1 CHEMICAL AVALANCHE

'There are poisons that blind you, and poisons that open your eyes.'
August Strindberg, *The Ghost Sonata*

The pallid light of a mid-winter afternoon, filtering through a tiny window set high in the wall of the small bathroom, illuminated mother and child in a moment of exquisite tenderness and pathos. Eugene Smith shifted uncomfortably in the cramped chamber to reframe the image: shrapnel wounds sustained in Okinawa as a war correspondent almost thirty years earlier still troubled him. Sightless, deaf, lame, claw-handed and emaciated, Tomoko Uemura lay helplessly in the bath, cradled in her mother's loving arms. Sixteen years earlier she had sustained terrible damage as she still lay in the womb, the venom that crippled her leaching unseen and undetected from the outlet pipe of the nearby chemical plant into the surrounding sea that furnished the food for her village.[1]

Smith was a veteran photographer and photo-journalist who had seen it all – war, suffering, human courage, character and compassion, industry and politics – and depicted it in an epic series of photographic essays, many published in *Life* magazine over several decades. Aroused by growing evidence of the devastation being inflicted on ordinary people by chemical pollution, Smith and his wife Aileen moved in 1971 to the town of Minamata, Japan, following reports of a mysterious disease that had been afflicting its inhabitants since the mid-1950s, to document its impact in images and words. The disease was caused by methylmercury, a substance so poisonous it has no 'safe' level of

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exposure, no matter how small the dose. It originated in discharges from the local chemical plant. Smith wrote:

> *The nervous system begins to degenerate, to atrophy. First, a tingling and growing numbness of limbs, and lips. Motor functions may become severely disturbed, the speech slurred, the field of vision constricted. In early, extreme, cases victims lapsed into unconsciousness, involuntary movements and often uncontrolled shouting. Autopsies show the brain becomes spongelike as cells are eaten away. It is proven that mercury can penetrate the placenta to reach the fetus, even in apparently healthy mothers.*[2]

The Smiths came for three months. They stayed three years and it almost cost the photographer his life. On 7 January 1972, barely a month after he captured the immortal image of Tomoko and her mother – later to be known as the 'Madonna of Minamata' – he accompanied a group of mercury-poisoning victims to cover a meeting arranged with a manager of the Chisso company which was responsible for running the chemical plant, and thus also for the mercury-laden discharges into local waters where they contaminated the marine food chain on which locals relied. The manager failed to show up. Smith later recounted:

> *But suddenly, a mob of workers rounded a factory building . . . They hit. They hit me hardest, among the first. The last exposure, bad, blurred, shows the man on the left, his foot at that moment finishing with my groin, reaching my cameras. The man on the right was aiming for my stomach. Then four men raked me across an upturned chair and thrust me into the hands of six who lifted me and slammed my head into the concrete, outside, the way you would kill a rattlesnake if you had him by the tail.*[3]

Battered and bruised, his cameras smashed, Smith survived but lost partial sight in one eye. It turned out to be his last assignment and he died in 1978.[4]

The bludgeoning of Eugene Smith showed the lengths to which some organisations and individuals were prepared to go

to block awareness of the effects of poisons discharged by their enterprises on the community. Despite such attempts to silence the truth, awareness has slowly spread, more so in some societies than others; more in some social strata than others. But the warning has spread neither far nor fast enough: today, most people still have barely an inkling of the universal chemical deluge to which they are now subject, daily, and of the growing peril that we – and all our descendants – face. If the dawn of that awareness for the educated publics of North America and Europe came with the publication of Rachel Carson's powerful book *Silent Spring* in 1962, where she revealed the impact of certain pesticides used in the food chain on wildlife and humans, then Eugene Smith's searing image of the *Madonna of Minamata*, transcending words and languages, was the shot heard round the world.

The subject matter of this book is plain, unvarnished science, as brutal in its facts as the fists and boots that fell on Eugene Smith. But it is the truth, insofar as any system devised by humans is able to determine and describe such things.

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Earth and all life on it are being saturated with chemicals released by humans, in an event unlike anything that has occurred ever before, in all 4 billion years of our Planet's story. Each moment of our lives, from conception unto death, we are exposed to thousands of substances emitted by our activity, some known to be deadly in even minute doses and most of them unknown in their effects upon our health and wellbeing or upon the natural world. These substances enter our bodies with each breath, with every meal or drink, the things we touch or encounter in our journey through each day. There is no escape from them.

Ours is a poisoned world, its system infused with the substances we deliberately or inadvertently produce in the course of extracting, making, using, burning or discarding the many marvellous products on which modern life depends. Relative to the span of human history, this has all happened quite quickly and

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has burgeoned so rapidly that most people are still unaware of the extent or scale of the peril in which it places each of us and our grandchildren. Our present plight has crept up on us unseen, piecemeal, with infinite subtlety and frequent inadvertence, in a social climate of trusting acceptance of authority, over barely the span of a single human lifetime. The impacts are only now starting to emerge into full view – and the forming picture portrays a catastrophic risk to our future as great and as all-pervading as climate change, ecological collapse or weapons of mass destruction. A risk to be urgently understood and overcome using all the creative ingenuity humans have relied on for survival throughout our journey.

Knowledge of the toxicity of industrial chemicals is not new: the ancient Greeks and Romans were both familiar with the diseases caused by lead and mercury among those who worked with them, and with silicosis among miners.[5] In the eighteenth century, scrotal cancers were linked with the occupation of chimney sweep.[6] 'Phossy jaw', a disfiguring ailment among workers in matchstick factories in contact with white phosphorus, was first diagnosed in 1839.[7] Aniline dyes, made industrially from coal tar for fabric dyes, poisoned thousands of workers in the mid-nineteenth century – and still do to this day. Poison gases such as chlorine, phosgene and mustard gas – often made by the same factories and firms that produced the textile dyes – inflicted 1.3 million casualties in World War 1. In the twenty years following the discovery of radium by Marie Curie in 1895, a hundred medical workers died from radiation poisoning. Curie herself died, aged sixty-six, on 4 July 1934, of aplastic anaemia, probably caused by prolonged exposure to radiation: she was known to carry test tubes of radium around in the pocket of her lab coat. Asbestos-related cancers and diseases were first diagnosed in the early part of the twentieth century. Following rapid expansion of the coal and petrochemical industries during World War 2, a spate of large-scale industrial poisonings arose: the Great Smog of London, Minamata, Agent Orange, Seveso, the 'Silent Spring', the Love Canal, Bhopal, Dzershinsk, Tianjin, the Asian Brown Cloud and the

Great Pacific Garbage Pool. However, these were mainly viewed by governments and society as single, largely local, misfortunes, the result of corrupt or careless local companies and officials – not as the heralds of a Planetary pandemic.

In our world, something vast has changed.

Today human-emitted chemicals, their byproducts, mixture products and breakdown products, are everywhere, in all that we do. They are to be found in homes, offices and factories; on farms; in clothing, bedding and furnishings; in electronics and plastics; in cars, aircraft and ships; in the air we breathe and the water we drink; in construction and manufacturing industry; in pest control; and in the many products that we put onto or into our own bodies such as cosmetics, medicines, food, drink, tobacco and drugs, both legal and illegal.

Unlike our great-grandparents and all the generations before them, we are now immersed in these human-generated substances 24/7, no matter where we live: the chemical byproducts of modern industrial life have spread around the Planet and their fingerprints are to be found from the remotest poles to the abyssal oceans, from our living blood, to our grave, to the genes of our grandchildren.

In modern society the world over, synthetic chemicals are integral to our daily lives. There is no industry or activity of advanced civilisation where they are not used in some form or other, with the aim of improving our quality of life. They solve problems, protect, adorn, kill pests, save lives, improve efficiency and enhance convenience. An advanced society without such chemicals is almost unimaginable. They are a part of who we are – but in far more ways than most of us suspect. Figure 1.1 summarises the risks associated with common, everyday chemical-based products and services.

In 2018 the United Nations Environment Programme (UNEP) estimated the number of industrial chemicals in general commerce globally was between 40,000 and 60,000.[8] However, the United States Environmental Protection Agency (US EPA) listed more than 86,000 different chemical substances manufactured, used or being researched in the USA alone.[9] (The US chemical

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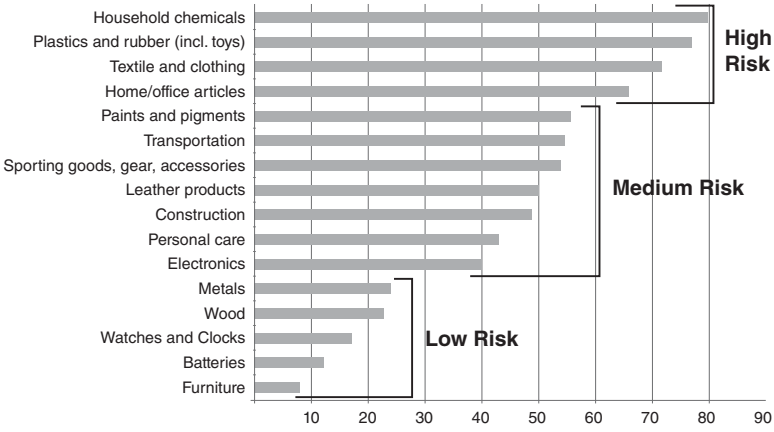

Figure 1.1. Risks associated with common chemical-based products in our daily lives. Source: UNEP.

industry denied this, claiming only 8707 chemicals were used in America.[10]) The US Agency for Toxic Substances and Disease Registry (ATSDR) estimated that 'more than 100,000 chemicals are used by Americans'.[11] The European Union (EU) stated that more than 106,000 chemical substances were used within in its member countries.[12] Furthermore, the EU assessed that almost two-thirds of the chemicals used pose a known health hazard. In China, the Chemical Inspection and Regulation Service (CIRS) listed 49,000 different substances used in the People's Republic, which has become the fastest growing and largest chemical producer in the world.[13] UNEP stated 'The exact number of chemicals on the global market is not known but under the pre-registration requirement of the EU's chemicals regulation, REACH, 143,835 chemical substances have been pre-registered. This is a reasonable guide to the approximate number of chemicals in commerce globally.'[14]

It turns out that all these well-intentioned efforts to quantify the scale of global chemical production were woeful underestimates. In 2020, an international scientific team, led by Zhanyun Wang of Switzerland's Institute of Environmental Engineering,

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examined the chemical inventories of nineteen countries in Europe, North America, Oceania and part of Asia and concluded:

> *Over 350 000 chemicals and mixtures of chemicals have been registered for production and use, up to three times as many as previously estimated and with substantial differences across countries/regions. A noteworthy finding is that the identities of many chemicals remain publicly unknown because they are claimed as confidential (over 50 000) or ambiguously described (up to 70 000). Coordinated efforts by all stakeholders including scientists from different disciplines are urgently needed . . .*[15]

The total included 157,000 identifiable chemicals, 75,000 mixtures, polymers and substances of unknown composition, and 120,000 other substances that could not be conclusively identified. Besides revealing that manufactured chemicals far outnumber previous estimates, the world's first-ever attempt to compile a global chemical inventory also pointed to widespread secrecy, mis-identification and obfuscation.

However, even these formal registers cover only chemicals purposefully manufactured by industry. They do not include the far, far larger volumes of substances released directly or as unintended consequences of human activity in the form of construction, land development, farming, mining, mineral refining, energy generation, the use of machinery, deforestation, combustion, transport and other acts that put chemicals in places and concentrations where they would not otherwise naturally occur. And these do not include the millions of breakdown products derived from man-made chemicals, nor the daughter products they give rise to when interacting with other substances in our environment.

Together, these substances – purpose-made and unintentional, simple and evolved – have been entering our lives, our bodies and our living spaces largely unmonitored and, in many cases, undetected, in a rising global flood since the mid-twentieth century, when they first became commonplace. Purpose-made chemicals are thus the mere tip of the iceberg of

humanity's total chemical exposure resulting from our own activity.

Without being conscious of it, we poison ourselves every day, every moment of our lives.

Chemical Flood

Chemicals are a burgeoning enterprise – expanding at rates faster, indeed, than economic growth or the human population itself. UNEP anticipates the value of chemical production worldwide to grow from $5 trillion in 2017 to $10 trillion in 2030 and triple again in value by 2050 – a sixfold increase in barely thirty years.[16] The US ATSDR estimates that 'about 1,000 new chemicals are introduced each year'.[17]

The chemical industry is the second largest manufacturing activity in the world. Between 2000 and 2017, its output nearly doubled, from about 1.2 to 2.3 billion tonnes.[18]

Consequently, the UN commented: 'Trends ... suggest that the doubling of the global chemicals market between 2017 and 2030 will increase global chemical releases, exposures, concentrations and adverse health and environmental impacts unless the sound management of chemicals and waste is achieved worldwide.'[19]

Another way to see the issue is that humanity is being exposed to nearly 3 billion *additional* tonnes of man-made substances – including toxins, carcinogens, nerve poisons and hormone disruptors – every year. That's a third of a tonne of man-made chemicals for every child, woman and man on the Planet. This release is effectively cumulative, year on year, and is on track to triple to *one tonne per person* by the mid-century.

To give some idea of the overwhelming scale of this release, during the 'Agent Orange' defoliant campaign (1961–71) in the Vietnam War the total amount of herbicides released for every member of the exposed rural Vietnamese population per year was about 2.5 kilograms; this was subsequently linked to 400,000 dead or maimed and half a million birth deformities.[20] In contrast, citizens globally are now exposed to combined

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annual emissions of around 325 kilograms of manufactured chemicals *each*.

These numbers are presented purely to give a sense of the scale of the chemical exposure of modern society. No comparison in toxicity is intended, since the overall toxicity of the chemical avalanche is unknown, so many substances never having been properly tested – and almost none of them tested in mixtures. However, while many of these chemicals are deemed harmless in single, small doses – it takes only a tiny quantity of a carcinogen to unleash a cancer – even harmless substances can recombine or break down to form toxic ones. Once used, chemicals never simply vanish. They or their constituents hang around and form new compounds or mixtures, both safe and deadly, in the living environment almost *ad infinitum* – an issue that has become horrifyingly apparent in the particular case of plastics.[21]

Nutrient Cascade

In addition to the 2.5 billion tonnes of manufactured chemicals produced and released each year, humanity also emits vast quantities of nutrients, soil particles, dust, gases and other substances unintentionally, through global agriculture, transport, energy production and manufacturing.

By far the largest part of this category of emissions consists of eroded topsoil, which is released chiefly by agriculture – especially mechanised cropping – forest removal and land clearing for development. Recent estimates of global soil loss range from 36 billion tonnes a year[22] to as high as 75 billion tonnes.[23] Thus, it requires the loss of from 4.5 to 10 tonnes of topsoil every year to feed each of us.

By eating we are now, effectively, devouring our Planet.

While soil is not usually regarded as a 'chemical', nevertheless its release on such a scale has vast biogeochemical impacts on the Earth, on waters and all life, including us. Soil consists of many chemical compounds, some of which are toxic – such as heavy metals or excessively acidic or alkaline minerals which

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can foul water. Most of these can react with other substances they encounter in the environment, in both the short and long term, creating new products and causing local pollution hotspots or diffuse contamination. Soil loss also leads to dust storms, sedimentation and the silting of rivers, lakes and dams. It is linked with lung disease, allergies, infectious agents such as anthrax and TB and the pollution of drinking water. Above all it causes malnutrition, which leads to many forms of disease and death. On average, human activity is causing the world to lose its precious topsoil at rates from ten to forty times faster than it is naturally replenished.[24] This places the modern industrial food system on a path of no return.

Soil also contains vast quantities of nutrients, both natural and man-made – nitrogen, phosphorus, potash, essential minerals and micronutrients. For example, only 22 per cent of the world's 250 million tonnes of fertiliser made each year actually ends up being consumed as human food;[25] the rest becomes an environmental contaminant that either feeds weeds and algal blooms or pollutes waterways. The staggering volume of nutrients emitted in lost soil ultimately ends up fouling rivers, lakes, groundwater and the sea, where it has created more than 700 'dead zones' in the world's oceans, places stripped of their oxygen and so, largely devoid of life.[26]

Released on such a scale by humans, nutrients have become a dangerous contaminant of the Earth system and now greatly exceed the volumes that circulate naturally in it. Indeed, nitrogen pollution of the Earth's biosphere is now considered to have breached a boundary more perilous, even, than our release of carbon into the atmosphere.[27] A boundary which, in the opinion of the scientists, humanity ought never to transgress for our own safety.[28]

At the same time food production uses around 5 million tonnes a year of specialised poisons designed to control weeds, insects, rodents and moulds in the farming and food chain. Use of pesticides has thus grown tenfold since Rachel Carson warned the world about them in *Silent Spring* in the early 1960s. However, it is estimated that up to 98 per cent of these

specialised poisons, generally delivered as sprays, manage to hit a non-target organism, including honeybees, farm workers and consumers.

Agriculture is thus, unintentionally, the source of one of the world's largest acts of general poisoning of the Earth system – an action that, in the absence of far sounder land management, is on track to redouble by the mid-century as demand for industrially produced food rises to meet both a growing population and rising living standards.

Mineral Landslide

The largest release of all is delivered by the worldwide mining industry. In the course of obtaining the 17 billion tonnes of mineral, energy and construction products used by humanity every year,[29] the activities of mining and refining unleash a colossal waste stream many times more voluminous than the metals or energy produced. World mining output has doubled since the mid-1980s and is expected to redouble by the 2050s – along with its waste stream. Only in Europe is it shrinking: in Asia it has grown by 98 per cent and in Oceania by 132 per cent since 2000. The waste it emits has grown in proportion.

The total volume of this colossal waste stream, which consists chiefly of 'overburden' (broken rock, rubble, soil, dust and sediment removed to expose the orebody or coalbed) and 'tailings', crushed material left over after mineral extraction, has never been calculated – and so represents a grave unknown in human contamination of the Earth system. Possibly the gravest of all. The volume of overburden removed to get at the ore or coal varies between one and fifteen times the weight of the product, especially in open pit mines, but averages about three to seven times.

Once metal ores are mined, they must be crushed and refined to extract the desired minerals. This process also generates vast amounts of waste, known as tailings. The ratio of tailings to metal produced varies widely, from 20:1 to 98:1. For example, world production of 60 million tonnes of aluminium also yields

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150 million tonnes of 'red mud', the highly caustic residue from bauxite refining.[30] Tailings are customarily deposited in tailings dams or dumps, into rivers and oceans, whence they usually spread through the wider environment over time causing episodes of poisoning of people and wildlife, killing rivers and lakes, and occasionally being released by disastrous dam collapses. There are thought to be more than 18,000 tailings dams worldwide.[31]

No-one has ever compiled an accurate figure for the total wastes from the mining process, but at a conservative estimate it is from three to ten times larger than the useable fraction of metals, minerals and energy products produced – generating between 50 and 170 billion tonnes of mining wastes a year. That such a shocking volume of material should be continually dumped around the Planet each year without even being measured or accounted for contrasts starkly with the effort that now goes into measuring carbon dioxide emissions and their impacts or other forms of industrial pollution. Except at the local level, and in developed countries, the chemical impact of mining contamination on the Earth system has been greatly underestimated, if not ignored altogether.

A possible explanation for this emerges from the work of a group called Earthworks Action, which searched the records of the world's top ten mining companies and established that, together, they dispose of 180 million tonnes of tailings into nearby rivers and lakes, mainly in developing countries where regulatory regimes are often lax or readily corrupted.[32] We may safely assume that the waste-dumping practices of many thousands of smaller mining houses are, in general, far more careless.

Many of the world's 5000+ most contaminated sites listed by the Blacksmith Institute, a New York-based environmental watchdog, are minesites.[33] Individual cases of mining pollution abound in the scientific literature, in government and media reports, and many involve death and disease in local populations as well as ruined landscapes and poisoned waterbodies.

Mining pollution is no trivial matter, either in scale or in persistence. A well-known impact is the acidification of

waterways, caused by the chemical interaction of mineral wastes with the environment, especially water. This kills rivers and lakes and renders their water undrinkable. In the case of 'Iron Mountain', California, the world's most famously polluted mine-site, acid runoff was first detected in 1902, continued after the mine closed in 1963, and is expected to last for another 3000 years.[34] Besides acid drainage, mining waste streams may also contain highly poisonous substances such as mercury, arsenic, cyanide, cadmium and lead.

Energy Exposure

To power modern civilisation by conventional means consumes around 7.5 billion tonnes of coal, 4.5 billion tonnes of petroleum, and 4 billion tonnes of gas every year.[35] This vast output of fossil energy is one of the largest human chemical impacts on the Planet – and does not come without grave cost.

Contaminants commonly found in coal include mercury, cadmium, radioactive elements, sulphur and nitrogen compounds, volatile organic carcinogens and other toxins. The carbon released when coal is burned is the major driver of global climate change. The mining and burning of coal also cause acid runoff and acid rain, which damage rivers and forests and are chiefly responsible for acidifying the world's oceans. By volume, the mining, burning and processing of coal constitutes the largest source of toxicity from any human activity. Coal combustion, for instance, releases about 8100 tonnes of highly poisonous mercury into the Earth system every year. This accumulates year after year, affecting the food chain, such as in long-lived fish. Likewise, petroleum contains many substances, such as benzene, that are toxic or may cause cancer.

The burning of all fossil fuels – coal, oil, gas, tar sands etc. – poses multiple threats to human health, especially for developing children and unborn babies.[36] It releases a range of poisons into the environment including polyaromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), mercury, sulphur dioxide, nitrogen oxides and microscopic particles of black

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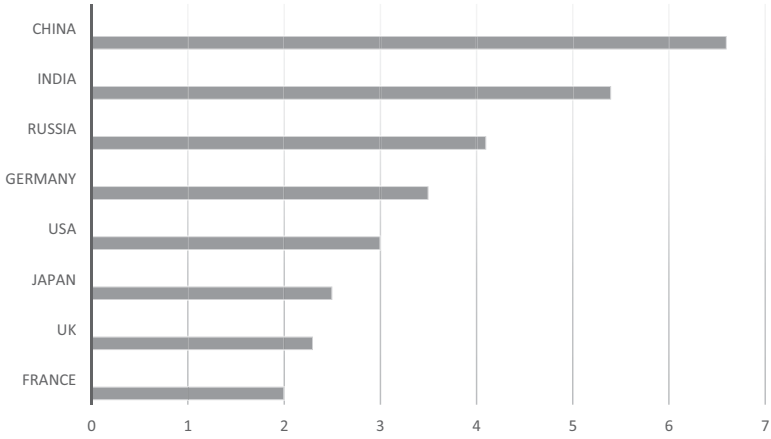

Figure 1.2. Annual cost of air pollution caused by fossil fuels, as percentage of GDP. Source: CRECA.

carbon which impair air quality, water and food. The direct impacts of these on health, especially of infants and children, include lung disease, asthma, developmental and sexual disorders, brain disease and cancers. Furthermore, the burning of fossil fuels releases 37 billion tonnes of carbon into the atmosphere each year, driving climate change, which in turn causes malnutrition, heat stress, infectious disease and mental problems. All of these interact with the direct effects of poisoning to make them worse.

In the world's first endeavour to quantify the costs of air pollution alone, the Centre for Research into Clean Energy and Air (CRCEA) put it at $2.9 trillion in 2018 (Figure 1.2), equal to around 3.3 per cent of world economic turnover.[37] Air pollution also killed around 8 million people from lung disease, heart disease, stroke and cancer, and caused the loss of 1.8 billion days of work, 4 million new cases of child asthma and 2 million premature births.[38]

This, however, is by no means the full toll of fossil fuels, which also includes industrial workers poisoned, the toxic emissions from plastics, packaging, furnishings, paints, cleaning agents and solvents, creating indoor air pollution in homes and

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workplaces which is often worse than the city air outside. It includes pesticides and microplastics in the home and food chain, the side-effects of drugs both illegal and legal, a flood of 'gender bender' substances and nerve poisons. In short, the fossil fuels industry, while powering society, is also the primary source of most of the poisoning of people and life on Earth.

In October 2017, *The Lancet* Commission on Pollution and Public Health concluded:

> *Pollution is the largest environmental cause of disease and premature death in the world today. Diseases caused by pollution were responsible for an estimated 9 million premature deaths in 2015—16% of all deaths worldwide—three times more deaths than from AIDS, tuberculosis, and malaria combined and 15 times more than from all wars and other forms of violence. In the most severely affected countries, pollution-related disease is responsible for more than one death in four.*[39]

The fossil fuels industry, for all its convenience and many economic, social and even health benefits, is thus implicated in the worst case of mass homicide in human history – an annual death toll far greater than that of either of the World Wars.

A toll equivalent in impact to a fresh Holocaust every eight months. A toll that is entirely preventable.

Weaponised Chemicals

Stocks of chemical weapons, continued research into new, more deadly substances and the huge volume of nerve poisons dumped in the world's oceans over the last century pose a continuing threat to human and environmental health. As of 2020, around 70,000 tonnes of the world's declared stocks of 72,000 tonnes of chemical agents and weapons had been declared destroyed under the Chemical Weapons Convention (CWC).[40] In 2020, 193 countries had signed and ratified the convention, while four had not done so. However, cases of the use of chemical weapons in local conflicts and as tools of

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assassination continued to occur throughout the 2010s,[41] suggesting at least some countries were lying. Concern persists over vast quantities of chemical weapons dumped in the world's oceans between 1918 and 1972, which have never been made safe and may leak out at any future time into the ocean food chain, and over the safety of high-temperature incineration methods used to destroy existing stocks.

Nuclear Legacy

The world produces around 60–70,000 tonnes of uranium oxide every year as the first step in making the fuel for its 450 operational nuclear reactors and for nuclear weapons. The total amount of uranium ore produced globally since mining began a century ago is about 2.5 million tonnes, however the low-level waste generated by the mining, crushing and refining process is thought to run into billions of tonnes. Global uranium reserves total 6.1 million tonnes. In 2019 world stocks of refined product contained 1340 tonnes of highly enriched uranium and 550 tonnes of plutonium. The weapons stockpile held 13,865 warheads, of which 3750 were deployed ready for use.[42] To these sources of radiation must be added the contamination released by nuclear accidents such as Chernobyl and Fukushima,[43] or from disintegrating storage facilities, such as Hanford, USA, where a quarter of a billion litres of radioactive fluids from the H-bomb program are slowly leaching into the environment.[44]

The world's total nuclear waste inventory from power generation, mining, nuclear weapons, decommissioned nuclear plants and nuclear medicine was estimated by the UK at 6.7 million tonnes in 2019 – most of it, low-level waste.[45] The issue of storage remains unsolved: more than seventy years after the start of the nuclear age, no country in the world has a deep geological repository for spent nuclear fuel in operation.[46] There is a fear that, if mounting nuclear waste stockpiles were to be disposed of by illegal dumping at sea, the radiation could affect humanity through the food chain and contamination of the wider environment.[47]

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Eating Garbage

The world currently throws away over 10 billion tonnes of domestic and industrial waste materials a year – all of which has chemical consequences for our environment and our health. This mountain of refuse is forecast to almost double by the mid-century. Most of it is stored in city dumps, is burned or simply discarded, mainly in the oceans – all processes that eventually release toxic chemicals back into the air, water and food supply, thus causing us to eat, breathe and drink our own garbage.

Waste from the thirty-seven members of the OECD was estimated at 3.8 million tonnes a year in 2015, and since the OECD represents about half of the world economic activity this implies world total waste emissions of more than 10 billion tonnes in 2021.[48] Reinforcing this, the European Union estimates its total waste output at 2.5 billion tonnes a year.[49] As Europe constitutes 22 per cent of world economic activity, this gives a global waste estimate of more than 11 billion tonnes. All of which has chemical consequences.

Part of this chemical flood consists of 400 million tonnes of 'hazardous wastes'[50] – meaning they are very toxic to the environment and threaten the health of people and animals. Hazardous wastes are the dangerous leftovers from activities such as manufacturing, farming, water treatment, construction, vehicle servicing, laboratories, hospitals, firefighting and other industries. They may be liquid, solid or sludge and contain numerous toxic chemicals, heavy metals, radioactive substances, disease-causing organisms and other harmful materials. Even homes generate hazardous waste when they throw away old batteries, electronic equipment and unwanted paints, cleaning fluids or pesticides. Much of this dangerous flood goes into landfills, whence it leaches into the environment or else is shipped to developing countries where primitive recycling industries ensure the toxins end up recirculating in air, water, food, manufactured products – and people. In 1992 the Basel Convention was signed under which signatory nations agreed to restrict the international transport and dumping of toxic waste.

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Every day we throw things away and forget completely about them; but this does not mean these things or their chemical components are gone for good. Many return to haunt us. Chemicals and their byproducts can leach out of landfill pits into groundwater or seep out as vapours. Some of them hitch rides on dust particles, leapfrogging around the Planet in cycles of absorption and re-release in a phenomenon known as the 'grasshopper effect'. Burning of hazardous wastes may give rise to gases and vapours more toxic still. Some break down into relatively harmless substances, but others form more poisonous compounds and many combine and recombine with one another over long periods, giving rise to generations of unintended byproducts. As cities expand, buildings rise over old dumps, their citizens unmindful of what is in them and living on top of potentially toxic zones. In most of the world's big cities today, drinking water contains the lethal residue of yesterday's wastes. While it is possible to clean up one or two toxic substances from a particular site, remediating the witches' brew of toxics produced in the stream of human industrial waste to a safe level is, generally speaking, beyond current technology or affordability, especially once these substances have escaped into groundwater and dispersed through the wider environment.

Finally, the world's water supplies – and through them the entire global food chain – are becoming increasingly contaminated by a wide range of substances capable of damaging the human brain, reproductive and hormonal systems. These are known as endocrine-disrupting chemicals (EDCs), and their main sources include prescribed medical drugs and contraceptives, illegal drugs, pesticides and industrial petrochemicals, plastics and wrapping found in both food and household goods. So far, more than 1500 of these chemicals have come to the attention of science; a few are now banned in Europe, but rarely elsewhere. This issue is discussed more fully in Chapter 3.

To give a fuller impression of the scale of human contamination of the Earth system, Table 1.1 shows the main categories of man-made chemical emissions.

Table 1.1 Global emissions of chemical substances due to human activity, per year

Total disposed waste	10–11 billion tonnes	OECD, EC
Household waste	2 billion tonnes	TWC 2020
E-waste	50 million tonnes	TWC 2020
Hazardous waste	400 million tonnes	TWC 2020
Food waste	730 million tonnes	FSI 2020
Manufactured chemicals	2.5 billion tonnes	UNEP 2019
Pesticides	5 million tonnes	Worldometer 2020
Fertilisers	250 million tonnes	FAO 2016
Plastics	400 million tonnes	WWF 2019
Food output	5 billion tonnes	FAO 2019
Forest output	5.8 billion tonnes	FAO 2018
Total mining output	17 billion tonnes	WMC 2019
Gas	4 billion cubic metres	GESY 2019
Petroleum	4.5 billion tonnes	GESY 2019
Coal	7.5 billion tonnes	GESY 2019
All metals	5 billion tonnes	
Cement	4.1 billion tonnes	Statista 2019
Steel	1.8 billion tonnes	Statista 2019
Uranium oxide	63,000 tonnes	WNA 2019
Mining wastes	36–84 billion tonnes	
	5–10 billion tonnes (tailings)	
Carbon (all sources)	37 billion tonnes	IPCC 2019
Soil, eroded by farming and land development	36–75 billion tonnes	*Nature* 2017
Total emissions per year	**120–220 billion tonnes**	

Chemical Deluge

Table 1.1 represents an attempt to quantify human chemical emissions, in order to visualise the true scale of the problem we are facing, for the purpose of trying to solve it.

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Although the numbers are necessarily imprecise, owing to wide variances or lack of data on issues such as land degradation, mining and mineral wastes, it is clear at a glance that our combined emissions of chemically reactive substances are very large indeed, amounting to a billion tonnes every few days.

Total human chemical emissions are thus in the range 15 tonnes to 28 tonnes per person per year – which contrasts with 6 tonnes of climate emissions each. And they are climbing rapidly.

We now inhabit the Anthropocene,[51] an age in which human action occurs at such a scale that it changes the very Earth and its systems, reshaping them beyond repair or recall. An age in which humans have become a geological force.

One of the chief ways we do this is chemical. While this is acknowledged in the particular case of climate, our combined chemical impact is still poorly understood, inadequately researched and quantified and seriously neglected, especially in policies aimed at cleaning up the Planet. Understanding of the problem and attempts to remedy it are therefore occurring piecemeal and without any clear view of the magnitude or complexity of the challenge. And they are failing, disastrously, as this book will show. Like the blind men feeling the elephant in the Indian folk tale, we tend to perceive the parts – but not the whole beast. And this gives us dangerously flawed understanding of its true nature.

It is therefore necessary to give the beast a name – the Anthropogenic Chemical Circulation (ACC), an ugly name for an ugly thing – so that it may be fully seen and understood for the first time, as an essential step in learning how to master it, before it rages amok and ruins us. The ACC describes not only the entire quantum of human emissions of chemically reactive substances, but also the way they interact and mix, travel around the Planet, take new forms, persist sometimes for millennia affecting the health and wellbeing of humans and all other forms of life. The ACC is just like our carbon emissions – only much bigger and far more noxious.

It began with the industrial revolution and widespread burning of coal, but it has expanded massively since the growth of the chemical industries in World Wars 1 and 2, since the emergence of modern industrial agriculture, mining, construction, packaging and pharmaceuticals in the postwar era. Like the radioactive traces of early atomic bomb tests, it is a hallmark of the modern age.

For the first time in the Earth's history, a single species – ourselves – is poisoning an entire Planet.

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