HIGH TECH TRASH

Digital Devices, Hidden Toxics, and Human Health

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For Emily, Jane, Olivia, and Phil, and for my parents

Preface

In August 2004 I stood on the tussocky tundra banks of Imnaviat Creek looking out toward the Brooks Range on the North Slope of Alaska and watched a biologist set up his laptop—an hour's walk from the nearest electrical outlet—and measure the depth of the permafrost. Last spring I called my parents in New York on a crystal clear wireless connection from a small town in Lappland. There are now computers in the Himalayas, the Andes, and the Amazon, and cell phone use is booming in rural Africa. The virtues of remaining unplugged aside, there is hardly a place left on earth to which someone has not brought a computer or mobile phone, and even those who write all their letters longhand now have lives that depend on digital technology.

High-tech electronics have become virtually ubiquitous and have transformed the world in ways that benefit us all. But for most of the forty or more years since commercial semiconductor and computer manufacture began, we have paid relatively little attention to the environmental and health impacts of producing and disposing of the microchip-powered gadgets that enable the Digital Age.

High-tech electronics are the most complex mass-produced consumer products ever manufactured—a complexity that presents special challenges when it comes to dealing with this equipment at the end of its useful life. And because the production of high-tech electronics involves many toxic and hazardous materials—and takes place on a global scale—their environmental impacts are now being felt by communities from the Arctic to Australia, with poorer countries and communities receiving a disproportionate share of the burden. If not addressed comprehensively and with solutions that show we have learned from past mistakes, these problems risk undermining the ecological and economic sustainability of affected communities worldwide, whether in Silicon Valley, the American Rust Belt, or southern China.

High technology has given us lightning-speed computation, instant messaging, and libraries without books, yet in creating the equipment that makes all this possible we have also unleashed tons of chemicals into the environment with impacts far more pernicious than an e-mail in-box full of spam. How we choose to make high-tech products and how we take out the high-tech trash will affect the quality of life for everyone from California to Africa, from Greenland to Malaysia, for decades to come. Computers and cell phones can be replaced, but watersheds and human beings cannot have their hard drives wiped and operating systems reinstalled if something goes wrong.

After learning how high-tech manufacturing was compromising the quality of the water in the Willamette River, which flows two minutes' walk from my front door, I set out to explore what other effects Information Age technology might be having on human health and the environment—and what is being done to solve these problems and improve on past practices in ways that will ensure a safer, cleaner, and healthier future.

To place high-tech electronics in an ecological context—and to explore their physical connection to the natural world—I wanted to see what goes into making machines like the computer on which I am writing and what happens to them when they are discarded. While researching this book, I have worn a lot of borrowed hard hats and safety glasses and have gone through

several sets of disposable earplugs. I have toured Superfund sites, descended to the bottom of a mine, visited with people whose homes are contaminated with toxic vapor, peered through the glass into clean rooms of an enormous semiconductor plant, watched old electronics be mined for gold, and have seen literally tons of discarded and dismantled computer equipment.

I have spoken to dozens of scientists who are trying to discover how chemicals embedded in and used to make the appliances that sit on our desks have wound up in people and in the food we eat—and what this means for our health and that of our children. I have spoken to people who make silicon wafers, semiconductors, computers, and all sorts of other high-tech devices. I have interviewed elected officials, experts in solid waste, engineers, and a former prison inmate. I have also taken notes at hours and hours of presentations by high-tech industry professionals, electronics recyclers, scientists, policy makers, and environmental advocates—all of too many different nationalities to name—who are working to understand and solve the problems posed by high-tech trash. While these problems are far more complex than I imagined, there are solutions on the horizon to at least some of them, and—thanks to the dedicated work of environmental advocates along with industrial engineers, manufacturers and legislators—some changes in how high-tech electronics are designed, produced, and disposed of are already under way.

In the months since *High Tech Trash* first went to press, concern over the problems posed by electronic waste has continued to grow. More U.S. states have introduced and passed legislation regulating disposal of high tech equipment – including Washington State's landmark producer-responsibility bill. Manufacturers continue to expand their take-back and recycling programs. European legislation requiring electronics recycling and restricting certain hazardous substances from electronics are now in effect. These are rays of hope. But effective U.S. federal policy on these issues is still lacking, as is legislation in many states and in other countries around the world. As use of computers, cell phones, and other digital devices continues to burgeon on a global scale, coping with the hazards their production and disposal pose is more urgent than ever.

There are many people to whom thanks are due for their help in making this book possible. For support from the John D. and Catherine T. MacArthur Foundation, I am deeply grateful and honored. For his faith in this project, his dedication, buoyant enthusiasm, and acumen, enormous thanks and admiration to Jonathan Cobb at Island Press.

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HIGH TECH TRASH

Contents

CHAPTER ONE

The Underside of High Tech

The rapidity of change and the speed with which new situations are created follow the impetuous and heedless pace of man rather than the deliberate pace of nature.[1]
—Rachel Carson, *Silent Spring,* 1962

If future generations are to remember us with gratitude rather than with sorrow, we must achieve more than just the miracles of technology. We must leave them a glimpse of the world as God really made it, not just as it looked after we got through with it.[2]
—President Lyndon B. Johnson, 1965

A harbor seal arches her back and dives, a graceful comma of brown on the steel blue water of San Francisco Bay. A school of herring darts through the saltwater off the coast of Holland. A polar bear settles down to sleep in a den carved out of Arctic ice. A whale cruises the depths of the North Sea and a chinook salmon noses her way into the Columbia River on her way home to spawn. In the Gulf of Mexico, a bottlenose dolphin leaps above the waves. A seagoing tern lays an egg. A mother in Sweden nurses her baby, as does a mother in Oakland, California. Tissue samples taken from these animals and from these women's breasts contain synthetic chemicals used to make the plastics used in

computers, televisions, cell phones, and other electronics resist fire. Americans have the highest levels of these compounds in their blood of any people yet tested, and the same chemicals have been found in food purchased in grocery stores throughout the United States.

On the shores of the Lianjiang River in southern China, a woman squats in front of an open flame. In the pan she holds over the fire is a smoky stew of plastic and metal—a melting circuit board. With unprotected hands she plucks out the microchips. Another woman wields a hammer and cracks the glass of an old computer monitor to remove the copper yoke. The lead-laden glass screen is tossed onto a riverside pile. Nearby, a man sluices a pan of acid over a pile of computer chips, releasing a puff of toxic steam. When the vapor clears a small fleck of gold will emerge. Up and down the riverbanks are enormous hillocks of plastic and metal, the discarded remains of electronic appliances—monitors, keyboards, wires, printers, cartridges, fax machines, motors, disks, and cell phones—that have all been exported here for inexpensive, labor-intensive recycling. A bare-legged child stands on one of the mounds, eating an apple. At night, thick black smoke rises from a mountain of burning wires. In the southern Chinese city of Guiyu—one of the places in Asia where this primitive recycling takes place—an estimated 80 percent of the city's 150,000 residents are engaged in processing the million or more tons of electronic waste that have been arriving there each year since the mid-1990s.[3]

Mines that stretch for miles across the Arizona desert, that tunnel deep under the boreal forests of northern Sweden, and others on nearly every continent produce ore and metals that end up in electronic gadgets on desktops, in pockets, purses, and briefcases, and pressed close to ears all around the world. In a region of the Democratic Republic of the Congo wracked by horrific civil war, farmers have left their land to work in lucrative but dangerous, landslide-prone coltan mines. Sales of this ore, which is used in the manufacture of cell phones and other devices, have helped finance that war as well as the fighting between Uganda and Rwanda in this mineral-rich region of Africa. Although they are mostly hidden, metals make up over half the material in the world's 660 to 700 million computers. A typical desktop computer can contain nearly thirty pounds of

metal, and metals are used in all electronics that contain semiconductors and circuit boards (which are themselves 30 to 50 percent metal)—from big plasma screen TVs to tiny cell phones. Extracted and refined at great cost, about 90 percent of the metal that goes into electronics eventually ends up in landfills, incinerators, or some other kind of dump.

Traffic on the highway that runs between San Francisco and San Jose is bumper to bumper. Haze rises from the vehicle-clogged road. Office plazas, strip malls, and housing developments stretch out against the backdrop of hills that frame the valley. Pooled beneath the communities of Santa Clara, Cupertino, and Mountain View, California—to name but a few—are thousands of gallons of poisonous volatile organic compounds left by the manufacture of semiconductors. California's Silicon Valley now has more toxic waste sites subject to cleanup requirements under the federal government's Superfund program than any other region of comparable size in the United States. In parts of Mountain View, the U.S. Environmental Protection Agency (EPA) has found in groundwater levels of trichloroethylene (TCE)—a solvent used in semiconductor production that the EPA recognizes as a carcinogen—that may be sixty-five times more toxic than previously thought.[4] Official estimates say it will take decades, if not a century or more, to complete the cleanup. Families in Endicott and other communities in Broome and Dutchess counties in upstate New York are grappling with the same problem, living above a groundwater plume contaminated for over twenty years with TCE and other solvents used in microchip manufacture.

In the high desert country of New Mexico, the ochre and mustard colored cliffs of the Sandia Mountains rise above the Rio Grande valley. Globe mallow and prickly pear sprout from the sandy soil. This is the third most arid state in the nation, and the past decade has been marked by drought. Yet one of the handful of semiconductor manufacturers located near Albuquerque has been using about four million gallons of water a day—over thirty times the water an average American household uses annually[5]—while sending large quantities of toxics into the local waste stream. Similar scenarios have emerged in other parts of the country where semiconductor manufacture has taken place—among them, the Texas hill

country around Austin, the Boston area landscape that gave rise to the American Revolution, and the suburban sprawl that surrounds Phoenix. Residents of Endicott, New York, and Rio Rancho, New Mexico, have asked the Agency for Toxic Substance and Disease Registry (part of the U.S. Department of Health and Human Services) to assess the health impacts of hazardous air pollutants—including trichloroethylene, methanol, ethylene chloride, and several perfluorocarbons—emitted by high-tech manufacturers located in their communities.

Semiconductors come off the assembly line in numbers that dwarf other manufactured products, but because microchips are so tiny, we're less inclined to think about their environmental footprint. One of Intel's Pentium 4 chips is smaller than a pinky fingernail and the circuit lines on the company's new Itanium 2 chips are smaller than a virus—too small to reflect a beam of light.[6] Producing something of this complexity involves many steps, each of which uses numerous chemicals and other materials and a great deal of energy. Research undertaken by scientists at United Nations University and the National Science Foundation found that at least sixteen hundred grams of fossil fuel and chemicals are needed to produce one two-gram microchip. Further, the secondary material used to produce such a chip amounts to 630 times the mass of the final product, a proportion far larger than for traditional low-tech items.[7] In 2004 some 433 billion semiconductors were produced worldwide.[8]

The Information Age. Cyberspace. The images are clean and lean. They offer a vision of business streamlined by smart machines and high-speed telecommunications and suggest that the proliferation of e-commerce and dot-coms will make the belching smokestacks, filthy effluent, and slag heaps of the Industrial Revolution relics of the past. With this in mind communities everywhere have welcomed high technology under the banner of "clean industry," and as an alternative to traditional manufacturing and traditional exploitation of natural resources. But the high-tech industry is far from clean.

Sitting at my desk in Portland, Oregon, the tap of a few keys on my laptop sends a message to Hong Kong, retrieves articles filed in Brussels, shows me pictures of my nieces in New York, and plays the song of a wood stork recorded in Florida. Traveling with my laptop and cell phone, I have access to a whole world of information and personal communication—a world that exists with increasingly little regard to geography, as electricity grids, phone towers, and wireless networks proliferate. This universe of instant information, conversation, and entertainment is so powerful and absorbing—and its currency so physically ephemeral—that it's hard to remember that the technology that makes it possible has anything to do with the natural world.

But this digital wizardry relies on a complex array of materials: metals, elements, plastics, and chemical compounds. Each tidy piece of equipment has a story that begins in mines, refineries, factories, rivers, and aquifers and ends on pallets, in dumpsters, and in landfills all around the world.

Over the past two decades or more, rapid technological advances have doubled the computing capacity of semiconductor chips almost every eighteen months, bringing us faster computers, smaller cell phones, more efficient machinery and appliances, and an increasing demand for new products. Yet this rushing stream of amazing electronics leaves in its wake environmental degradation and a large volume of hazardous waste—waste created in the collection of the raw materials that go into these products, by the manufacturing process, and by the disposal of these products at the end of their remarkably short lives.

Thanks to our appetite for gadgets, convenience, and innovation—and the current system of world commerce that makes them relatively affordable—Americans, who number about 290 million, own over two billion pieces of high-tech consumer electronics: computers, cell phones, televisions, printers, fax machines, microwaves, personal data devices, and entertainment systems among them.[9] Americans own over 200 million computers, well over 200 million televisions, and over 150 million cell phones.[10] With some five to seven million tons of this stuff becoming obsolete each year,[11] high-tech electronics are now the fastest growing part of the

municipal waste stream, both in the United States and in Europe.[12] In Europe, where discarded electronics create about six million tons of solid waste each year, the volume of e-waste—as this trash has come to be called—is growing three times faster than the rest of the European Union's municipal solid waste combined.[13]

Domestic e-waste (as opposed to e-waste imported for processing and recycling) is accumulating rapidly virtually everywhere in the world that PCs and cell phones are used, especially in populous countries with active high-tech industries like China—which discards about four million PCs a year[14]—and India. The United Nations Environment Programme estimates that the world generates some twenty to fifty million metric tons of e-waste each year.[15]

The *Wall Street Journal*, not known for making rash statements about environmental protection, has called e-waste "the world's fastest growing and potentially most dangerous waste problem."[16] Yet for the most part we have been so bedazzled by high tech, adopted its products with such alacrity, been so busy thriving on its success and figuring out how to use the new PC, PDA, TV, DVD player, or cell phone, that until recently we haven't given this waste—or the environmental impacts of manufacturing such products—much thought.

Compared to waste from other manufactured products, particularly the kind we are used to recycling (cans, bottles, paper), high-tech electronics—essentially any appliance containing semiconductors and circuit boards—are a particularly complex kind of trash. Soda cans, bottles, and newspapers are made of one or few materials. High-tech electronics contain dozens of materials—all tightly packed—many of which are harmful to the environment and human health when discarded improperly. For the most part these substances do not pose health hazards while the equipment is intact. But when electronics are physically damaged, dismantled, or improperly disposed of, their toxics emerge.

The cathode ray tubes (CRTs) in computer and television monitors contain lead—which is poisonous to the nervous system—as do circuit boards. Mercury—like lead—a neurotoxin, is used in flat-panel display screens. Some batteries and circuit boards contain cadmium, known to