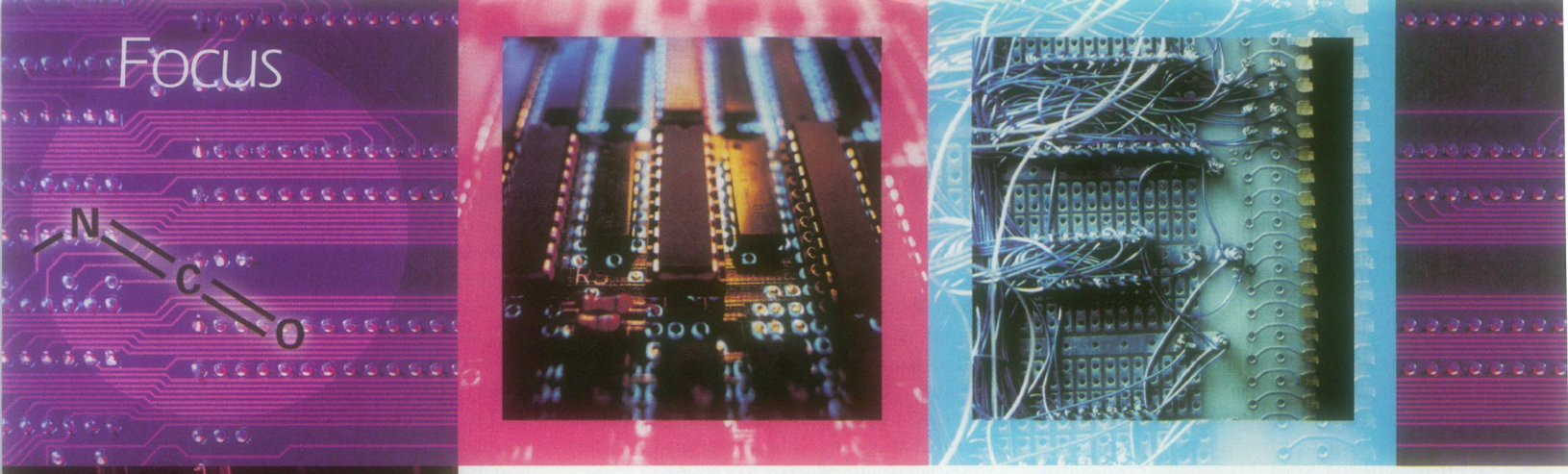
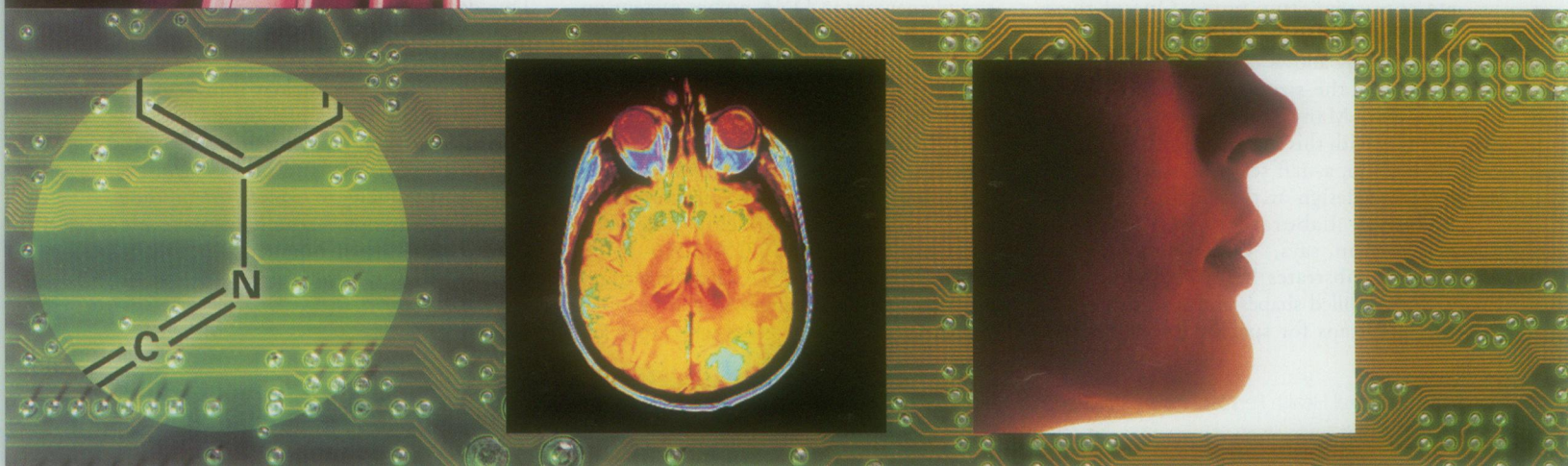


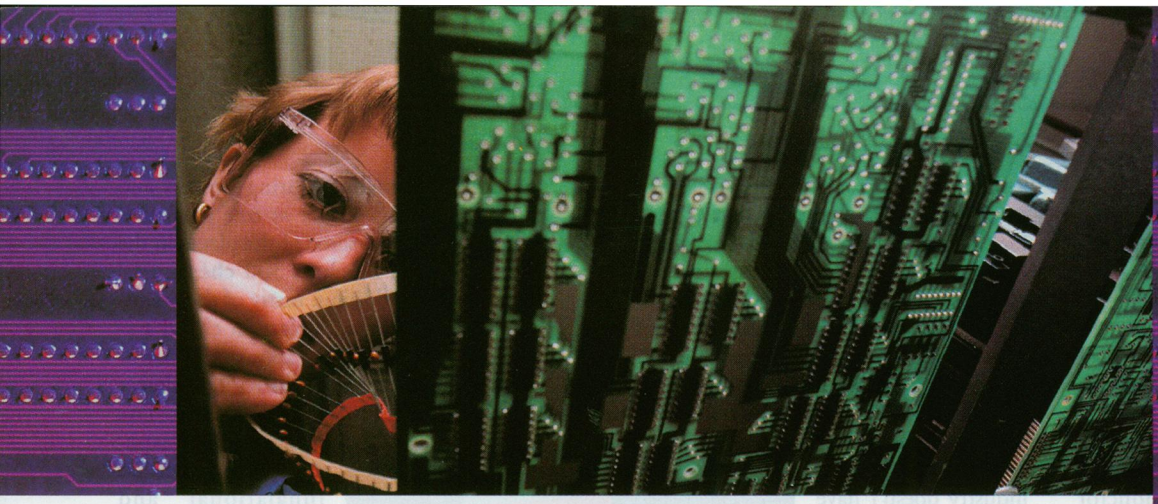
Where the Chips Fall:

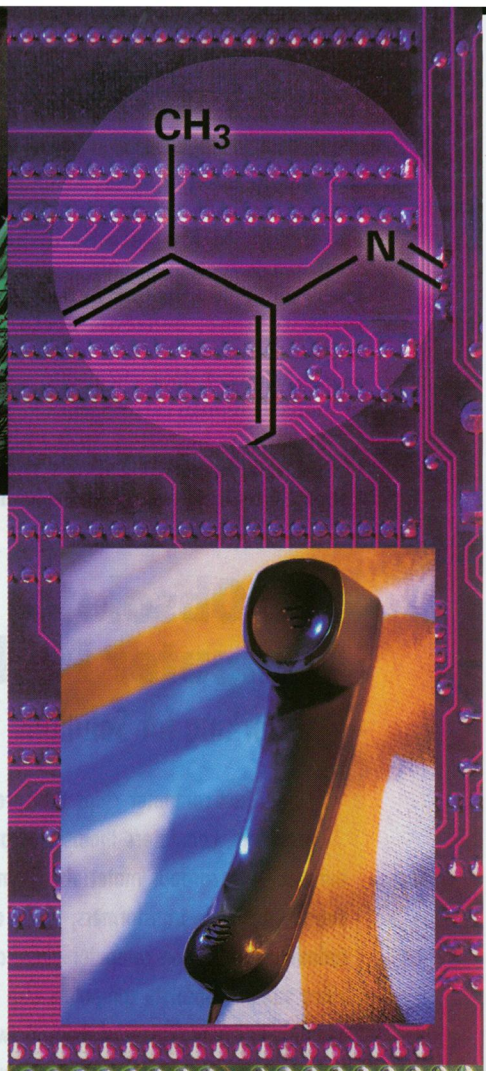
In 1996, 128 former IBM workers and their families, including those of 11 workers who have died of cancer, filed suit against the chemical manufacturers Eastman Kodak Company, Union Carbide Corporation, J. T. Baker, and KTI Chemicals, claiming they had suffered adverse health effects, including cancers and miscarriages, as a result of exposure to hazardous chemicals on the job. Although worker's compensation laws in New York State prevent the former employees from suing IBM directly, their children can sue, and 16 of them have filed a lawsuit against the company, claiming birth defects from *in utero* exposure to these same chemicals.

The New York case is one of three current major environmental health lawsuits involving the semiconductor industry, also known as the computer chip industry. In San Jose, California, another group of former IBM employees (who developed cancer) and their families have filed suit against the company and its chemical suppliers, alleging that workers at the local IBM plant were exposed to unhealthy doses of cancer-causing chemicals over three decades. Meanwhile, 70 women in Scotland are suing another U.S. company, the Santa Clara, California–based National Semiconductor Corporation, claiming they too were exposed to cancer-causing chemicals.

The lawsuits are bringing high-profile attention to the environmental and occupational effects of what is now the world's largest and fastest growing manufacturing sector. The $150 billion semiconductor industry began quietly in Santa Clara County's Silicon Valley a little



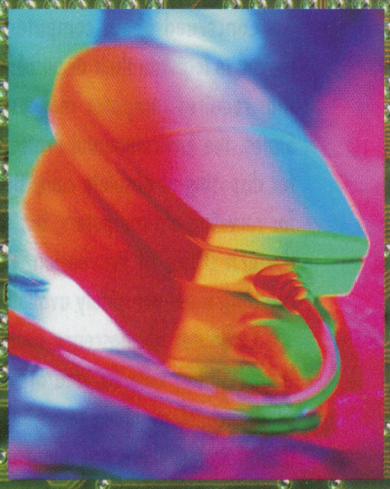




Environmental Health in the Semiconductor Industry

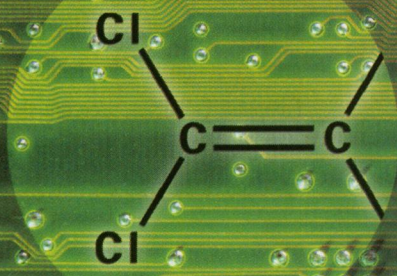
more than a quarter century ago but has since experienced phenomenal growth. Today, more than 900 computer chip plants can be found in Arizona, Massachusetts, Virginia, Texas, New Mexico, Oregon, and Idaho, as well as in countries throughout Asia, Europe, Latin America, and the Caribbean.

Because of its size and growth, the computer chip industry has been described as the "pivotal driver of the world economy." According to the January 1998 issue of *Semiconductor International*, at least 127 new semiconductor fabrication plants were then in various stages of planning and construction worldwide, with the total expenditure expected to exceed $115 billion. "I think it's accurate to say that the world is seeing the largest industrial expansion in history," says Dan Herr, research director of the Semiconductor Research Association in Research Triangle Park, North Carolina.



Toxic Jobs?

This prodigious economic growth comes with a hefty environmental price tag, however. The semiconductor industry uses large amounts of toxic chemicals to manufacture the components that make up a computer, including disk drives, circuit boards, video display equipment, and silicon chips themselves, the basic building blocks of computer devices. The toxic materials needed

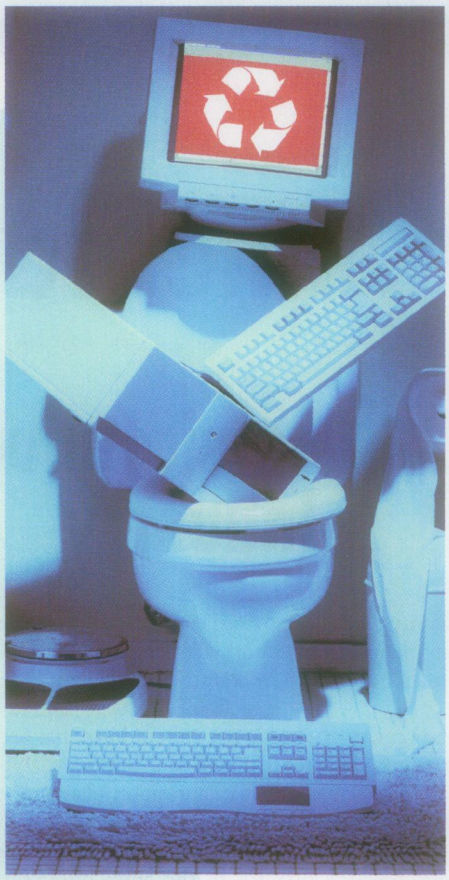


to make the 220 billion silicon chips manufactured annually are staggering in amount and include highly corrosive hydrochloric acid; metals such as arsenic, cadmium, and lead; volatile solvents such as methyl chloroform, toluene, benzene, acetone, and trichloroethylene; and toxic gases such as arsine. Many of these chemicals are known or probable human carcinogens.

Statistics published in April 1999 by the U.S. Department of Labor's Bureau of Labor Statistics show that semiconductor workers have a rate of occupational illnesses resulting in lost workdays that is twice as high as that of workers in other manufacturing sectors. Bruce Fowler, director of toxicology at the University of Maryland in College Park, has been studying some of the toxic chemicals used in chip manufacturing. Fowler believes the health problems linked to such chemicals may be the result of exposures to mixtures of chemicals. "The industry doesn't have one definitive manufacturing process and you can't point a finger at one particular compound because some of the plants in the industry use as much as 300 chemicals," Fowler says. In addition, many of the manufacturing processes take place in closed systems, which means that exposures to harmful substances are often difficult to detect unless monitored on a daily basis. The major routes of exposure of concern are inhalational and dermal exposures. Although workers wear protective clothing from head to toe, researchers are concerned that recycling the air in so-called "clean rooms" (where microchips are made) exposes workers to toxic chemicals.

Lee Neal, a public relations director of safety, health, and environmental affairs with the San Jose–based Semiconductor Industry Association, says it's false to assume that workers are automatically exposed to the chemicals used in the semiconductor industry. "The electronics industry employs state-of-the-art process equipment and chemical transfer systems that limit or prevent physical exposure to chemicals," he says. "Besides, many of the chemicals found in our industry are used in other industries, and we aren't seeing major health and safety problems in their environments."

Still, a study of 15 semiconductor manufacturers published in the December 1995 issue of the *American Journal of Independent Medicine* showed that women working in silicon wafer manufacturing rooms who handled chemicals including glycol ethers suffered a 14% miscarriage rate, compared to women in the industry who did not work in fabrication areas, who suffered a rate of 10%. The study was conducted by researchers at the University of California at Davis and was cosponsored by the semiconductor industry. According to Neal, these findings were the primary basis for removal of glycol ethers from the workplace by the semiconductor industry.



The Obsolete Computer Problem

Working for Solutions

It's not just computer chips that present environmentally related health problems. Computers themselves are manufactured with and include a number of hazardous materials. Of major concern are platinum in circuit boards, copper in transformers, nickel and cobalt in disk drives, barium and cadmium coatings on computer glass, and lead solder on circuit boards and video screens. Obsolete computers also require special (and often expensive) handling to safely dispose of them. Between 1998 and 2007, computer industry experts predict that 45 million computers will be junked as new technology replaces the old.

Concerned about computer-generated hazards, some countries have moved to legislate their disposal. Germany, for example, passed a law in 1994 that requires computer makers to take back old machines. In the United States, the Environmental Protection Agency (EPA) has established guidelines for disposing of obsolete computers. "It used to be that there was no industry for recycling old computers, but not anymore," says Lynn Goldman, former assistant administrator of the EPA Office of Prevention, Pesticides, and Toxic Substances, although she concedes that such recycling is not yet widely available.

Computer obsolescence could create a waste crisis, but an emerging recycling industry in the United States, Canada, and other industrialized countries could siphon the much-needed, if slightly used, technology along to schools, as well as give it away to nonprofit groups and charities. In the United States, there are about a dozen large nonprofit computer recyclers. One of the largest, the Computer Recycling Center in Santa Clara, California, gave away 30,000 computers during a three-year period.

Internationally, a campaign to deal with obsolete computers has been jointly launched by the International Campaign for Responsible Technology and Clean Production Action. The campaign seeks to clean up the computer life cycle by focusing on the producer's responsibility for clean product design and for taking back computers at the end of their usefulness. The group's Clean Computer Campaign program statement declares, "We are forming a broad-based new campaign to shift [the] costs back to the producers in order to create economic incentives to place greater priority—and resources—on cleaning up the entire computer life cycle."

The most recent controversy surrounding semiconductor workers and miscarriages concerns the National Semiconductor Corporation plant in Greenock, Scotland. Seventy women have recently filed suit against the corporation, claiming they developed cancer and reproductive problems as a result of their work at the plant. The company has defended its health record in a statement published in the 27 May 1999 issue of the *Journal of Commerce*, stating, "We believe the lawsuit is without merit. An individual's health is affected by various factors, such as family history, eating, drinking, and smoking habits."

Little is known about the long-term health consequences of exposure to chemicals by semiconductor workers. Indeed, there has never been a study of cancer rates among U.S. semiconductor workers. "We know, in general terms, that roughly 10% of all cancer is caused by worker exposure, but there is no way to prove in an individual case that a chemical caused that particular cancer," says Joseph LaDou, director of the Division of Occupational and Environmental Medicine at the University of California at San Francisco. "Absolutely nothing is known of long-term exposure to low levels of these chemicals and absolutely nothing is known about long-term exposure to low levels of combinations of chemicals and reaction products," says LaDou. "That's what concerns us about the electronics industry." He adds, "It's often been said that here is a technology of the 21st century in which the toxicology of its manufacturing materials is still in the 19th century."

Several scientists, including Fowler and LaDou, have gone on record to predict that the cancer rate in the computer chip industry will rise significantly in the future because the industry is relatively new and cancer can take as long as 20–25 years to show up in populations of exposed workers. "We are going to see more reports of cancer among computer chip workers during the next decade," says Fowler.

For the semiconductor employees who are party to the lawsuits against the industry, the future is now. In 1995, Keith Barrack, one of the plaintiffs in the New York case, felt a sharp pain in his groin while playing a pickup game of basketball. When Barrack touched his left testicle, he felt a lump the size of a quarter. A visit to the doctor the next day revealed he had testicular cancer. Barrack, who had worked at the IBM semiconductor plant in East Fishkill, New York, between 1986 and 1990, prided himself on being an athletic type who didn't smoke or drink and who worked out regularly. He believes his cancer is due to chemical exposures he received while working at the IBM plant.

Debbie Drew, another plaintiff and worker at the plant, claims that she suffered occupationally induced brain tumors and is paralyzed as a result of surgeries to remove them. Drew left the semiconductor industry in 1989. Her husband, Henry, adamantly believes that the U.S. government, particularly the Occupational Health and Safety Administration (OSHA), should have played a stronger role in monitoring the semiconductor industry in the 1980s to protect worker health and prevent safety problems. "I wrote a letter to OSHA and never got a reply," he says. "I can recall officials from that agency coming to inspect the plant only once or twice. Given the number of people getting sick, you would think that OSHA would have taken a closer look."

Spokesmen for both OSHA and the semiconductor industry are quick to defend themselves against charges that their organizations have helped expose semiconductor workers to dangerous chemicals and occupational health and safety hazards. "OSHA's primary goal is to save lives, prevent injuries, and protect the health of America's workers and that certainly includes those employed in the semiconductor industry," says Rick Fairfax, OSHA's director of compliance programs. "In the semiconductor type of workplace, exposures only occur during unpredicted, upset conditions that can result in significant short-term exposures to workers but [that] are difficult to predict and monitor. While [OSHA] does monitor [the semiconductor] industry and conducts inspections, the industry typically doesn't show up on any OSHA programmed inspection targeting system due to its relatively low injury and illness rate."

The U.S. Bureau of Labor Statistics has routinely portrayed the semiconductor industry as one of the safest, with a worker illness rate of about one-third of the average of all manufacturers. "From what I've seen, the semiconductor industry takes safety very seriously," says Don Lassiter, a health care consultant to the semiconductor industry who has worked for OSHA and the National Institute for Occupational Safety and Health (NIOSH). "It's a model of what a manufacturing industry should be."

David P. Stangis, environmental health and safety regulatory issues manager at the Santa Clara offices of Intel Corporation, the semiconductor industry giant that enjoys 88% of the market share, says that from Intel's perspective, it is inappropriate to comment on specific cases involving employees. He says, "The personal stories . . . are tragic and we empathize with the employees and their families; however, using them to characterize an entire industry goes against the facts."

William DeProspo, a lawyer with the DeProspo, Petrizzo, Longo, and Bartlett law firm in Goshen, New York, which is representing Barrack, Drew, and the other plaintiffs in the New York IBM suit, dismisses arguments that the chemicals are not the cause of his clients' injuries. "Here we have plaintiffs who were in excellent health, not allowed to smoke on the job, and had access to great company [health] benefits. I have such a clean class of plaintiffs that I couldn't have handpicked better clients," he says.

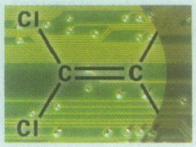
Chipping Away at the Environment?

Potential human health effects are not the only adverse side effect of the semiconductor industry. According to industry critics, the manufacture of semiconductor technology can produce negative consequences for the environment as well. JoLani Hironaka, executive director of the Santa Clara Center for Occupational Safety and Health, which provides assistance, training, and advocacy support to low-wage computer chip industry workers in Santa Clara County, says, "There has been a tremendous growth in the number of industries manufacturing chemicals and other materials for use at computer chip plants and in the amount of waste generated in the production process." For example, according to an article in the May–June 1997 issue of *E/The Environmental Magazine*, the manufacture of just one eight-inch computer wafer containing hundreds of chips requires on average 27 pounds of chemicals and 29 cubic feet of hazardous gases. Manufacturing this same wafer also produces 9 pounds of hazardous waste and 3,787 gallons of wastewater, which then requires extensive chemical treatment to remediate.

The semiconductor industry's environmental impact is well documented. Consider that Silicon Valley is the home of 29 U.S. Environmental Protection Agency (EPA) Superfund National Priorities List sites—more than any other county in the United States—and that more than 100 different contaminants have been measured in hazardous amounts in the local drinking water. Historically, much of the liquid waste from chip making in Silicon Valley was stored in underground tanks, many of which leaked toxic waste into groundwater supplies.

The designation of Superfund sites in the 1970s and 1980s closed dozens of drinking water wells in Silicon Valley. For example, in 1982 California state officials closed a drinking well near the Fairchild Semiconductor Corporation's South San Jose Plant after it was discovered that nearby residents had been drinking water contaminated with toxic solvents, including 1,1,1-trichloroethane and

Chemicals of Concern in the Semiconductor Industry



Acetone
- Inhalation of moderate to high levels causes nose, throat, lung, and eye irritation; confusion; and possibly coma
- Ingestion of very high levels causes unconsciousness and damage to the skin in the mouth
- Long-term exposure in animals causes kidney, liver, and nerve damage; increased birth defects; and lowered ability to reproduce in males

Arsenic
- At low levels causes nausea, vomiting, diarrhea, decreased production of red and white blood cells, abnormal heart rhythm, and blood vessel damage
- At high levels over 60 parts per million causes tissue damage (nerves, stomach, intestine, skin) and may be fatal
- Chronic exposure causes lung cancer
- Known human carcinogen

Arsine
- Causes headache; malaise; weakness; dizziness; dyspnea; abdominal and back pain; nausea; vomiting; jaundice; peripheral neuropathy; and damage to the blood, kidneys, and liver

Benzene
- Causes damage to bone marrow and decreased production of red blood cells leading to anemia, excessive bleeding, immune system effects, increased chance of infection, reproductive effects, and leukemia
- Known human carcinogen

Cadmium
- Causes lung damage, renal dysfunction, hepatic injury, bone defects, hypertension, reproductive toxicity, and teratogenicity
- Reasonably anticipated to be a human carcinogen

Hydrochloric Acid
- Highly corrosive
- Causes severe eye and skin burns and conjunctivitis; prolonged or repeated skin contact may cause dermatitis
- Inhalation causes severe respiratory irritation with coughing, burns, breathing difficulty, and possible coma
- Ingestion causes digestive tract irritation, abdominal pain, vomiting, and possible death
- Also causes photosensitization in certain individuals and circulatory system failure

Lead
- Damages kidneys and the immune system
- Causes premature birth; low birth weight; decreased mental ability; learning deficits in children; decreased reaction time; weakness in fingers, wrists, and ankles; anemia; memory effects; spontaneous abortion; and damage to the male reproductive system

Methyl Chloroform
- Causes headache; CNS depression; poor equilibrium; eye, nose, throat, and skin irritation; and cardiac arrhythmia

Toluene
- Long-term exposure to low to moderate levels causes tiredness, confusion, weakness, memory loss, nausea, and hearing loss
- Inhalation of high levels over a short period of time can cause permanent damage to the brain and speech, vision and hearing problems, loss of muscle control, and poor balance
- Causes neurological problems and retarded growth in children
- Reasonably anticipated to be a human carcinogen

Trichloroethylene
- Irritates the eyes and respiratory tract
- Inhalation causes dizziness, sleepiness, and headache
- Chronic exposure causes speech and hearing impairment, kidney disease, blood disorders, stroke, anemia, diabetes, and skin rashes
- Probable human carcinogen

1,1-dichloroethene, from a Fairchild underground storage tank. In 1984, the California State Department of Health Services released an epidemiological study concluding that these residents had suffered a cluster of birth defects and miscarriages. In 1986, Fairchild agreed to pay an undisclosed sum to more than 500 claimants in the contaminated local neighborhood. Toxic gases can pose a problem as well. In 1992, for example, one San Jose neighborhood had to be evacuated after toxic smoke poured out of a local chip-manufacturing plant.

Chlorofluorocarbons (CFCs), chemicals that deplete atmospheric ozone, were once used to clean computer chips, but by 1995 IBM, Intel, Toshiba America, Hewlett-Packard Company, and other computer companies reported that they had eliminated CFCs from their manufacturing process in accordance with the Montreal Protocol, an international agreement for the phase-out and eventual elimination of all CFCs. Stangis says that Intel has a program that identifies and implements substitutes for CFCs as they become feasible.

According to Lynn Goldman, a visiting scholar at the John Hopkins University School of Public Health in Baltimore, Maryland, who served as assistant administrator of the EPA's Office of Prevention, Pesticides, and Toxic Substances from 1993 to 1998, the semiconductor industry has put its worst outdoor environmental problems behind it. "In the early 1980s and before, Silicon Valley had a lot of problems with solvents and cleaning up toxic waste, but today the industry is monitored as closely as any sector in the economy, and its environmental record has improved considerably," she says. "The main concerns today are worker exposures and conditions in the clean rooms."

When the Chips Are Down

The semiconductor industry aggressively defends itself against the charge that it has been an irresponsible steward of the environment. Industry spokespersons maintain that electronics manufacturers are working hard to remove from the manufacturing process the toxicants that pose dangers to worker health and the environment. They point out, for example, that liquid wastes are no longer stored in underground tanks and that ethylene-based glycol ethers have been largely phased out of the industry after a 1992 IBM-sponsored study of workers at two of its plants showed that one-third of the female employees who were exposed to the chemicals had miscarriages.

The semiconductor industry has also established several research partnerships with the government and academic sectors

during the past 20 years. In 1982, the Semiconductor Research Corporation was established by the Semiconductor Research Association to serve as a nonprofit industry cooperative. Today, it spends $3 million annually on environmental research. "It's good business to research ways of reducing toxic chemicals and pollutants used in the industry," Herr says. "That's the only way we were going to advance semiconductor technology and stay competitive." In 1987, SEMATECH, a nonprofit consortium of semiconductor manufacturers based in Austin, Texas, was formed with an annual budget of $200 million, half of which originally came from the U.S. Department of Defense. According to Ted Smith, executive director of the San Jose–based Silicon Valley Toxic Coalition, a public interest organization that has monitored the environmental record of the semiconductor industry since 1982, 10% of the budget is earmarked for research on environmental technology due to a successful lobbying effort led by the Campaign for Responsible Technology, a national labor–environment organization.

In November 1995, Intel's premier chip-manufacturing facility in Chandler, Arizona, was selected to participate in an EPA program called Project XL, which allows semiconductor manufacturers to develop what the federal agency hopes will be innovative, proactive approaches to environmental compliance and cleanup in partnership with the EPA and the public. As part of the program, in November 1996, Intel pledged to work toward developing "equal or better environmental standards than the previous command-and-control regulatory methods." In January 1997, the company entered into a joint contract with the EPA and the Arizona Department of Environmental Quality to begin this process.

Project XL allows semiconductor manufacturers to avoid what they consider to be costly and time-consuming permit reviews by replacing the existing regulatory structure with an alternative cooperative operating agreement. Critics, including several labor, environmental, and public interest organizations across the United States, consider the program to be a sweetheart deal for environmental deregulation, one that undercuts the hard-won laws protecting the environment. "The agreement doesn't deliver on President Clinton's promise to make corporations like Intel more accountable to their workers and to the communities in which they operate," says Smith. "The agreement is going to expose workers and the people of Arizona to increased toxic chemicals."

But the U.S. government has strongly defended the agreement. Because the basis of Intel's Project XL agreement is a single multimedia environmental operating permit for its Chandler facility, both the EPA and Intel expect to save time and money by linking together water, air, and other operating permits that are currently issued under a variety of jurisdictions. Officials say there will be other benefits as well. For example, Project XL is expected to provide a boon to construction of wafer manufacturing facilities and to provide Intel's Chandler facility with a greater measure of flexibility in its manufacturing process. Felicia Marcus, the EPA's Region IX administrator, says, "This is where the future of environmental protection lies—in the cooperation between industry, regulators, and communities to protect the public health and the environment in a commonsense manner that shows that a strong environment and economy go hand in hand."

Recently, the semiconductor industry has been criticized for failing to support proposed environmental and occupational health research projects that target environmental problems in the industry. Says LaDou, "When ideas for studies have been advanced, industry representatives have found every means available to point out problems and, often, the impossibility of moving ahead."

In 1997, the California Department of Health Services, with the support of the EPA, developed a proposal to utilize California health registries as a way of studying the rates at which disease occurs among electronics workers and their families. The project would have developed a record-keeping system for the semiconductor industry to monitor and identify the incidence of cancer and birth defects among its workers. Access to employee records was vital to the project, but by January 1998, the industry had publicly refused to participate. Tim Mohin, an Intel spokesperson, told the press in a widely reported statement, "To participate in a project like this would be like giving discovery to plaintiffs. I might as well take a gun and shoot myself."

On 27 January 1998, LaDou wrote a letter to NIOSH director Linda Rosenstock, asking that the agency intervene in the matter and arguing that NIOSH "can provide our first real opportunity to see the prevalence and incident rates of cancer and birth defects in electronics workers." Three weeks later, Rosenstock replied that "NIOSH has the authority to compel the production of NIOSH field research and surveillance programs," but added that the agency "lacks the authority to compel companies or industry sectors to participate in research or surveillance activities among third parties." According to Stangis, however, a team of industry health and safety officials have met several times with the California Department of Health Services in "the mode of open engagement to discuss issues surrounding press claims, worker protection, and health research."

The intense economic competition in the electronics industry is accelerating the pace at which the types of tools and materials used in the semiconductor manufacturing process change. In the mid-1970s, the typical cycle of a new technology from research to full manufacturing took six to eight years. Heading into the 21st century, the industry is now developing a new chip-making process about every two to three years. Intel reports that each of its computer chip factories makes an average of 30–60 significant changes each year in its operations in order to ramp up production of new types of computer chips. But industry critics say that while hundreds of new chemicals are being introduced into commerce annually, adequate toxicological assessments almost never precede their introduction into manufacturing settings. "One can say that the workers are being used as guinea pigs," Smith charges.

These problems concern the semiconductor industry as well, say industry officials, who believe that the process development stage offers a prime opportunity for environmental improvement. "We are setting our environmental goals at the beginning of each development cycle and working closely with suppliers of tools and chemicals," Stangis says.

As for monitoring, Goldman says, "The industry is so innovative that every time it changes equipment it has to apply for a new permit from the federal government." But despite all of the permitting activity, community members and workers do not trust that the monitoring is sufficient. Goldman says this suggests "that we need to consider alternative approaches to environmental regulation for this industry, and perhaps others as well, that can provide more flexibility for industry and more accountability for the public and workers."

Ron Chepesiuk