

P L A N E T  I N C R I S I S

TRANSFORMING PLASTIC



FROM POLLUTION TO EVOLUTION



Albert Bates

Library of Congress Cataloging-in-Publication Data

Names: Bates, Albert K., 1947- author.

Title: Transforming plastic : from pollution to evolution / Albert Bates.

Description: Summertown, Tennessee : GroundSwell Books, [2019] | Series: Planet in crisis | Includes bibliographical references.

Identifiers: LCCN 2019007472 | ISBN 9781570673719 (pbk.)

Subjects: LCSH: Plastic scrap—Environmental aspects. | Plastics—Recycling. | Plastics—Technological innovations.

Classification: LCC TD798 .B37 2019 | DDC 363.738—dc23

LC record available at <https://lcn.loc.gov/2019007472>



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Printed in the United States of America

GroundSwell Books
an imprint of Book Publishing Company
PO Box 99
Summertown, TN 38483
888-260-8458
bookpubco.com

ISBN: 978-1-57067-371-9

24 23 22 21 20 19 1 2 3 4 5 6 7 8 9

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Arithmetic

If a path to the better there be, it begins with a full look at the worst.

THOMAS HARDY

The late University of Colorado mathematics professor Albert Bartlett is said to have given his famous lecture on the exponential function more than one thousand times. I show the YouTube video of that lecture at the start of my permaculture courses, and I suspect many other instructors do the same. The audience continues to grow each year since Bartlett passed. In his one-hour talk, the professor says:

Legend has it that the game of chess was invented by a mathematician who worked for a king. The king was very pleased. He said, “I want to reward you.” The mathematician said, “My needs are modest. Please take my new chessboard and on the first square, place one grain of wheat. On the next square, double the one to make two. On the next square, double the two to make four. Just keep doubling till you’ve doubled for every square; that will be an adequate payment.” We can guess the king thought, “This foolish man. I was ready to give him a real reward; all he asked for was just a few grains of wheat.”

But let’s see what is involved in this. We know there are eight grains on the fourth square. I can get this number, eight, by multiplying three twos together. It’s $2 \times 2 \times 2$; it’s one two less than the number of the square. Now that continues in each case. So on the last square, I’d find the number of grains by multiplying sixty-three twos together.



Now let's look at the way the totals build up. When we add one grain on the first square, the total on the board is one. We add two grains, that makes a total of three. We put on four grains, now the total is seven. Seven is a grain less than eight, it's a grain less than three twos multiplied together. Fifteen is a grain less than four twos multiplied together. That continues in each case, so when we're done, the total number of grains will be one grain less than the number I get multiplying sixty-four twos together. My question is, how much wheat is that?

You know, would that be a nice pile here in the room? Would it fill the building? Would it cover the county to a depth of two meters? How much wheat are we talking about?

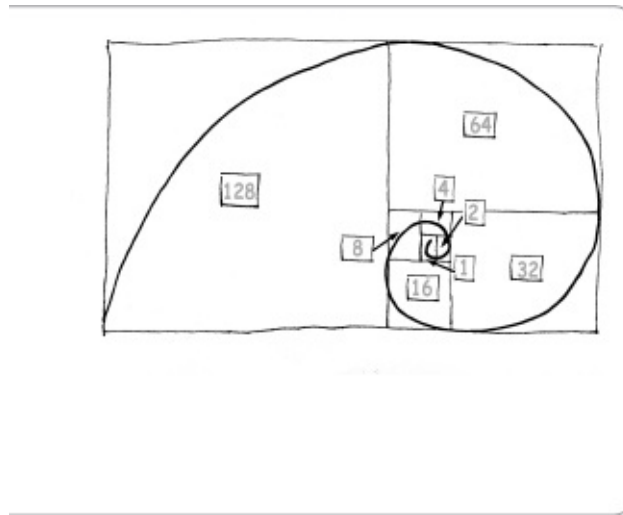
The answer is, it's roughly four hundred times the 1990 worldwide harvest of wheat. That could be more wheat than humans have harvested in the entire history of the earth. You say, "How did you get such a big number?" and the answer is, it was simple. We just started with one grain, but we let the number grow steadily until it had doubled a mere sixty-three times.

"The greatest failing for the human race," Bartlett was fond of telling his students, "is its failure to understand the exponential function."

Now there's something else that's very important: the growth in any doubling time is greater than the total of all the preceding growth. For example, when I put eight grains on the fourth square, the eight is larger than the total of seven that were already there. I put thirty-two grains on the sixth square. The thirty-two is larger than the total of thirty-one that

were already there. Every time the growing quantity doubles, it takes more than all you'd used in all the proceeding growth.

At another point in the lecture, Bartlett gives the example of bacteria filling a bottle. The doubling rate is every minute, so Bartlett poses this challenge to his students:



In exponential growth, each doubling provides more than all the previous doublings combined. In just seven doublings, 1 becomes 128.

If you were an average bacterium in that bottle, at what time would you first realize you were running out of space? Well, let's just look at the last minutes in the bottle. At 12:00 noon, it's full; one minute before, it's half full; two minutes before, it's a quarter full; then an eighth; then a sixteenth. Let me ask you, at five minutes before 12:00, when the bottle is only 3 percent full and is 97 percent open space just yearning for development, how many of you would realize there's a problem?

This brings us to plastics, which are now in their fourth doubling since 1968. By any fourth doubling, the curve's trajectory is still at the bottom of the J and only beginning to bend upward. By 2030, the slope up will be much more obvious, just as it is for climate change.

Today the equivalent of five grocery bags of plastic trash piles up behind every foot of coastline on the planet, washed in from the ocean. A few years from now, that will be ten bags per foot. Huge garbage patches have formed in our oceans, created by the drift of trash from rivers into ocean currents. If we

had one Great Pacific Garbage Patch twice the size of Texas in 2015, before 2030 we would have one that's four times the size of Texas and eight times the size of Texas by midcentury. If the present Garbage Patch kills one hundred thousand marine birds yearly, by midcentury it may be killing eight times that many. And that particular patch accounts for only five ten-thousandths (0.0005) of marine-mammal mortality from all plastics globally.

If each human baby born now has detectable microplastics in its blood, in ten or twenty years (depending on the doubling rate), that child's child will have twice that much, and with each generation it will double and then double again as we go through this century.

Isn't it time we asked why we design a material to last forever and then put that into objects intended to be discarded after a single use?

An honest assessment of why we, the clever bipeds, make such gargantuan faux pas in design would conclude it is because we seldom reason together. Usually we reason separately or in small groups. We run in packs. So more often than not, we consign decisions of this type to the pack that has the skills or inclination—in this case, chemical or manufacturing companies. But we need to acknowledge that these companies are in business to make a profit and make decisions that favor them most. While we can't say sustainability doesn't factor in at all, we know that *economic* sustainability over the course of one or more business cycles is what gets primary consideration. Environmental and social costs may only matter if those threaten profits.

The chemists working in well-financed research labs are only doing what they are told, which is to design something with the following attributes:

- cheap (without reference to social, environmental, disposal, or cleanup costs);
- durable (even indestructible by natural decay processes);
- lightweight (even buoyant), strong, and compact.

These design parameters apply equally to bio-based plastics, now growing at 40 percent per year (with a doubling time of fourteen months), thanks to green consumer demand. Of course, bioplastics are still plastics: still cheap, durable, and lightweight, and often just as much of an environmental problem. They may even consume as much fossil fuel to produce. Priced at a premium over their fossil-based cousins, they assuage guilt while building the bottom line.

Confronted by the next-gen market challenge to go ever greener, producers

have come up with replacements for the worst plastics: the heavy-metal-based additives and coatings, halogenated flame retardants, carcinogenic styrenic petrochemicals (the ones found in polystyrene foam), endocrine-disrupting phthalate plasticizing additives, and ozone-depleting foaming agents. They have not found a substitute for the chlorine in PVC, even with corn- or cane-derived bio-PVC. There is just something about vinyl that's ... better.

A request to company executives and chemists: please stop digging us into a deeper hole. To place the burden entirely on consumers, as most "solutions" do, is unfair. In the next few years, we need new products designed to degrade under natural conditions. At a minimum, packaging materials (the largest stream of plastics) should break down into harmless components in saltwater. For products that need to function in marine environments, we might even consider replacing them with whatever was used *before* plastics.

Recycling is mostly an illusion when it comes to plastic. In the United States, plastics are recovered at lower rates from municipal solid waste than all other major material types, and for a good reason. Even when uncontaminated, separating by type and form is as hard for recycling facilities as it is for consumers. Moreover, there are technical limits on the amount of recycled resin that can be used in a given product, most resins can be reused only once, in some cases the cost of recycled plastic may be higher than virgin plastic, and the range of products where recycled content is acceptable is limited.

Since the first plastic polymers were introduced, about six billion tons of plastics have been made and spread around the planet, nearly one ton for every person now living. Even if we decide to change our plastic-using ways, the damage has already been done. Whether we like it or not, our landfills will be excavated by future archaeologists, and our Plastic Age will take its place after the Bronze Age and the Iron Age in the history of human civilization.

On Hawai'i's Kamilo Beach, a new mineral called plastiglomerate has been discovered. It has yet to be found elsewhere, but it is "natural" at least in the sense that it formed the same way many other volcanic rocks of Hawai'i have. It is the aggregate of melted plastic trash mixing with sediment, basaltic lava fragments, seashells, and organic debris. There are two types: clastic and in situ. Clastic plastiglomerate has been incorporated into rocks by heat. In situ plastiglomerate is glued together by pressure. While both kinds are found on Kamilo Beach, neither was caused by lava flows, although that could be happening elsewhere. The Kamilo plastiglomerates are produced by plastics being burned in campfires or by the plastic residues in the black beach sand

being baked by the sun's rays.

Plastics are a problem for our culture, whether you believe in market forces, controlled economies, or social democracy as your favored regulatory mechanism. We need something to change, and we need it to happen quickly. The important consideration now is not whether the Plastic Age can be prevented—it's too late for that—but whether it can be shortened and made friendlier, and what kind of age will follow.

CHAPTER 2

Addiction

I sometimes think that there is a malign force loose in the universe that is the social equivalent of cancer, and it's plastic. It infiltrates everything. It's a metastasis. It gets into every single pore of productive life.

NORMAN MAILER, *HARVARD MAGAZINE*, 1983

I am addicted to plastic. How can I freak out about dolphins drowning in plastic nets or seagulls eating lighters and condoms off the beach, when I give no second thought to picking up a plastic comb in an airport shop, even if I decline the plastic bag?

The word “plastic” comes from the Greek verb *plassein*, which means “to mold or shape.” Its flexibility derives from long, bouncy chains of carbon, oxygen, and hydrogen atoms arrayed in repeating patterns that behave like a snake's skin.

Snakeskin is a good example because biology has been knitting these molecular daisy chains for hundreds of millions of years. The cellulose that makes up the cell walls in reptiles is a polymer. Before there were plastic Wellies and galoshes, there were snakeskin boots.

“Polymer” is Greek for “many parts”; any polymer is a long chain of nearly identical molecules. The proteins that code the stems and flowers of daisies and also code our muscles, skin, and bones and the long spiraling ladders of DNA that entwine the genetic destinies of daisies and bones are all polymers. Take some of these protein chains, rearrange them slightly, and their choreography or dancers will dictate specific characteristics, just as different dance arrangements do.

Bring chlorine into that molecular conga line, and you can get polyvinyl

chloride, otherwise known as vinyl; tag on fluorine, and you can wind up with that slick nonstick material Teflon.

SUSAN FREINKEL, AUTHOR OF *PLASTIC: A TOXIC LOVE STORY*

Take just a moment and let's walk back a step. The dancing line of carbon, oxygen, nitrogen, and hydrogen was no more than air and water, rearranged. But now we throw in chlorine and fluorine and what happens? Permanence. That substance has withdrawn from the contract with nature whereby all things must return full cycle, each with its own sunset clause.

For most of history, combs were made of almost any material humans had at hand, including bone, tortoiseshell, ivory, rubber, iron, tin, gold, silver, lead, reeds, wood, glass, porcelain, paper-mâché. But in the late nineteenth century, that panoply of possibilities began to fall away with the arrival of a totally new kind of material—celluloid, the first man-made plastic. Combs were among the first and most popular objects made of celluloid. And having crossed that material Rubicon, comb makers never went back. Ever since, combs generally have been made of one kind of plastic or another.

SUSAN FREINKEL

The first artificial plastics—celluloid combs developed in 1869 by a young inventor in upstate New York—arrived at a moment of cultural transition. The turn of the twentieth century marked the birth of the consumer culture, the global switch from growing and preparing our own food and making our own clothing (excluding the aristocracy) to consuming mass market simulacra from factories. As historian Jeffrey Meikle pointed out in *American Plastic*: “By replacing materials that were hard to find or expensive to process, celluloid democratized a host of goods for an expanding consumption-oriented middle class.” Or as Susan Freinkel put it, plastics “offered a means for Americans to buy their way into new stations in life.”

They also offered a way for bacteria to shirk *their* stations in life.

Unintended Consequences

Celluloid combs and cellophane tape were gateway drugs. In 1907, Leo Baekeland combined cancerous formaldehyde with phenol derived from foul-smelling and nasty coal tar, and voila! His Bakelite was a tough, slick polymer that could be precisely molded and machined into nearly anything.

Families gathered around Bakelite radios to listen to programs sponsored by the Bakelite Corporation, drove Bakelite-accessorized cars, kept in touch with Bakelite phones, washed clothes in machines with Bakelite blades, pressed out wrinkles with Bakelite-encased irons—and, of course, styled their hair with Bakelite combs.



Bakelite inspired companies such as DuPont, Dow, Standard Oil, Union Carbide, and 3M to get into the race. Discoveries followed, and mass production of plastic products commenced. But Bakelite introduced something new to nature that was largely unappreciated at the time. Once those molecules were linked into a daisy chain, they couldn't be unlinked. Microbes don't care to spend the energy required to break those tough bonds if they can find food more obliging elsewhere.

“From the time that a man brushes his teeth in the morning with a Bakelite-handled brush until the moment when he removes his last cigarette from a Bakelite holder, extinguishes it in a Bakelite ashtray, and falls back upon a Bakelite bed, all that he touches, sees, uses will be made of this material of a thousand purposes,” *Time* magazine enthused in 1924 in an issue that sported Baekeland on the cover.

You can break a piece of Bakelite, but you can't make it into something else. It does not degrade. It never goes away. This is why you'll still find vintage Bakelite phones, frames, radios, and combs that look nearly brand new, and why today plastic debris is piling up on land and in the open ocean, in the entrails of dead whales on shorelines, and in living crustaceans on the deepest seabed of the Marianas Trench.

In nature nothing is permanent. Everything is food for someone else. Composers and decomposers coevolved in an endless dance—a harmony and rhythm that defines life. There is birth, and there is death. But we could not accept that.

In the last half century, there have been many drastic changes to the surface of our planet, but one of the most astonishing is the ubiquity and abundance of plastic. Even if we go extinct, that plastic will persist. We have only slowly moved from thinking of this as an aesthetic problem—litter and flotsam—to grokking that the choking wildlife we are seeing is actually a threat to *us*. Dead reefs and red tides are sending warnings: destroy the marine food chain and you'll choke your own.

When consumers first considered the permanence of plastic, we thought it was a good thing. Bakelite replaced rhino horn, elephant tusk, and tortoiseshell but was even better—cheaper, tougher, wildlife-hunter safe. Remember: All of those flesh and bone things break down over time and need to be replaced. We were running out of rhinos, elephants, and tortoises.

In 1955, *Life* magazine ran the headline “Throwaway Living” below a photograph showing a family flinging plates, cups, and cutlery into the air. The items would take forty hours to clean, *Life* said, “except that no housewife need bother.” What *Life* failed to mention is that all those “disposable” items would still be around forty years later, and four hundred, and four million.

usually within minutes of purchase. Consider the 1,200 billion plastic bottles Coca-Cola produces each year or the plastic wrappers on your “garden-fresh” produce. What about Huggies, toothbrushes, or birth control packets?

The Last Straw

If I can trace my addiction to its roots, it may have started in the 1950s with the Flav-R-Straw. Flav-R-Straws were a bendy straw with hundreds of tiny flavor pellets in the bellows that could turn plain milk into chocolate or strawberry.

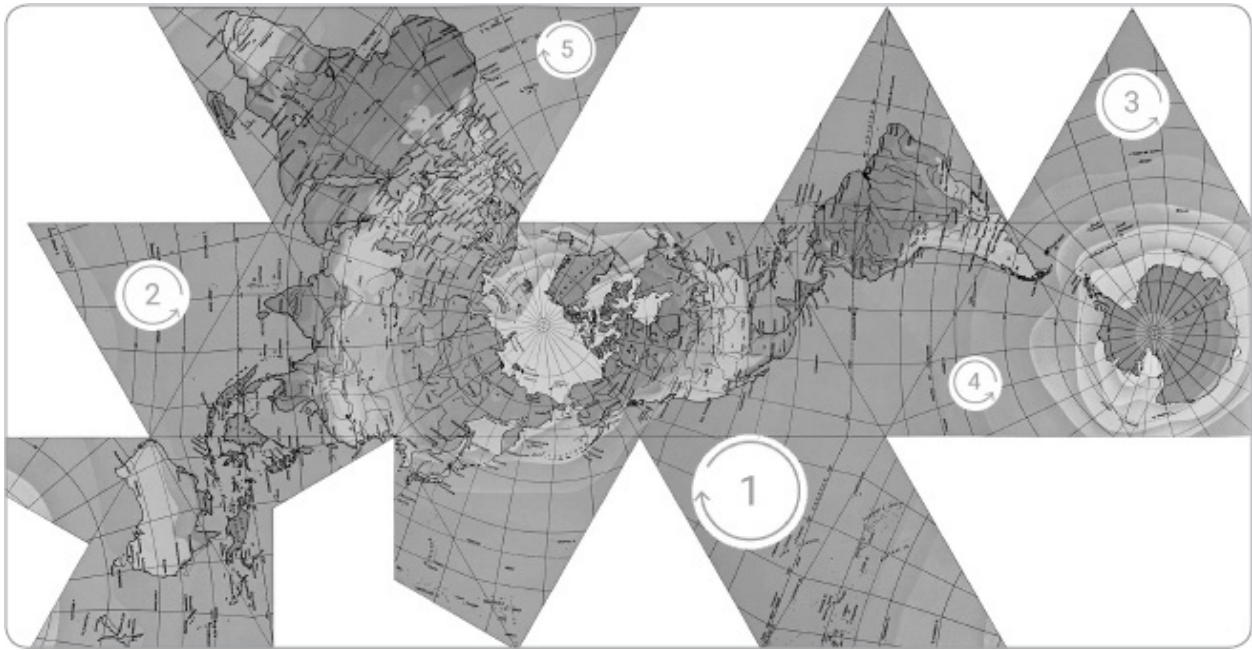
Flav-R-Straws were withdrawn in 1961 but not plastic straws. 500,000,000. Five with eight zeros. That is how many plastic straws go into drink cups. Not every year—every day. And that’s just in the United States.

I can remember my delight as a child when a friend showed me how to take off the end of the paper wrapper and blow the wrapper at some unsuspecting target across the room. That was half the fun of straws when you were a kid. The other half was making noises and bubbles at the bottom of the cup.



The oldest straw still intact and in a museum was discovered in a Sumerian tomb dated 3,000 BCE—a gold tube inlaid with the precious blue stone lapis lazuli. It wasn’t until the late nineteenth-century era of extravagant world

expositions that people started making paper straws wrapped in wax to keep them from dissolving in gin or bourbon. After World War II, we started to see plastic. I am old enough to remember early paper straws that had a narrow bore similar to the grass stems used for millennia. It was common to use two of them to reduce the effort needed to take each sip. Modern plastic straws are made with a larger bore so only one is needed for ease of drinking, but when they hand you your 64-ounce Biggie through the drive-up window, chances are it's got two, purely out of habit.



Ocean garbage patches

And it's single-use plastic.

You can complain and they will take back the straws, but when you aren't looking, those are going straight into the trash, which goes straight into a dumpster (in a plastic bag), which goes maybe to separation and maybe not, and then to either a landfill or to some watercourse that leads to the ocean and thence the gullet of seabirds or the digestive organs of fish, turtles, dolphins, and whales. Robot subs have found plastic in the stomachs of creatures thirty-six thousand feet down.

Eighty-eight to 95 percent of the plastic polluting the world's oceans pours in from just ten rivers—eight in Asia and two in Africa. These rivers account for about five trillion pounds of plastic garbage floating in the seas. It kills an estimated two hundred million marine mammals annually.

Besides the North Atlantic and North Pacific patches already discovered, there are now three spots located in the South Pacific, South Atlantic, and Indian Oceans that are subject to the same phenomenon. Actually, those are just natural concentration points. Plastic waste can be found *everywhere* in the oceans—from beaches where people go on holidays to remote uninhabited islands. Plastics have been fragmenting and accumulating in the oceans for more than fifty years, and a full recovery may never be possible.

In 2018, I had the good fortune to meet Jackie Nunez, founder of The Last Plastic Straw. She said when plastic was first applied to paper straws, straws became a gateway drug because they were so easy and ubiquitous. But that is also what makes straws a gateway solution, or “sipping point.”

Nunez said, “I had my Last Plastic Straw moment in 2011 after receiving a glass of water with a plastic straw at a local beachside bar in Santa Cruz, California. I didn’t ask for a straw. I had just arrived into town after traveling the Caribbean. While there, everywhere I went I saw plastic pollution. On the beaches, in the water, on land. Plastic pollution was everywhere; there was no getting away from it. There is no ‘away.’”

After unloading on her waiter, she decided to be more strategic and start The Last Plastic Straw. “Basically what we are asking you to do is DO LESS ... less consumption, less waste, less straws. It’s a win-win!” she says. She made an invitation to bars and restaurants to be part of her movement to eliminate plastic pollution from the source. By simply stating “Straws available upon request” on menus, bars and restaurants can become part of the solution.

Thanks to Nunez, restaurants, bars, and cities from London to Miami are banning plastic straws voluntarily. When you return yours to your server, you should politely instruct them to

- provide a straw only when requested by a customer;
- provide either compostable or reusable straws; or
- get rid of straws completely.

On April 19, 2018, ahead of Earth Day, a proposal to phase out single-use plastics was announced during the meeting of the Commonwealth Heads of Government, a biennial summit of the heads of government from all Commonwealth nations. This includes plastic drinking straws and cups. It is estimated that as of 2018, about twenty-three million straws are used and discarded daily in the UK alone. Add to that India, Australia, Canada, and the

other forty-nine members of the Commonwealth and you have a big source of plastic pollution, but one that they are now resolved to do something about. And the alternatives are literally grassroots.

A few months before that announcement, Queen Elizabeth II banned plastic straws and other one-use plastic items from her palaces. Canada had already been planning on banning straws nationwide after 70 percent of voters polled endorsed a plastic straw ban.

Some thirteen thousand schools, workplaces, and event venues will be free of plastic bags and stirrers by 2019, thanks to a new push by food service company Sodexo, following similar steps by food service giants Aramark and Bon Appétit. In addition to bags and stirrers, Sodexo plans to phase out Styrofoam containers by 2025. The move, says a representative from the company, will eliminate 245 million single-use items that would have otherwise been used at its locations.

How hard would it be, after all, to go back to paper or to reeds such as hemp and papyrus? That is the subject of studies underway by straw makers as the pressure of single-use plastics bans forces their largest customers to scramble.

In 2018, *Business Insider South Africa* tested five alternatives to plastic straws: stainless steel, etched copper, glass, bamboo, and Khanyiso reed. All are reusable, and two are both biodegradable and renewable. Prices for each straw ranged between fifteen and ninety-five times its plastic counterpart. Metal straws, both copper and, to a lesser extent, stainless steel, had serious problems with heat because they heated or cooled to the temperature of the drink, which made them harder to handle or sip from. The bamboo straw left a bad taste, and the reed straw was nearly as bad. With the reed, everything hot tasted woody quickly, and anything cold tasted woody eventually. Bamboo left a foul green aftertaste and ruined the flavor of coffee. Glass had none of these problems and had the added advantage of being see-through. But glass could not be carried around safely. *Business Insider* concluded, “So this glass straw is a clear winner with one important caveat: it requires a sturdy carry case. Most likely something made of rigid plastic, rather than the hemp sleeve its makers provide.”

We will look more into the emerging alternatives to plastics in later chapters, but this example of fiber straws illustrates an important part of the problem. Replacement with natural products is not always a viable solution. The experience may be less satisfying or less fit for purpose than provided by the plastic product. The question then becomes one of making choices less for utilitarian reasons than for ethical or ecological ones. Because the price was

more than likely set with some long-dead economic theorist's thumb on the scale, or because a consumer who receives a take-out container for no extra charge feels no economical obligation to preserve it, the choice to go toward biodegradable bioplastic will most likely be made for reasons of conscience.

SOME QUICK FACTS ABOUT PLASTIC POLLUTION

Annual polymer production has grown from fifteen million tons in the 1960s to over four hundred million tons now and is expected to triple that number by 2050.

The quantity of plastic in the ocean is expected to nearly double to 250 million metric tons by 2025.

Ninety-nine percent of all plastic is produced from fossil fuels. While greenhouse gas emissions from plastics themselves are not significant, production of fossil fuels—especially from drilling, refining, and transporting “unconventional” discoveries as the “conventional” sources are depleted—has a very large impact on climate.

Estimates of how much global fossil fuel use goes to plastics range from 4–10 percent per year.

The ocean will contain one ton of plastic for every three tons of fish by 2025, and by 2050 more plastic than fish, by weight.

Economic damage to commercial fishing caused by plastic amounts to at least \$13 billion every year, roughly one-third of the economic damage caused to all sectors.

Five countries—China, the Philippines, Indonesia, Vietnam, Thailand—together account for 55–60 percent of the total plastic waste going into the environment. The cost of ocean plastics to the tourism, fishing, and shipping industries is \$1.3 billion in the Asia-Pacific region alone.

The amount of municipal waste produced on average by each European citizen is projected to increase from 520 kilograms in 2004 to 680 kilograms by 2020, an increase of 25 percent.

Today, 95 percent of plastic packaging material value—\$80 billion to \$120 billion annually—is lost to the economy after a short first use.

The recycling rate for plastics, in general, is even lower than for plastic packaging, and both are far below the global recycling rates for paper (58 percent) and iron and steel (70–90 percent).

Health Surprises

Recent technological advances permit new formulations at microscopic or atomic scales. The plastics industry is a leader in nanotechnology innovation. It is estimated that by 2020 the share of nanocomposites among plastics in the United States will be 7 percent, including materials that are reinforced with nanofillers (nanoclay and nanosilica) for weight reduction, nanocarbon for improved mechanical strength, and nanosilver as an antimicrobial agent in food packaging and medical products.

Like the consequences of the large-scale plastics experiment begun in the previous century, the consequences of nanoplastics are similarly left to be discovered and to being externalized. A team of Japanese researchers found some 40 percent of ocean fish caught for food had microplastics in their digestive systems. It is estimated from computer models that the oceans now contain some fifty-one trillion microplastic particles and another ten million tons of macroplastics enter the sea annually, to be slowly broken into smaller and smaller pieces by the effects of salt, sunlight, and agitation.

In 2004, Richard Thompson of the University of Plymouth, UK, analyzed the micro-debris on the beaches and waters in Europe, the Americas, Australia, Africa, and Antarctica. Thompson and his associates found that plastic pellets from both domestic and industrial sources were being broken down into pieces having a diameter smaller than a human hair. Thompson said there might be three hundred thousand plastic items per square kilometer of sea surface and one hundred thousand plastic particles per square kilometer of the seabed.

Another study collected samples of polyethylene pellets from thirty beaches in seventeen countries and analyzed them for micro-pollutants. Pellets from beaches in America, Vietnam, and southern Africa contained compounds from pesticides that had migrated into the polymeric chain. Other pellets contained cancer-causing and ecosystem-disruptive DDT and PCBs.

Ten years ago, Holger Koch of the German government's occupational safety office and Antonia Calafat of the US National Institutes of Health began looking at hospital monitoring data that was then becoming available from Germany and the United States. They saw a chemical called bisphenol A (BPA) and phthalates, two common ingredients of many polymers, appearing in urine samples for all parts of those two populations. They concluded that daily phthalate intakes might be substantially higher than previously assumed and even close to or

exceeding thresholds previously observed for toxic effects in laboratory animals. “The toxicological significance [for] susceptible subpopulations (e.g., children, pregnant women) ... remains unclear and warrants further investigation,” they wrote in 2009.

Both Koch and Calafat continued to pursue those investigations. With her name appearing on more than twenty articles in the peer-reviewed literature in 2018 alone, Antonia Calafat has done everything she can to raise the alarm. Her studies now show that microplastics in the blood of pregnant women cross the placental barrier and directly result in embryonic developmental disorders, gestational diabetes, decreased birth weight, allergic asthma, and other respiratory problems in newborns. Worse, microplastics can be transmitted through mother’s milk, meaning that infants who may already be adversely impacted receive an even higher dose at a most critical period in their development.



A century of plastic design improvements now let us keep our foods fresher for longer periods, provide us timed-release pharmaceuticals and non-degrading biomedical implants, and can prevent electronics and other household items from starting or spreading fires. But for each of these benefits, there are counterweighing human health risks related to exposure. We now know that some of the same chemicals used in plastics to provide beneficial qualities also act as endocrine-disrupting compounds (EDCs) that lead to problems in human and other populations.

In men, environmental or occupational exposures to EDCs can lead to declined reproductive capacity or possibly increased risk of testicular or prostate cancer. In women, exposure may give an increased risk for endometriosis,

reproductive and other endocrine-related cancers, or impaired oocyte competence, ovarian function, or menstrual cycling. Effects of early life exposures may lead to altered sex differentiation, effects on neurological and reproductive development, and increased risk of reproductive problems or cancer later in life. Testicular dysgenesis syndrome can afflict males in utero or in infancy, later showing up as disturbed gonadal development, including cryptorchidism, hypospadias, and smaller reproductive organs, as a reduction in semen quality and infertility, and as an increased risk for testicular cancer.

PHTHALATES

The diesters of 1,2-benzenedicarboxylic acid (phthalic acid), commonly known as phthalates, are a group of man-made chemicals widely used in industrial applications. High-molecular-weight phthalates are used as plasticizers in flexible vinyl, which in turn is used in consumer products such as credit cards, flooring and wall coverings, food containers, medical implants, and window frames. Low-molecular-weight phthalates are in personal-care products (cosmetics, lotions, and perfumes) and in coatings, lacquers, solvents, and varnishes. They are also used to provide timed releases in some oral and subdermal pharmaceuticals.

As a result of all these consumer products, human exposure to phthalates is widespread. Skin contact is enough. For those identifying as men, it might come from cologne or aftershave. For those identifying as women, it might be from skin lotion or lipstick. For infants and children, mouthing fingers after handling plastic toys or food packaging can lead to higher phthalate exposures. So can breast milk, infant formula, and cow's milk, according to studies. Opting for almond, coconut, or rice milk won't save your child if that cardboard carton has a plastic liner or cap.

In newborns, the amount of phthalates in umbilical cord blood directly correlates to a risk of premature birth. Among girls, phthalate concentration correlates with premature breast development and early-onset puberty. Other developmental effects: allergies, rhinitis, asthmatic reactions, and direct toxicity. In one case-control study from Sweden, phthalate concentrations in indoor dust for 198 children ages three to eight showed a strong association with allergic asthma and eczema in a dose-dependent manner. Another study in Bulgarian children produced similar results, where increased plastic in house dust proportionally related to wheezing and rhinitis. A study of preterm infants who

were provided polyvinyl chloride (PVC) respiratory tubing showed higher rates of hyaline membrane disease, proportional to the phthalate exposure.

Significant associations have also been reported between urinary phthalate concentrations and increased insulin resistance and waist circumference. These findings provide preliminary evidence of a potential contributing role for phthalates in insulin resistance, obesity, and related clinical conditions.

BISPHENOLA

BPA is in the epoxy resins used to line food cans, older plastic baby bottles, some dental sealants and fillings, adhesives, protective coatings, flame retardants, water storage tanks, and supply pipes. It starts as part of a polymer, but with normal heat over time, it degrades into its small-chain monomeric form. In that form, BPA can leach from its source into adjacent materials, such as water (in the case of bottles, pipes, or tanks) or food products (such as from the lining of a box, can, or pouch). There is widespread BPA lingering in body fluids, bones, and organs of people. It can be found in over 90 percent of the US population, where 96 percent of pregnant women test positive for BPA in their urine. It is now in US women's follicular fluid, amniotic fluid, umbilical cord blood, and breast milk.

BPA's hormone-changing properties were known as early as 1936, and evidence for other biological activity, such as effects on thyroid function, soon followed. In one epidemiological study, serum BPA levels were reported to be associated with recurrent miscarriage. Investigators also reported higher rates of polycystic ovary syndrome. Multiple studies have associated BPA exposure with weight gain and linked it to cancer, diabetes, heart disease, genital malformations, insulin resistance, neurological disorders, thyroid dysfunction, and more. However, most studies to date have only addressed single chemicals or classes of chemicals, and there are limited data on the interactions between chemicals within a class or across classes. Chemicals may interact additively, multiplicatively, or antagonistically in what is commonly referred to as the "cocktail effect."

The health effects of ingested plastics are not just limited to phthalates and BPA. We know of ill effects from esters of aromatic mono-, di-, and tricarboxylic acids, aromatic diacids, and di-, tri-, or polyalcohols, and many other additives and composite materials. The exploration of these medical effects is still in its infancy, and few governments have shown any willingness to disturb

the marketplace until it is more clear which does what to whom.

In the meantime, it is nearly impossible to take a prescription medication or even use an over-the-counter vitamin without encountering time-release coatings on capsules, plastic lids on plastic pill bottles, microbead plastic desiccant pouches, and even a (synthetic) cellophane wrap for tamper-proofing. You can tell the checkout clerk at the grocery store you won't need a plastic bag because you brought your reusable cloth bag, but you may find it difficult to avoid having skin contact with the plastic handle on the shopping cart or basket, the laminate on the checkout counter, the credit card in your wallet, or the shock-resistant cover on the mobile phone that you might use for digital payment. You will likely be unable to do anything to prevent yourself from inhaling the microplastics in the hairspray the clerk used that morning, absorbing some of the microplastic-contaminated tap water you use to rinse and prepare your fresh vegetables, or eating the microplastic particles absorbed into the food as it was grown.

As addictions go, this one is a real brute.



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