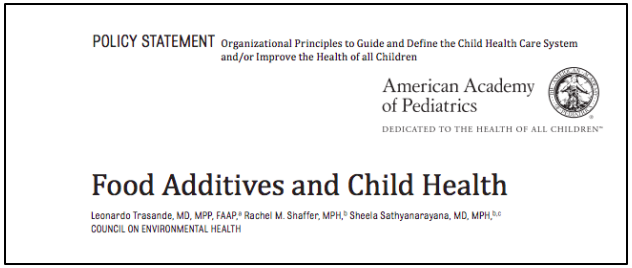
Mainstream recognition

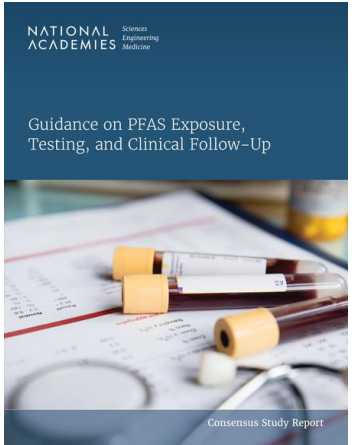

POLICY STATEMENT Organizational Principles to Guide and Define the Child Health Care System and/or Improve the Health of all Children

American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN™

Food Additives and Child Health

Leonardo Trasande, MD, MPP, FAAP,[a] Rachel M. Shaffer, MPH,[b] Sheela Sathyanarayana, MD, MPH,[b,c]
COUNCIL ON ENVIRONMENTAL HEALTH



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ETIOLOGY AND PATHOPHYSIOLOGY

OBESITY REVIEWS WILEY

Endocrine-disrupting chemicals and obesity risk: A review of recommendations for obesity prevention policies

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Summary
Emerging evidence indicates that industrially produced endocrine-disrupting chemicals (EDCs) may be as obesogenic as poor dietary patterns and should be considered in obesity prevention policies. The authors conducted two reviews: (a) a systematic search of four electronic databases for papers published since January 2010 to identify the policy recommendations contained in scientific reviews of EDC exposure and obesity risk and (b) a narrative review of obesity policy documents published since January 2012 to identify the recommendations of national and international agencies. A search of four electronic databases found 63 scientific reviews with policy recommendations, of which 26 suggested individual responsibility to avoid exposure, 11 suggested medical interventions to counter the effects of exposure, and 42 suggested regulatory control of hazardous chemicals. Of sixty policy documents examined, six mentioned pollutants as a possible risk factor for obesity, and only one made explicit reference to strategies for reducing exposure to EDCs. The UN Sustainable Development Goals include targets to prevent ill health from hazardous chemicals (Targets 3.9 and 12.4) and to remove unsafe industrial chemicals from the environment (Targets 6.3, 11.6, 12.4, and 14.1). The authors suggest these should be explicitly linked to World Health Assembly targets to halt the rise in obesity.

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Plastics are a crucial source of EDCs

- Bisphenols (polycarbonate plastics, aluminum can linings)
- Phthalates (food packaging)
- Per- and polyfluoroalkyl substances (PFAS, nonstick cooking and fluoropolymer plastics)
- Brominated flame retardants (additives to reduced flammability)
- Burning plastics → dioxins

Bisphenols

- Used in polycarbonate plastics and epoxy resins (aluminum cans, thermal paper receipts)

- Bisphenol A disrupts multiple metabolic mechanisms, at levels commonly seen in humans
  - Increases fat cell size, disrupts adiponectin function and low-grade synthetic estrogen

- As concern has increased, ~40 chemically similar replacements now in use: bisphenol S (BPS), BPF, BPAF, BPZ, BPP…
  - BPS: similar estrogenicity, embryotoxicity (potentially others)

Masuno et al. *J Lipid Res.* 2002;43(5):676-684; Sakurai K et al. *Br J Pharmacol.* 2004;141(2):209-214;

Phthalates

Low-molecular weight (LMW) phthalates used in shampoos, cosmetics, lotions and other personal care products to preserve scent

- Anti-androgenic properties (reduced transcription of the androgen receptor)

High molecular weight (HMW) phthalates used to produce vinyl plastic for flooring, clear food wrap and intravenous tubing.

- Mono-(2-ethylhexyl) phthalate (MEHP), a metabolite of one HMW phthalate used in food packaging, di-2-ethylhexylphthalate (DEHP), increases expression of receptors which play key roles in lipid and carbohydrate metabolism

Bornehag and Nanberg 2010; Colon et al. 2000; Engel et al. 2010; Miodovnik et al. 2011; Sathyanarayana 2008; Swan 2008; Swan et al. 2005; Desvergne et al. 2009, Grun and Blumberg 2007, Philips et al Repro Tox 2019

Phthalates and preterm birth

- 5006 mother–child dyads from 13 US birth cohorts
- Phthalic acid, diisodecyl phthalate (DiDP), di-n-octyl phthalate (DnOP), and diisononyl phthalate (DiNP) were most strongly associated with gestational age, birth length, and birthweight, especially compared with DEHP or other metabolite groupings.
- Although DEHP was associated with preterm birth (odds ratio 1·45 [95% CI 1·05–2·01]), the risks per $\log_{10}$ increase were higher for phthalic acid (2·71 [1·91–3·83]), DiNP (2·25 [1·67–3·00]), DiDP (1·69 [1·25–2·28]), and DnOP (2·90 [1·96–4·23]).
- We estimated 56 595 (sensitivity analyses 24 003–120 116) phthalate-attributable preterm birth cases in 2018 with associated costs of US$3·84 billion (sensitivity analysis 1·63– 8·14 billion).

Trasande et al Lancet Planet Health
. 2024 Feb;8(2):e74-e85. doi: 10.1016/S2542-5196(23)00270-X.

Phthalates → cardiovascular mortality

- Low T either predictor of or marker of cardiovascular mortality in adult men

- High molecular weight phthalates were associated with lower total, free, and bioavailable testosterone among men age ≥60.
  - Attina et al Lancet Diab Endo 2016; Hauser et al JCEM 2015

Cardiovascular mortality was significantly increased in relation to a prominent DEHP metabolite, mono-(2-ethyl-5-oxohexyl)phthalate.

- Extrapolating to the population of 55-64 year old Americans, 50,200 attributable deaths and $23.4 billion in lost economic productivity.

Trasande et al Env Pollution 2021

Bisphenols → cardiovascular mortality

BPA associated with:

- Reduced carotid intima-media thickness of 12-30 and >70 year olds

  Lin et al Atherosclerosis 2015, Lind et al Atherosclerosis 2011)

- Severity of coronary artery disease in angiography

  Melzer et al PLOS One 2012

- Reduced heart rate variability in adults

  Bae et al Hypertension 2012

- All-cause mortality, and cardiovascular disease mortality

  Bao et al JAMA Network Open 2020

Table 3. Adjusted associations between exposure to BPA and BPS and the risk of type 2 diabetes in the D.E.S.I.R. cohort (single-pollutant models).

	At baseline		At year 3		Average exposure at baseline-year 3	
Bisphenol exposure/detections	n/N[a]	aHR (95% CI)[b]	n/N[a]	aHR (95% CI)[c]	n/N[a]	aHR (95% CI)[d]
BPA exposure		N = 726		N = 623		N = 623
BPA-G concentration (ng/mL)						
<0.71	62/233	1	11/94	1	10/75	1
0.71–1.75	48/182	0.80 (0.53, 1.21)	28/162	1.42 (0.66, 3.07)	33/176	2.56 (1.16, 5.65)
1.75–3.78	39/158	1.01 (0.65, 1.55)	44/190	2.40 (1.16, 4.98)	36/198	2.35 (1.07, 5.15)
≥3.78	38/153	0.85 (0.54, 1.35)	25/177	0.99 (0.44, 2.21)	29/174	1.56 (0.68, 3.55)
BPS detection		N = 644		N = 579		N = 529
BPS-G concentration ≥LOD						
No	139/546	1	92/522	1	61/389	1
Yes	32/98	1.68 (1.09, 2.58)	15/57	1.92 (1.02, 3.62)	38/140	2.81 (1.74, 4.53)

Note: Groups of BPA exposure were defined on the pooled baseline and year 3 BPA-G concentrations in subcohort members. aHR, adjusted hazard ratio; BMI, body mass index; BPA-G, BPA-glucuronide; BPS-G, BPS-glucuronide; CI, confidence interval; D.E.S.I.R., Data from an Epidemiological Study on the Insulin Resistance Syndrome; LOD, limit of detection (0.3 ng/mL).

[a]n/N indicates the numbers of type 2 diabetes cases relative to the total number of participants in each exposure category.

[b]aHRs quantify the association between exposure to BPA/BPS and incidence of diabetes between baseline and year 9. Cox models with age as the timescale and stratified on smoking status were adjusted for sex and the following variables from baseline: urinary creatinine level, education level, employment, marital status, physical activity, caloric intake, family history of diabetes, hypertension, and BMI.

[c]aHRs quantify the association between exposure to BPA/BPS and incidence of diabetes between year 3 and year 9. Cox models with age as the timescale and stratified on smoking status were adjusted for sex and the following variables from year 3: urinary creatinine level, education level, employment, marital status, physical activity, caloric intake, family history of diabetes, hypertension, and BMI.

[d]aHRs quantify the association between exposure to BPA/BPS and incidence of diabetes between year 3 and year 9. Cox models with age as the timescale and stratified on smoking status were adjusted for sex, average urinary creatinine level, and the following variables from year 3: education level, employment, marital status, physical activity, caloric intake, family history of diabetes, hypertension, and BMI.

Ranciere et al EHP 2019

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Per- and polyfluoroalkyl substances (PFAS)

Synthetic organic fluorinated compounds with high stability and thermal resistance

Detectable in blood of >98% of the US population.

Food packaging is a major route of exposure (nonstick cooking, microwaveable popcorn bags)

Meta-analysis of 24 studies: −10·5 g (95% CI: −16·7, −4·4) birth weight per ng/ml increase in maternal or cord blood PFAS

Steenland et al Epidemiology 2018

PFAS and adult weight gain/diabetes

- Diabetes Prevention Program lifestyle intervention trial:
- Total PFAS were associated with increased weight gain exclusively among the control group.

Cardenas et al 2018

- Follow-up of the successful POUNDS LOST trial:
- Perfluorooctane sulfonate (PFOS) and perfluorononanoic acid (PFNA), were associated with reductions in resting metabolic rate.

Liu et al 2018

- PIVUS (Sweden), Nurses (US), DPPOS (US):
- PFAS associated with incident diabetes

Cardenas et al 2019, Sun et al 2018, Lind et al 2014

Brominated flame retardants

- Thyroid hormone has long been known to be critical to early brain development
  - Predictable outcomes of its disruption include global IQ deficits, as well as neurodevelopmental disabilities such as autism spectrum disorder (ASD), and attention-deficit hyperactivity disorder (ADHD).

- Four well-designed longitudinal birth cohorts have identified PBDE effects on child neurodevelopment, despite controlling for many potential confounders (alternate explanatory factors).

Chen et al EHP 2014; Eskenazi et al EHP 2013; Herbstman et al EHP 2010, Gascon et al Environment International 2011

Endocrine disruption and fertility

- Fertility is a condition of a couple, where reproductive health of both sexes plays a role

Louis et al 2013

- Fetal exposure to phthalates with reduced infant anogenital distance (AGD)

Swan et al EHP 2005, Bornehag et al EHP 2014

- Shortened adult AGD is associated with reduced semen quality and testosterone level

- Multiple studies have identified reduced male fertility and poor semen quality with multiple EDCs, including phthalates, bisphenol A, and polyfluorinated chemicals

Juul et al Nat Rev Endo 2014

Microplastics in humans

- Widely detected in human samples to date

- One study of adults and kids found polyethylene and polycarbonate microplastics in most (PET) or all (PC) adult stool samples but at concentrations an order of magnitude lower than in infants for PET MPs (<LOQ–16,000 ng/g, median, 2600 ng/g).

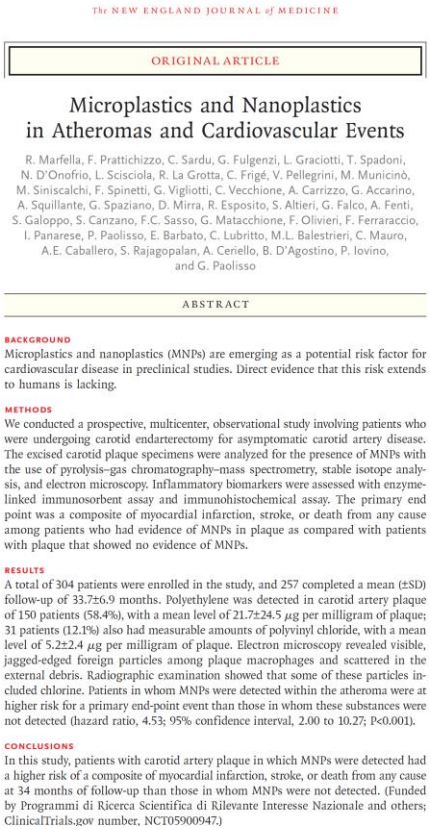
- The estimated mean daily exposures from the diet of infants to PET and PC MPs were 83,000 and 860 ng/kg body weight per day, respectively, which were significantly higher than those of adults (PET: 5800 ng/kg-bw/day; PC: 200 ng/kg-bw/d).

What do we know about microplastics and human health?

Early findings raise serious concerns

Cautions

- Particle size
- Assays not harmonized yet
- Chemicals on lining of microplastics may vary



The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Microplastics and Nanoplastics in Atheromas and Cardiovascular Events

R. Marfella, F. Prattichizzo, C. Sardu, G. Fulgenzi, L. Graciotti, T. Spadoni, N. D'Onofrio, L. Scisciola, R. La Grotta, C. Frigé, V. Pellegrini, M. Municinò, M. Siniscalchi, F. Spinetti, G. Vigliotti, C. Vecchione, A. Carrizzo, G. Accarino, A. Squillante, G. Spaziano, D. Mirra, R. Esposito, S. Altieri, G. Falco, A. Fenti, S. Galoppo, S. Canzano, F.C. Sasso, G. Matacchione, F. Olivieri, F. Ferraraccio, I. Panarese, P. Paolisso, E. Barbato, C. Lubritto, M.L. Balestrieri, C. Mauro, A.E. Caballero, S. Rajagopalan, A. Ceriello, B. D'Agostino, P. Iovino, and G. Paolisso

ABSTRACT

BACKGROUND

Microplastics and nanoplastics (MNPs) are emerging as a potential risk factor for cardiovascular disease in preclinical studies. Direct evidence that this risk extends to humans is lacking.

METHODS

We conducted a prospective, multicenter, observational study involving patients who were undergoing carotid endarterectomy for asymptomatic carotid artery disease. The excised carotid plaque specimens were analyzed for the presence of MNPs with the use of pyrolysis–gas chromatography–mass spectrometry, stable isotope analysis, and electron microscopy. Inflammatory biomarkers were assessed with enzyme-linked immunosorbent assay and immunohistochemical assay. The primary end point was a composite of myocardial infarction, stroke, or death from any cause among patients who had evidence of MNPs in plaque as compared with patients with plaque that showed no evidence of MNPs.

RESULTS

A total of 304 patients were enrolled in the study, and 257 completed a mean (±SD) follow-up of 33.7±6.9 months. Polyethylene was detected in carotid artery plaque of 150 patients (58.4%), with a mean level of 21.7±24.5 μg per milligram of plaque; 31 patients (12.1%) also had measurable amounts of polyvinyl chloride, with a mean level of 5.2±2.4 μg per milligram of plaque. Electron microscopy revealed visible, jagged-edged foreign particles among plaque macrophages and scattered in the external debris. Radiographic examination showed that some of these particles included chlorine. Patients in whom MNPs were detected within the atheroma were at higher risk for a primary end-point event than those in whom these substances were not detected (hazard ratio, 4.53; 95% confidence interval, 2.00 to 10.27; P<0.001).

CONCLUSIONS

In this study, patients with carotid artery plaque in which MNPs were detected had a higher risk of a composite of myocardial infarction, stroke, or death from any cause at 34 months of follow-up than those in whom MNPs were not detected. (Funded by Programmi di Ricerca Scientifica di Rilevante Interesse Nazionale and others; ClinicalTrials.gov number, NCT05900947.)

N Engl J Med 2024;390:900-10.
DOI: 10.1056/NEJMoa2309822

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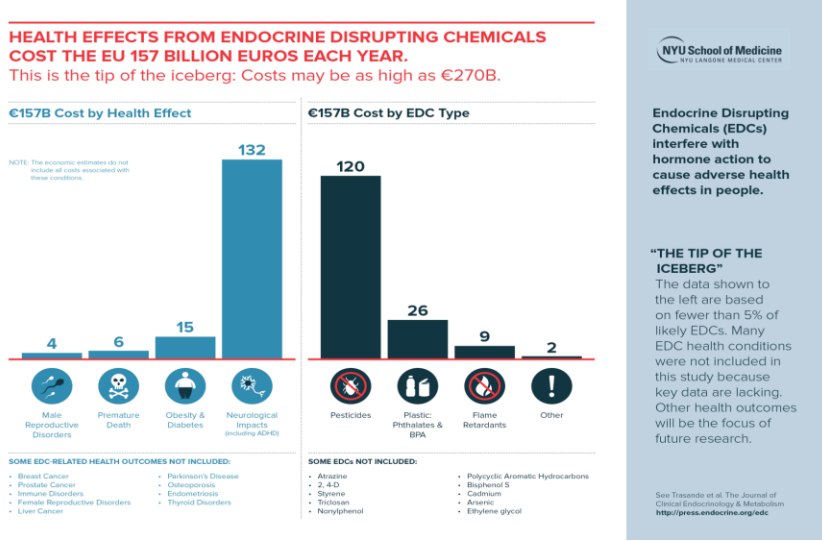
What is the burden of disease burden and are the health costs due to EDCs?

- Expert panels identified conditions where the evidence is strongest for causation
  - Developed ranges for fractions of disease burden that can be attributed for EDCs
  - Adapted GRADE Working Group and WHO criteria for evaluating epidemiologic evidence
  - Adapted Danish EPA criteria for evaluating toxicology evidence
  - Adapted IPCC approach to integrate epidemiology and toxicology evidence and estimate probability of causation



Fewer than 5% of EDCs

Subset of diseases due to EDCs selected

Subset of costs due to conditions examined

Severe underestimate of total costs

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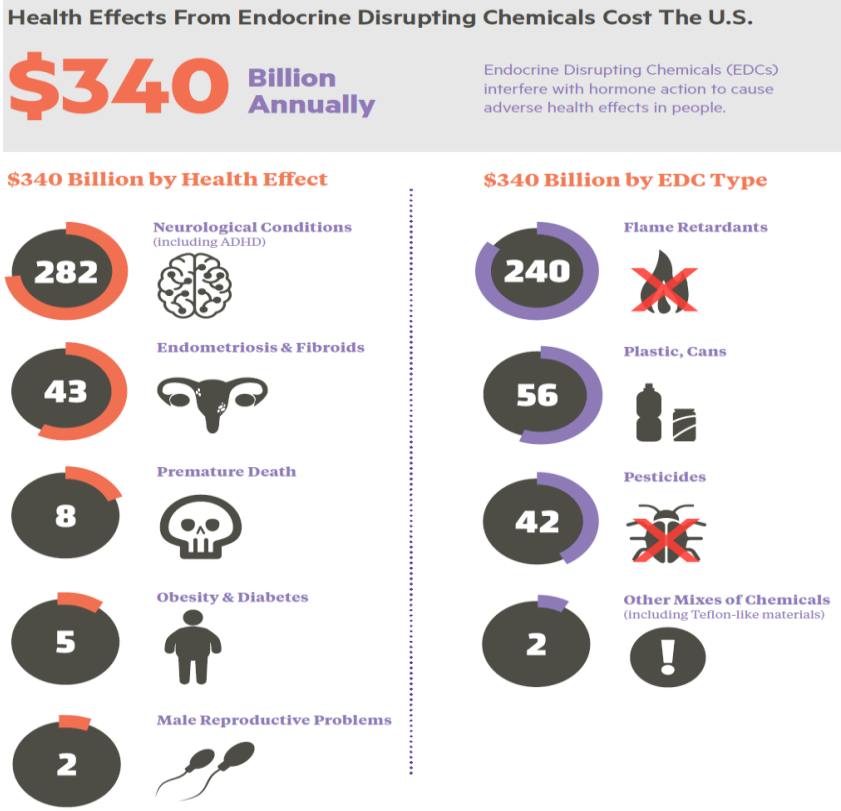
Policies predict exposure.

Exposure contributes to disease.

Disease affects us all.

- Costs in US higher than EU
  - Largely due to PBDE legacy
- Lower costs due to pesticides in US
  - Thanks to the Food Quality Protection Act!



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PFAS disease burden and costs

PFAS-attributable disease costs in the US: $5.52-62.6 billion/year across 13 conditions

- LBW due to prenatal exposure
- childhood obesity due to prenatal exposure
- kidney cancer due to lifetime exposure
- testicular cancer due to lifetime exposure
- hypothyroidism in females due to lifetime exposure
- adult obesity due to exposure over the lifespan
- T2D in females due to exposure over the lifespan
- GDM due to exposure measured in pregnancy
- endometriosis due to exposure over the lifespan
- PCOS due to exposure over the lifespan
- couple infertility due to lifetime exposure in females
- female breast cancer due to lifetime exposure, and
- pneumonia in children due to prenatal exposure

Obsekov et al Exposure and Health 2022

Data from 70 countries suggest exposure to PFAS contributed to approximately 461,635 (95% CI: 57,418-854,645) cases per year of LBW during the past two decades, predominantly from Asian regions.

Fan et al ES&T 2022

How much of the disease burden due to EDCs is related to plastic?

- 97.5% for bisphenol A (96.25-98.75% for sensitivity analysis)
- 98% (96%-99%) for di-2-ethylhexylphthalate
- 100% (71%-100%) for butyl phthalates and benzyl phthalates,
- 98% (97%-99%) for PBDE-47
- 93% (16%-96%) for PFAS

Chemicals Used in Plastic Materials: An Estimate of the Attributable Disease Burden and Costs in the United States

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Abstract

Context: Chemicals used in plastics have been described to contribute to disease and disability, but attributable fractions have not been quantified to assess specific contributions. Without this information, interventions proposed as part of the Global Plastics Treaty cannot be evaluated for potential benefits.

Objective: To accurately inform the tradeoffs involved in the ongoing reliance on plastic production as a source of economic productivity in the United States, we calculated the attributable disease burden and cost due to chemicals used in plastic materials in 2018.

Methods: We first analyzed the existing literature to identify plastic-related fractions (PRF) of disease and disability for specific polybrominated diphenylethers (PBDE), phthalates, bisphenols, and polyfluoroalkyl substances and perfluoroalkyl substances (PFAS). We then updated previously published disease burden and cost estimates for these chemicals in the United States to 2018. By uniting these data, we computed estimates of attributable disease burden and costs due to plastics in the United States.

Results: We identified PRFs of 97.5% for bisphenol A (96.25-98.75% for sensitivity analysis), 98% (96%-99%) for di-2-ethylhexylphthalate, 100% (71%-100%) for butyl phthalates and benzyl phthalates, 98% (97%-99%) for PBDE-47, and 93% (16%-96%) for PFAS. In total, we estimate $249 billion (sensitivity analysis: $226 billion-$289 billion) in plastic-attributable disease burden in 2018. The majority of these costs arose as a result of PBDE exposure, though $66.7 billion ($64.7 billion-67.3 billion) was due to phthalate exposure and $22.4 billion was due to PFAS exposure (sensitivity analysis: $3.85-$60.1 billion).

Conclusion: Plastics contribute substantially to disease and associated social costs in the United States, accounting for 1.22% of the gross domestic product. The costs of plastic pollution will continue to accumulate as long as exposures continue at current levels. Actions through the Global Plastics Treaty and other policy initiatives will reduce these costs in proportion to the actual reductions in chemical exposures achieved.

- In total, we estimate $249 billion (sensitivity analysis: $226 billion-$289 billion) in plastic-attributable disease burden in 2018.
- The majority of these costs arose as a result of PBDE exposure, though $66.7 billion ($64.7 billion-67.3 billion) was due to phthalate exposure and $22.4 billion was due to PFAS exposure (sensitivity analysis: $3.85-$60.1 billion).

Trasande et al J Endo Soc 2024

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Unequal impacts

- OECD predicts majority of chemical production and consumption will occur in low- and middle-income countries by 2030
- Landfills in low- and middle-income countries are teeming with plastic waste as well.
- Waste picking increasingly a way of life for people in these communities.
- Women of childbearing age comprise a substantial proportion of waste pickers, setting in motion multigenerational consequences of plastic production and consumption.

Disparities in high-income countries

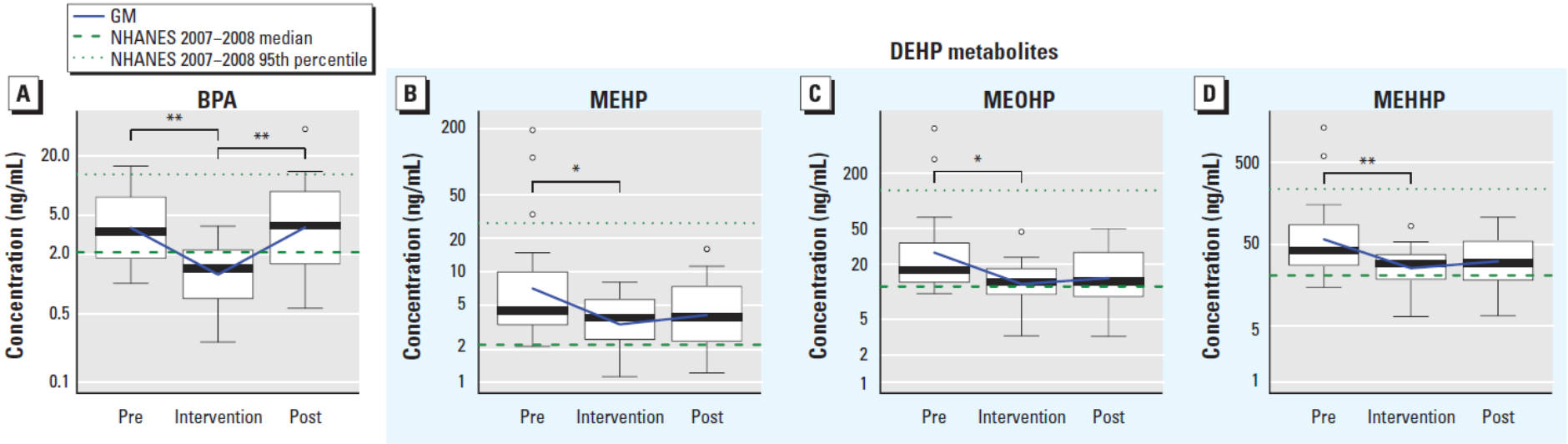
- EDC exposure levels and associated burden of disease and costs higher in non-Hispanic Blacks ($56.8 billion; 16.5% of total costs) and Mexican Americans ($50.1 billion; 14.6%) compared with their proportion of the total population (12.6% and 13.5%, respectively).

- Associated costs among non-Hispanic whites comprised 52.3% of total costs ($179.8 billion) although they comprise 66.1% of the US population.

What can we do limit EDC exposures?

- **Fortunately, there are safe and simple steps families can take at home to limit these exposures.**

- We can also advocate for proactive policies that limit exposures.



Rudel et al EHP 2011

Bisphenol and phthalate exposures are preventable (also in high SES populations)…

- Youth-led, community-based participatory research intervention
- 100 Latina girls using personal care products whose labels stated they did not contain these chemicals for 3 days
- Urinary concentrations of monoethyl phthalate decreased by 27.4% (95% CI: –39.3, –13.2) on average over the 3-day intervention

Harley et al EHP 2016

…and low-resource communities as well

- 15 PFAS, 8 PBDEs, and 19 organophosphorus esters (PBDE replacements) measured in dust from offices, common areas, and classrooms having undergone:
  - no intervention (conventional rooms in older buildings meeting strict fire codes)
  - full “healthier” materials interventions (rooms with “healthier” materials in buildings constructed more recently or gut-renovated), or
  - partial interventions (other rooms with at least “healthier” foam furniture but more potential building contamination).
- Rooms with full “healthier” materials interventions had 78% lower dust levels of PFAS than rooms with no intervention ($p<0.01$).
- Rooms with full “healthier” interventions also had 65% lower OPE levels in dust than rooms with no intervention ($p<0.01$) and 45% lower PBDEs than rooms with only partial interventions ($p<0.1$), adjusted for covariates related to insulation, electronics, and furniture.

Young et al Env Int 2020

Household environment matters too!

Safe and simple steps to limit exposure

- Avoid canned foods. Bisphenol A (BPA) doesn't discriminate by the type of can – soda, vegetables, tuna. Acidity is probably the biggest driver of absorption into food, but all types of canned food have detectable levels of BPA.
- Don't microwave plastic containers or put them in the dishwasher. Heat and harsh cleaning agents are effective at getting the chemicals out of plastic.
- Avoid plastic bottles with the numbers 3, 6 or 7.
- If plastic bottles were meant for single use, keep them that way. Besides, reusing them raises the chance of bacterial contamination.
- If plastic food containers are etched, it's time to throw them away. Etching increases the odds of leaching.
- Use stainless steel or cast iron cookware.
- Vacuum regularly with a HEPA filter and mop with a wet mop to prevent dust from accumulating.

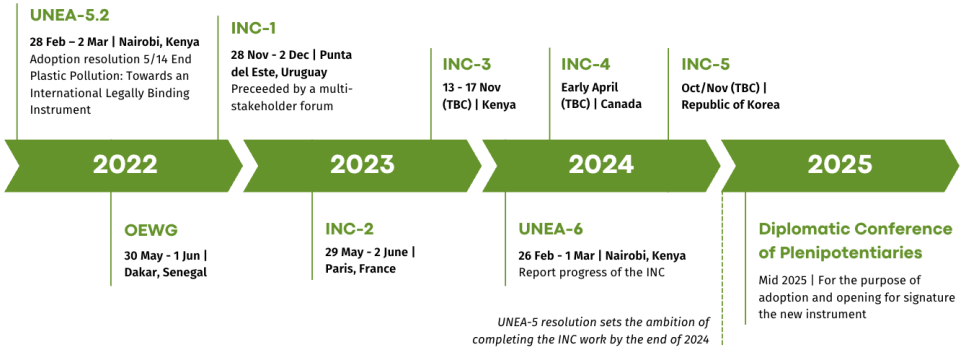
What can we do limit EDC exposures?

- Fortunately, there are safe and simple steps families can take at home to limit these exposures.

- **We can also advocate for proactive policies that limit exposures.**

A Global Plastics Treaty

- March 2022 at resumed fifth session of the UN Environment Assembly: resolution requested the Executive Director of the UN Environment Programme to convene an Intergovernmental Negotiating Committee
- Purpose: to develop an international legally binding instrument on plastic pollution, including in the marine environment, which addresses the full life cycle of plastic, including its production, design, and disposal.



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Reduce, reuse or recycle?

- Recycled plastics themselves present health threats.

- Recycling itself is energy intensive and more expensive than creating plastic from fossil fuels.

- Recycled polyethylene plastic bottles also have been identified to contain higher levels of bisphenols, phthalates and metals than newly-produced bottles due to cross-contamination during disposal, collection and reprocessing.

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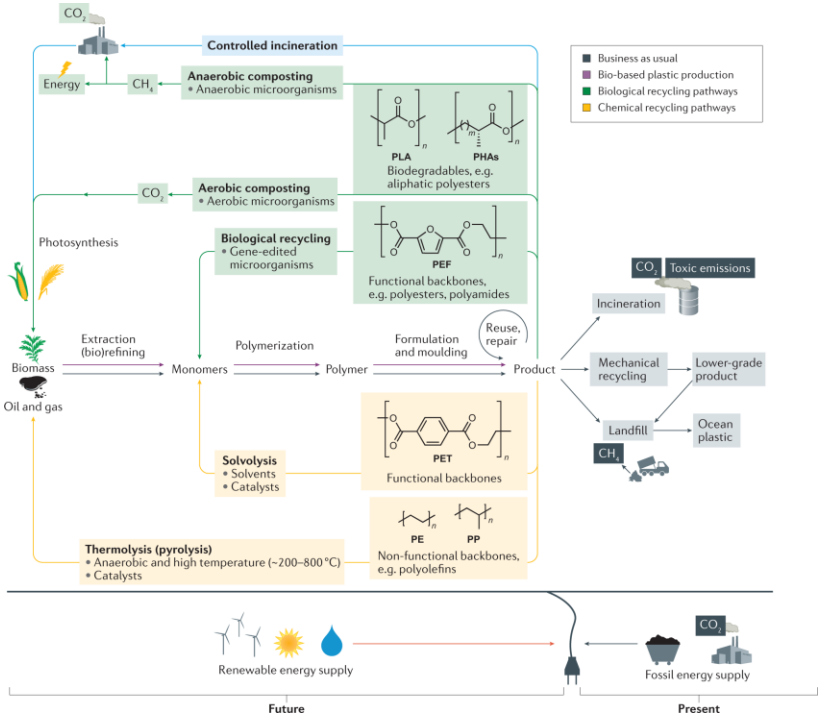
Bioplastics?

- Plant- and other bio-based plastics have also been touted as a planet-friendly alternative and form of sustainable innovation.
- However, they require high temperature to be recycled, and when the high costs force bioplastics into landfills, they produce methane, which is more potent than carbon dioxide in driving climate change.
- Laboratory studies also suggest greater oxidative stress and antiandrogenicity of chemicals found in liquids obtained from bioplastic bottles.

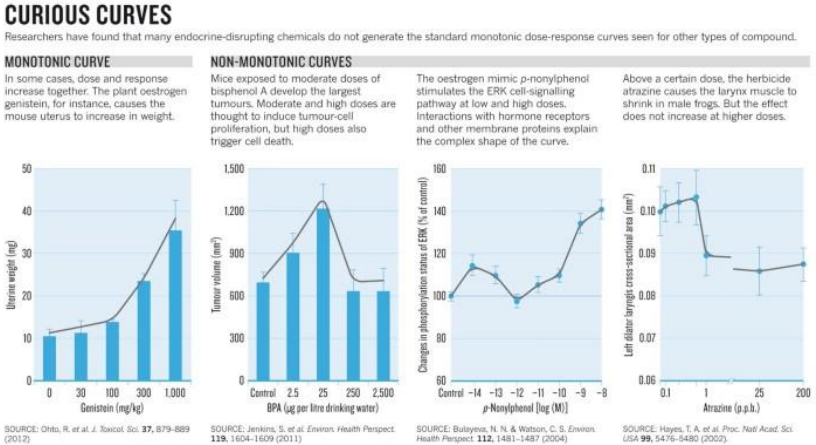


Scientific knowledge: risk assessment fails for EDCs (hazard-based paradigm needed)

Lag from identifying new exposures to completing human studies of effects, especially for disease outcomes with longer latencies such as diabetes or cancers

Non-monotonic exposure-response relationships exist for many synthetic chemicals including EDCs → inability to extrapolate to no adverse effect levels

While some risk-based approaches try to account for age-related vulnerability, they falsely presume that the population sensitivity (children, elderly) can be quantified *a priori*



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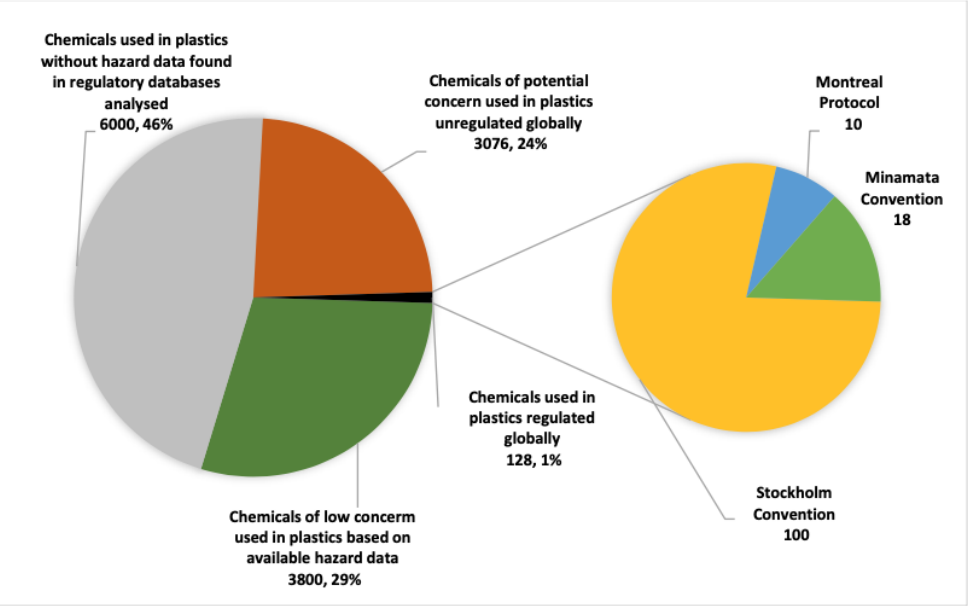
A vehicle for chemicals regulation?



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Expanding biomonitoring globally

If persist with risk based approach, need broader and stronger human biomonitoring platform

- Particularly to address gaps in low- and middle-income countries
- Can also inform educational campaigns about safe and simple steps to limit exposure

- Disclosure of ingredients also crucial (right-to-know)

An International Agency for Research on EDCs

We suggest the establishment of a new international agency, or a broadening of the International Agency for Research on Cancer (IARC)'s scientific charge, to include endocrine disruption

- Established in 1965, IARC tasked with evaluating the evidence of carcinogenesis due to environmental hazards
- Autonomous body like IARC can bring together diverse experts for international collaborative reports on EDCs would foster global movement on regulations
- An International Agency for Research in Endocrine Disruption would further support post-2020 process of Strategic Alliance for International Chemicals Management

We need a global plastics treaty that:

- Reduces plastic production
- Recognizes hazards posed by recycling and use of bioplastics
- Uses hazard rather than risk to evaluate and remove endocrine disrupting chemicals from plastic
- Expands biomonitoring globally
- Establishes an independent scientific body to evaluate hazards of endocrine disrupting chemicals

Thank you

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