

Chapter 2: Driving Forces of the Epidemic: A Polluted and Polluting Planet

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Nearly 20 million new cancer cases are diagnosed across the world each year. By stressing that the majority of cancers can be prevented, Philip Landrigan focuses on the troubling consequences of pollution on individual, social, and planetary health. Since 1990, reduction has occurred in the traditional forms of pollution associated with deep poverty and in the numbers of deaths caused by these forms of pollution. But the modern forms of pollution—ambient air pollution and chemical pollution—are on the rise, as well as the numbers of deaths due to these forms of pollution. Moreover, the health consequences of pollution are inequitably distributed, with the most significant increases in cancer incidence and mortality occurring in low- and middle-income countries—i.e., the countries least capable of confronting the disease and least well able to afford costly therapies. Finally, the author suggests science-based strategies for pollution control and cancer prevention.

The world today is experiencing an unprecedented global pandemic of cancer. Cancer has become one of the top two causes of death in 134 countries, the leading cause of death in most high-income countries, and the leading cause of death by disease among children in high-income countries. Nearly 20 million new cancer cases are diagnosed across the world each year. By 2040, this number is expected to rise to nearly 30 million and to result each year in 16.4 million deaths.¹

Cancer is very inequitably distributed. Most increases in cancer incidence and mortality are occurring in low-income and middle-

¹ See American Cancer Society, *Global Cancer Facts and Figures*, 4th ed. (Atlanta: American Cancer Society, 2018), www.cancer.org/content/dam/cancer-org/research/cancer-facts-and-statistics/global-cancer-facts-and-figures/global-cancer-facts-and-figures-4th-edition.pdf.

income countries—the countries least capable of confronting the disease and least well able to afford costly therapies. In the absence of intentional intervention, these disparities will widen further in coming decades. The majority of cancers can be prevented. Relatively few are of purely genetic origin. The great majority of cancers are due to dietary factors, personal behaviors, and hazardous materials in the environment that act either alone, or more commonly, in concert with each other and with variations in individual susceptibility. The purpose of this chapter is to explore the contribution of pollution to the global cancer pandemic, the global disparities in cancer morbidity and mortality, and, at the same time, the science-based strategies for pollution control and cancer prevention.

Pollution

Pollution—unwanted waste of human origin released to air, land, water, and the ocean without regard for cost or consequence—is an existential threat to human and planetary health.² Like climate change, biodiversity loss, and depletion of the world's fresh water supply, pollution endangers the stability of the earth's support systems and threatens the continuing survival of human societies. Pollution includes air contaminated by fine particulate matter (PM_{2.5}), ozone, and oxides of sulfur and nitrogen; biological and chemical contamination of fresh water; contamination of the ocean by plastic waste, petroleum-based pollutants, toxic metals, manufactured chemicals, pharmaceuticals,

² See Philip J. Landrigan, Richard Fuller, Nereus J. R. Acosta, Olusoji Adeyi, Robert Arnold, Niladri Nil Basu, Abdoulaye Bibi Balde, Roberto Bertollini, Stephan Bose-O'Reilly, Jo Ivey Boufford, Patrick N. Breyse, Thomas Chiles, Chulabhorn Mahidol, Awa M. Coll-Seck, Maureen L. Cropper, Julius Fobil, Valentin Fuster, Michael Greenstone, Andy Haines, David Hanrahan, David Hunter, Mukesh Khare, Alan Krupnick, Bruce Lanphear, Bindu Lohani, Keith Martin, Karen V. Mathiasen, Maureen A. McTeer, Christopher J. L. Murray, Johanita D. Ndahimananjara, Frederica Perera, Janez Potocnik, Alexander S. Preker, Jairam Ramesh, Johan Rockstrom, Carlos Salinas, Leona D. Samson, Karti Sandilya, Peter D. Sly, Kirk R. Smith, Achim Steiner, Richard B. Stewart, William A. Suk, Onno C. P. van Schayck, Gautam N. Yadama, Kandeh Yumkella, and Ma Zhong, "The *Lancet* Commission on Pollution and Health," *Lancet* 391, no. 10119 (2018): 462–512.

pesticides, nitrogen, phosphorus, fertilizer, and sewage; and poisoning of the land by lead, mercury, pesticides, industrial chemicals, electronic waste, and radioactive waste.

The *Lancet* Commission on Pollution and Health found that pollution is responsible each year for an estimated nine million deaths—16 percent of all deaths globally—as well as for economic losses totaling US \$4.6 trillion, 6.2 percent of global economic output.³ The Commission noted pollution’s deep inequity. Ninety-two percent of pollution-related deaths, as well as the greatest burden of pollution’s economic losses, occur in low-income and middle-income countries (LMICs) ([Figure 1](#)).⁴

[Table 1](#) presents the distribution of pollution-related deaths by pollution source and gender.⁵

Pollution is closely linked to climate change.⁶ Fossil fuel combustion is the main source of both airborne fine particulate (PM_{2.5}) pollution and of the carbon dioxide, black carbon, and other greenhouse gases that drive climate change. Methane, released to the atmosphere in enormous volumes in the extraction of natural gas by hydraulic fracturing (‘fracking’) as well as from agricultural operations, is an additional potent driver of climate change.

The *Lancet* Commission on Pollution and Health observed that pollution and climate change can both be “directly attributed to the

³ See Landrigan et al., “The *Lancet* Commission on Pollution and Health.”

⁴ The Figure 1 is from GBD Risk Factors Collaborators, “Global Burden of 87 Risk Factors in 204 Countries and Territories, 1990–2019: A Systematic Analysis for the Global Burden of Disease Study 2019,” *Lancet* 396, no. 10258 (2020): 1223–1249. The acronym GBD means Global Burden of Disease. See also Institute for Health Metrics and Evaluation (IHME), “Global Burden of Disease (GBD),” *Institute for Health Metrics and Evaluation*, 2019, www.healthdata.org/gbd/2019.

⁵ See GBD Risk Factors Collaborators, “Global Burden of 87 Risk Factors in 204 Countries and Territories, 1990–2019: A Systematic Analysis for the Global Burden of Disease Study 2019,” *Lancet* 396, no. 10258 (2020): 1223–1249.

⁶ See A. J. McMichael, Alistair Woodward, and Cameron Muir, *Climate Change and the Health of Nations: Famines, Fevers, and the Fate of Populations* (New York: Oxford University Press, 2017).

currently prevalent, linear, take-make-use-dispose- economic paradigm—termed by Pope Francis ‘the throwaway culture’—in which natural resources and human capital are viewed as abundant and expendable and capital are viewed as abundant and expendable and the consequences of their reckless exploitation are given little heed.⁷

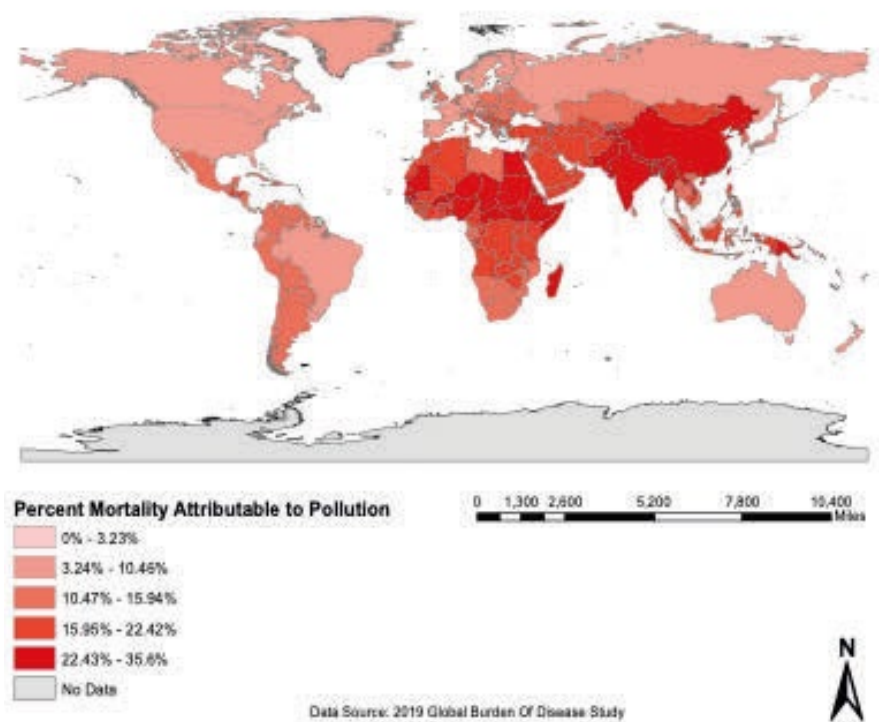


Figure 1. Global Inequity in the Distribution of Pollution-Related Deaths

Ninety-two percent of pollution-related deaths occur in low-income and middle-income countries. In all countries, pollution disproportionately affects the poor, the marginalized and minorities.

⁷ See Landrigan et al., “The *Lancet* Commission on Pollution and Health,” 465. The quote refers to Francis, *Laudato Si'*, nos. 16, 22, and 43. See e Raworth, *Doughnut Economics: Seven Ways to Think Like a 21st Century Economist* (White River Junction, VT: Chelsea Greens Publishing, 2017).

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Table 1. Global deaths attributable to pollution by source and gender, 2019

	Female	Male	Total
	Number of Deaths (millions)	Number of Deaths (millions)	Number of Deaths (millions)
Air (Total)	2.92	3.75	6.67
Household air	1.13	1.18	2.31
Ambient particulate	1.70	2.44	4.14
Ambient ozone	0.16	0.21	0.37
Water (Total)	0.73	0.63	1.36
Unsafe sanitation ⁺	0.40	0.36	0.76
Unsafe source ⁺	0.66	0.57	1.23
Occupational (Total)	0.22	0.65	0.87
Carcinogens	0.07	0.28	0.35
Particulates (dust)	0.15	0.37	0.52
Lead	0.35	0.56	0.90
Total	3.92	5.09	9.01

Note: The total numbers of deaths for air, water and all pollution are less than the arithmetic sum of the individual risk factors within each of these categories because there are overlapping contributions—e.g., household air and ambient air pollution each can contribute to the same outcomes.

Pollution Trends

Reduction has occurred since 1990 in the traditional forms of pollution associated with deep poverty-household air pollution, unsafe drinking water, and inadequate sanitation—and in the numbers of deaths due to these forms of pollution. Thanks to the work of national governments, international organizations, private philanthropies, faith groups, and non-governmental organizations in introducing cleaner fuels, improving sanitation and water supplies, and providing new vaccines, antibiotics, and treatments, deaths from these ancient scourges continue slowly to decline.⁸

By contrast, the more modern forms of pollution—ambient air pollution and chemical pollution—are on the rise, and the numbers of deaths due to these forms of pollution have increased substantially over the past twenty years in all regions of the world, but most especially in South, East, and Southeast Asia. Ambient air pollution was responsible for 4.5 million deaths in 2019, up from 2.9 million in 2000. Deaths from chemical pollution doubled in this time from 0.9 million to 1.8 million.⁹

⁸ See Landrigan et al., “The *Lancet* Commission on Pollution and Health.”

⁹ See Landrigan et al., “The *Lancet* Commission on Pollution and Health”; GBD Risk Factors Collaborators, “Global Burden of 87 Risk Factors in 204 Countries and Territories, 1990–2019: A Systematic Analysis for the Global Burden of Disease Study 2019.”

Increases in deaths from the more modern forms of pollution are occurring as countries urbanize, build infrastructure, and develop their industrial bases. They are driven by rising levels of pollution together with demographic factors that include an aging global population and increased numbers of people exposed to pollution. The number of deaths due to ambient air pollution is on track to double by 2050.¹⁰

Chemical Pollution

Chemical pollution is a highly complex and particularly insidious threat (Table 2). It includes carcinogens, neurotoxins, reproductive toxicants, and endocrine disruptors. Fossil fuels—mainly oil and natural gas—are the principal feedstocks to both chemical and plastic manufacture and thus the root source of chemical pollution.

Table 2. Key Facts on Chemical Pollution

- 350,000 chemicals in commerce.
- These are mostly new, fabricated chemicals invented since 1905. They never existed on Earth.
- Used in millions of consumer reports.
- Widely disseminated in the environment.
- Nearly universal human exposure, but disproportionately heavy exposure of the poor and minorities—environmental injustice.
- Global production is on track to double in the next 25–30 years.
- Two thirds of chemical production are now in developing countries.
- The majority of chemicals have never been tested for safety or toxicity.

A recent comprehensive study of 22 chemical inventories from 19 countries has identified over 350,000 manufactured chemicals, thus tripling previous estimates of the number of new synthetic chemicals

¹⁰ See Jos Lelieveld, John S. Evans, Mohammed Fnais, Despina Giannadaki, and Andrea Pozzer, “The Contribution of Outdoor Air Pollution Sources to Premature Mortality on a Global Scale,” *Nature* 525, no. 7569 (2015): 367–371.

invented since 1950.¹¹ Some are used in the manufacture of plastics. Others are incorporated into millions of consumer goods and industrial products ranging from foods and food packaging to clothing, building materials, electronics, motor fuels, cleaning compounds, pesticides, cosmetics, toys, and baby bottles.

Worsening chemical pollution is driven by relentless growth in the production, use, and disposal of industrial chemicals, heavy metals, pesticides, and plastics. Global chemical production is increasing at an annual rate of 3.0–3.5 percent, and it is on track to double in the next two to three decades. Plastic production is increasing in parallel ([Figure 2](#)). Approximately two-thirds of chemical and plastic production now takes place in low-income and middle-income countries where environmental and occupational safeguards are often weak. The consequence is disproportionately heavy and uncontrolled exposures of workers, children, and other vulnerable populations.

The great majority of manufactured chemicals have never been tested for safety or toxicity.¹² Because of major gaps in chemical policy, most chemicals (except pharmaceuticals and vaccines) are introduced into commerce without any pre-market safety assessments. Major gaps therefore exist in knowledge about the potential of many widely used chemicals to damage ecosystems or harm human health. Many manufactured chemicals have been found—sometimes only after years or even decades of use—to have caused grave damage to planetary support systems and to human health. Historical examples include asbestos, tetraethyl lead, chlordane, DDT, and the ozone-destroying chlorofluorocarbons. More recently developed chemicals such as phthalates, neonicotinoid insecticides, brominated flame retardants,

¹¹ See Zhanyun Wang, Glen W. Walker, Derek C. G. Muir, and Kakuko Nagatani-Yoshida, “Toward a Global Understanding of Chemical Pollution: A First Comprehensive Analysis of National and Regional Chemical Inventories,” *Environmental Science & Technology* 54, no. 5 (2020): 2575–2584.

¹² Philip J. Landrigan and Lynn R. Goldman, “Children’s Vulnerability to Toxic Chemicals: A Challenge and Opportunity to Strengthen Health and Environmental Policy,” *Health Affairs (Millwood)* 30, no. 5 (2011): 842–850.

and perfluorinated substances (PFAS) appear repeat this dismal history. Even less is known about the possible combined effects of exposures to chemical mixtures.

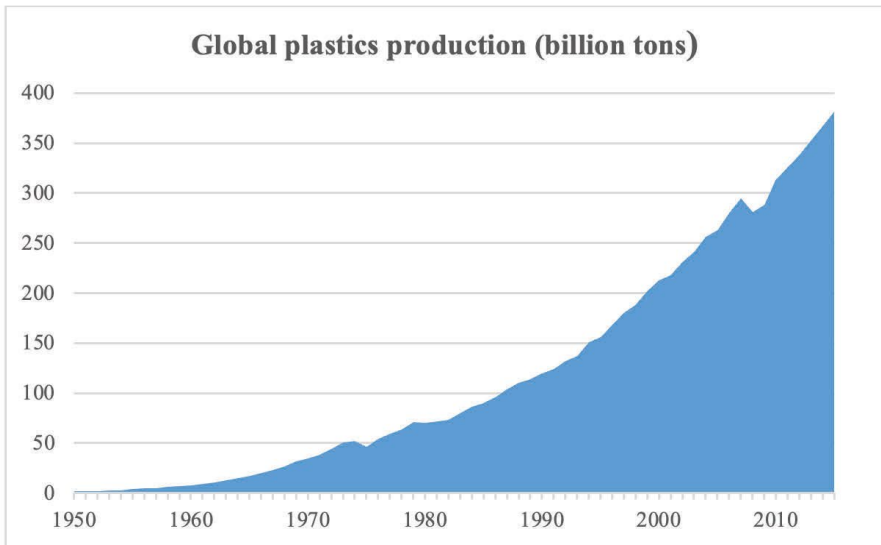


Figure 2. Global plastic production 1950–2015. The sum of annual global polymer resin, synthetic fiber, and plastic additive production. Most of this plastic still exists. See Hannah Ritchie and Max Roser, “Plastic Pollution,” *Our World in Data*, September 2018, ourworldindata.org/plastic-pollution.

Pollution and Cancer

Environmental pollutants have been recognized to be potent causes of human cancer for more than two centuries since Dr. Percivall Pott (1714–1788) of London discovered in 1776 that the cause of an epidemic of skin cancer of the scrotum among young boys employed as chimney sweeps was soot that became lodged in folds in the boys’ skin when they were lowered naked into chimneys ([Figure 3](#)).¹³ Later research has documented that

¹³ See Percivall Pott, “Cancer Scroti,” in P. Pott, *Chirurgical Observations Relative to the Cataract the Polypus of the Nose, the Cancer of the Scrotum, the Different Kin s of Ruptures, and the Mortification of the Toes and Feet* (London: T.J. Carnegy, for L. Hawes, W. Clarke, and R. Collins, 1775), 179–180.

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chimney soot and other forms of smoke, including tobacco smoke, contain polycyclic aromatic hydrocarbons (PAHs)—a potent class of chemical carcinogens.

In recent decades, multiple links have been established between pollution and cancer, including air pollution, water pollution, and chemical pollution ([Table 3](#)).



Figure 3. London Chimney Sweep (a “Climbing Boy”), Mid-1700s Jessica Brain, “Chimney Sweeps and Climbing Boys,” *Historic UK*, April 7, 2021, www.historic-uk.com/CultureUK/History-Boy-Chimney-Sweep/.

Table 3. Pollution and Cancer—The Multiple Connections

Ambient air pollution

- Potent cause of lung cancer—responsible for an estimated 40 percent of all lung cancer deaths worldwide. It is more important than tobacco smoking as a cause of lung cancer in lower-middle and low-income countries.
- Constituents of air pollution are proven human carcinogens:

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- Polycyclic aromatic hydrocarbons (PAH)—also known as black soot.
- Diesel exhaust.

Water pollution

- Arsenic in drinking water is responsible for massive outbreaks of skin and bladder cancer in Southeast Asia, Taiwan, northern Chile (Antofagasta), and northern Argentina.

Chemical pollution

- Multiple chemical pollutants are proven human carcinogens.

Chemicals and Cancer

Multiple chemical pollutants have been identified as causes of cancer. They include asbestos, benzene, the benzidine-based dyes, beryllium, 1,3-butadiene, chromium, ethylene oxide, ionizing radiation, nickel, nitrosamines, plutonium, radium, 2,3,7,8-tetrachlorodibenzo-dioxin, and wood dust. Most of the links between chemicals and cancer have been identified through astute clinical observation and confirmed through toxicological and epidemiological research. Many of the initial clinical observations linking toxic chemicals to cancer were made in heavily exposed occupational populations, and the findings were subsequently extended to community populations where exposures are generally lower but include highly vulnerable groups such as young children and pregnant women.

To systematically evaluate chemical pollutants for carcinogenic hazard, the International Agency for Research on Cancer (IARC), the cancer arm of the World Health Organization, established the IARC Monographs Programme in the early 1970s.¹⁴ This exemplary global program applies rigorous procedures for the scientific review and evaluation of carcinogenic hazards. In reaching its overall evaluations of the carcinogenicity of chemical pollutants, the IARC Monographs

¹⁴ See Robert A. Baan and Kurt Straif, “The Monographs Programme of the International Agency for Research on Cancer: A Brief History of Its Preamble,” *ALTEX* (2021), 10.14573/altex.2004081.

Programme carefully examines epidemiological and toxicological data linking chemical exposures to human cancer as well as mechanistic evidence based on key characteristics of carcinogens. The IARC assessment process is based solely on data published in the peer-reviewed literature. It is fiercely independent of commercial interests. Since its inception in 1971, it has evaluated more than 1,000 chemicals and has assessed the carcinogenicity of these chemicals as follows:

- 121 proven human carcinogens (Group 1)
- 89 probable human carcinogens (Group 2a)
- 319 possible human carcinogens (Group 2b)
- 500 agents not classifiable (Group 3)

These IARC evaluations shape cancer control policies worldwide. They have helped to save tens of thousands of lives.

Trends in Childhood Cancer

In the past half century, mortality from childhood cancer has declined dramatically in high-income countries. This decline is the consequence of spectacular advances in medical and surgical treatments that, in turn, are based on great increases in understanding of cancer biology and therapeutics.

In this same time, however, the population-based incidence rate of childhood cancer has increased significantly and has offset the declines in mortality. Cancer is now the leading cause of death by disease among children under age 15 in the United States and other highly developed countries.

Increases in incidence have occurred for three major malignancies of children and young adults, in the United States according to data of the Surveillance, Epidemiology, and End Results Program (SEER) from the

National Cancer Institute.¹⁵ Similar increases have been seen in other high-income countries. In the USA, they include:

- *Leukemia*. Leukemia is the most common childhood cancer. Incidence of leukemia in 0–14 years-old U.S. children increased from 3.3 per 100,000 in 1975 to 5.1 per 100,000 in 2005: 55 percent increase. Acute lymphocytic leukemia increased in the same years from 2.2 to 4.0 per 100,000: 81 percent increase.
- *Primary Brain Cancer*. This is the second leading cancer of children. Incidence of cancer of the brain and nervous system in 0–14 years-old children increased from 2.3 per 100,000 in 1975 to 3.2 per 100,000 in 2005: 39 percent increase.
- *Testicular Cancer*. Incidence of testicular cancer in white men (most of them adolescents and young adult males) increased from 4.3 per 100,000 to 7.0 per 100,000 in 2005: 51 percent increase. Among the same years, both the absolute incidence and the rate of increase were much lower—from 0.9 to 1.3 per 100,000.

These increases are far too rapid to be of genetic origin. Some have argued that they may reflect improved access to medical care or the increasingly widespread availability of newer diagnostic technologies such as magnetic resonance imaging (MRI) and computed tomography (CAT) scan. While those explanations might point to a one-time “bump” in reported incidence around the time that Medicaid was introduced (on July 30, 1965) or newer imaging techniques became available, they fail to account for the steady increase in incidence of three different types of childhood and young adult cancer in multiple countries over a span of three decades.

A key question is whether these increases could be due, at least in part, to exposures to pollution or other hazards in the environment. This question is particularly germane in the case of pediatric cancer, because

¹⁵ See National Cancer Institute, “Surveillance, Epidemiology, and End Results Program,” *National Cancer Institute*, 2021, seer.cancer.gov.

children are far more sensitive to most toxic environmental exposures than adults.

Children's Great Vulnerability to Chemical Carcinogens

A 1993 analysis undertaken by the U.S. National Academy of Sciences established that children's unique vulnerability to toxic exposures in the environment stems from four sources:¹⁶

- Children have disproportionately heavy exposures to many chemicals.
- Children's metabolic pathways, especially in fetal life and in the first months after birth, are immature. Infants and children are therefore to detoxify and excrete many environmental chemicals and thus more vulnerable to them.
- Human development is complex, delicate, and therefore all too easily disrupted by environmental exposures.
- Children have many years of future life and thus time to develop disease of long latency initiated by early exposures.

Pollution and Childhood Cancer

Recognition is growing that hazardous exposures in the environment are powerful causes of cancer in children. In recent years, medical researchers have identified a number of environmental causes of childhood cancer. For example, maternal exposure to ionizing radiation such as X-rays during pregnancy, and early childhood exposures to CAT scans, have been found to increase risk of childhood leukemia and brain tumors.¹⁷ Prenatal exposure to the synthetic estrogen, diethylstilbestrol

¹⁶ See National Research Council, Committee on Pesticides in the Diets of Infants and Children, *Pesticides in the Diets of Infants and Children* (Washington, DC: National Academy Press, 1993).

¹⁷ See Alice Stewart, Josephine Webb, Dawn Giles, and David Hewitt, "Malignant Disease in Childhood and Diagnostic Irradiation in Utero," *Lancet* 271, no. 6940 (1956): 447, 10.1016/s0140-6736(56)91923-7.

(DES) causes adenocarcinoma of the vagina in young women.¹⁸ In more recent years, robust evidence has emerged for additional links between environmental exposures and childhood cancer. These include associations between traffic-related air pollution,¹⁹ paints, and solvents and elevate risks of leukemia, lymphoma and brain tumors.²⁰ Prenatal exposures to pesticides are associated with increased incidence of leukemia.²¹ Children living in communities surrounded by manufacturing facilities, refineries, or intensive agriculture—where residents are often low-income or people of color—may have particularly high exposures.

Yet these recognized causes of childhood cancer account for only a small fraction of cases. Known carcinogens are used throughout the economy to produce goods and services, but recent research suggests that many chemicals in addition to those known to be carcinogens may contribute to cancer. Because most of these chemicals have never been tested for safety or toxicity, we do not have a comprehensive list of those that may cause cancer in children.²²

Pollution Control and Cancer Prevention

¹⁸ See Arthur L. Herbst, Marian M. Hubby, Freidoon Azizi, and Michael M. Makii, “Reproductive and Gynecologic Surgical Experience in Diethylstilbestrol-Exposed Daughters,” *American Journal of Obstetrics and Gynecology* 141, no. 8 (1981): 1019–1028.

¹⁹ See Tommaso Filippini, Elizabeth E. Hatch, Kenneth J. Rothman, Julia E. Heck, Andrew S. Park, Alessio Crippa, Nicola Orsini, and Marco Vinceti, “Association between Outdoor Air Pollution and Childhood Leukemia: A Systematic Review and Dose Response Meta-Analysis,” *Environmental Health Perspectives* 127, no. 4 (2019): 10.1289/Ehp4381.

²⁰ See Frolayne M. Carlos-Wallace, Luoping Zhang, Martyn T. Smith, Gabriella Rader, and Craig Steinmaus, “Parental, in Utero, and Early-Life Exposure to Benzene and the Risk of Childhood Leukemia: A Meta-Analysis,” *American Journal of Epidemiology* 183, no. 1 (2016): 1–14.

²¹ See Andrew S. Park, Beate Ritz, Fei Yu, Myles Cockburn, and Julia E. Heck, “Prenatal Pesticide Exposure and Childhood Leukemia: A California Statewide Case-Control Study,” *International Journal of Hygiene and Environmental Health* 226 (2020): 113486, 10.1016/j.ijheh.2020.113486.

²² See Landrigan and Goldman, “Children’s Vulnerability to Toxic Chemicals: A Challenge and Opportunity to Strengthen Health and Environmental Policy.”

A key principle is that pollution can be controlled, and pollution-related cancer can be prevented.²³ The proof of this principle is seen in the experience of the many high-income countries and the increasing number of mid-income countries are making good progress against pollution. These countries have implemented science-based control strategies based on law, policy, and technology backed by effective regulation. As a result of these interventions, pollution-related disease and death rates have fallen sharply. A powerful case study is seen in the declines in asbestos-related cancers in many countries that imposed bans on all import and use of all forms of asbestos.²⁴ The *Lancet* Commission concluded that these solutions are ready to be globally scaled. The Commission observed that pollution prevention will slow climate change, improve human health, prevent disease, and help build national economies.²⁵

Interventions against pollution have proven to be highly cost-effective. They rebut the oft-heard but fallacious claim that pollution control stifles economic growth. In fact, pollution control stimulates growth, creates new jobs, and builds human capital, especially in low-income and middle-income countries by improving health, increasing children's intelligence quotient (IQ), and extending the life span, thus enhancing economic productivity, national security, and human well-being.²⁶

Four specific actions needed for prevention of cancers caused by manufactured chemicals are these:

- mandatory premarket testing of chemicals for safety and toxicity before they come to market;

²³ See Landrigan et al., "The *Lancet* Commission on Pollution and Health."

²⁴ See Bengt Jarvholm and Alex Burdorf, "Emerging Evidence That the Ban on Asbestos Use Is Reducing the Occurrence of Pleural Mesothelioma in Sweden," *Scandinavian Journal of Public Health* 43, no. 8 (2015): 875–881.

²⁵ See Landrigan et al., "The *Lancet* Commission on Pollution and Health."

²⁶ See Landrigan et al., "The *Lancet* Commission on Pollution and Health."

- post-market testing of the safety and toxicity of chemicals already on the market starting with those most highly suspect of causing disease;
- deployment of a risk assessment paradigm for cancer prevention that explicitly recognizes the unique vulnerability of fetuses, infants, and e-scale deployment of a risk assessment paradigm that protects the most vulnerable will protect all members of society.
- acting on what we know: reduce exposures to known toxins. Presume that all new chemicals are toxic until they are proven to be safe, a proactive approach to chemical regulation known as the Precautionary Principle.²⁷

Conclusion

Prevention of cancer caused by pollution will require ultimately that we confront the social, moral, and economic root causes of pollution—specifically the current, take-make-use-dispose economic paradigm that emphasizes short-term thinking, focuses single-mindedly on gross domestic product (GDP), and extols greed.²⁸ This worldview sees natural resources and human capital as abundant and expendable and gives little heed to the consequences of their reckless exploitation. It fails to link economic development to social justice or to maintenance of the Earth's resources. Pope Francis has termed this paradigm the “throwaway culture.”²⁹ It is profoundly unethical, and it is not sustainable.”³⁰

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²⁷ See Jeanne Rizzo, “Cancer Prevention through a Precautionary Approach to Environmental Chemicals: Policy and Research Recommendations for Moving Forward,” *Reviews on Environmental Health* 24, no. 4 (2009): 279–286.

²⁸ See Raworth, *Doughnut Economics*.

²⁹ See Francis, *Laudato Si'*, nos. 16, 22, 43.

³⁰ See McMichael, Woodward, and Muir, *Climate Change and the Health of Nations*.

follow-up of 20,000 9/11 rescue workers. From 2015 to 2017, he co-chaired the *Lancet* Commission on Pollution and Health.