Chapter 3
Trash Can Living

Abstract  The byproducts of consumption constantly flow between ecosphere and technosphere. LCA environmental impact categories—including global warming, eutrophication, acidification, and stratospheric and tropospheric ozone—form the basis to evaluate massive torrents of material and energy and their potential to degrade ecosystems.

Waste is defined not simply as unwanted or unusable material but more broadly as “material in the wrong place at the wrong time.” Earth is the first of three “trash cans” that humankind has created as a result of its inability to deal with its waste. Illustrated examples establish the amount of land available to support us, the general magnitude of the solid waste problem, and the inherent disparity between the two.

Air, the earth’s atmosphere, is the second “can” used to take up the lighter-than-air waste byproducts created by human activity. The evidence of an increase in greenhouse gasses correlates to the pronounced rise of fossil fuel-driven industrial production since the late 1700s through the present day. CO$_2$, tropospheric and stratospheric ozone problems, and methane are discussed.

Water comprises the third and final “trash can” survey, from solid waste fouling our waterways that ends up slowly churning in the great Pacific gyre to agricultural and industrial chemical elements and compounds that reduce the ability of the oceans, lakes, rivers, streams, and underground aquifers to support life.

Externalizing what is considered of no economic value transforms the world’s litho-hydro-atmospheres into receptacles for waste.

3.1 Environmental Impact of Exporting the American Way of Life

Maybe the most important feature of the American Way of Life today is that it is no longer only American. Over the last hundred years, we have been extremely successful in exporting a particular idea and amount of what individuals and families around the world need to live and to thrive. According to current projections, as China and India, the two most populous nations, continue to adopt this standard of living, we will strain an already taxed resource transformation and distribution system.
To simply state the problem:
As the global population increases and living standards continue to rise:

More **people** pay.
More **money** to use.
More **energy** to change.
More **natural raw material** into.
More **stuff** and more **experiences** that produce.
More **waste**.

Working backward through the list, we see what it takes to support this way of life. The broad outline shows final effects first:

More **waste** from.
More **stuff** and more **experiences**, derived from.
More **natural raw material**, for which we need.
More **energy** and exchange.
More **money** from.
More **people**.

Each stage relates to each of the others and contributes, alone and together, to changes we see on the planet as the world’s growing population constantly takes in and gives back more and more.

The solid forms of the first three components—waste, stuff, and raw material—are relatively easy to grasp because we can see and touch them. They have physical presence. We can put them in a pile, hold them in our hands, place them on a shelf, or sell them on eBay. The last three are more difficult to comprehend. **Energy** flow can be metered and its effects measured but, as discussed in the last chapter, cannot be directly seen or quantified. **Money** is merely a symbol of value and a convenient way to exchange goods and services. Yes, we can hold a dollar in our hand, but the paper on which it is printed has little inherent worth or utility until we exchange it for something we want.

Since the whole system has been created to support **people**, who are at the same time an integral part of the current production network, it is difficult to separate human efforts and activities, which are at work within the system, from the benefits we individually and collectively derive.

### 3.1.1 Waste

The complex interrelationships of each of the above components comprise the modern linear global economy. The end product of our traditional linear industrial economy is **waste**.¹ We think of it as inherently dirty, stinky, and useless. It is unwanted,

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¹The alternative to a linear industrial economy is a circular industrial economy first described by Walter Stahel as a system of loops in his 1976 report *The Potential for Substituting Manpower for*
deemed worthless, sometimes disgusting, or even dangerous. We want to throw it a-w-a-y—the farther, the better.

The problem with this view of waste, and our relation to it, is that there is no away. If we continue to reinforce these ideas in our own minds every time we think about the byproducts of our living, if we use language to describe our waste in only negative and fearful terms, it is almost impossible to see how some of what we discard could ever be a useful asset of tremendous worth. Another problematic outcome of trying to throw away our waste is that we are displacing huge amounts of raw material from places on the planet, where they are not harming anyone, altering them, and putting them in other places where they are causing problems for living creatures, including us.

The term “waste” is a context-dependent value judgment. The same physical material, as it moves through time and space, changes value as we use it. Carbon atoms, stored in fuel sources deep in the earth, are considered valuable resources to be extracted and set free to combine with oxygen during combustion. The instant they move from a necessary component of refined hydrocarbon fuel, used to do work, to an exhausted byproduct combining with oxygen in the air we breathe, their value as an asset changes to a liability cost in the form of too much atmospheric CO₂. The same is true for nearly every other natural resource we extract (take in), use, and discard (give back) to maintain our way of life in a linear global economy.

In order to externalize the costs of dealing with what is left of a thing that is deemed of having no value, we treat the air, land, and sea as three garbage cans with limitless capacity to absorb what we do not want. When we do this, we create problems. Throwing away requires that we collectively maintain the illusion that the earth is bigger than it is and that there are many fewer of us on the planet than there currently are. The truth is, though, that in a closed system, where technology and ecology comingle, waste byproducts remain extremely close by suspended and circulating in solid, liquid, and gaseous media. This new pollution directly and indirectly impacts biota that evolved for millions of years in environments in which it was absent.

3.2 Earth

Air and liquid water flow. They evade our direct perception as objects. Not so with the earth. It is the terra firma on which we stand, walk, ride, build, and live. Its solid surface literally supports all life. At the bottom of the deepest ocean, almost 7 miles down, you touch earth. Mount Everest and other peaks reach up more than 5 miles into the sky. Nearly all people on earth live comfortably between these extremes,
within a vertical zone of less than 2 miles above sea level. We live where oxygen is abundant, where we can breathe easily.

While we travel below and above of that range for exploration, recreation, or specialized work like mining or scientific research, most activities take place relatively close to sea level. The amount of land available in this fairly narrow range for all human activity is large, but not infinite.

From the earliest cartographers to today’s advanced satellite imagery and statistical surveys, we have made maps in order to measure and quantify territories and boundaries and the features they contain. We know that one-quarter of the nearly 60 million square miles of the earth’s land surface is found more than 2 miles up and that a third more is desert. What’s left is about 25 million square miles or 16 billion acres. That gives each of the nearly 8 billion people on earth (7.815B in the fall of 2020) less than 2 acres of habitable land, once we subtract public amenities such as airports, farms, rivers, roads, parks, recreational facilities, supermarkets, and landfills that we all share (Worldometer 2020).

3.2.1 Our Global Footprints

A person’s global footprint is the sum of all the resources that go into providing the things and experiences that person has come to expect. Tallies of the amount of land it takes to support a single person living the “American Way of Life” come to over 20 acres per individual. If these calculations are correct, we will need ten times the amount of land we currently have to support the lifestyles more and more people around the world increasingly demand.

The situation is complicated further now that we are producing more waste that has to be put somewhere. The collective “garbage can” is already overflowing. We can’t find places to put our trash anymore. We handle it, manage it, juggle it, and in the end just stick it on top of one of the piles we have already started. When we cannot pile it any higher, we look for new places to create more piles or holes to fill with it.

How Much Waste Do We Produce?

My young daughter, at just over 10 years old, has produced over 300 times her bodyweight in garbage; this is equivalent to the weight of a family of Asian elephants (Fig. 3.1). The volume it takes up would fill almost half our house from floor to ceiling. By the time she graduates from college, our family of three will have produced enough garbage to fill our entire house five times over. At nearly 50 tons, this solid waste will weigh the same as a humpback whale (Fig. 3.2). This all has to be put somewhere. Little by little, with each thing we throw “away” to be trucked off and dumped in a landfill, we are reducing the amount of land available to do the other things we want and need to do.
3.2.2 Pre- and Post-Consumer Solid Waste Components Travel

From the public’s perspective, solid municipal waste is perhaps the most visible form of the problem. Consumers have direct experience with individual components handled at the moment they lose value. Solid waste byproducts at every previous stage supporting a product’s existence up to that point can be orders of magnitudes larger and more harmful than the enormous waste footprint represented in the final disposal phase.

To accurately estimate the number of tons per person per year we must add to what goes into the landfills, the tonnage of all toxic or radioactive tailings produced.
and dumped into the landscape during the mining of raw materials, and the poisonous industrial sludge and ash created in turning raw materials into finished goods. The total mass footprint of low or no value solid compounds extracted can be orders of magnitude greater than the item created. The environmentalist and documentary film maker, Chris Jordan, recently shared what he had learned on location in South America that “the mining footprint of a single gold ring is 40,000 pounds of dust, a pile of 40,000 pounds of toxic dust that is sitting on a hillside somewhere in Chile, and it’s going to be leaching cadmium and mercury and arsenic into the soil for thousands of years” (Jordan 2020).

Through formal and accidental solid waste management practices, we are changing the physical, chemical, and thermal profiles of ground we stand on. As the population grows, we will discard more and more. The lasting effects brought about by our increasing piles of detritus will continue to mount. Environmental impacts reach beyond local garbage dumps where, even under controlled conditions, seepage into groundwater and off-gassing of harmful compounds continue.

The systems currently in place in the United States to contain and treat the nearly 270 million tons of municipal solid waste we produce are complicated and expensive. We know that without them, some of the garbage won’t just sit there. We line the bottoms of our dumps with plastic liners in order to keep “garbage juice” from seeping into groundwater supplies. We stick pipes into the layers of trash to capture methane from escaping into the atmosphere where, ton for ton, it is 30 times more potent than CO$_2$ as a heat trapping greenhouse gas. If this gas is not captured, treated, and used as fuel, it would join the earth’s enormous natural stores of methane currently escaping from previously frozen tundra soils. As global temperatures rise, these methane-rich ground sources, defrosting as fast as an unplugged freezer, will release a growing amount into the atmosphere, thus contributing to a vicious cycle of increasingly faster rising temperatures and even less permafrost to contain the ancient anaerobic decomposition byproduct.

### 3.3 Air

A clear majority of scientists regularly and unequivocally tell us that climate change is being driven by human activity. They identify increasing amounts of two primary greenhouse gasses, carbon dioxide and methane (Masson-Delmotte et al. 2018), that have been steadily added to the air for 200 years. Carbon dioxide, or CO$_2$, is produced when living beings breathe out. It gets produced at a much greater rate along with other long-lived greenhouse gasses when we burn things as we have for millennia and at a much faster rate during the last three centuries.

The US National Oceanic and Atmospheric Administration (NOAA) Annual Greenhouse Gas Index (AGGI) tracks the combined measurements of all long-lived greenhouse gases. In addition to NOAA’s own global air sampling network in operation since 1979, they use measurements of CO$_2$ going back to the 1950s from C.D. Keeling (1958), combined with atmospheric change evidence derived from air
trapped in ice and snow above glaciers (Etheddge and Steele 1996). Equivalent CO₂ atmospheric amounts (in ppm) are derived with the relationship between CO₂ concentrations and radiative forcing from all long-lived greenhouse gases and shown in Fig. 3.3 (NOAA/ESRL 2020).

Most scientists agree that only in the last two centuries have CO₂ levels been rising outside of a “normal range.” According to the evidence found in the historic record of ice core samples, the range in which human beings have lived and built our world civilizations since the middle ages has averaged just below 280 carbon dioxide molecules in every million molecules of atmospheric gas. We are now over 400 parts per million (PPM) and rising. According to NASA’s former head of the Goddard Institute for Space Studies, Dr. James Hansen, we must reduce this level to 350 PPM in order to stabilize global temperature and the changes in climate that higher average temperatures bring (Hansen et al. 2008). This position has been peer reviewed and is supported by other scientists (Rockström et al. 2009).

### 3.3.1 Denial

Once we started extracting coal in large quantities and burning it to run factories over 200 years ago and, soon after, started distilling oil that would eventually be used to power everything else, CO₂ levels began to rise. As population increased in tandem with a growing industrialized economy in the last quarter of the nineteenth century, the rise in CO₂ became more pronounced. The following is one of the
several “hockey stick” graphs that are now famous or infamous depending on which side of the Anthropocene argument you are on (Fig. 3.4).

Graphs like these are lightning rods in the debate between those who see what they show as proof of an existential threat to the human species and those who don’t. Denialist arguments consider the graphs to be either false or, if true, inconsequential.

Starting with the 1998 Mann, Bradley, and Hughes graph, they may be the most politically controversial scientific graph ever produced, because they indicate correlations between human industrial production and a rise in global temperature. According to the graph, which reaches back to the Medieval Warm Period, the temperature did not vary above an average range before the early twentieth century, after the start of the Industrial Revolution (Mann et al. 1998).

Nearly everyone in the climate science community accepts these illustrations as indicators of how carbon-based industrial economic activities are directly causing climate change. They call for action to address root causes. Since acknowledging the scientific evidence of a problem would require a change in behavior to slow,
stop, or reverse the flow of more CO₂ into the atmosphere, proponents of the growth of a carbon-based economy passionately argue that the graph itself is untrue. Critics of the graphs say there are serious problems with the underlying science and methods used to construct them and that there are records that actually show opposing (cooling) trends. Some say that maybe the graph is accurate but that atmospheric climate change is actually good for human beings for a host of either physical reasons or economic reasons. As criticisms are regularly addressed and more reconstructions corroborate the original findings (Masson-Delmotte et al. 2018), new ones spring up.

More important than what specific arguments are presented in the ongoing debate is to recognize the causal relationship between debate and inaction. A small amount of doubt introduced by a vocal minority makes reaching a consensus in clearly defining any problem to start with making it impossible to then move to address it. Doubt promotes a “paralysis through analysis” by extending the conversation indefinitely and delaying any large-scale action that would change the way we currently produce and consume. It creates the perfect excuse to not change anything until we know more; the thinking goes, “Until we are 100 percent sure, we should do nothing.” (More on the denialist’s views and tactics for sowing doubt for maximum effect in Chap. 6.)

3.4 China

As the global greenhouse gases debate continues, the ill effects of business as usual are especially pronounced in rapidly industrializing countries. The Chinese government has acknowledged a growing problem. Its citizens are getting sick. The suffering caused by toxic smog is rising. As many as 3.7 million premature deaths in China were attributed to air pollution in 2012 up from 1.3 million deaths in 2008 (Mokoena et al. 2019).

Greenhouse gases are not the only type of air pollution. The same industrial sources of carbon dioxide also produce levels of sulfur dioxide, nitrogen oxides, and ground-level ozone as well as other compounds in the form of fine dust that can collect in the lungs of anyone who breathes (Fig. 3.5). These unwanted ingredients in the air can trigger a host of maladies, according to Bai Chunxue, the head of respiratory medicine at Shanghai’s Zhongshan Hospital. Diseases including lung cancer, chronic pulmonary obstructive disease (COPD), asthma, chronic bronchitis, and emphysema as well as cardiovascular disease are becoming more common in China (Demick 2013).

The same industries responsible for driving Chinese prosperity for the last three decades are causing one of the largest public health crises in the history of humankind. The government has pledged to improve the air quality in Chinese cities and major industrial centers but has not been able to make much progress. Even after technological advances developed to improve industrial emissions have been employed, the largest, centralized, government-run economy in the world cannot
control rampant air pollution, which is largely a result of its growing need for electricity to power an ever-increasing number of factories and urban centers.

### 3.4.1 Off-Shoring: Far, but Not Away

Despite occasional trade war friction, China is the world’s factory. It is a factory run on the country’s most abundant energy source—coal. While China’s economy grows, its people are asking why they cannot breathe clean air. Except for in the most densely populated industrial areas, most US citizens can take the air we breathe for granted. But, it wasn’t always so. During the same period of time as China built its production capacity, the United States made the switch to a service economy and, along with many manufacturing jobs, effectively off-shored the majority of top polluting manufacturing industries. We sent many of our own pollution problems as far away as possible. We sent them to the other side of the world. Even though we have taken care of our immediate air pollution problems by relocating them, it has not been a complete success since climate issues caused by rising CO₂, NO₂, and other greenhouse gas levels are not confined locally and do not respect national borders. Another reminder that in a closed climate system, as easy as it is to think and act otherwise, there is no “away.”

The spring of 2020 recorded a pronounced improvement in air quality across the globe. This coincided with a global pandemic that shuttered production facilities to, at once, protect workers from COVID-19 and respond to a cratering global demand in consumer goods. Satellite maps show the improvement from month to month in Eastern China (Fig. 3.6).

They also show year-to-year improvements between 2019 and 2020 Wuhan Province NO₂ levels. Pollution levels usually drop during the Chinese Lunar New

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**Fig. 3.5** Visible evidence of suspended particulates and poor air quality in Eastern China. According to the photographer, both photos were taken in the “same location in Beijing in August 2005. The photograph on the left was taken after it had rained for 2 days. The right photograph shows smog covering Beijing in what would otherwise be a sunny day.” (Photo credit Bobak Ha’Eri licensed under the Creative Commons Attribution-Share Alike 2.5 Generic License)
Year Celebrations and then rise again in February when factories start production up again. In 2020 the levels did not rebound (Fig. 3.7).

### 3.4.2 Atmospheric Ozone

The atmosphere wraps the earth, and its currents are in constant motion, protecting all life from the vacuum of space and from multiple forms of radiation. It dampens the extreme temperature fluctuations between day and night. Temperatures on our own airless moon can swing more than 500 degrees Fahrenheit from a freezing night of minus 250 degrees to a boiling 250 degrees plus during the day.

The different layers of our atmosphere provide different kinds of utility and protection to the biosphere. Winds blow in three-dimensional currents reaching 10 miles above the earth’s surface. Most weather activity occurs within the lower two-thirds of that region called the troposphere. Above that height is the next layer of the atmosphere called the stratosphere where the thin dry air is relatively still but stratospheric clouds occasionally form. For the next 10 or so miles up, oxygen gas molecules (O₂) are hit by ultraviolet radiation, breaking the bonds between the two

![Fig. 3.6](image-url) NASA and European Space Agency (ESA) pollution monitoring satellites have detected significant decreases in nitrogen dioxide (NO₂) over China due to COVID-19 shutdown. (Photo credit: NASA)

3.4 China
atoms forming the oxygen molecule. The single freed atoms (O) then combine with unbroken O₂ molecules creating ozone (O₃) that make up the ozone layer. Ozone is unstable and rare. In every ten million air molecules, only an average of three are ozone molecules. Ninety percent of all ozone is found between 10 and 30 miles (16 and 50 km) above the earth’s surface. This stratospheric ozone serves as a shield to the sun’s high-frequency ultraviolet rays (Butler 2017). This ionizing radiation, when allowed to pass through the upper atmosphere unabated, can disrupt normal cellular functions causing skin cancer and other health problems in humans and many other organisms (NIEHS 2016).

### 3.4.3 Rational Global Policy and Action

In the 1970s and 1980s, reports of a growing hole in the ozone layer over the South Pole, and the crisis it represented, galvanized unanimous global action to ban the use of certain chemicals called chlorofluorocarbons that were used as refrigerants; as propellants in hairspray, deodorants, and other personal-care aerosol products; and as industrial blowing agents for foams and packing materials. In 1979,
predictions showed the ozone hole rapidly growing to 20 times its size, from 1.1 million square kilometers to 22.4 million square kilometers, by 1987. International governments listened to the science and took clear and definitive international action. To limit increased expansion of the ozone hole, they signed a binding agreement to limit the amount of ozone-depleting gasses each country could emit. Because of the relatively quick agreement and response by industry and government leaders with strong public support, the hole that was steadily growing 30 years ago has stopped expanding and is now expected to heal itself through the production of natural stratospheric ozone within the next 50 years. By 2000 the mean area of ozone hole was nearly 25 million square kilometers and by 2019 to 9.3 million square kilometers (Fig. 3.8) (NASA 2019).

If the arc of the ozone depletion crisis had followed the current trend in the larger climate debate, the rate of skin cancer and cataracts in humans would likely be much higher, as would reproductive abnormalities in numerous smaller animals and organisms. Living organisms from the largest to the smallest would have experienced harm. For instance, phytoplankton numbers would have dropped as an increased amount of harmful ultraviolet radiation penetrated into ocean waters. These simple single-cell organisms absorb as much as half of the CO₂ produced through burning fossil fuels and are a foundational component of the ocean food chain. As stratospheric ozone goes, so goes their and, eventually, our ability to live healthy lives. If the debate had continued past the 1987 Montreal Protocol signing, we might still be waiting for more evidence that an actual problem exists, considering what solutions would be best, or verifying that implementing the agreed upon solutions would not cause any negative economic effects. We would have been paralyzed by process and deliberation while being bathed in more dangerous UV waves with each passing day.

**Fig. 3.8** The latest false-color view of total ozone over the Antarctic Pole compared to those over the previous views taken approximately 10 years apart shows a stabilizing of the ozone hole expansion. The purple and blue colors are lower ozone concentrations, and the yellows and reds show higher ozone concentrations. (Individual images courtesy of NASA, 2020)
The ozone depletion crisis seems to have peaked in the late twentieth century, but conditions require constant monitoring as new technologies are introduced to the market. The fact that the amount of protective ozone over Antarctica has measurably stabilized since just before the start of the millennium proves that our species has the ability to change climate destiny. We have not yet found the catalyzing argument to mobilize the world’s decision-makers to effectively address the long-term CO₂ environmental crisis.

3.5 Water

The water we drink and cook and clean with is over 4.5 billion years old, older than our sun. It is not easy to destroy water. It takes a lot of energy to split one molecule of water into its constituent building blocks, that is, one oxygen atom bonded to two separate hydrogen atoms. Water endures through the three-phase changes we are all most familiar with and use each day—ice, liquid, and vapor. Nearly three-quarters of the earth’s surface is covered with water, almost all of it salty. Over half of the typical human body is made up of water. Our dependency on clean fresh water to sustain life is clear. Without it, we would cease to exist.

In recent years, we have gained a deeper appreciation for just how much we depend on water to sustain our daily lives as we have failed to properly manage this vital resource. People live in places where water is growing scarcer year-by-year due to drought on the one hand and chemical contamination and biological waste pollution on the other. Moreover, we have used our waterways and oceans as a "convenient" place to discard things we no longer want.

3.5.1 Solid Waste Disposal into the Water

For much of the twentieth century, giant barges heaped with garbage were sent out to sea. They returned empty, ready to be filled again. While this practice is no longer routine in the United States and many other parts of the world, the flow of waste into the ocean has continued at an alarming rate. In addition, gravity and the flow of storm water through our streams and rivers, and to a greater degree through giant pipes and spillways, carry some refuse to our shores and out to sea. Even municipal storm and wastewater treatment systems, built to catch pieces of solid waste before they reach the ends of pipelines that lead directly to the ocean, miss a material percentage of what gets washed into and out of them.

Although we continue to build improved systems of collecting, treating, and filtering the waste we make, in the absence of funding for new infrastructure projects, we still must use leaky pipes built decades or even a century ago. As our systems age and the global population increases, our best planned and executed systems strain to keep pace. The bottom line is that we generate a greater total amount of waste than
ever before, and we have not been able to keep all of it from ending up in our streams, rivers, lakes, and oceans.

As a result, giant islands the size of Texas, discovered at the end of the twentieth century but accumulating long before, have formed in the Pacific Ocean. Wind and ocean currents allow these floating islands of garbage not only to persist but to continue to grow. As the churning flotsam breaks down over time, pieces of plastic, at various stages of weathering and disintegration, form three-dimensional columns of waste that extend down below the surface of the Pacific. There, fish and other marine life mistake the smaller particles for plankton and ingest them. Likewise, on the surface, hungry seabirds mistake colorful pieces of plastic for food for themselves and their young. Artist and film producer Chris Jordan’s documentary, Albatross, focuses on a new generation of birds as they hatch and grow on Midway Island. He carefully traces the tragic distribution pathway of plastic flotsam that parents spend weeks at sea unwittingly gathering to feed their chicks (Fig. 3.9).

An estimated 225 million tons of plastic produced each year is contributing to the accumulating waste in both terrestrial and aquatic habitats worldwide. While the horrific effects of macroplastic debris on wildlife are well documented, the potential impacts of microplastic (<1 mm) debris which may account for 80% of all plastic stranded in the environment may have even longer lasting effects on the biosphere. Ingested microplastics can release toxic monomers that have shown to release toxic nonomers linked to cancer and reproductive abnormalities in humans, rodents, and invertebrates (Browne et al. 2007). As large a problem as plastic solid waste poses, it is only one of the many ongoing pollution crises affecting all life on earth.
3.5.2 Chemical Waste Runoff

Not limited to plastic bottles, bags, and wrappers that eventually float out to sea, our daily output includes other manufactured substances that contribute to dying waterways and oceans. The harm done by visible waste is easier to understand and react to than that caused less tangible flows. Our agriculture system is based on a foundation of chemical fertilizers that contaminate our waterways. The massive quantities of synthetic fertilizers used to replenish the nitrogen, potassium, and phosphates that crops draw from the soil and metabolize in order to grow are fossil fuel dependent. They require high-pressure, high-temperature, high-energy processes to produce and are used in greater amounts each year (Smil 2004). The monoculture cash crops of wheat, corn, soy, cotton, and softwood lumber all require massive quantities of fertilizer (and pesticides) annually to guarantee the harvest. Without steady chemical treatment of depleted soils, we cannot grow plants to feed and clothe and house ourselves. Some are spread as solid granules or sprayed as a liquid. In either form, they are applied to the surface of commercial cropland by the ton using trucks or planes. The soil, however, does not absorb these completely, nor do the crops use all of it. Strictly speaking, this fossil fuel-based way of feeding the plants that sustain us is inherently inefficient.

Excess synthetic fertilizer that is not taken up by the plants does not stay in place to be used the following growing season; it travels. Along with waterborne pollution from poorly managed sewerage and septic systems, some of it gets carried away when it rains either flowing downhill or, if the land is porous enough, through the hill. Flowing water, along with what it carries, also mixes and mingles downstream with more water. As rain carries leftover nitrogen, phosphorous, potassium, and other nutrients downhill, they can accumulate in the underground aquifers and contaminate wells from which we cook, clean, and drink. What excess that does not get pulled straight down into our groundwater in lower soil strata ends up as surface runoff in streams and rivers and eventually flows out into the bays, marshes, and other coastal waters.

3.5.2.1 The Effect of Nutrient Contamination in Water

The chemical elements that plants require to grow impact the well-being of other species as well. These elements are normally not found in abundance in waters where fish and other aquatic creatures live. When chemical nutrients, intended for surface plants, are introduced into these habitats, the effects are pronounced. Algae, unintentionally nourished by the excess nitrogen, potassium, and phosphorous in agricultural effluent, multiply in abundance. While alive, they can create a thick blanket on the surface that blocks sunlight that oxygen-producing underwater plants need to live. When the algae die, bacteria eat the remains. These bacteria reduce oxygen levels and produce carbon dioxide to a point where most aquatic animal life suffocates (NOAA 2020). Additionally, anaerobic bacteria that produce toxins can
flourish in this oxygen-depleted environment. Death spreads as the algae bloom (Fig. 3.10). This is called “eutrophication.”

The global hydrospheric garbage can accepts whatever we intentionally or unintentionally attempt to throw away. Our waters, as vast and abundant as they are, are limited in what they can receive without negative consequences. Agricultural, industrial, and even domestic waste runoff ends up downstream in a poisonous soup incapable of supporting the range of life forms that naturally evolved under, atop, and beside the water’s surface. We degrade our waters, normally teeming with life, through unchecked polluting. We impact an untold number of species, including our own, with steady streams of purposeful or accidental pollution.

3.6 Disordered and Harmful Out-of-Place Elements

There is nothing inherently bad or good outside a context. In terms of human survival and development, a thing becomes “waste” when it is not in a place that benefits humans. Any chemical, element, or compound, either naturally or synthetically derived, can be either good or bad depending on its context.

When a chemical element is a part of the soil, for instance, where a plant root can reach it, it acts as a necessary input for growing a plant that a human being will eventually use either as food or to make something out of. When an excess amount of the same single element escapes into a waterway, it can cause harm, perhaps destroying food sources like fish or rendering the water unfit for human consumption or even contact.

The plastic that ends up swirling around in the great Pacific garbage gyre served a purpose for someone at one time. Perhaps it was a plastic bottle filled with clean drinking water somebody needed for 10 minutes but then discarded. It was useful as
a container until there was no water left in it. As soon as the person drinking from it was no longer thirsty, it became unnecessary. At that moment, it instantly became waste. The same is true for all food packaging as well as airborne and waterborne microplastic fibers used in clothing, cosmetics, and many other mass-produced consumer products (Cox et al. 2019).

Contrary to the perceptions of the average consumer, who casually discards it, the plastic bottle didn’t disappear. It continued on long after it was empty. The same durability that held the water in without disintegrating keeps this synthetic compound from returning to its constituent parts, chemical elements available for use by other living beings without harming them. The plastic container might be buffeted by sun, wind, waves, and sand for years. It might get broken into smaller and smaller pieces of plastic that spread out for miles but remains, although fragmented and disbursed, essentially the same. Fish and birds that eat these plastic pieces are not fed by them. And these pieces and particles as well as other smaller foreign elements now exist where they were never found before. Living systems cannot integrate them; they can only do harm in inappropriate contexts.

### 3.6.1 Feedback Loops Affecting Solids, Liquids, and Gasses

Broadly dividing the earth’s ecosphere into its discreet solid-lithospheric, liquid-hydrospheric, and gas-atmospheric components helps to conceptualize and measure the toll human activity takes on each of them. In every complex closed system, however, dynamic effects in one part of the system affect and influence those in other parts. As we produce and consume, the negative effects our waste creates in any one of the three “garbage cans” are constantly overflowing their boundaries into one or both of the other two.

Interacting positive feedback loops between the three have changed nature’s self-regulating processes. The net effect of our actions, impacting the world’s solids, liquids, and gasses that sustain all life, is what some label “anthropogenic” or human-caused climate change. Solid waste and liquid compound chemicals, which are not successfully sequestered, flow incessantly from our shores to pollute the oceans. They change the water’s chemistry, kill aquatic life, and are adding a new stratum of human processed trash to the ocean floor. Some components of gaseous waste carried in the atmosphere, responsible for long-term climate change, migrate back into both solid ground and moving waters, causing other faster-acting problems through acidification.

Over months and years, the atmosphere mixes with the oceans. As moisture is continuously carried up through evaporation and returned by way of rainstorms on both land and sea, clouds become more acidic as they take up increased carbon dioxide, sulfur dioxide, and nitrogen oxides released from burning coal, oil, and natural gasses. The same substances that directly affect human health in the form of ground-level smog travel high into the atmosphere to mix with water and oxygen and other elements that eventually fall back to earth in the form of acid rain.

Rain mixes with soil and freshwater on land and salt water in the ocean increasing acidity over time. As soils become more acidic, their capacity to support plant
growth diminishes. Harmful metals, stable in more alkaline soils, dissolve and are free to be taken up by plants as the pH levels in soil drop. As aluminum, mercury, and other heavy metals are released, trees weaken and forests suffer.

Oceans also act as one of the most effective sponges or “sinks” for airborne carbon dioxide. As oceans become more acidic, it makes it more difficult for marine organisms to form shells and skeletons that are primarily made of calcium, because calcium is dissolved by acids. These vulnerable species, which evolved in less acidic oceans, are now beginning to show severe signs of stress as alkaline habitats become less and less available. At some point, if the trends continue at the same rate, the acidity of the oceans will reach a point where calcium cannot coalesce to form shells or skeletons, and calcifying species, such as corals, clams, mussels, sea urchins, and others, will go extinct.

3.7 Conclusion

It is easy to think we can do something about the waste problems we face, that technological solutions are readily available, but effective tactics used to solve one problem may exacerbate another. Global climate summits set international targets for the net reduction of greenhouse gas emissions. Commitments are made. Some are kept and some are not. Some come with other side effects. In fact, one solution to reduce the use of common ozone-depleting chlorofluorocarbons increased the production and use of hydrofluorocarbons, which are powerful greenhouse gases. Transitional technology strategies like these are stabilizing half-measures that often simply shift negative ecological impacts while we search for better, more encompassing solutions. Calcifying marine phytoplankton (Fig. 3.11), having dodged the UV bullet as

![Fig. 3.11](image-url) The most diverse genus of phytoplankton is the diatoms, with an estimated 200,000 different species. Photo of diatom algae with spherical plant pollen. (Photo from Berezovska 2016, used under Creative Commons Attribution-Share Alike 4.0 International)
stratospheric ozone levels increase, may not be able to avoid the threat posed by a drop in the oceanic pH level.

When a species disappears, other living things are either directly or indirectly affected by its disappearance. Imagine that single species as a home to several different smaller organisms; as a predator or maybe a predator of a predator to another animal; or as prey for another that can no longer survive without it and whose own disappearance is felt higher up the food chain.

Whether collapse happens quickly or slowly by our standards, the end is the same, and it impacts the entire system. We cannot know the full effect of any given species as it interacts in pronounced and subtle ways in the food chain over time. We do know that a reduction of biodiversity makes the overall food system much less resilient. We do know that once a species is gone, it is gone forever. In the case of tiny phytoplankton, they form the foundation of the entire aquatic food web, and they process as much atmospheric carbon through photosynthesis as all the earth’s forests, jungles, and other land vegetation (Armbrust 2009). Even those who do not eat seafood must still breathe air.

We are changing the biosphere’s equilibrium. Our actions impact the fundamental conditions supporting all life on earth. The physical and biological systems, which have been continuously developing over millennia and on which we have become so dependent for our own survival, are changing in complex, subtle, and deep ways; we cannot foresee all the outcomes.

As we extract and transform natural materials, we inevitably increase what goes to the three garbage cans. Because materials flow, the things we throw away eventually intermingle with the natural environment. Elements, compounds, and the products we make out of them flow through the air and through the water, and over time, they penetrate and even form parts of the solid earth beneath us. The more materials we take in and use to support the consumptive habits we have developed and passed down through generations, the more we give back as waste.

As the global populations rise, the rate at which we have been distributing our increasing waste into the “three garbage cans” also rise. The sheer volume of it is producing chemical and physical changes in the environment registering at a scale that no other single species can match. The magnitude of changes that coincide with the inflection point in “hockey stick” graphs defines a distinct period in geologic time—the last 200 years—the Anthropocene, in which human activity has influenced climate and environment.

The record of our global production and consumption activities that define the Anthropocene is being meticulously captured by the earth’s gravity. Each of the trillions of particles, thrown up into the air or flowing into the water, eventually settles on the earth’s surface. There is no way of erasing the physical evidence of our lives and actions. Deposits of artificial compounds and increased carbon, radioactive isotopes, and plastic waste will be sequestered for eons in a thin layer of the earth’s crust to be read as distinct from the rest of the Holocene interglacial period.

While we are alive, taking in and giving back, it is impossible to do nothing. Even without ascribing moral labels of “good” or “bad,” our actions have consequences. When we all tacitly agree to do nothing to reduce the amount of these
compounds that enter our air and our waters, we now do it with the full knowledge that the effects are not neutral nor are they simple.

The next chapters will present methods to first understand what we can measure and track and offer approaches to act, to make informed decisions.

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