Evaluating Chlorine and Chlorinated Compounds

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Executive Summary

Chlorine, one of the 20 or so elements found in abundance in all living things, is under attack. Environmentalists have tried to condemn many man-made chlorine products as hazardous and have called for the government to ban them. However, chlorine is not only a constituent of man-made products but also is found in abundance in nature in the same formulations. It could no more easily be banned than sunlight or aflatoxin, a natural carcinogen produced by mold.

Responding to the pressure of activist groups and a media barrage, the Environmental Protection Agency (EPA) began to investigate the gradual elimination of chlorine use in certain industries. However, the exaggerated accusations regarding chlorine’s damaging health effects do not stand up to scientific scrutiny. Prestigious and well-respected scientific groups, including the Society of Toxicology, the American Chemical Society and the American Medical Association, have spoken out against simplistic strategies for grouping and eliminating chlorinated compounds.

Chlorine and chlorinated compounds are essential for maintaining America’s health and for improving the standard of living in both the Western world and emerging nations. Consider the following: There is no suitable substitute for chlorine to protect people from waterborne diseases. Chlorinated pesticides allow the production of an adequate and inexpensive supply of fruits and vegetables. Chlorinated compounds are essential for the production of lifesaving pharmaceuticals. Polyvinyl chloride (PVC) is the building block for much of our manufacturing industry and an invaluable component of building materials, consumer goods, medical equipment and many other products.

Certain chlorinated compounds can be considered health threats at high doses. But as with any potentially harmful chemical, chlorinated or not, safe management is the key to preventing harmful exposures and toxic consequences. In the past, harmful compounds have been identified and subsequently either controlled or banned. Similar efforts will continue in the future, and selective removal is the most responsible way to protect our health while continuing to reap the benefits of chlorine chemistry.

The Charges

Numerous reports in the media have ascribed possible detrimental health effects to chlorine, dioxin and other chlorinated chemicals, often subjecting the public to exaggerated and misleading
information. Most of these stories have no basis in scientific fact.

Greenpeace, a worldwide environmental activist group, has led the attack, pushing for a total ban on chlorine and chlorinated chemicals. With its document *The Product is the Poison—The Case for a Chlorine Phase-Out*, Greenpeace took the first step in a campaign to shut down the chlorine industry. In that document Greenpeace recommended phasing out “the use, export, and import of all organochlorines, elemental chlorine, and chlorinated oxidizing agents,” charging, without scientific justification:

• that the small amounts of dioxins produced during the chlorine bleaching of paper pulp pose an unacceptable risk to the population;
• that polyvinyl chloride (PVC), a chlorine-containing polymeric chemical widely used in consumer products, is “uniquely damaging during production, use and disposal,” and that it is a potent producer of dioxins during incineration; and
• that all chlorinated chemicals may be carcinogenic and may have negative reproductive effects.

Shortly after the release of the Greenpeace report and the subsequent media barrage, the Environmental Protection Agency announced, under the authority of the Clean Water Act, the initiation of a 2 1/2-year study with the goal of “develop[ing] a national strategy for substituting, reducing or prohibiting the use of chlorine and chlorinated compounds.” Nothing in the EPA’s statement indicated that the health effects of chlorinated compounds would be evaluated.

The EPA announcement came on the heels of a major study by the International Joint Commission (IJC), a U.S.–Canadian group that oversees implementation of the Great Lakes Water Quality Agreement. In its “Seventh Biennial Report Under the Great Lakes Water Quality Agreement of 1978” published in early 1994, the IJC recommended severe reductions in chlorine use. The recommendation, which would affect the future use of chlorine and chlorinated chemicals, totally disregarded the scientific data about these chemicals and was not supported by the group’s own science advisers, who concluded that there was a need for “a thorough and complete analysis of chlorine chemistry before any schedule for sunsetting chlorine is implemented.”

**Scientists Respond**

In response to these events, several groups of scientists have emphasized that current regulations dealing with chlorinated chemicals are sufficient and that there is no need to ban the entire
group. For example:

- The Society of Toxicology declared in October 1994 that toxicologic principles do not support the banning of chlorine. In only the third position statement in its 35-year history, this 3,500-member professional organization stated that the Clinton Administration’s proposal to “develop a national strategy for substituting, reducing or prohibiting the use of chlorine and chlorinated compounds” is simplistic and ignores the basic principles of toxicology that govern risk assessment. All chlorine-containing compounds are not equally hazardous, and so a broad-based ban of this class “would be irresponsible and unscientific.” Moreover, the society added that the most scientifically sound approach is “to assess the toxicity of agents on a chemical-by-chemical basis.”

- In April 1994, the American Chemical Society wrote to Congress saying that it “sees no reason for singling out such an extensive group of chemicals for study,” and it urged the EPA to focus on chlorinated chemicals of primary concern. And in June 1994, the American Medical Association urged the EPA to evaluate environmental risks on the basis of reliable data specific to each chlorinated compound.

- A panel of Michigan scientists that reviewed the IJC report concluded in July 1994 that there is “insufficient scientific evidence” to suggest that short-lived chlorinated compounds produce environmental and health threats. The panel opposed “sunsetting” all uses of chlorine and organochlorines and stated that not all chlorine-containing compounds are harmful. Dr. Lawrence Fischer, Director of the Institute for Environmental Toxicology at Michigan State University and Chairman of the panel, said that “the focus on chlorine is misplaced.” The panel also found that current regulations are “reasonably adequate,” but that “periodic review, aggressive enforcement, and better monitoring” are needed.

- A extensive study published in Regulatory Toxicology and Pharmacology evaluated the use of chlorine in several industries, including the PVC, pulp and paper, drinking water, incineration and pesticide industries. The 1,100-page study, published in September 1994, concluded that “although much remains to be learned about chlorinated organic chemicals, enough is known to ensure that now and in the future, they can be used and discharged with assurance that adverse effects will be absent.”

The Benefits of Chlorine
Without understanding the role of chlorine in our society, the public is more willing to accept a ban on this chemical than it would be to tolerate bans on the lumber industry, the textile industry or the steel industry. The chlorine industry is larger than these other three, however, and is equally important—if not more so—to our way of life.9

From a human health and environmental standpoint, chlorine and chlorinated chemicals are safe when properly used. Almost everything we encounter in our daily life—from wood-veneer furniture, to luggage and shoes, to medical devices such as pacemakers—has had a chlorinated compound included at some point in its production. Nearly 1.3 million American jobs are linked to chlorine chemistry.

Furthermore, many of the chlorinated chemicals that are targets of the proposed ban are naturally produced and cannot be “banned” any more than air, gravity or sunlight. Chlorine is part of our natural ecosystem. The scientific data do not support claims that this group of chemicals poses a risk to the health of Americans.

**Chlorine as Part of the Natural Environment**

Chlorine is one of more than 100 elements that make up our universe and is one of the 20 or so elements that make up all living things. Chlorine occurs in nature in several forms, such as inorganic chloride salts (i.e., sodium chloride, common table salt) and the numerous chlorinated organic (i.e., containing carbon) compounds found in plants, the soil, the atmosphere and ocean life.

The natural world contains more than 1,500 chlorine-containing chemicals.10 Many organochlorines—the very same class of chemicals that are on environmental hit lists—are produced naturally. For example, 2,4-dichlorophenol, used to manufacture several pesticides and herbicides, including Agent Orange, is produced naturally by a species of *Penicillium*, the genus of mold that produces penicillin. The roster of living organisms known to produce natural chlorinated organic compounds is a long one: seaweeds, algae, assorted plants, some vegetables and fruits, fungi and mushrooms, lichen, microorganisms, marine creatures, frogs, insects and even some mammals.11 In the human body, white blood cells generate hypochlorite to fight infection. Hydrochloric acid in the stomach is essential for proper digestion; chloride ions are necessary for muscle and nerve function.

Chlorine compounds are synthesized by many species of plants and animals for very specific metabolic purposes. As such, they are essential for the normal growth and reproduction of those
organisms. The ability of organisms to synthesize these compounds has evolved over time under the stress of natural selection.

Hydrogen chloride is produced in massive amounts in volcanoes, and many chloride salts are present in the earth’s crust. Combustion is also a major source of organochlorines. Natural combustion sources include lightning-induced forest and brush fires as well as volcanoes. Whenever organic material is burned in the presence of chloride, organochlorines are produced. These include dioxins, chloromethane and other chlorine-containing compounds.

As one extensive 1994 report concludes, “The significance of the quantities of chlorinated chemicals produced by natural processes is not well understood, but their existence clearly demonstrates that the earth’s ecosystems have evolved with a metabolic capacity to recognize and accommodate the presence of such chemicals.”

The abundance of chlorine in our environment and our ability to harvest it cheaply from seawater have led to its adoption for numerous uses.

**Uses of Chlorine to Promote Health**

Chlorine is used to purify drinking water and to disinfect swimming pools, both of which might otherwise be contaminated with fecal microorganisms that could cause diseases such as cholera, typhoid fever and dysentery. Some 98 percent of our public water systems are purified by chlorine or chlorine-based products. Chlorination is the water treatment of choice in North America, preventing inestimable deaths every year. In the words of the director of the International Life Sciences Institute’s Risk Science Institute, “chlorination and disinfection of the water supplies are the public health success story of the century.”

The World Health Organization estimates that worldwide 25,000 children die every day from waterborne diseases resulting from a lack of water disinfection. In Peru, the termination of water chlorination as a tragic experiment in 1991 resulted in a massive and unnecessary epidemic—causing more than one million cases of cholera and 19,000 deaths to date—that has spread to 14 other South and Central American countries.

The American Cancer Society has estimated that each year in the United States, approximately 8,000 cases of rectal cancer and 4,500 cases of bladder cancer are associated with drinking chlorinated water. It is unclear what specific chemicals, if any, are responsible. Many of these cancers are
treatable or even curable, and chlorination has not been linked with other cancers.

Improvements in drinking-water disinfection technology have greatly lowered the concentration of chlorination by-products from the higher levels measured in the 1960s and 1970s. The benefits of using chlorine to kill life-threatening pathogens far outweigh any risks posed to humans or the environment by the low concentrations of chlorinated by-products.

Ozone has been suggested as a safer substitute for chlorine in water disinfection; but ozone is, in fact, less effective than chlorine. Ozone breaks down very rapidly and thus does not guard against recontamination, while chlorine provides residual disinfection from the treatment plant to the tap. Additionally, there is no assurance that ozone’s by-products, including bromate (an animal carcinogen) will be any less toxic than by-products produced during chlorination. A general switch to ozone for treating drinking water and waste water would cost six billion dollars per year.13

Chlorine is an essential component in the production of many lifesaving pharmaceuticals. Among the chlorine-containing pharmaceuticals is vancomycin—an antibiotic used to fight hospital staphylococcal infections. Other pharmaceuticals that contain chlorine include drugs used to treat depression, arthritis, fungal diseases, glaucoma, psoriasis, yeast infections, allergies, osteoporosis, ulcers, malaria, coronary disease and cancer. The millions of American children who develop middle-ear infections are now best treated with the chlorine-containing antibiotics Ceclor and Lorabid.

Two of the ten most prescribed pharmaceuticals, Ceclor and Xanax, contain chlorine. The best drug for the treatment of testicular cancer is cisplatin, which contains chlorine, as does toremafene, a treatment for breast cancer used in Europe. Some 85 percent of all pharmaceuticals and vitamins are made directly or indirectly through chlorine chemistry. In short, chlorine is an important—if not essential—component in our present-day health care system.

Chlorine is also used to manufacture crop protectants such as pesticides and herbicides. It has allowed Americans to enjoy safe, high-quality, insect-free produce at much lower prices than would otherwise be possible. Some 96 percent of all crop-protection chemicals are chlorine based; a chlorine ban would virtually eliminate high-production, high-quality farming. A 1993 study that examined the effect a chlorine phase out would have on farm food production indicated that such a ban would affect 90 percent of all grain farms and would cost U.S. consumers $22.1 billion annually, or about $85 per person.15
Chlorine and Paper Production

Chlorine is used to bleach pulp in the manufacture of paper, recycled paper and other paper products. The toxicity of chlorinated wastes from paper-pulp mills has been reduced significantly in recent years. A well-designed and well-maintained paper plant with secondary treatment removes up to 90 percent of the effluent toxicity. Furthermore, many mills have switched to chlorine dioxide, a less reactive form of chlorine that produces fewer toxic emissions. The amount of chlorine used for pulp and paper bleaching in the United States will fall from 1.4 million tons in 1990 to 920,000 tons in 1995, and the amount of chlorine dioxide used by the industry will increase from 670,000 to 975,000 tons over the same period.

The dioxins that are produced and discharged to rivers and streams in small quantities when chlorine is used to bleach paper pulp—less than one pound annually from the whole U.S. paper industry—are exactly the same chemicals that are produced naturally in fires or by enzymatic action in living organisms.10

PVC: The Building Block for Useful Man-made Products

One of the most important uses of chlorine is in the production of polyvinyl chloride (PVC, or vinyl). PVC is a versatile and nontoxic material that has a distinct advantage in many product applications and in the marketplace. The presence of chlorine in PVC makes this material inherently flame retardant, which is why PVC is used in many construction and furnishing applications. PVC is the world’s leading electrical-insulating material, with more than 500 million pounds used annually for wire, cable and other electrical applications. In fact, PVC is used in a vast array of everyday products. On a typical day the average person will use more than a dozen PVC products, including luggage; shoes; raincoats and umbrellas; fabric and paper coatings; computers and keyboards; magnetic recording tape; recreational equipment; inflatable boats and water floats; baby strollers; furnishings; food packaging; garden hoses and lawn furniture; floor and wall coverings; and more.

Like all plastics, PVC is made by a series of processing reactions that convert hydrocarbon materials (petroleum, natural gas or coal) into chemicals called polymers. PVC is unusual because less than half of its structure is derived from hydrocarbons; most of PVC’s structure is derived from natural chlorine (sea salt). Thus PVC is much less dependent on petroleum supplies than are many other materials. The manufacture of PVC produces far less air and water pollution than does the
manufacture of products derived from metal ores or wood.\textsuperscript{16}

PVC is an inert material and can be transported safely. Millions of pounds of PVC resin are shipped by rail and truck each year without incident. Like concrete, steel and Teflon, PVC is nontoxic, structurally sound and plays an enormously important role in our society. PVC is an ideal replacement material for wood and aluminum, particularly in the siding and window-frame markets.

If PVC waste pipes were to be replaced with iron piping, the emissions from the iron pipe manufacture would cause more serious environmental problems than are caused by emissions from PVC pipe production. PVC provides noncorroding, lead-free pipe and connections for potable water supplies and reduces municipal costs. PVC pipes resists corrosion, sediment buildup and harsh water conditions and outlasts other types of piping. The use of PVC piping eliminates concerns over lead exposure in drinking water.

Under normal usage, PVC materials are completely safe. They will not degrade as do organic materials such as wood; nor do they leak toxic chemicals. PVC has as much chemical integrity as steel or Teflon, which show no tendency to emit iron or fluorine, respectively.

PVC has inherent flame-retardant properties, unlike many other non–chlorine-containing polymers. PVC resists ignition and flame spread, burns at a higher temperature than many other materials and usually will not continue to burn once the flame source is removed. The use of PVC in building materials is partly responsible for the fact that the U.S. death rate from fire has decreased from 76 per million population in the 1940s, when most construction and decorative products were made of “natural” materials, to 29 per million in the 1980s, by which time PVC had replaced natural materials in many applications.\textsuperscript{17}

PVC is used for blood storage, in food packaging and for bottled-water containers and shows no tendency to break down and contaminate the blood, food, water or other products that come into contact with the material. Harmful chemicals are not transferred from PVC to food.

Several chemical additives and modifiers are present in the various formulations of PVC and contribute to the desired properties (rigidity, flexibility, impact resistance, weather and heat resistance, color). These additives include plasticizers, stabilizers, impact modifiers, processing aids and colorants. All the additives used in food and drug packaging have been declared safe by the Food and Drug Administration or have been given special regulatory clearance. Because of the physical
nature of PVC, the additives are locked within the PVC polymer matrix.

A few of the PVC additives used in the past are now recognized as posing health or environmental threats; these former additives are being replaced with safe substitutes. DEHP (di-2-ethylhexyl phthalate), a plasticizer, is no longer used in PVC food wrap on products like cheese because DEHP is not compatible with fatty foods. Neither are heavy metals used in PVC packaging materials. Some heavy-metal heat stabilizers containing cadmium and lead are also being phased out. However, certain heavy metals will remain in use in selected PVC applications. For example, lead stabilizers will continue to be used in applications in the wire and cable market because the lead imparts beneficial electrical properties that substitutes cannot, to date, achieve.

PVC materials are as recyclable as paper, aluminum or glass and can be recycled both safely and economically. In 1991 there were nearly 1,200 communities in the United States with access to PVC recycling-collection programs. A study conducted by the University of Toledo in 1989 identified nearly 100 potential applications for recycled PVC and estimated the potential demand at about 500 million pounds per year. The number of companies involved in the recycling of PVC plastics has tripled in just a few years and now numbers more than 175. Another 60 companies make second-generation products from recycled PVC.

Not only has the recycling of PVC packaging increased, but PVC durable goods, currently a 4.9-million-ton-per-year market in the U.S. and Canada, are also being recycled at an increasing rate. For example, Vermont Republic Industries recycles PVC computer-chip shipping tubes into 150 tons of PVC pipe per year; the Davidson Instrument Panel company in New Hampshire converts PVC automotive instrument panels into several million pounds of reusable recycled PVC annually.

It has been claimed by Greenpeace, without supporting evidence, that burning PVC will lead to the formation of dioxins and other “dangerous chlorinated compounds. In fact, research has shown that PVC can be incinerated safely. One study showed that the presence or absence of PVC had no effect on the amount of dioxin produced during the incineration process. Rather, it was determined that incinerator operating conditions (primarily temperature) were the key to controlling dioxin formation. At temperatures of 1500° to 1800°F, typical of modern municipal waste incinerators, the generation of dioxin is minimal.

A 1993 study by the National Renewable Energy Laboratory concluded that whether or not PVC plastics are present in municipal solid waste (MSW), dioxins can be formed during incineration
in amounts that presently are of regulatory concern unless control measures are applied. However, proper control measures can limit dioxin emissions to levels that are below current regulatory concern even if PVC is present.²⁴

The burning of any material containing chlorine or chloride will result in the production of organochlorine compounds and hydrochloric acid. If an incinerator is properly maintained and operated at the necessary high temperature, and if the best available air pollution control technology and scrubbers are installed, however, there is no danger to the public from these emissions. Caustic scrubbers trap and neutralize the hydrochloric acid, and the high temperatures destroy the organochlorines before they can be released. In fact, dioxin levels near incinerators are not substantially elevated compared to background levels.²⁵ The amount of organochlorine chemicals released to the environment during the operation of a well-maintained incinerator are insignificant, and no harmful effects on human health are expected from their use.

Just as with the burning of municipal wastes containing PVC, the burning of coal, wood, gas and oil also produces dioxins and furans (or polychlorinated dibenzofurans, another class of organochlorines chemically and biologically related to the dioxins). The EPA estimates that there are 22 million homes that burn wood in the U.S., compared to only 160 municipal waste incinerators. The combined total of dioxin emissions from the burning of wood in homes greatly exceeds the amount from municipal waste incineration; and the amount from forest fires dwarfs these amounts by thousands of times. Motor vehicles, steel mills and metal smelters also emit dioxins. Overall, it has been estimated that an individual living near a typical, modern incinerator will receive less than one percent of his or her daily dioxin exposure from that incinerator.²⁵

In Europe, where PVC has come under close scrutiny, several organizations have concluded that PVC should be the material of choice.²³ The British retailer Marks and Spencer regards PVC as an “environmentally friendly” material. Britain’s Green Consumers’ Supermarket Shopping Guide has called PVC “one of the most energy efficient materials.” In Norway the environmental group Bellona has concluded that “a generally reduced use of PVC will, given today’s circumstances, lead to a worsening of the environmental situation.” Switzerland’s largest retailer, Migros, has stated that once the country’s incinerators are equipped with scrubber technology, “our whole attitude to PVC will change. It has outstanding properties not easily matched by alternatives.”²⁶
Past Problems Identified and Solved

It is important to note that chlorinated compounds that cause either health or environmental problems—such as vinyl chloride monomer, PCBs (brief reviews of each follow) and some chlorinated insecticides—have been banned or strictly regulated. When a real problem exists with a chemical—chlorinated or not—regulations will be put in place to control exposure to that chemical or to remove it from production and use. This has been done in the past and will continue to be the policy in the future.

Vinyl Chloride Monomer

Within 10 to 15 years of the initial use of vinyl chloride monomer, a building block of PVC, there were warnings in both the laboratory and the workplace of its potential toxicity and carcinogenicity. Rodent studies and epidemiological studies of workers suggested that the chemical was hazardous; by the early 1970s the deaths of 13 workers from angiosarcoma, a extremely rare cancer of the liver, confirmed the carcinogenicity of vinyl chloride monomer.

In 1974, just four years after passage of the Occupational Safety and Health Act of 1970, the Occupational Safety and Health Administration and the PVC industry reduced the allowable workplace standards for vinyl chloride monomer from 500 parts per million (ppm) to 50 ppm and then to 1 ppm.27 Such strict standards forced the industry to develop safer technologies. Today, with vinyl chloride being handled properly, workers are no longer at risk. A study in 1977 of more than 15,000 workers in PVC fabrication plants found no further evidence of vinyl chloride–related health effects.28 Another study concluded that modern PVC production facilities have greatly reduced emissions of vinyl chloride monomer in the workplace, and that the health impact on workers is now negligible.8

PCBs

Polychlorinated biphenyls (PCBs) are a family of compounds consisting of two benzene rings and two or more chlorine atoms. First used in 1929, they became ubiquitous as coolants and lubricants and in manufacturing because of their remarkable insulating and flame-retardant characteristics. But past disposal practices that were once thought to be acceptable and hazard-free led to the release of PCBs; their stability allowed for increasing accumulation in the environment.
Durability alone does not make PCBs dangerous, however. High-dose animal experiments have raised concerns about possible health hazards in humans, but studies conducted by the National Institute for Occupational Safety and Health on workers exposed to PCBs over many years through skin absorption and inhalation have shown no adverse human health effects.\textsuperscript{29,30} It is therefore highly unlikely that the much lower exposures found in the general population present any significant hazard.

Nonetheless, PCBs are no longer produced in this country. A wide range of regulations currently control human exposure to PCBs by requiring replacement, monitoring and strict disposal of equipment and by setting limits for PCB levels in fish and dairy products. Considering the lack of evidence of any effects of low-level PCB exposure in humans, some might even say that such regulations have been carried too far. According to the July 17, 1985, \textit{Federal Register}, the five-year costs for regulation of PCBs by the EPA totalled nearly $750 million.\textsuperscript{31} (For more information see ACSH’s booklet \textit{PCBs: Is the Cure Worth the Cost}?)

\textbf{Current Controversies}

\textit{Dioxin}

The name “dioxin” refers to a family of about 75 chemicals, among them 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), generally considered the most toxic of the group. Dioxins were first synthesized in the late 1950s at Ohio State University. Their toxic effects in animals were noted soon after.

Dioxins have no known use. They are by-products of some industrial processes that use chlorine, such as the bleaching of paper pulp. Dioxins are also produced during any combustion process—waste incineration, running motor-vehicle engines, steel-making and smelting, residential wood burning and even forest fires.

Despite assorted claims over the past 20 years, the dioxin known as TCDD (is not the “doomsday chemical of the 20th century,” nor is it the “deadliest substance ever created by chemists.” The people who have been exposed to high levels of TCDD number in the thousands. Physicians and epidemiologists have been observing the health of those individuals—industrial workers, civilians, Vietnam veterans—who were exposed to TCDD at high levels during the past 40 years. Even after all these studies, described in more detail below, not one has been able to attribute
unequivocally any human cancers or deaths to TCDD exposure. The only documented adverse health effect is the skin disease chloracne. Although it is often persistent and disfiguring, chloracne is not life-threatening and is often reversible when exposure ceases.\textsuperscript{32,33}

While dioxin tissue levels among Vietnam veterans in general are not significantly different (11.7 parts per trillion [ppt]) from the levels of non-Vietnam veterans (soldiers who had never been to Vietnam; 10.9 ppt) or a civilian control group (12.4 ppt),\textsuperscript{34} certain groups of Vietnam veterans were exposed to higher levels of dioxin, a contaminant of the defoliant Agent Orange. Studies following these individuals show no association between dioxin tissue levels and cancer or other health effects. A two-part, 20-year mortality and health-effects evaluation of 995 Air Force Ranch Hands, the personnel who handled and sprayed Agent Orange, revealed that some had high tissue concentrations of dioxin (>300 ppt) 15 years after exposure.\textsuperscript{35,36} Among this group, there was no chloracne observed, no increase in nine immune-system tests and no increase in either melanoma or systemic cancer (cancers of the lung, colon, testicle, bladder, kidney, prostate; Hodgkin’s disease; soft tissue sarcoma or non–Hodgkin’s lymphoma). The authors of this 1990 study concluded that “there is insufficient scientific evidence to implicate a causal relationship between herbicide exposure and adverse health in the Ranch Hand Group.”\textsuperscript{35}

Studies of more than 800 dioxin-exposed workers in nine industrial-plant accidents in the United States, England, Germany, France, Czechoslovakia and the Netherlands fail to indicate serious long-term health effects in these men, some of whom have dioxin concentrations exceeding 1000 ppt 30 years after their initial exposure. Some 465 cases of chloracne were observed in these workers.\textsuperscript{37}

A study of 2,200 Dow Chemical workers who were potentially exposed to dioxin revealed that they had a slightly lower mortality than a control group and that they have had no total cancer increase.\textsuperscript{38} A study of 370 wives of dioxin-exposed men showed no excess miscarriages and no excess fetal deaths or birth defects in their children.\textsuperscript{39}

The Institute of Occupational Health at the University of Milan has published detailed evaluations of the human health effects of the July 1976 dioxin accident involving 37,000 people in Seveso, Italy.\textsuperscript{32} Some of the exposed children in “Zone A,” the area of heaviest exposure, had dioxin tissue levels as high as 56,000 ppt immediately following the accident; but the only adverse health effect to date has been chloracne. Of the 193 cases of chloracne, 170 were in children under the age of 15; and
the skin lesions in all but one of these cases had disappeared by 1985. Although it is essential to continue to monitor the health of the people in Seveso, the Institute report concluded that there were “no increased birth defects due to dioxin exposure,” since the children born during the period from 1977 to 1982 failed to demonstrate an increased risk of birth defects.\textsuperscript{32}

The Seveso cancer mortality findings after 10 years do not allow firm conclusions. On the one hand, mortality from cancer of the liver, one of the organs targeted by dioxin, was no different from that of unexposed people; and breast cancer mortality tended to be below expectations. On the other hand, “increases in biliary cancer, brain cancer, and lymphatic and hemopoietic cancer did not appear to result from chance. However, no definite patterns related to exposure classification were apparent.”\textsuperscript{32}

In the words of a leading dioxin analyst, Dr. Michael Gough:

“No human illness, other than the skin disease chloracne, which has occurred only in highly exposed people, has been convincingly associated with dioxin. In short, epidemiologic studies in which dioxin exposures are known to have been high, either because of the appearance of chloracne or from measurements of dioxin in exposed people, have failed to reveal any consistent excess of cancer. In those studies that have reported associations between exposure and disease, no chloracne was reported, and there are no measurements of higher-than-background levels of dioxin in the people who are classified as exposed.”\textsuperscript{38}

Life-threatening health effects in humans have not been linked definitively to dioxin, despite our fears to the contrary. Over 40,000 scientific papers have provided enormous information about this greatly misunderstood chemical, and the scientific and medical communities will continue to monitor the health of those people who have been exposed to large amounts of dioxins. (For more information see ACSH’s booklet \textit{Dioxin in the Environment}.)

\textit{Estrogenic Effects on Fertility and Breast Cancer}

Besides cancer, there are other health “endpoints” about which there is concern relating to dioxin and other organochlorines. It has been alleged that dioxin and other chlorinated chemicals mimic estrogen, adversely affecting the immune system and possibly inducing birth defects. Although dioxin is a teratogen (birth-deforming agent) in laboratory animals, none of the many
studies undertaken show that dioxin causes birth defects in humans. The most heavily exposed group of women in Seveso showed no increased incidence of birth abnormalities in their newborn children.\textsuperscript{32,37} Moreover, the examination of medically aborted fetuses during the period following the Seveso accident failed to indicate birth defects.\textsuperscript{32} Tragically, many women in Seveso needlessly elected to have abortions out of fear that their children would be born with defects.

Various reports linking decreased human sperm counts worldwide to chlorinated chemical exposure are based on questionable data and grand exaggeration. Much of the furor over sperm counts came from a 1992 report in the \textit{British Medical Journal} citing a 50 percent decline in sperm counts from 1938 to 1990 among men from industrialized countries.\textsuperscript{40} After promoting, in a 1993 \textit{Lancet} article, the hypothesis that this decline was associated with estrogenic compounds, the authors later admitted that the apparent decrease in sperm counts was due to computational error and was not supported by a reanalysis of the data.\textsuperscript{41} A 10-year study of the semen quality of Wisconsin men showed no change over time in sperm concentration or motility.\textsuperscript{42} (It must be noted, however, that virtually all studies of sperm health suffer from methodological problems, including how subjects are selected and the number of samples taken.)

While sperm concentration and motility are not the only determinants of male fertility, the 1965 Princeton National Fertility Study and the large, broad-based surveys conducted by the National Center for Health Statistics in 1976, 1982 and 1988 indicate that rates of infertility have remained constant over the past three decades at 8 to 11 percent, with male infertility accounting for approximately one third of the cases.\textsuperscript{43}

Furthermore, reproductive problems have not been detected in the groups of people who were most heavily exposed to dioxin: Vietnam Air Force Ranch Hands, occupationally exposed workers and the populations of Times Beach and Seveso.

Investigations into the causes of breast cancer are another area of controversy in which chlorinated estrogenic chemicals have been controversially linked to disease. A 1993 \textit{Journal of the National Cancer Institute} report found that DDE, a breakdown product of the now-banned pesticide DDT, was present in higher concentrations among a small group of Long Island women with breast cancer when they were compared with a control group.\textsuperscript{44} This observation led the researchers to suggest that there is an association between DDT exposure and breast cancer. But a more recent larger study published in the same journal found no association between breast cancer and higher levels of DDE.
or PCBs. Without agreement in even a small number of studies, it is highly premature to assume that chlorinated environmental contaminants are influencing breast cancer rates.

Conclusion

It is important to recognize that there is a downward trend in the emissions of chlorinated compounds. Chlorinated pesticides that formerly were associated with adverse effects on wildlife are no longer being used. The concentrations of these chemicals are declining in the environment, and previously affected species are recovering. Industrial and incineration-emission technology has improved dramatically in recent years, leading to decreased emissions of chlorinated compounds and by-products. The EPA has reported that dioxin emissions, which peaked in 1970, have been decreasing since 1980, demonstrating that the regulatory system is working well to protect the environment.

Chlorine is an inextricable part of our lives and is necessary for the maintenance of the present high standards in our food, water and housing. Chlorine contributes in the fields of medicine, transportation and communications. Chlorine is a building block for nearly all chemical processes; it plays a vital role in the health of the population and in maintaining a clean and safe environment. From chlorine-containing pharmaceuticals to fire-resistant and recyclable PVC construction materials, and from water purification to the raising of safe, insect-free food crops, chlorine makes a crucial contribution to the health and well-being of our society.

If chlorine and its chemical derivatives are banned, the expense to the American people in finding replacements will cost billions of dollars and result in the loss of hundreds of thousands of jobs. The loss of useful products—plastics, pharmaceuticals, even safe drinking water—will be a needless tragedy. We will have taken a giant step backward in our standard of living.

The benefits—and the adverse consequences—of chlorinated compounds must be carefully evaluated before any attempt is made to ban specific compounds or entire classes of compounds. New efforts in Congress to evaluate chemicals using risk assessment and to evaluate regulations based on cost/benefit analysis should help in this process. Policymakers and regulators must have an informed understanding of the toxicity of chlorine and of the thousands of chlorinated compounds in use today. They must also have a more informed understanding of both the benefits and the difficulties associated with substitutions and outright bans.
The scientific community in industry, academia and government must continue to ensure that the future use of chlorine, PVC and other chlorinated chemicals is based on sound science, thoughtful risk assessment and cost/benefit analysis, along with full consideration of health and environmental factors.

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