The *Lancet* Countdown on health and plastics

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Plastics are a grave, growing, and under-recognised danger to human and planetary health. Plastics cause disease and death from infancy to old age and are responsible for health-related economic losses exceeding US$1·5 trillion annually. These impacts fall disproportionately upon low-income and at-risk populations. The principal driver of this crisis is accelerating growth in plastic production—from 2 megatonnes (Mt) in 1950, to 475 Mt in 2022 that is projected to be 1200 Mt by 2060. Plastic pollution has also worsened, and 8000 Mt of plastic waste now pollute the planet. Less than 10% of plastic is recycled. Yet, continued worsening of plastics' harms is not inevitable. Similar to air pollution and lead, plastics' harms can be mitigated cost-effectively by evidence-based, transparently tracked, effectively implemented, and adequately financed laws and policies. To address plastics' harms globally, UN member states unanimously resolved in 2022 to develop a comprehensive, legally binding instrument on plastic pollution, namely the Global Plastics Treaty covering the full lifecycle of plastic. Coincident with the expected finalisation of this treaty, we are launching an independent, indicator-based global monitoring system: the *Lancet* Countdown on health and plastics. This Countdown will identify, track, and regularly report on a suite of geographically and temporally representative indicators that monitor progress toward reducing plastic exposures and mitigating plastics' harms to human and planetary health.

Introduction

Plastics are the defining material of our age.[1] Plastics are complex, manufactured chemical materials comprising a polymer matrix and multiple additional chemicals.[2] More than 98% of plastics are made from fossil carbon—gas, oil, and coal.[3–5] Plastics are flexible, durable, convenient, and perceived to be cheap. Plastics are ubiquitous in modern societies, and have supported advances in many fields, including medicine, engineering, electronics, and aerospace. It is increasingly clear, however, that plastics pose grave, growing, and underappreciated dangers to human and planetary health.[6] Moreover, plastics are not as inexpensive as they appear and are responsible for massive hidden economic costs borne by governments and societies.[7]

Early warnings of the ecological dangers posed by plastics[8] became reality in the 1960s and 1970s with reports of plastic waste obstructing the gastrointestinal tracts of seabirds, entangling sea turtles, and killing marine mammals.[9] These dangers were followed by the discovery of abundant plastic particles in the Sargasso Sea[10] and the recognition that microplastic particles are ubiquitous in surface waters and ocean sediments, with microplastics and plastic chemicals detected in marine and terrestrial species worldwide.[11–15]

The potential for plastics to harm human health was recognised in the 1970s with the observation of four cases of hepatic angiosarcoma among polyvinyl chloride (PVC) polymerisation workers in Kentucky, USA, occupationally exposed to vinyl chloride monomer.[16] Additional harms to health are seen given the high incidence of injuries, illnesses, and deaths among workers who extract carbon feedstocks for plastic production by fracking, oil drilling, and coal mining. Elevated rates of stillbirths, premature births, asthma, and leukaemia in fenceline communities adjacent to fracking wells and plastic production facilities show that plastics' harms extend beyond the workplace and affect people of all ages.[17] National biomonitoring surveys support these findings and documents the presence of multiple widely used plastic chemicals, including bisphenols, phthalates, brominated flame retardants, and perfluorinated and polyfluorinated substances (PFAS) in the bodies of nearly all people examined, including newborn infants and pregnant women.[18,19] Microplastic and nanoplastic particles (MNPs) are increasingly reported in human biological specimens, including blood, breastmilk, liver, kidney, colon, placenta, lung, spleen, brain, and heart in populations worldwide.[20] Also, brominated flame retardants are widely encountered in house dust.[21] A 2020 consensus statement warned of the health threat of multiple plastic

Search strategy and selection criteria

To identify newly reported information on the health impacts of plastics, we used PubMed to identify articles published in English between Sept 30, 2020, and Jan 24, 2025. Our two search questions were: "What are the effects of plastics and plastic chemicals on health-related outcomes?", and "What are the underlying pathways or mechanisms through which these effects occur?". Our search terms were: "plastics", "plastic-associated chemicals", "plastic waste", and "health-related outcomes". Two authors (MT and JR) independently screened the titles and abstracts of the identified and deduplicated records (n=2887) using our pre-defined scope and objectives. Additional references were included based on the authors' expert knowledge of the relevant literature.

chemicals in food contact materials.[22] Reviewing these data, the Minderoo–Monaco Commission on plastics and human health concluded in 2023 that plastics endanger human and planetary health at every stage of their lifecycle—in feedstock extraction, primary production, product fabrication, transport, use, recycling, and following disposal into the environment.[23]

Plastics' harms to human and planetary health are worsening,[24] driven mainly by continuing annual increases in the production of new plastics. Global plastic output has grown more than 250-fold—from less than 2 megatonnes (Mt) in 1950, to 475 Mt in 2022,[25–27] with the most rapid increases seen in the production of single-use plastics. Consequently, plastic waste generation has increased in parallel. Without intervention, it is projected that global plastic production will nearly triple by 2060 (figure 1).[29]

The need for intervention

Continued worsening of plastics-associated harms is not inevitable. Similar to ambient air pollution, lead, mercury, climate change, and chlorofluorocarbons, plastics' harms can be successfully and cost-effectively mitigated with evidence-based laws and policies that are supported by enabling measures (eg, transparency, regulation, and monitoring) and facilitated by effective implementation measures (eg, fair enforcement and adequate financing; panel 1).

In response to plastics' increasingly visible harms, governments have begun to act at the subnational, national, and in the case of the EU, the supranational level. These interventions are varied, and generally target specific harms, products, or plastic uses, and so, are necessarily fragmented. Examples of these interventions include banning specific single-use plastics;[40] removing or restricting harmful chemicals in plastics;[19,41,42] setting state-wide reduction targets for plastic packaging;[43] incentivising reuse;[43] and monitoring for microplastics in drinking water.[44,45]

To curb plastics' harms globally, the UN Environment Assembly (UNEA) unanimously resolved in March, 2022, to develop an international legally binding instrument on plastic pollution—the Global Plastics Treaty.[46] Development and implementation of this treaty creates a unique opportunity to reduce plastics' harms throughout the plastic lifecycle and to safeguard human and planetary health.

During negotiations, a diverse group of UN member states, including the members of the High Ambition Coalition to End Plastic Pollution, have supported the protection of human health as a treaty objective. At the time of writing, more than 100 UN member states have supported setting global targets for reducing the production of primary plastic polymers to sustainable levels,[47] with even more calling for the phasing out of the most harmful plastic products and plastic chemicals.[48–50]

WHO, which is engaging in the negotiations process as an observer, has put forth three guiding principles: first, that attainment of the highest standard of human and environmental health should be a core objective of the Global Plastics Treaty; second, that the known and predicted health risks associated with plastic polymers, chemicals and additives, and MNPs should be addressed across all stages of the plastics lifecycle; and third, that ensuring access to safe and effective health products that are of good quality and affordable to all is key.[51] Furthermore, health-focused stakeholders have argued that the health-care sector, with its considerable use of plastics, should not be exempt from the Global Plastics Treaty.[52]

The *Lancet* Countdown on health and plastics

Coincident with the expected finalisation of the Global Plastics Treaty, we are launching a health-focused, indicator-based, global monitoring system on plastics—the *Lancet* Countdown on health and plastics. The goal of this Countdown, which will be guided and informed by the *Lancet* Countdown on health and climate change, is to provide a credible, independent global monitoring system

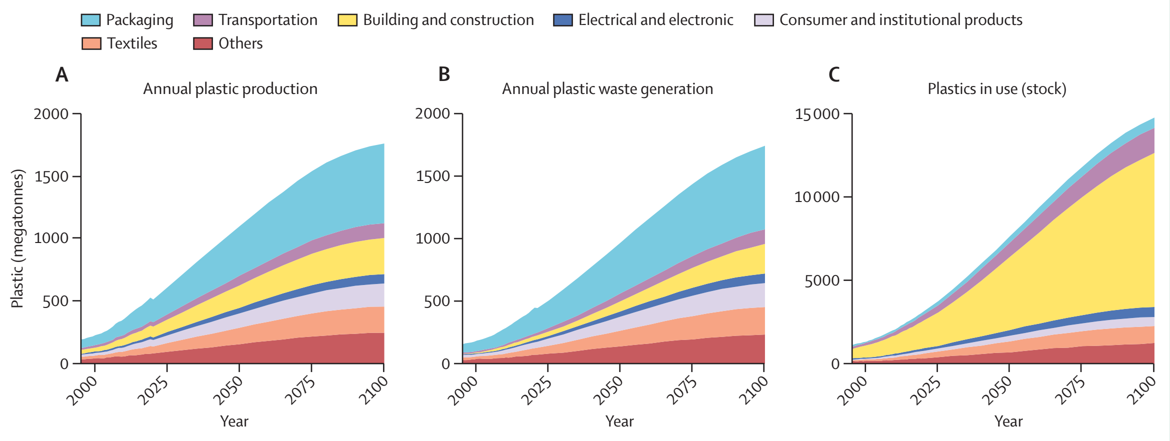

Figure 1: **Global trends in plastic production, plastic waste generation, and plastic use—total and by sector, 2000–2100**
(A) Annual plastic production. (B) Annual plastic waste generation. (C) Plastics in current use (stock). Adapted from Stegmann and colleagues.[28]

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For the **High Ambition Coalition to End Plastic Pollution** see https://hactoendplasticpollution.org/hac-member-states-ministerial-joint-statement-for-inc-5

For the **Lancet Countdown on health and climate change** see https://lancetcountdown.org

Panel 1: Lessons learned from other global health threats

Successes achieved in the control of other environmental health threats offer lessons for the control of the plastic crisis. Clean air legislation has reduced ambient air pollution in multiple countries, thus improving air quality and preventing millions of premature deaths.[30] Lead has now been removed from automotive petrol in every nation, resulting in sharp reductions in children's blood lead levels and increases in cognitive function among children, and contributing to decreased risks of hypertension, heart disease, and stroke in adults.[31] The Montreal Protocol on Substances that Deplete the Ozone Layer has considerably reduced emissions of ozone-depleting chlorofluorocarbons and their alternatives, leading to the recovery of the stratospheric ozone layer and helping to prevent deaths from malignant melanoma.[32,33] The Minamata Convention on Mercury is coordinating a global phase-out of mercury to protect infants and children from developmental neurotoxicity.[34]

These interventions have proven highly cost-effective. For example, each dollar invested in air pollution control in the USA since 1970 is estimated to have yielded an economic benefit of US$30 by reducing health-care costs and increasing the economic productivity of a healthier, longer-lived population.[30] The removal of lead from petrol has benefitted the health of entire nations by increasing intelligence, human capital, and economic productivity. In the USA, lead removal is estimated to have added $200 billion to the economy in each annual birth cohort since 1980—an aggregate benefit of more than $8 trillion in the past four decades.[31]

Two key lessons emerge from these interventions. First, health matters. The recognition that an environmental threat damages human health, especially children's health, is far more probable to catalyse public engagement and drive meaningful change across every level of society than a conversation that focuses solely on the environment. Second, data matter. Data are needed to identify the sources of a health threat, measure the extent and severity of exposure across populations, quantify health effects, track time trends and geographic patterns, assess the effectiveness of interventions, and guide course corrections. Data play a key role also in countering disinformation and attempts at greenwashing, such as the false claims by the plastic industry that all plastics can be recycled,[35–37] or that plastic waste can safely be burned for energy and to generate plastic credits in industries, such as in cement production.[38,39]

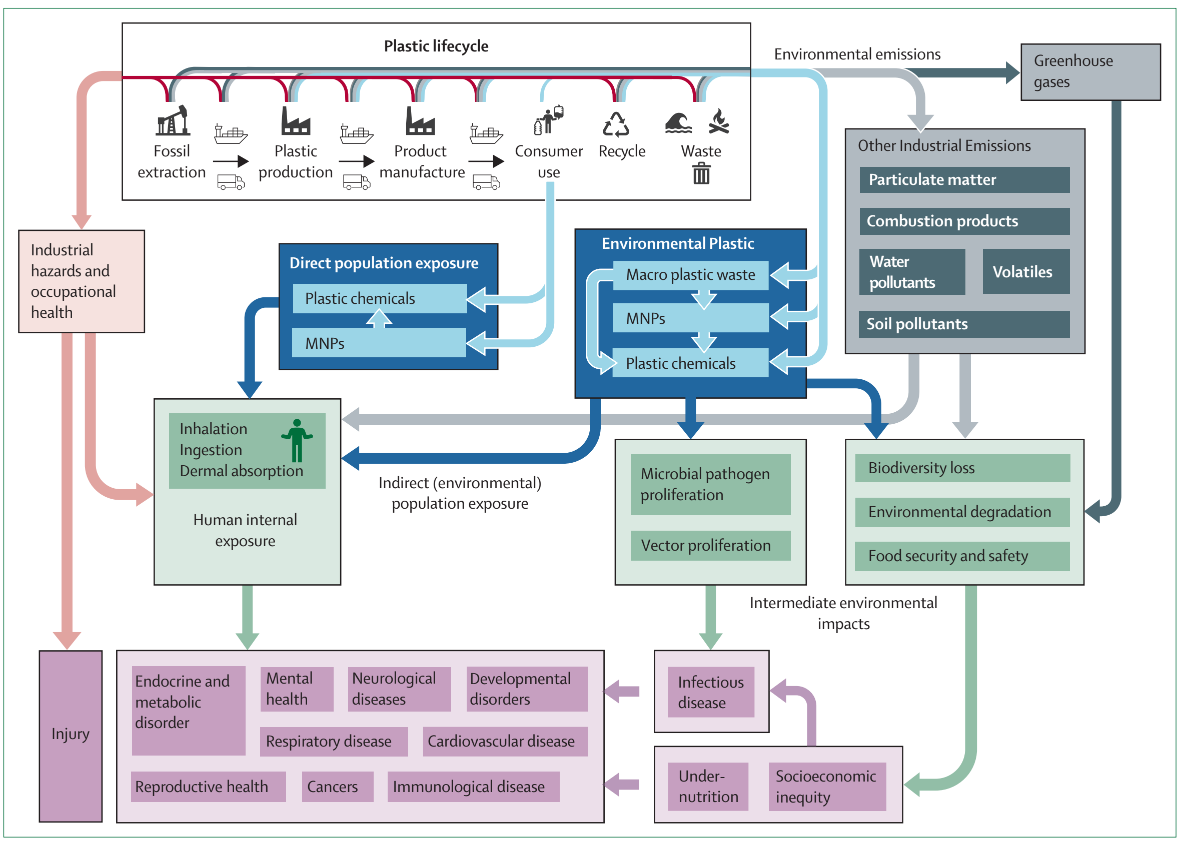

Figure 2: **The potential impacts of plastics on health across the plastic lifecycle**
MNP=microplastic and nanoplastic particle.

that will track progress toward reducing plastic exposures and mitigating plastics' harms to human and planetary health as the Global Plastics Treaty comes into force. This Countdown will identify, track, and regularly report on a suite of scientifically meaningful and geographically and temporally representative indicators that document the impacts of plastics and plastic chemicals on human and planetary health across all stages of the plastic lifecycle.

This Countdown will track global trends and patterns in plastic production, consumption, and waste generation, and will monitor exposures to plastic-associated pollution, plastic chemicals, and MNPs. The Countdown will track and quantify plastics-associated harms to human and planetary health and the health-related economic costs that result from those harms. The Countdown will document plastics' impacts on at-risk populations and will track and report on governmental policy responses, non-governmental interventions and innovations, and impediments to the resolution of the global plastics crisis. Furthermore, the Countdown will highlight the health benefits of interventions, and the opportunities lost because of inaction, which will provide data that can inform decision making at all levels for the benefit of public health.

A particular aim of this Countdown will be to move consideration of plastics' health impacts to centre stage of the conversation on plastics—to emphasise that the plastics crisis is more than an environmental problem and also is a serious and worsening threat to human and planetary health. The Countdown's origins, structure, and plans for its future development are described in this Health Policy.

Plastics' harms to human and planetary health

To underscore the need for the *Lancet* Countdown on health and plastics, which will independently track progress as the Plastics Treaty comes into force, we present here a brief overview of plastics' harms to human and planetary health across the plastic lifecycle, with particular emphasis on new information that has emerged since publication in 2023 of the report of the Minderoo–Monaco Commission on plastics and human health.[23]

Building on that previous work, the *Lancet* Countdown on health and plastics has developed a pathway diagram summarising plastics' impacts on health (figure 2). Most of these established harms are mediated by exposure to plastic chemicals while others might be due to MNPs. Additional health effects are the consequence of industrial and occupational hazards and of pollutant and greenhouse gases (GHGs) released to the environment in carbon feedstock extraction, plastic production and fabrication, and waste disposal (figure 2). The UN Office of the High Commissioner on Human Rights has emphasised that sustainable solutions for worsening plastics-associated harms will require justice-focused policies that advance human rights.[53] The Minderoo–Monaco Commission found that plastics harm human and planetary health at every stage of the plastic lifecycle (panel 2).

Panel 2: Summary of key findings from the Minderoo–Monaco Commission

The Minderoo–Monaco Commission on plastics and human health presented a comprehensive assessment of plastics-associated harms to human and ecosystem health.[23] Key findings were the following:

- Current patterns of plastic production, use, and disposal cause disease, disability, and death at every stage of the plastic lifecycle.
- Infants and young children are highly susceptible to plastics-associated harms. Early-life exposures to plastics and plastic chemicals are linked to increased risks of miscarriage, prematurity, stillbirth, low birthweight and birth defects of the reproductive organs, neurodevelopmental impairment, impaired lung growth, and childhood cancer. Early-life exposures to plastic chemicals can contribute to reduced human fertility and increased risks of non-communicable diseases, such as cancer, diabetes, and cardiovascular disease in adult life.
- Plastic production is highly energy-intensive, releases more than 2 gigatonnes of CO_2 equivalent and other climate-forcing greenhouse gases to the atmosphere each year, and harms health by accelerating climate change.
- Increasing plastic production is the main driver of worsening harms to human and planetary health.
- Because less than 10% of plastic is recycled and plastic waste can persist in the environment for decades, an estimated 8 billion tonnes of plastic waste or 80% of all plastic ever made, now pollute the planet.[25]
- The ocean is the ultimate destination for much plastic waste, and each year, an estimated 10–12 million tonnes of plastic enter the ocean. Many plastics appear to resist breakdown in the ocean and could persist for decades.
- Microplastic and nanoplastic particles (MNPs), which result from the breakdown of larger plastic materials, are an emerging threat to health. While the health impacts of MNPs are still incompletely understood, increasing numbers of studies report the presence of microplastics in multiple human tissues and are beginning to link MNPs to disease.
- Plastic is expensive**.** It is responsible for health-related economic losses that include health-care costs (eg, costs of physician services, hospitalisation, and medications) and productivity losses (eg, lost economic output or earnings resulting from disease, disability, or premature death). In 2015, the health-related costs of plastic production amounted to almost US$600 billion globally—more than the gross domestic product of New Zealand or Finland.[23] Chemicals in plastics, such as PBDE (flame retardant), bisphenol (BPA; monomer), and di(2-ethylhexyl)phthalate (DEHP; plasticiser) are responsible for additional health-related economic costs. In the USA alone, the annual costs of diseases caused by PBDE, BPA, and DEHP exceed $675 billion.
- These estimates undercount the full costs of plastics-related health damages because they examine only a few countries and only a subset of plastic chemicals. The costs are externalised by fossil fuel and plastic manufacturing industries and borne by governments and taxpayers.
- Current patterns of plastic production, use, and disposal are unsustainable and socially and environmentally unjust. Plastics-associated harms disproportionately damage disempowered and marginalised populations.[54] Addressing these inequities will require a multifaceted approach that centres on justice and incorporates equity and inclusivity into all levels of policy and decision making.

Plastic production

Global annual plastic production has increased from 2 Mt in 1950, to 475 Mt in 2022.[29] Cumulative production of primary (or virgin) plastic since 1950 exceeds 10 gigatonnes (Gt). Half of all plastic ever made has been produced since 2010 (figure 1).[55] In the absence of intervention, global annual output is projected to rise to between 749 Mt[56] and 976 Mt by 2050,[29] and to 1·2 Gt by 2060.[29]

A key driver of recent acceleration in plastic output is a pivot by the fossil fuel corporations and nations that are the major plastic producers of plastic and petrochemicals in response to declining demand for fossil energy.[24,57] For example, the Saudi Arabian Oil Company plans to channel about one third of its oil production to plastics and petrochemicals by 2030, and Shell has recently opened a new cracking plant in western Pennsylvania, USA, that will transform fracked gas from Appalachia into plastic pellets.[57]

China is the largest producer of primary plastics (208 Mt), outproducing both North America (71 Mt) and Europe (66 Mt) in 2020.[56] Plastic use per capita is, however, higher in North America (195 kg/year) and Europe (187 kg/year) than in China (138 kg/year).[56] Disposable, single-use plastics, especially packaging materials, are the most rapidly growing segment of plastic production.[58] Single-use items account for an estimated 35–40% of current plastic output and contribute disproportionately to plastic waste, accounting an estimated 65% of discarded plastics.[59] Municipal solid waste data indicate that plastic consumption levels in many countries could be higher than reported in official sources.[60]

Plastic production and climate change

Plastic production is energy intensive. In 2018, the International Energy Agency estimated that 14% of primary oil use and 8% of primary natural gas use went into petrochemical manufacturing, with about half of that going into plastic production.[3,61,62] Predictions indicate that with projected future increases in plastic production, as much as 20% of all fossil fuels could be used in plastics manufacturing by 2050.[61,63,64]

In 2020, plastic production was responsible for the release of 2·45 Gt CO_2 equivalent (CO_2e) of GHGs,[56,65] accounting for roughly 5% of industrial GHG emissions globally. An estimated 44% of these emissions came from coal, 40% from petroleum, and 8% from natural gas.[3] These amounts vary by region, reflecting differences in fossil carbon feedstock mix. Thus, in Asia, coal is the predominant source of GHG emissions in plastic production, whereas in North America, gas and oil are more considerable.

Business-as-usual projections that assume a 4·0% annual growth rate in plastic production and no interventions, estimate that plastic-associated GHG emissions could approximately triple by 2050 to reach 6·78 Gt CO_2e per year.[65] Interventions such as decarbonisation of the electricity grid[65] and other climate mitigation policies[56] could limit these projected increases. In the face of these business-as-usual projections, there is increasing pressure to curb continued unchecked increases in fossil fuel-based plastic production,[66] and to break entrenched and accelerating plastic-driven lock-in to climate change.[65,67,68]

Governmental subsidies for plastic production

Governments of many countries provide support for the production of primary plastic polymers and their monomers through various mechanisms. Subsidies are conferred chiefly through the underpricing of hydrocarbon feedstocks (primarily alkanes such as ethane and propane, and alkane mixes such as naphtha), and of the energy used to produce monomers (ethylene, propylene, etc) and polymers (polyethylene, polypropylene, etc), but also via grants, tax breaks, and below-market lending. Globally, the subsidies conferred through price subsidies for feedstocks and energy are estimated to have been US$43 billion in 2024, and are projected to increase to US $78 billion by 2050 under a business-as-usual scenario.[69]

Health effects of plastic production

Workers who produce plastic are exposed to a wide range of toxic chemicals, including carcinogens, such as benzene, 1,3-butadiene, formaldehyde, vinyl chloride, and hazardous airborne dusts, which can lead to disease and premature death. Furthermore, workers are also at high risk of traumatic injury. The Minderoo–Monaco Commission conservatively estimated that approximately 32 000 premature deaths occurred globally among plastic production workers in 2015, resulting in annual health-related economic costs of $40 million.[23]

Beyond the workplace, plastic production causes air, water, and soil pollution. Airborne emissions from plastic production include particulate matter ($PM_{2·5}$), sulphur dioxide, and nitrogen oxides, and other hazardous chemicals to which plastic workers are exposed. These emissions result in elevated rates of disease, disability, and premature death in fenceline communities adjacent to oil and gas wells and production facilities among people of all ages, including infants and children. In 2015, $PM_{2·5}$ emissions from plastics production were responsible for an estimated 158 000 premature deaths globally and for health-related economic losses of more than $200 billion.[23] More than 75% of these deaths occurred in China and other parts of Asia.

GHG emissions from plastic production magnify the health impacts caused by plastics. As reported by the *Lancet* Countdown on health and climate change, GHG emissions are linked to a wide array of health risks, including heat waves, fires, floods, droughts, crop failure, and vector-borne diseases.[71]

Plastic chemicals

More than 16 000 chemicals can be present in plastics.[2] Most of the established harms to health associated with plastic use are due to chemicals of concern,[72] including chemicals intentionally used in plastic manufacture, such as starting substances (eg, monomers and catalysts), processing aids (eg, lubricants), and additives (eg, plasticisers, flame retardants, fillers, dyes, and stabilisers).[73,74] Chemicals of concern also include non-intentionally-added substances, such as impurities, byproducts, contaminants, and degradation and transformation products.[2,74]

Most plastic chemicals, including additives, are not chemically bound to polymer matrices. Instead, they are physically blended into polymers and can be released from plastics and into the surrounding environment by leaching, volatilisation, and abrasion.[75–77] These chemicals can then enter the human body via ingestion, inhalation, and dermal absorption.[23]

Human exposure to plastic chemicals is extensive. National biomonitoring surveys detect measurable levels of several hundred synthetic chemicals, including plastic chemicals, in people of all ages, including newborn infants exposed in utero, across all global regions.[18,78–80] Chemicals widely detected in these surveys include plastic-related bisphenols,[81–83] benzophenones,[82] phenolic antioxidants,[84] phthalates,[85] brominated[86,87] and organophosphate[88] flame retardants, and PFAS.[80] Plastic goods and MNPs contribute to human exposure to these chemicals to differing extents in different countries, as many of these substances are also used in other consumer products and industrial applications.

Food contact materials are an important source of human exposure to plastic chemicals.[22] Food containers,[89] drinking water bottles and sachets,[90] baby food pouches,[91] tableware, and food-processing equipment can all release plastic chemicals directly into foods and beverages. A systematic review of 947 studies on plastic food contact materials reported that 1481 (40%) of 3696 chemicals are released into food or food simulants under specific conditions.[92–94] More than 1396 plastic food contact chemicals have been detected in humans of all ages.[95,96] Migration of plastic chemicals into foodstuffs increases at higher temperatures and with longer periods of contact time. Fat content and acidity of foodstuffs also influence the extent of release, as does serving size, since the packaging surface-to-food volume ratio increases with decreasing portion sizes; this aspect is particularly concerning for plastic-packaged foodstuffs specifically marketed for infants and children.

Other sources of exposure to plastic chemicals include house dust;[21] packaging of personal care products; clothing, furniture, and carpets; electronic equipment, such as mobile phones and computers; building materials; and medical tubing, fluids, and devices.[23]

Health impacts of plastic chemicals

Plastic chemicals present high risks to health because of their large production volumes, wide use, and potential for human exposure. A recent umbrella review of the synthesised human epidemiological research on the health impacts of plastic chemicals examined almost 1000 meta-analyses from 52 systematic reviews, representing data from the equivalent of nearly 1·5 million participants.[72] Relevant data were available for five chemical classes: PFAS, polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls, ortho-phthalate esters, and bisphenols. While polychlorinated biphenyls are now regulated in many jurisdictions, global responses to ortho-phthalate esters and bisphenols have been inconsistent, and these chemical classes are still widely used.

This umbrella review found consistent evidence for multiple health effects at all stages of human life for many plastic chemicals. Infants in the womb and young children are especially at-risk.[97] These effects include impaired reproductive potential (eg, polycystic ovary syndrome and endometriosis), perinatal effects (eg, miscarriage, reduced birthweight, and malformations of the genital organs), diminished cognitive function (eg, intelligence quotient loss), insulin resistance, hypertension and obesity in children, and type 2 diabetes, cardiovascular disease, stroke, obesity, and cancer in adults.[72]

Lack of information on plastic chemicals

Despite their large production volumes and widespread human exposure, hazard data are not publicly available for more than two-thirds of known plastic chemicals. Where hazard data are available, they are often incomplete.[2] A recent systematic evidence map found that approximately 75% of the plastic chemicals examined have not been assessed in human health studies.[98]

Of the plastic chemicals for which data are available, approximately 75%—more than 4200 substances—have been found to be highly hazardous due to their toxic effects, persistence, bioaccumulation, and mobility.[2] Almost 1500 of these chemicals are carcinogenic, mutagenic, or toxic to reproduction, and more than 1700 are toxic to specific organs, such as the liver. 47 of these chemicals are endocrine disruptors recognised in the EU and more than 1800 have been shown to be released from plastics and have a high potential for human exposure.[2] Meanwhile, beyond these chemicals of known hazard, little to no information on chemical composition, toxic effects, or potential hazard is available for most plastic products to which people are exposed, including chemicals commonly encountered in daily life.[99]

A lack of transparency on which chemicals are present in plastics, on plastic chemicals' uses and applications, on their production volumes, and on their toxic effects limits our understanding of the full range of plastic chemicals' potential harms to human and planetary health.

These knowledge gaps reflect the limitations in current legislation.[100] Under existing laws, industry is not compelled to support independent toxicity testing of new plastic chemicals, to conduct post-market surveillance of chemicals, or to make testing data publicly available. Despite their potential for wide-scale human exposure and harm to health, plastic chemicals are subject to far less scrutiny than chemicals intended for use as pharmaceuticals.[97]

In the absence of transparent, publicly available data, product analytics and human biomonitoring are often the only tools available to identify the chemicals present in plastic products and to assess their contributions to human exposure and disease.[18,77–80,101] A problem with relying on these indirect indicators is that government agencies, academics, and civil society must carry out the complex and resource-intensive task of identifying, characterising, and assessing the health risks of chemicals in plastics, and can typically do so only after chemicals have already come to market. Given the vast number of plastic chemicals in commerce, the wide range of formulations, and the limited number of chemicals that have been officially evaluated and classified as a hazard, gathering this information is a formidable challenge.

Given the considerable gaps in knowledge of plastic chemicals, it is reasonable to conclude that the full extent of these chemicals' harms to health is underestimated and that the burden of disease currently attributed to them is undercounted. Given the current post-market approach to plastic evaluation, and continuing examples of regrettable substitution,[98] there could be plastic chemicals currently in wide use with ongoing harms to human health that have not yet been discovered.[97]

Economic costs of plastic chemicals

Disease, disability, and premature deaths resulting from exposures to plastic chemicals can lead to large economic losses, which include health-care costs and productivity losses. In the 2023 Minderoo–Monaco Commission report, Cropper and colleagues estimated the magnitude of these health-related costs for PBDE (flame retardant), bisphenol (BPA; monomer), and di(2-ethylhexyl)phthalate (DEHP; plasticiser) in one country, the USA.[19] Their analysis found that the annual health-related costs attributable to these three chemicals are $675 billion (measured in 2015 US$ adjusted for purchasing power parity).

Cropper and colleagues have recently updated their estimates.[19] They examined the same three plastic chemicals—PBDE, BPA, and DEHP—but with much broader geographic coverage, encompassing 38 countries covering one third of the world's population. Linking exposures to epidemiological data, and assuming the reported links are causal, Cropper and colleagues estimated that in 2015, BPA was associated with 5·4 million cases of ischaemic heart disease and 346 000 cases of stroke, resulting in 237 000 ischaemic heart disease deaths and 194 000 stroke deaths. DEHP was associated with 164 000 deaths among those aged 55–64 years. Prenatal PBDE exposure resulted in the loss of 11·7 million IQ points among children born in 2015. The estimated economic cost of these outcomes was $1·5 trillion (measured in 2015 US$ adjusted for purchasing power parity).[19]

Another study on the same chemical classes estimated that disease-associated costs were equivalent to 1·22% of the US gross domestic product in 2018.[102] In that analysis, the health costs of PFAS exposure in the US in 2018 were estimated to be $22 billion.[102]

Microplastic and nanoplastic particles

MNPs can be intentionally generated or formed from the breakdown of plastic products. While intentional uses of manufactured MNPs (eg, cosmetics) are being curtailed in many jurisdictions,[100,103,104] the release of increasing volumes of plastic waste into the environment has resulted in environmental accumulation of MNPs and increasing MNP concentrations in multiple environmental media.[105]

Various industrial sectors contribute to MNP emissions. In the EU, tyres, textiles, paints, plastic pellets, detergent capsules, and textiles are estimated to contribute as much as 90–93% of MNP emissions,[106] with an overall rising trend of 7–9% between 2016 and 2022.[107] In addition, mechanical recycling releases considerable quantities of MNPs to the environment.[108] Similar to the plastic products from which they originate, MNPs consist of a polymer matrix plus thousands of embedded and adsorbed chemicals as well as adsorbed biological materials and bacteria.[109]

Due to their persistence and transboundary transport,[110–112] MNPs have been found in the most remote reaches of the planet, from the Arctic[113] to deep seas,[114] at high altitudes,[115] and in soil and groundwater.[116] MNPs have been detected in meats, fish, shellfish, fruit and vegetables, drinking water, and processed foods.[117–122] Food contact materials are an additional source of MNPs and are credibly linked to human exposure.[123–130]

Airborne MNPs are also ubiquitous. Outdoor sources include atmospheric fallout,[131,132] coastal ocean spray,[133] plastic-modified roads, tyre wear on roadways, paving materials,[134] and mechanical recycling plants.[108] MNPs have been detected indoors in classrooms and homes.[135,136] Occupational exposure to airborne MNPs occurs in multiple instances, including plastic moulding, recycling, and synthetic textile (eg, nylon flock) manufacturing.[137]

Human health effects of MNPs

In the past 2–3 years, MNPs have been increasingly reported in human tissues and body fluids in the general population,[138] including blood, breastmilk, liver, kidney, colon, placenta, lung, spleen, brain, heart, great vessels, meconium, and feces.[20] These findings suggest that MNPs might be able to cross key biological barriers, including the gastrointestinal lining, the alveolar–endothelial interface, the blood–brain barrier, and the placenta. These findings require further validation, as measuring MNPs in biological samples in the size range smaller than 1–10 μm—those that most plausibly cross biological barriers and enter organs and tissues—remains challenging, as does excluding potential contamination.[139]

Potential mechanisms of MNP toxicity include the disruption of the structure and function of cells and tissues due to the physical presence of MNPs, the toxic properties of the polymer matrix, the toxic properties of released plastic chemicals, and transport of environmental chemicals and pathogens into cells via MNPs.[23] MNP characteristics, including size, shape, polymer, and chemical composition, have each been reported to be relevant to cellular effects in vitro.[23] Understanding and quantifying human health risk in relation to these cellular effects will require further research on exposure pathways, pharmacokinetics, and possible internal exposures, and animal, clinical, and epidemiological research to evaluate dose–response relationships.

Such research is in the early stages. A recent systematic review investigating the digestive, respiratory, and reproductive effects of MNPs reports high or moderate quality evidence for impact across multiple outcomes, primarily from animal studies, with suggested links to lung and colon cancer.[140] Human clinical and epidemiological research will be dependent on further developments in the methods for detecting and quantifying exposure,[139] but early studies have now been published with emerging techniques. These studies include reports of possible links between MNPs and lung diseases,[137] inflammatory bowel disease,[141] liver cirrhosis,[142] myocardial infarction, and stroke.[143]

While further analytical method development in support of clinical and epidemiological research is urgently needed to more confidently evaluate health risks,[139] the potential that MNPs could harm human health cannot be ignored. Given current widespread human exposure to MNPs and the concatenation of findings across in vitro mechanistic research, animal studies, and early human observational studies, a precautionary approach is essential.[139,144,145]

Plastic waste

The cumulative global generation of plastic waste between 1950 and 2020 was an estimated 8 Gt.[55] The generation of plastic waste closely tracks global plastic production (figure 1), and half of all waste plastic has been generated since 2011.

Globally, less than 10% of plastic is recycled into reusable products, a fraction far less than the proportions of paper, glass, steel, and aluminium that are recycled and reused.[23,25] Two principal impediments to plastic recycling and to the creation of a clean and safe circular economy are the chemical complexity of plastics and their content of toxic chemicals, including legacy chemicals.[37,146]

There are clear regional disparities and differences by country in plastic waste management strategies and capacities, reflecting socioeconomic differences.[55] The fraction of plastic waste estimated to be mismanaged is low in China (1·5%), North America (2·7%), and Europe (3·6%), but is reported to be much higher—an estimated 43·0%—in the rest of the world, as shown in the Global Plastics Hub. Reflecting these differences, release of plastic waste to the environment shows sharp contrasts between and also within countries (figure 3).

For the **Global Plastics Hub** see https://globalplasticshub.org/

Plastic waste and air pollution

An estimated 57% (95% CI 48·3–56·3 Mt) of waste plastic is open-burned, while 43% is either placed in landfills or dumped into the environment.[147] Open burning of plastic waste typically lacks pollution and emission controls and is responsible for the release of an estimated 52·1 Mt (95% CI 48·3–56·3 Mt) of pollutants into the atmosphere annually. These atmospheric pollutants are a major source of air pollution in low-income and middle-income countries.[60,148]

The air pollution released from the open burning of waste plastic contains multiple hazardous chemicals, which include heavy metals, carbon monoxide, hydrogen cyanide, and styrene, and persistent organic pollutants and unburnt microplastic particles.[149] Combustion of chlorine-containing plastics, notably PVC, is especially hazardous because unless combustion temperatures are maintained higher than 900°C, a condition seldom achieved in open burning, it can result in the generation and release of highly toxic polychlorinated dioxins and furans.[147]

Health impacts to waste pickers

Informal waste workers contribute considerably to waste management services in countries at every income level, and especially in low-income and low-middle income countries where they take on multiple roles that range from household collection, to picking waste in dumpsites, to shredding and pelletising plastics for recycling. Waste

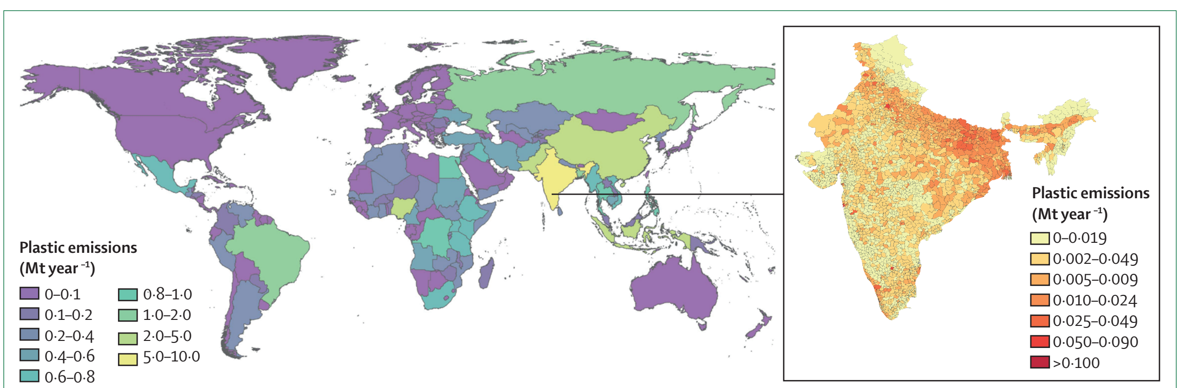

Figure 3: **Macroplastic waste generation by country and by municipality for India, 2020**
Adapted from Cottom and colleagues.[60] Mt=megatonnes.

workers are a highly susceptible group who typically lack protective equipment, health care, and negotiating power, and are stigmatised by society.

Waste pickers often live and work in precarious and dangerous conditions. They collect and process waste in dumpsites that are regularly on fire.[150] Pickers and their children can live in informal settlements adjacent to these dumpsites and are exposed to hazards from operating heavy machinery, being exposed to burning waste, and sorting waste plastics that can be contaminated by multiple toxic chemicals, including pesticides, pharmaceuticals, and industrial chemicals.[151,152] Health effects associated with informal waste picking include traumatic injuries, burns, respiratory illnesses, miscarriages, and cancer.[23] Formal waste workers are also exposed to occupational hazards but have fewer compounding susceptibilities.

Electronic waste (e-waste) pickers are heavily exposed to plastic-related pollutants. A particularly dangerous practice is open burning of PVC-coated computer cables to recover copper, which releases black smoke containing dioxins, benzene, and airborne $PM_{2·5}$.[153]

Plastic waste and vector-borne diseases

Plastic waste contributes to the global spread and amplification of vector-borne infectious diseases, such as dengue, Zika, and chikungunya.[154,155] *Aedes* mosquitoes, which transmit many of these diseases, thrive in urban environments, and recent data indicate that they have adapted to favour laying their eggs in artificial containers, such as discarded plastic bottles, containers, tyres, and bags.[156–158] Unplanned urbanisation and limited waste management in the context of global climate change might have contributed to the strong upsurge in dengue observed in recent decades.

Plastic waste and antimicrobial resistance

Recent data show that plastic debris and MNPs in the environment create unique habitats that support the growth of and interactions among diverse microorganisms. The microbial communities that colonise plastics are known as the plastisphere. Within this unique habitat, at least three key mechanisms are shown to drive the spread and evolution of antimicrobial resistance in the environment, particularly in aquatic and soil environments.[159,160] First, the formation of biofilms on MNPs brings different bacteria into close juxtaposition and promotes biofilm-inducing quorum-sensing systems that facilitate cell-to-cell communication and horizontal gene transfer, including transfer of antibiotic resistance genes.[159–162] Second, MNPs have a considerably higher adsorptive capacity than natural debris, due to their large surface area relative to volume. MNPs thus accumulate chemical substances from the environment that might contribute to the selection or co-selection of antimicrobial resistance, including antibiotics, pesticides, biocides, heavy metals, and other xenobiotics.[160,163,164] Third, MNPs can serve as physical vectors, facilitating the movement and transport of antibiotic-resistant bacteria and antibiotic-resistance genes over long distances in aquatic environments and into remote, previously uncontaminated areas.[160,163,164]

All these factors increase risks to human and animal health and to food security as pathogen-resistant bacteria spread to plants, animals, and humans via the environment. Examples of resistant pathogenic bacteria identified in plastic-polluted waters include *Escherichia coli*, *Aeromonas* sp, *Shigella* sp, *Klebsiella pneumonia*, *Pseudomonas* sp, and *Bacillus*.[164] The proliferation of antimicrobial-resistance genes in pathogenic and non-pathogenic bacteria on MNPs hinders societal efforts to halt the global pandemic of antimicrobial resistance.

Plastic waste and ecosystems

Visible plastic debris and MNPS derived from waste have been detected worldwide in ocean waters for decades.[20,165] Increasing numbers of studies now report the presence of MNPs in marine environments and marine biota in many parts of the world, and in freshwater lakes and biota.[166,167] MNPs are found in arctic sea ice[113] and in the Antarctic.[168] Although the amounts of waste plastic entering the ocean annually and their distribution within the water column are difficult to establish on a global scale,[169] it is estimated that in 2020 11 Mt of plastic entered the oceans[35] with a cumulative total of 139 Mt in aquatic environments.[24]

In aquatic ecosystems, MNPs considerably affect both animal and plant health. MNPs alter the behaviour and physiology of animals, impair their swimming abilities, and make them more susceptible to predators.[170] MNPs cause injury and death in important plant species, such as mangroves, seagrasses, and salt marshes.[171] These plants are crucial to ecosystem health as they provide habitat and food for various organisms, stabilise coastlines, and aid nutrient cycling and CO_2 uptake. MNPs have been shown to reduce photosynthesis in terrestrial and aquatic plants, thus threatening food security and hindering CO_2 sequestration.[172] Additionally, MNPs cause oxidative stress in plants, disrupting physiological, metabolic, and reproductive processes, including seed germination and absorption and translocation of nutrients, affecting plant growth and proliferation.[173]

In terrestrial ecosystems, improperly discarded plastic waste contaminates soil, harming its microbiome, reducing soil health and fertility, and affecting essential ecosystem functions, such as nutrient cycling and water filtration.[174–176] Similar to marine mammals, wildlife and livestock can be harmed by plastic waste. Additionally, waste plastic that washes into waterways can clog drainage systems and increase the risk of flooding.

The environmental degradation caused by plastics disrupts food webs, nutrient cycling, and entire ecosystems,[171,177] leading to a decline in biodiversity. All these effects contravene the Kunming–Montreal Global Biodiversity Framework, which clearly lays down the principle to reduce plastic pollution to preserve coastal and marine biodiversity.[178]

By degrading ecosystems, plastic waste and MNPs harm human health as they disrupt provisioning, supporting, regulating, and cultural ecosystem services crucial for health, wellbeing, and sustainability of human societies.[179,180] These services include providing fish and seafood, crops, fresh water for drinking and irrigation, and raw materials, such as seaweed, timber, and salt, while supporting the nutrient cycle and regulating water and air quality.

Plastic pollution in natural environments reduces recreational opportunities, diminishes aesthetic and economic value, and degrades beautiful places of spiritual and cultural importance. All these harms fall most heavily on poor and at-risk populations and in Small Island Developing States, communities already severely and disproportionately impacted by climate change.

Besides affecting ecosystem services, MNPs and plastic chemicals accumulated from trophic cascades can directly expose humans by vectoring plastic particles and plastic chemicals.[181] For example, plastic waste ingestion can lead to intestinal obstruction in livestock, causing severe health issues and even death. Livestock are also exposed to MNPs and plastic chemicals, with possible effects on human health via consumption of meat, eggs, and dairy products.[182] Furthermore, plastic waste in informal and formal dumpsites can create distinct ecosystems that attract scavenger animals, such as rats and seagulls[183] that can serve as reservoirs or hosts for zoonotic pathogens. These habitat changes can have cascading ecological effects, further disrupting the balance of natural ecosystems and potentially affecting human and animal health.

Plastic waste and climate change

New data indicate that interactions between climate change and plastics extend beyond GHG emissions. For example, plastics deteriorate more rapidly at higher ambient temperatures, thus accelerating the release into the environment of MNPs, plastic chemicals, and GHGs as the planet warms.[184] MNPs also attach to marine snow, increasing its buoyancy and thus slowing the displacement of carbon from the ocean surface to its depths. MNPs in glacial snow and ice can decrease albedo, accelerating the melting of polar and mountain ice.

Climate-associated changes in hydrological and oceanographic patterns can alter the geographic distribution and population exposure to plastic waste. For example, MNP discharges into the Bay of Bengal from the Ganges River are estimated to range from 1–3 billion particles per day with greater numbers of particles released during the monsoon (wet season) compared with pre-monsoon, due to the increased flow rate and greater volume of water in the monsoon.[185] Oceanic currents transport plastics long distances and lead to the massive accumulation of macroplastic and microplastic waste (eg, garbage patches, or gyres) in the South and North Atlantic, the Pacific, and the Indian Oceans.[186]

Wildfires, increasingly frequent and intense due to climate change, become much more hazardous when they spread into urban and peri-urban areas, as recently seen in Los Angeles, due to the high flammability of plastic construction and insulation products. When burnt, these materials release toxic particles and chemicals into the atmosphere, water, and soil, exposing residents, rescue workers, and those involved in clean-up and reconstruction.[187]

Policy interventions to mitigate plastics-associated harms

Multiple analyses, including from the Organisation for Economic Co-operation and Development (OECD),[42] Pew,[188] and the UN Environment Programme,[189] find that comprehensive, multi-layered policies that address the entire plastic lifecycle, including its upstream production stages, would be most effective for controlling plastic pollution and protecting human health. The OECD found that multi-layered interventions are also more cost-effective than interventions with a purely downstream or a solely environmental focus.[42]

To date, however, most responses to the plastics crisis have targeted the downstream stages of the plastic lifecycle and have focused on environmental issues. A survey conducted by the World Trade Organization (WTO) Dialogue on Plastic Pollution found that the overwhelming majority of 223 interventions reported by WTO member states were downstream-focused and aimed at single-use plastics, waste management, and recycling.[190]

Few assessments have been conducted to establish which of the interventions to address plastic pollution to date are effective, why they work, and the extent to which they could be adapted and deployed for use in other settings.[191,192] For the most part, these evaluations have focused only on some specific interventions, such as plastic bag bans or taxes, and they have employed limited analytical measures that do not take into account the systemic interactions. Moreover, these studies do not show whether such policies reduce the risks to human or planetary health associated with plastics.

Launching the *Lancet* Countdown on health and plastics

Coincident with the expected finalisation of the Global Plastics Treaty, we are launching a health-focused, indicator-based, global monitoring system on plastics—the *Lancet* Countdown on health and plastics. The goal of this Countdown is to provide a credible, independent global monitoring system that will track progress toward reducing plastic exposures and mitigating plastics-associated harms to human and planetary health.

Countdown origins

A consortium involving Boston College, Heidelberg University, the Centre Scientifique de Monaco, and the

Minderoo Foundation came together in 2024, and initiated discussions with the editors of *The Lancet*. A series of exploratory online meetings culminated in a 2 day, in-person meeting in Monaco in October, 2024. This meeting was attended by 23 experts from different regions and by those representing multiple disciplines, and *Lancet* editors. The outcome of the meeting was a decision to launch the *Lancet* Countdown on health and plastics that builds on and carries forward the work of the Minderoo–Monaco Commission on plastics and human health.[23]

The *Lancet* Countdown on health and plastics will be guided by the approach of the *Lancet* Countdown on health and climate change. With its publications in the past decade, the Health and Climate Change Countdown has played a crucial role in moving consideration of the health impacts of climate change to the mainstream of the climate conversation.[71] The Countdown has played a key role in the decision to incorporate an explicit focus on human health into the annual climate negotiations, starting with the UN Climate Change Conference 28.[193]

Indicator selection

In the first meeting of experts (October, 2024), participants collaboratively developed a preliminary framework for indicator selection. Following structured deliberation and consensus-based voting, four primary indicator domains were identified (figure 4). The first three of these domains are, production and emissions, exposures, and health impacts. These domains follow a classic source–exposure–effects model and provide a framework for tracking the impacts of plastics on human health across every stage of the plastic lifecycle. The fourth domain, interventions and engagement, will track societal responses to the plastics crisis and will encompass both top-down policy interventions and bottom-up public responses from international to individual levels. Depending on data availability and feasibility, selected indicators in these four domains will be developed as the Countdown evolves.

Production and emissions

This domain will develop indicators that monitor polymer production by polymer type and, where possible, by country. The domain will also develop indicators to track production of plastic chemicals. Furthermore, the volume of plastic waste generated by country will be tracked. Also, the domain will track particulate and hazardous air pollutants and pollutants released into water and soil at all stages of the plastic lifecycle, including in production, fabrication, recycling, landfilling, incineration, and open burning. Last, plastic-associated GHG emissions by country will be tracked.

Exposures

Exposures will develop and track indicators that monitor environmental and biological concentrations of plastics, plastic chemicals, plastic-related waste products and pollutants, and MNPs. Ecological indicators tracked in this domain could include MNP levels in seawater, freshwater, glaciers, and sea ice.[113] Additional possible ecological targets are MNP levels in soil, food crops, livestock, freshwater fish, and saltwater fish. Human exposure indicators tracked in this domain could include levels of plastic chemicals and MNPs in food packaging, personal care items, household goods, building materials, and other consumer products and in environmental media (eg, air, food, and drinking water). Additionally, this domain could track internal human exposures to plastic chemicals using data on blood and urine levels of plastic chemicals obtained from epidemiological studies and national biomonitoring surveys.[18] For tracking human internal MNP exposure, potential indicators are expected to be structural, monitoring methodological progress towards characterisation and quantification of human internal exposure.

Health impacts

Health impacts will track effects on human health that are or have the potential to be influenced by plastics throughout the full plastic lifecycle. These health effects

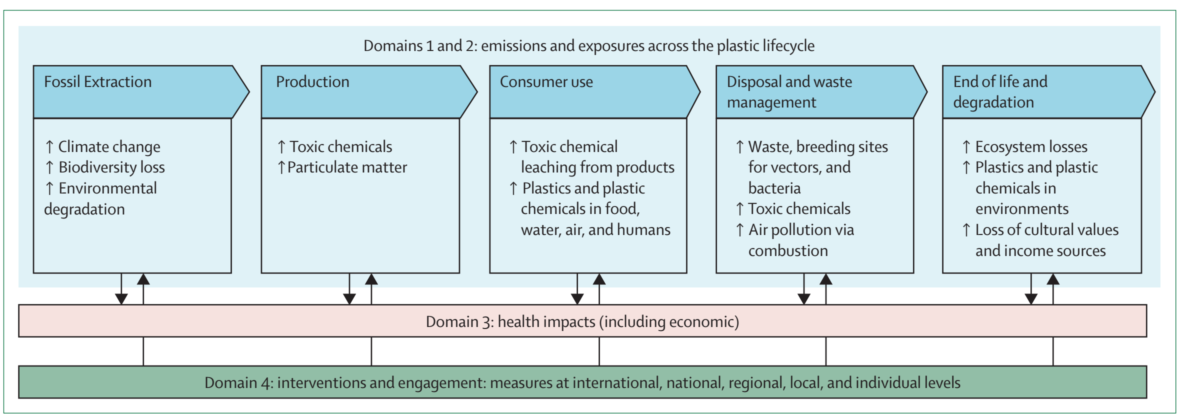

Figure 4: **Conceptual domains in the *Lancet* Countdown on health and plastics**

could include those that are (or potentially are) influenced by plastic chemicals, MNPs, plastic-related pollutants, and plastic-related GHG emissions in general populations, workers, fenceline community residents, waste pickers, and other at-risk populations. Health outcomes to be tracked could include stillbirths, low birthweights, and malformation of the reproductive organs in infants; asthma, obesity, type 2 diabetes, and cancers in children; and cardiovascular disease, obesity, lipid abnormalities, diabetes, pulmonary disease, decreased fertility and fecundity, and various cancers in adults. This domain will track the health-related economic impacts of plastics. Furthermore, there will be tracking of human health effects that could potentially be mediated by the impacts of plastics on planetary ecosystems (eg, as a driver of climate change), a vector for spread of harmful bacterial pathogens, and a provider of breeding sites for disease-carrying mosquitoes.[194]

Interventions and engagement

This domain will track interventions across the plastic lifecycle that have the potential to reduce plastic-related exposures and reduce the harms to human and planetary health resulting from those exposures. Activities that enable and support these interventions will also be tracked.

Interventions to be tracked could include governmental efforts at all levels to reduce plastic production, restrict use of single-use plastics, restrict the use of chemicals of concern in plastics, improve management of legacy plastics, improve occupational health protection for plastic workers, reduce leakage of plastics to the environment, move towards potentially safer alternatives and substitutes for fossil-fuel-based plastics, and reduce or eliminate exposure pathways that harm human health.

Efforts to reduce plastic use in the health care sector are of particular concern to this Countdown, and indicators tracking such reduction will be included in this domain.

Enabling measures to be tracked could include education and outreach campaigns, financial mechanisms, efforts to strengthen value chains as countries transition to circular economy models, and data collection and monitoring. Potential indicators include media hits, research funding, research outputs, and survey data on public awareness of plastics and health.

Interventions and engagements can be initiated, developed, or implemented by single actors or by combinations of public and private actors at various scales—international, regional, national, subnational and local. Actors could include intergovernmental organisations, national and subnational governments and authorities, private actors (eg, corporations, financial institutions, and small-and medium-enterprises), civil society organisations, formal or informal workers collectives and labour unions, research and academic institutions, media, community organisations, foundations, and individuals.

Indicator development

As in the *Lancet* Climate Countdown, indicators within each domain will be chosen using an open, transparent, science-based, multidisciplinary approach that includes review and synthesis of existing evidence, primary and secondary data collection, and analysis. The work of developing and reporting on indicators will be performed by working groups dedicated to each domain, each led by two co-leads who are experts in that domain. External collaborators will have the opportunity to contribute to the Countdown by submitting white papers on proposed indicators for review. Key considerations in indicator selection will include whether the indicator is meaningful, understandable, interpretable, and timely; scientifically credible, reproducible, quantifiable, and based on validated methods; feasible and updatable, including data that are available or can be acquired; temporally and geographically representative; and socially representative, encompassing a range of social groups and allowing assessment of health and environmental inequities. Indicator selection will consider balance across the domains and inter-relatedness, including the capacity to measure systemic factors and impacts. The Countdown will aim to make indicators available for public use at the country scale.

Governance and operational leadership

The *Lancet* Countdown on health and plastics will be led by a steering committee and guided by an advisory board. The steering committee includes the two Countdown co-chairs, who are responsible for the delivery of the Countdown, and the co-leads of each working group. The co-chairs and steering committee will be supported by a dedicated project manager, and an independent consultant tasked with organising stakeholder and focus group consultations to ensure that selected indicators are relevant, inclusive, and effective.

The broader Countdown membership includes expert contributors across multiple disciplines relevant to plastics and health, including public health, medicine, environmental science, toxicology, chemistry, law, policy, and economics. As the initiative grows, we will continue to ensure that its composition reflects a broad range of knowledge and maintains a strong commitment to diversity, equity, and inclusion, with particular attention to regional and gender balance.

Translation of science to policy

The *Lancet* Countdown on health and plastics will actively engage policy makers, industry leaders, academic researchers, civil society stakeholders, and the public in the dissemination, communication, and translation of its research findings and scientific output. This collaborative approach ensures that the Countdown's indicators and recommendations are both scientifically robust and relevant and actionable. By fostering dialogue among diverse actors and communicating reliable data, the

Countdown will seek to amplify its reach and catalyse evidence-based interventions.

Engagement activities can include policy briefings, stakeholder workshops, and targeted campaigns tailored to specific regions and audiences. These efforts aim to bridge the gap between research and real-world applications, enabling informed decision making and driving systemic change. The pathways to impact are depicted in figure 5, highlighting how knowledge and indicator generation can create actionable information for evidence-based policy frameworks and decision making.

Conclusion

The world is in a plastics crisis. This crisis has worsened alongside the other planetary threats of our time and is contributing to climate change, pollution, and biodiversity loss. Long unseen and unaddressed, the magnitude of the plastics crisis is now widely recognised, and its implications for both human and planetary health are increasingly clear.

An estimated 8000 Mt of plastic waste pollute the environment.[25] MNPs and multiple plastic chemicals are found in the most remote reaches of the planet[112–114] and in the bodies of marine and terrestrial species worldwide, including humans.[18] The 2023 analysis by the Minderoo–Monaco Commission on plastics and health found that plastics harm human health at every stage of the plastic lifecycle, that these health-related damages result in massive economic losses that are borne by society, and that plastics-associated harms fall disproportionately on low-income people and at-risk populations (panel 2).[23]

Three factors are responsible for worsening of the plastic crisis. The first and most fundamental is that global plastic production is accelerating.[57] Current increases in production are projected to continue, and in the absence of intervention, global plastic output is on track to nearly triple by 2060.[24] Inadequate recovery and recycling, coupled with a lack of operationalised circularity, is a second driver. Despite decades of effort, less than 10% of plastics are recycled, and thus 90% are either burned, landfilled, or accumulate in the environment.[60] Unlike paper, glass, steel, and aluminium, chemically complex plastics cannot be readily recycled. It is now clear that the world cannot recycle its way out of the plastic pollution crisis. The persistence of plastics is a third key driver. Most plastics do not biodegrade in the environment, nor do they break down into their constituent elements; instead, they fragment into ever smaller particles (eg, MNPs) that can

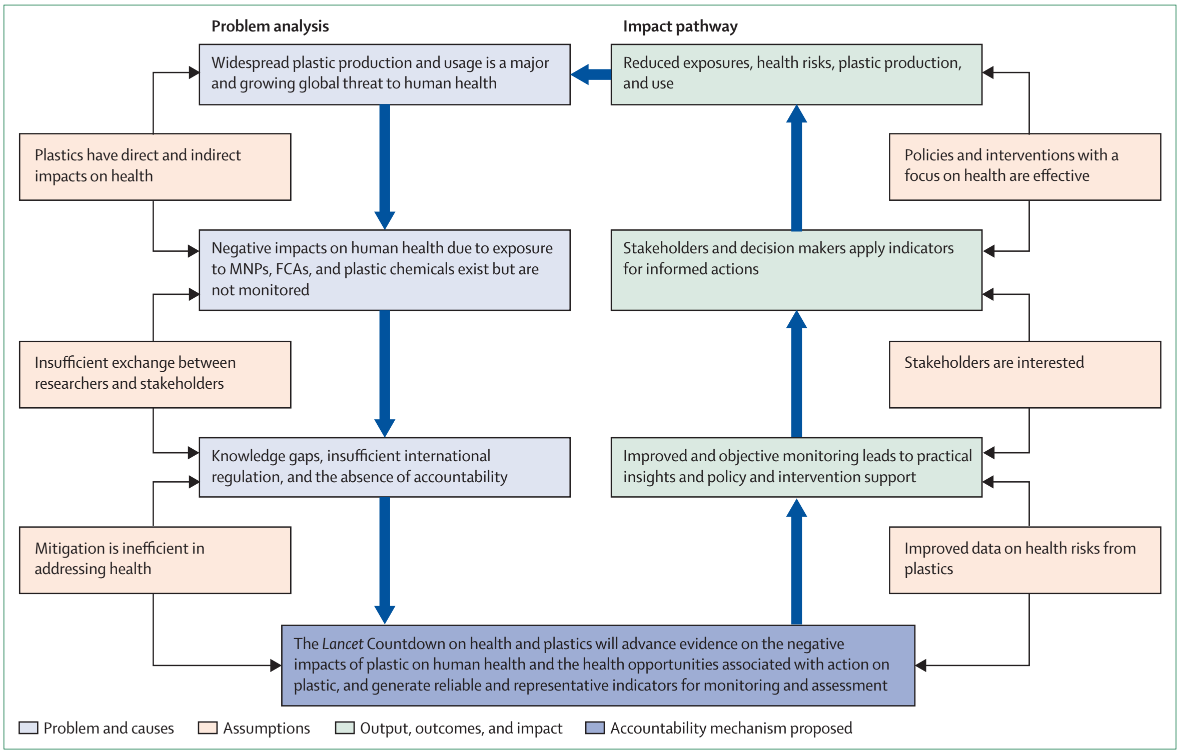

***Figure 5*: Schematic representation of impact pathways for the *Lancet* Countdown on health and plastics based on the theory of change**

On the left side, the problem analysis outlines the growing threat of plastic production and pollution, highlighting gaps in monitoring, the need for strengthening the science–policy interface, limited industry accountability, and insufficient regulatory interventions for health protection across the plastic lifecycle. On the right side, the impact pathway envisions a series of outcomes starting with improved data on health risks from plastics, which will enable stakeholders and decision makers to apply health-focused indicators to leverage effective actions. Figure adapted from the Dutch Research Council.[195] FCA=food contact articles. MNP=microplastic and nanoplastic particle.

persist for decades in salt and fresh water, on land, and in living organisms. Polymers, such as PVC and some plastic chemicals (eg, PFAS) that are based on carbon–halogen bonds, are especially durable. The consequence is that at least 80% by the weight of all plastic ever made is still present in the environment (figure 1). For much of this plastic, its ultimate repository is the ocean.[180]

The plastic crisis is not inevitable. Although there is much we still do not know about plastics' harms to human health and the global environment, and more research is certainly needed, we have enough data now to know that these harms are already considerable, and there is enough information on trends in plastic production to recognise that in the absence of intervention, they will get worse.

Control of the plastics crisis will require continuing research coupled with the science-driven interventions—laws, policies, monitoring, enforcement, incentives, and innovations—that have successfully and cost-effectively controlled other forms of pollution and catalysed systems change.[30,32,34]

The purpose of this *Lancet* Countdown on health and plastics is to be an independent, indicator-based, health-focused global monitoring system that tracks and regularly reports on progress toward reducing plastic exposures and mitigating plastics-associated harms to human and planetary health as the Global Plastics Treaty comes into force and as regional, national, and subnational interventions are implemented.

By making plastics-related impacts on human and planetary health visible, this Countdown will bring health to the centre of the plastics conversation. Our hope is that the reports generated by the Countdown provide robust data and insights to inform evidence-based policy making on plastics at all levels—international, regional, national, sub-national, and local—for the benefit of public health.

Contributors

PJL, JR, MT, SD, HR, JS, MS, JM, CS, and TCC were responsible for the conceptualisation of the *Lancet* Countdown on health and plastics, project administration, and led the supervision and writing of this paper. PJL led, and all authors contributed to, the writing of the original draft and to the editing of the full text.

Declaration of interests

PJL received study and travel support from the Minderoo Foundation; and consulting fees from the Centre Scientifique de Monaco. SD received travel support from the Minderoo Foundation and Centre Scientifique de Monaco; and is employed by the Minderoo Foundation. CS is employed by and received travel support from the Minderoo Foundation; and is on the data safety monitoring board for Murdoch Children's Research Institute. JM received grants from the Minderoo Foundation, Fondation Didier et Martine Primat, Minerva Stiftung, the Adessium Foundation, the Broad Reach Foundation, the Marisla Foundation, the Spronck Foundation, the Sympany Foundation, the Norwegian Research Council and Norwegian University of Technology Trondheim, and the European Commission Utrecht; honoraria from the Pew Charitable Trust, Japan Endocrine-Disruptor Preventive Action, and HEJ Support; travel support from Gordon Research Conference on Environmental Endocrine Disruptors 2024, Zero Waste Europe, the Stoelzle Group, Boston College (MA, USA), Uppsala Health Summit, New York University Plastics Summit, Heinrich–Böll–Stiftung, and the Plastic Health Council; was on the advisory board for the MOMENTUM project and the UN Global Plastics Treaty; is a committee member for Bio Suisse; is member of the foundation board for Global Footprint Network; is Director of the FAN Initiative Foresight Analyses Nexus; and is a member of the steering board for the Scientists' Coalition for an Effective Plastics Treaty. 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