RACHEL'S FOLLY

THE END OF CHLORINE

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OVERVIEW

The environmentalists are right about one thing: Dirty water kills. Millions are people are dying needlessly all over the world because of it. But are the main culprits man-made pollution and chlorinated chemicals? Try endemic poverty, bad plumbing and lack of access to basic water chlorination techniques. Every year, nearly 1.5 billion people — mostly children under five — suffer from preventable water-borne diseases such as cholera, typhoid fever, amoebic dysentery, bacterial gastroenteritis, giardiasis, schistosomiasis, and various viral diseases such as hepatitis A. Yet now there is a mounting campaign, led by environmental activists in wealthy industrialized nations, to eliminate every last man-made chlorine molecule from the face of the earth.

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Greenpeace, the international environmental advocacy group, launched the first salvo in 1991 with its call to phase out completely "the use, export, and import of all organochlorines, elemental chlorine, and chlorinated oxidizing agents (e.g. chlorine dioxide and sodium hypochlorite)."[1] As Greenpeace's Joe Thornton explains, "There are no uses of chlorine which we regard as safe."[2] Yet chlorination — considered one of the greatest advances ever in public health and hygiene — is almost universally accepted as the method of choice for purifying water supplies.[3] In the United States alone, 98 percent of public water systems are purified by chlorine or chlorine-based products. Alternative chemical disinfectants such as ozone and other short-lived free radicals have been used in water treatment, but none has demonstrated the safety and efficacy of chlorination.[4]

Chlorine is a ubiquitous element, one of the basic building blocks of all matter in the universe. In fact, scientists are only now beginning to discover and identify the great number of natural organohalogens present in our world. By one estimate, Mother Nature manufactures at least 1,500 chlorine-containing chemicals.[5] Volcanic activity, forest and grass fires, fungi, algae, ferns and the decomposition of seaweed all release chlorinated organics into the environment.[6] Our own bodies produce hypochlorite to fight infection and hydrochloric acid for proper digestion.[7] And there is, of

course, sodium chloride — common table salt — present naturally in mines, lakes and seawater, found in our blood, sweat and tears, and essential to the diets of humans and animals.

Clearly, a goal of total chlorine removal from the environment would be unattainable. And the potential human toll resulting from its eradication is manifest and staggering. Every major scientific investigation of chlorinated water has concluded that the real and proven health risks from microbial contamination of drinking water far exceed the uncertain and hypothetical risks of cancer from chlorination and its byproducts. *Why, then, are governmental bodies around the world embracing Greenpeace's caprice — absolute zero tolerance for man-made chlorine — when the hazards to humanity are so explicitly large?*

The potential human toll resulting from chlorine's eradication is manifest and staggering.

Perhaps the answer can be traced back to the publication of Rachel Carson's *Silent Spring* in 1962. The book is a lyrical tract, the bible of the environmental movement. Carson was the first to bear witness against chlorinated hydrocarbons and other "elixirs of death" created by "the ingenious laboratory manipulation of molecules." She condemned these arrogant manipulations, prophesied a man-made cancer epidemic, and popularized the zero-based approach to regulating synthetic chemicals. A daunting theme runs throughout *Silent Spring* — that man's ingenuity would be his own worst enemy. And therein lies the essence of Rachel's folly. Carson and her intellectual heirs in the environmental movement embrace a mistaken vision of technology. It is an impaired vision that considers only the risks of industrial chemical compounds, and not the risks created by their absence.

As the late Aaron Wildavsky observed, there are few unalloyed good things in the world. Rarely does one find a substance that has benefits but not costs.[8] "Sunsetting" all uses of chlorine may reduce the hypothetical risks associated with such compounds as dioxin, DDT and PCBs. At the same time, however, a blanket ban on chlorine would increase the enormous risks of waterborne microbial infection here and in underdeveloped countries that can now barely afford chlorine disinfectants (let alone costly substitutes such as ozone or ultraviolet light treatment).

Even more daunting, a chlorine phase-out would halt the production of most plastics, pesticides and chlorine-containing drugs like chloroquine, a key anti-malarial drug; halogenated tetracycline-based antibiotics like chlortetracycline; and the family of halogenated antipsychotics such as chlorpromazine.[9] According to one industry-backed report, almost 85 percent of the pharmaceuticals manufactured worldwide require chlorine at some stage of production; 96 percent of crop-protection chemicals are chlorine-dependent.[10] From safe drinking water, clean swimming pools and pest-free crops, to flame retardants and food packaging, quality white paper

and bright socks, Saran wrap, plastic bottles, garden hoses, window frames and sturdy plumbing pipes, the end of chlorine would spell the end of modern civilization itself.

CHLORINE IN THE TIME OF CHOLERA

There is no plainer example of the health benefits of chlorine, and the health risks of its absence, than the cholera epidemic in Latin America. In February 1991, the first cholera outbreak to hit Peru since the turn of the century was reported.[11] According to the journal *Nature*, U.S. and international health officials blamed the occurrence on Peruvian government officials who made a "gross miscalculation" in not chlorinating the water supply.[12]

Local water officials in Lima had decided to stop chlorinating many of the wells because U.S. Environmental Protection Agency (EPA) studies conducted in the mid-1980s showed an increased hypothetical cancer risk from trihalomethanes (THM), a chlorination byproduct. One of those studies (based on high-dose experiments on animals exposed over their lifetimes) estimated a risk of up to 700 additional cancer cases per year in the U.S. from THMs; by contrast, however, the Latin American cholera epidemic claimed nearly 4,000 lives in 1991 alone.[13]

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EPA administrators denied that risk communication failures on their part could be faulted for touching off the epidemic. Many researchers, however, questioned whether EPA should have given more emphasis to the disaster potential of not disinfecting municipal water supplies.[14] Whatever the actual impact EPA calculations had in Lima, a follow-up study in Peru's second largest city, Trujillo, pointed to the two bottom-line causes of the outbreak and its rapid spread. Plain and simple, they were lack of chlorinators and a shortage of funds to buy them.[15]

Preliminary data examined by Mintz et al. suggest that intervention costs for point-of-use disinfection in developing countries is low: "The annual cost per family for both a special water storage vessel and (chlorinated) disinfectant, for the shortest estimated useful life of the vessel and the highest cost of hypochlorite, would be between $1.17 and $1.62, an amount affordable almost anywhere in the world."[16] In the March 1995 issue of *Journal of the American Medical Association,* the researchers endorsed the expanded use of sodium and calcium hypochlorite — deemed "relatively safe, easy to distribute and use, inexpensive, and effective against most bacterial and viral pathogens" — to prevent persistent waterborne disease.[17] In addition to cholera, these infectious diseases include typhoid fever, amoebic dysentery, bacterial gastroenteritis, shigellosis, salmonellosis, Campylobacter eteritis, Yersina enteritis, Pseudomonas infections, schistosomiasis, giardiasis and various viral afflictions, such as hepatitis A.

While non-chlorine disinfectants have been used to treat water on a limited basis, none has demonstrated the safety and cost-effectiveness of chlorination.

In a campaign to increase access to potable water in poor countries, the World Health Organization declared the 1980s the "Drinking Water Supply and Sanitation" decade. Access to proper chlorination, however, remains a major barrier and efforts to improve both municipal water treatment and home storage techniques continue. At last count, the WHO estimated that 25 million people — 70,000 per day, mostly children under five — die around the world each year from dirty drinking water. While non-chlorine disinfectants like iodine, ozone and short-lived free radicals have been used to treat water on a limited basis, none has demonstrated the safety and cost-effectiveness of chlorination.[18]

THE "CHLORINE KILLS" CAMPAIGN

As the Latin American cholera epidemic escalated, environmental activists a world away were building their arsenal against chlorine. Greenpeace, the international environmental advocacy group, launched the first salvo in early 1991 with its call to phase out completely "the use, export, and import of all organochlorines, elemental chlorine, and chlorinated oxidizing agents (e.g. chlorine dioxide and sodium hypochlorite)."[19] As Greenpeace's Joe Thornton concluded, "There are no uses of chlorine which we regard as safe."[20]

Dismissing the proven benefits of clean chlorinated water, the environmentalists focused attention instead on a short string of chlorine compounds such as polyvinyl chlorides (PVCs) used widely in modern consumer products and dioxin produced during bleaching by the pulp and paper industry. Greenpeace targeted the publishers of *Time* magazine and other major producers of chlorinated paper products from Canada to Ireland. They accused PVCs of being "uniquely damaging during production, use and disposal," and they claimed that all chlorinated chemicals could cause cancer and reproductive damage. In short, as Greenpeace's Thornton explained, "People should be considered innocent until proven guilty; chemicals should not."

Greenpeace's Joe Thornton has concluded, "There are no uses of chlorine which we regard as safe."

Trademark antics in the early days of the campaign included blockades of ships and railcars carrying chlorine, and the unfurling of sensational, simplistic banners with slogans like "Chlorine Kills!" and "Take the Poison Out of Paper." To underscore claims of environmental harm allegedly caused by chlorinated organic chemicals, activists sent a trawler called *Moby Dick* — aptly named after Melville's novel of a vengeful captain on an obsessive hunt — to tour the Great Lakes region in late summer 1991. *Moby Dick* took the anti-chlorine message to 40 cities; calls for a "zero discharge" policy escalated. Soon the cover of *E, The Environmental Magazine,* was asking "Is Chlorine Killing the Great Lakes?"

Inside, the magazine quoted Barry Commoner, who likened the proliferation of chlorine compounds in modern life to the Invasion of the Body Snatchers: "You can think of chlorinated biological compounds as aliens, and like aliens from outer space, the reason they cause problems is that they're readily assimilated into the normal chemistry of life. It's just like the movies."[21] Another doomsaying activist warned that "If we continue to use chlorine, the entire planet will become another Love Canal. We were able to evacuate Niagara Falls; we won't be able to evacuate the planet."

Initially, this far-out rhetoric about organochlorines was limited to a few green Ahabs in the environmental movement. But the concept of chlorine zero-discharge soon gained credibility with an endorsement from the venerable International Joint Commission (IJC).

The six-member IJC, a joint regulatory agency of non-scientists from the U.S. and Canada, was created in 1909 to monitor commerce on, and assess the water quality of, the Great Lakes. For most of its history, the panel refrained from alarmist policy pronouncements. In 1990, however, after emotional public hearings, demonstrations and intense lobbying efforts led by Greenpeace, the commission urged adoption of "a binational toxic substances management strategy" based on the "philosophy of zero discharge."[22] The panel's full-throttle endorsement of zero discharge was issued in 1992, when members called on both countries to "develop timetables to sunset the use of chlorine and chlorine-containing compounds as industrial feedstocks, and (examine) the means of reducing or eliminating other uses."[23] Two years later, the IJC redoubled its call — the most far-reaching by any government body.[24]

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What was the evidence that swayed the IJC to endorse a chlorine phase-out? Then-chairman Gordon Durnil, a lifelong Republican (with no prior scientific background) who was appointed to the commission by President George Bush in 1989, explained that he stayed up late at night reading studies to educate himself. He was appalled by various reports of breast cancer and reproductive harm in wildlife and humans which some scientists linked to industrial chemicals in the Great Lakes region. In his recent autobiography, Durnil confesses that, "The truth is, in the beginning of my tenure, I wanted to disbelieve. But being a good conservative, with the ability to think for myself instead of being told how to think, I was willing to change my way of thinking. Evidence is evidence and facts are, indeed, facts."[25]

There is nothing wrong with putting capable non-scientists in charge of fact-finding missions. But Durnil and his colleagues proved to be incapable of making the critical distinction between possibility of harm and probability of harm. They ignored studies that failed to bolster environmentalists' worst-case scenarios. They failed to consider the costs and risks associated with drastic regulatory action. And they succumbed to the

environmental movement's bad habit of assuming harm, rather than assessing it. As a result, the IJC concluded that it had become "necessary to shift the burden of responsibility for demonstrating whether substances should be allowed in commerce. The concept of reverse onus, or requiring proof that a substance is not toxic or persistent before use, should be the guiding philosophy of environmental management agencies in both countries..."[26]

This endorsement of a mathematically and scientifically impossible standard of proof, i.e. proving a negative, did not exactly go over well with responsible toxicologists. Environmental activists, however, were ecstatic. As Greenpeace's Rick Hind, legislative director of the Toxics Campaign, told Science reporter Ivan Amato, "The IJC lit up our life."[27]

The IJC concluded that the concept of reverse onus, or requiring proof that a substance is not toxic or persistent before use, should be the guiding philosophy of environmental management.

Indeed, the IJC's "sunset" proposal sparked governmental bodies and public health groups around the world to adopt zero tolerance policies that echoed Greenpeace's initial call to phase out chlorine. In September 1992, the Paris Convention on the North Sea — a European analogue of the IJC representing 13 nations — endorsed a ban on chlorine emissions in the northeast Atlantic Ocean. The Canadian provinces of Ontario and British Columbia enacted regulatory timetables to reduce chlorine use in the paper and pulp industry to zero by the year 2002.

In the U.S., 1993 proved a watershed year for anti-chlorine activists. At the beginning of the year, the Clinton administration weighed in with a Clean Water Act initiative to develop a "national strategy for substituting, reducing or prohibiting the use of chlorine and chlorinated compounds."[28] By summertime, Rep. Bill Richardson (D-NM) had offered up the "Chlorine Zero Discharge Act of 1993." Copping language used by the IJC (which was in turn copped from Greenpeace), the proposal called for a total phase-out of chlorine in the pulp and paper industry — i.e., "absolutely no output or release, including nonpoint source output or release, into water."[29]

Anti-chlorine activists were also buoyed by an endorsement from the American Public Health Association (APHA). In October 1993, the group of 30,000 public health professionals passed a divisive resolution calling for treatment of chlorine-containing organic compounds as a class. It recognized, as had the IJC, "that the only feasible and prudent approach to eliminating the release and discharge of chlorinated organic chemicals and consequent exposure is to avoid the use of chlorine and its compounds in manufacturing processes."[30] Echoing almost verbatim the Greenpeace philosophy, APHA spokesman Peter Orris declared that "The APHA has found that the class of chlorine-containing chemicals should be considered guilty until proven innocent."[31]

Did the vote reflect the true assessment of APHA? The membership had considered the resolution once before — and rejected it; several years of in-fighting preceded adoption of the new position. The APHA leadership,

like the IJC's, apparently succumbed to intense pressure from environmental lobbyists. In fact, Greenpeace publicized the APHA resolution for the organization after it was passed at the APHA's annual meeting in San Francisco.[32]

Other environmental groups joined the clamor for a chlorine phase-out. The National Wildlife Federation, for example, called on the White House to support a sunset provision, and noted that "the administration's commitment to promulgate a final strategy for substituting, reducing, or prohibiting the use of chlorinated compounds within two and a half years is critical."[33] The Environmental Defense Fund, Friends of the Earth, National Audubon Society and others wrote to President Clinton to express their "alarm and frustration" with the administration's delay on an executive order mandating government use of "totally chlorine-free" paper.[34] And the Sierra Club called for "immediate action to stop exposing men, women and children to these poisons. Regulation of [dioxin and other chlorinated] chemicals as a class is the only way that we can adequately address this issue."[35]

The National Wildlife Federation called on the White House to support a sunset provision.

In the spring of 1995, Rep. Richardson resurrected the Chlorine Zero Discharge Act with even more conviction: "Federal intervention to ensure that the use of these unnecessary, dangerous chemicals is eliminated is needed now to protect the public from potentially life-threatening health and environmental impacts."[36] But just as the environmentalists seemed poised to score major legislative triumphs in the U.S., however, institutional momentum slowed. The proposed executive order mandating government use of "totally chlorine-free" paper was withdrawn; the EPA's call for a chlorine study leading to product bans was put on hold. Richardson's proposal, H.R. 1400, is currently pending before the House Transportation Subcommittee on Water Resources and the Environment. Thirty-seven co-sponsors have signed on.

Meanwhile, the Latin American cholera epidemic entered its fourth year with nearly 1 million cases and 10,000 deaths directly attributable to dirty water and lack of chlorine disinfectants.[37]

STOMACH PAINS

In the chlorination process, chlorine reacts mainly with natural water constituents to produce a complex mixture of byproducts, including a wide variety of halogenated compounds, the actual levels of which depend on the amount of chlorine added and the type of water source.[38] Besides trihalomethanes (which include chloroform, bromodichloromethane, chlorodibromomethane and bromoform), other chlorination byproducts include halogenated acetic acids, chlorinated ketones and chlorinated furanones.

The idea that chlorination byproducts in disinfected water cause cancer has gained widespread currency among the popular press and many environmentalists in wealthy developed countries. But the evidence of harm is weak. A review of studies published in the *Journal of the National Cancer Institute* found only equivocal evidence for carcinogenicity in female rats that received chlorinated or chloraminated drinking water seven days per week for two years in amounts ranging from 70 to 275 parts per million (ppm) and 50 to 200 ppm respectively; there was *no* evidence of carcinogenic activity in male rats or male and female mice administered the same amounts.[39] By way of comparison, the EPA-regulated permissible residual level for chlorine in water is 1.5 ppm, and for chloramine, 4 ppm.[40]

While the Environmental Protection Agency has long contended that the carcinogenicity of chloroform (the most common THM) is substantial, the most up-to-date research has cast serious doubt on the agency's cancer estimates — and its primary method of inducing tumors in animals. Conventional EPA analysis suggests that an increased human cancer risk of 1 in 100,000 can be expected from drinking water containing 4.3 parts per billion of chloroform over a lifetime. The basis for this estimate? Mouse experiments using a technique called "gavage" in which large globs of chloroform dissolved in corn oil were pumped into the animals' forestomachs through a tube forced down the throat, five times a week over a 2-year lifespan.

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Unsurprisingly, a group of private researchers discovered that cell damage due to the unusual administration of such high doses of chloroform caused excess liver cancer in the genetically tumor-prone mice. In their own animal studies of chloroform administered normally in drinking water, toxicologist Byron Butterworth et al. found no induced cellular proliferation in rodent livers even when the concentration of chloroform was 1,800,000 parts per billion (or 1,800 ppm) — an amount several orders of magnitude above current regulatory limits.[41] (The current total limit for THMs is 100 micrograms per liter; the occupational limit is 2 ppm for an 8-hour day.) As Butterworth noted, "our studies thus far indicate no increased risk of cancer from the levels of chloroform found in drinking water."[42] In scientific journals (but not the lay press), even the EPA conceded that their estimates were wrong. EPA toxicologist Rex Pegram admitted that "Butterworth's work has gone a long way toward showing us that chloroform is not the worry it once was."[43]

INDEFINITE EXPOSURE

Epidemiological evidence of harm from chlorinated byproducts in drinking water is no more convincing. The International Agency for Research on Cancer (IARC) concluded, after exhaustive review, that epidemiologic studies on the relationship between cancer and consumption

of chlorinated drinking water were inadequate to draw definitive conclusions.[44] After evaluating scores of both animal and human studies, IARC rated chlorinated drinking water "not classifiable" as to its carcinogenicity. Among the many exposure-related difficulties in making any connection between harm and consumption:

- Correlation studies are generally of uncertain validity. Exposure variables assessed for whole communities do not necessarily reflect exposure of individuals.

- In both correlation and case-control studies, information on the nature of the water source and chlorination status was obtained after or contemporaneously with the period over which cancer occurrence was measured. Because of the long latency between exposure and disease, it is better to correlate cancer rates with characteristics of water supplies identified before cancers occurred.

- Most studies didn't address the problem of migration in and out of studied communities over time.

- Recall bias was hard to remedy. Limited availability of water supply records hampered efforts to verify recollections.

- Water consumed outside the home, as well as the daily quantity of water consumed, were rarely taken into account.

- Exposure misclassification was common. Surrogates such as surface water, well depth and residence in community with chlorinated water supply can be used — but if these do not reflect exposure to chlorinated water during possibly relevant time periods for the etiology of cancers in question, they will result in misclassification of subjects by exposure and will introduce bias.

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As the IARC monograph noted, "even in the best studies, errors in exposure measurement may still be a problem."[45] Moreover, chlorinated water is different in different locations and cannot be considered to be the same entity. The relationship between chlorine dose and organic carbon present greatly affects the by-products formed; this in turn complicates the evaluation of whether chlorine residue maintained in chlorinated waters or byproducts of chlorination are responsible for any effects observed epidemiologically.

A more recent "meta-analysis" of studies on chlorination, chlorination byproducts and cancer "suggests a positive association" between consumption of chlorination byproducts in drinking water and bladder and rectal cancer in humans.[46] The authors estimated that 9 percent of bladder cancers and 18 percent of rectal cancers per year are associated with the consumption of chlorinated water. However, the analysis acknowledges many of the same problems with exposure assessment noted by IARC — namely, inadequate information about the environment to which a subject was exposed (the source of tap water), the level of the proposed agent present

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in the environment (concentrations of chlorinated byproducts in the tap water), and the degree to which the person was exposed to that environment (the amount of tap water consumed). In addition, the studies failed to adjust for diet as a confounding factor.

Finally, the authors emphasized that "Our findings are in no way intended to suggest that the disinfection of drinking water should be abandoned. The potential health risks of microbial contamination of drinking water greatly exceed the risks described (in the study). . ." It is an important caveat repeatedly issued by researchers — and repeatedly ignored by environmentalists and the media.

IT'S ELEMENTARY

As Greenpeace activist, Christine Houghton, sees it: "Since its creation, chlorine has been a chemical catastrophe...It's either chlorine or us."[47] Yet chlorine is an ubiquitous element, one of the basic building blocks of all matter on the planet. (In its elemental state, chlorine is a greenish-yellow gas formed by passing electricity through salt water.) The chemical industry manufactures over 15,000 different chlorine-containing compounds; Mother Nature produces at least 1,500 more.[48] In fact, scientists are only now beginning to discover and identify the great number of natural organohalogens present in our world.

Volcanic activity, forest and grass fires, fungi, algae, ferns and the decomposition of seaweed all release chlorinated organics into the environment.[49] The smoke of burning wood alone contains more than 100 orga-

Figure 1 — Chlorine in Nature

Natural Chlorinated Organic Chemical	Source
2,3,7,8 tetrachlordibenzo-p-dioxin	Forest and brush fires
2,4 dichlorophenol	Produced by lone star tick as sex pheromone
2,5 dichlorophenol	Secreted by grasshoppers
Methyl chloride	Marine algae, kelp, wood-rotting fungi
Hydrogen chloride	Volcanoes
Hypochlorite	White blood cells
Jydrochloric acid	Produced by stomach in humans to aid proper digestion

nochlorine compounds, including polychlorinated dioxins and polychlorinated dibenzofurans; the total annual global emission rate of chlorinated organic chemicals is 5 million tons.[50] By comparison, annual anthropogenic emissions total only 26,000 tons.[51] Our own bodies produce hypochlorite to fight infection and hydrochloric acid for proper digestion.[52] And there is, of course, sodium chloride — common table salt — present naturally in mines, lakes and seawater, found in our blood, sweat and tears, and essential to the diets of humans and animals. Even if Greenpeace's wish came true and all man-made sources of chlorine were shut down, natural mass production of compounds containing the condemned atom would continue undaunted (see Figure 1).

Almost 85 percent of the pharmaceuticals manufactured worldwide require chlorine at some stage of production.

The "trouble" with chlorine is its sex appeal. Negatively-charged chloride ions have a high electron affinity that make them irresistibly attractive to other electron-rich atoms — most notably, carbon. Together, carbon and chlorine can be synthesized into a vast number of molecular structures called organochlorines. These and other chlorine-dependent processes and compounds, including polyurethanes, polycarbonates, epoxy resins, Saran wrap, insulation for electrical equipment, titanium dioxide (which whitens paint and toothpaste), silicones, and dry cleaning solvents, are integral to modern life. According to one industry-backed report, almost 85 percent of the pharmaceuticals manufactured worldwide require chlorine at some stage of production (see Figure 2); 96 percent of crop-protection chemicals are chlorine-dependent; and up to 60 percent of all commercially produced chemistry depends on chlorine that can be added to, or removed from, other elements with ease and specificity.[53]

The long-lasting bonds that make some of these compounds so useful to humanity also make them baneful to environmentalists. As a writer for

Figure 2 — Uses of Chlorine in Pharmaceuticals

Chlorinated Compound	Pharmaceutical Product
Dimenhydrinate	Nausea preventatives
Pseudoehdrine hydrochloride	Decongestants
Procaine hydrochloride	Local anesthetics
Chloroquine	Anti-malarial drug
Chlortetracycline	Antibiotics
Chlorpromazine	Antipsychotics
Diphenhydramine hydrochloride	Antihistamine, cold and allergy treatments

Sierra magazine explained it rather darkly, "The hallmark of organochlorines is their tendency to bioaccumulate, and to pass from one generation to the next through the placenta. They are, in this respect, the molecular version of Original Sin."[54]

Sinful? Not exactly. It is true that chlorine's attractiveness to electrons tends to stabilize some chemical structures so that they don't break down easily. Some chlorinated chemicals persist for long periods until swept up into the stratosphere, where ultraviolet light helps break them into molecular fragments that destroy ozone. Others may persist in human fat tissue, where they may accumulate. As Willes et al. point out, however, the vast differences among chlorinated organic chemicals with respect to their physical and chemical properties and behavior in the environment preclude the generalization that all organic chemicals containing chlorine behave similarly in the environment and act as persistent, bioaccumulative chemicals.[55]

Even environmentalist icon Mario Molina has dismissed the movement to ban chemicals as a class: "It isn't taken seriously from a scientific point of view."

CHEMICAL CONVICTS

Underlying the attack on chlorine is that since we "know" that some of these chemicals, such as DDT and dioxin, are so terribly harmful to humans, we might as well ban the whole spectrum. As self-styled "conservative environmentalist" Gordon Durnil, former chairman of the International Joint Commission, explains: "We decided you can't distinguish among different compounds of chlorine as to which is harmful and which is not . . . . We decided we needed to look at chlorine as a class and decided because of the effects of dioxin, that use of chlorine as (an industrial) feedstock should be sunset."[56] But even if the cases against one or two chlorinated compounds were proven, it would hardly make sense to wipe out an entire element in the periodical table because of a few proven culprits within the huge spectrum known as organochlorines. "Guilty-until-proven-innocent" has no place in the law or the courts — neither should it have one in science or public policy. The stakes for humanity are just too high.

A typical argument for class action against chlorinated chemicals, as illustrated by Greenpeace's Claire O'Grady Walsh, goes something like this: "Seveso, Bhopal, the ozone hole, the greenhouse effect, Agent Orange, dioxin, DDT, PCBs, have one thing in common — chlorine."[57] From there, the hanging judges argue that "trying to regulate thousands of organochlorine poisons one-by-one is doomed to failure. The phase-out strategy needs to be applied to the root cause — chlorine."[58] Trial over. Case closed. But as Philippe Shubik, cancer researcher and toxicologist at Oxford University, observes: "Any scientifically based toxicologist finds that kind of general approach abhorrent."[59] Even environmentalist icon Mario Molina, an atmospheric chemist at the Massachusetts Institute of Technology who first pointed out the link between chlorofluorocarbons and ozone depletion, has

dismissed the movement to ban chemicals as a class: "It isn't taken seriously from a scientific point of view," he told *Science* magazine.[60]

On appeal, it is clear that many of the members of Greenpeace's chlorinated chemical chain gang are victims of a bum rap:

DDT

DDT (dichloro-diphenyl-trichloro-ethane) was essentially the first modern pesticide. It replaced highly toxic pesticides based on heavy metals, dramatically improved crop yields in America and abroad, and was instrumental in virtually wiping out malaria in this country and many others by destroying mosquito populations. Indeed, it has been credited with saving over 100 million lives worldwide. But the pesticide's fate was sealed when it became no longer a chemical but a symbol. Rachel Carson made it so in *Silent Spring,* although ironically she said that as bad as DDT was, other pesticides made it seem harmless in comparison. Neither did she implicate DDT as a carcinogen.

We know that whatever harm DDT may have caused, ceasing its use in many countries was absolutely catastrophic.

Despite Carson's being demonstrably wrong on a number of important issues (for example, she said that DDT threatened the robin with extinction, even as the increase in DDT usage coincided with a huge increase in the robin population), establishing the lethality of DDT has become an environmentalist obsession on par with *The Nation's* effort to clear the name of Alger Hiss. They got it banned all right, but had to cheat a bit to do it. Then-EPA Administrator William Ruckelshaus established the agency's anti-science reputation in 1972 by overriding the decision of the hearing examiner who surveyed 9,000 pages of documents from 125 expert witnesses on all sides of the issue. Among the examiner's recommended findings, conclusions, and orders:[61]

- DDT is not a carcinogenic hazard to man.
- The adverse effect on beneficial animals from the use of DDT under the registrations involved here is not unreasonable on balance with its benefit.
- The Petitioners have not met fully their burden of proof.
- There is a present need for the continued use of DDT for the essential uses defined in this case.

In defiance of these recommendations, Ruckelshaus ordered a virtual ban on all uses of DDT effective January 1, 1973. His Final Order stated boldly that "The evidence of record showing storage [of DDT] in man and magnification in the food chain, is a warning to the prudent that man may be exposing himself to a substance that may ultimately have a serious effect on his health.[62] Yet his decision was based neither on existing research, nor on the examiner's findings — which Ruckelshaus himself failed to read.

With regard to the decline of raptor and pelican populations in the 1950s and 1960s (as well as the thinning of their eggshells), a majority of scientists agree that DDT contributed to these adverse effects. But in the opinion of the hearing examiner, these adverse effects were "not unreasonable on balance with" DDT's benefit. Since the curtailment of its use, declining tissue concentrations in wildlife species like the bald eagle and brown pelican have resulted in some degree of population recovery. These recoveries provide evidence, as Willes et al. point out, "that any adverse effects of these chemicals are reversible and appear to be dose-related."[63] In other words, they refute environmentalists' claims that chlorinated organic chemicals cause irreversible effects and have no carcinogenic thresholds.

We know that whatever harm DDT may have caused, ceasing its use in many countries was absolutely catastrophic. Well-documented is the case of Sri Lanka, in which 2.8 million malaria cases per year in 1948 dwindled to but 17 cases after 15 years of DDT spraying. But after spraying was stopped in 1964, as a direct result of Carson's book, malaria cases quickly shot back up to almost their original level. Moreover, as DDT was phased out and alternatives such as the organophosphate parathion phased in, mortalities increased significantly among farm workers. In addition to being more highly toxic in minute doses, these substitutes were more expensive and required more frequent applications than the vilified DDT.

Substitutes must be safe, affordable and cost-effective — not merely chlorine-free — in order to do more good than harm.

Synthetic pyrethroids were developed over time to replace DDT as safe and effective alternatives, but they were not marketable in time to prevent the health and economic damage that the hasty DDT ban wrought. Now environmentalists are seeking a worldwide phaseout of DDT. But as Salif Diop, a Senegalese delegate to the United Nations pointed out recently, "In our countries we need chemicals like DDT to fight malaria. If you want a global ban, then you must come up with alternatives."[64] These substitutes must be safe, affordable and cost-effective — not merely chlorine-free — in order to do more good than harm.

PCBs

PCBs (polychlorinated biphenyls) were once widely used as liquid coolants, lubricants and insulators in industrial equipment, e.g., power transformers. Following a high-profile tragedy in Kyushu, Japan, where over 1,000 people contracted skin disorders from eating rice oil contaminated with high doses of PCB, researchers began to search for PCB residues in the environment. Despite lack of evidence at the time showing that trace amounts of PCBs in wildlife were causing harm, the mere presence and durability of the chemical provoked immediate regulatory activity.

At first, the Food and Drug Administration took smart action — weighing both the health and economic costs and benefits of a ban, the

agency decided instead to set practical tolerance levels of PCBs in fish. It noted in a standard-setting document that a complete ban on PCB residues would "unnecessarily deprive the consumer of a portion of his food supply and disrupt the Nation's food distribution system."[65] Pressure from environmental groups for zero tolerance mounted, however, and in October 1976, President Gerald Ford signed the Toxic Substances Control Act — which required a complete phase out of all production and sales of PCBs — into law.

Dioxin was long touted as "the most deadly chemical created by man."

Evidence from animal studies was equivocal. Rats fed levels 5,000 times the regulatory limit for humans developed excess liver tumors. Ignored was the fact that test rats actually had fewer reproductive-system cancers than expected, making their overall cancer rate no higher than that of untreated rats.[66] Reproductive effects of PCBs in high doses among monkey species were similarly mixed. Meanwhile, epidemiological studies among workers exposed to PCBs for prolonged periods have proved inconclusive. Studies conducted by the National Institute for Occupational Safety and Health on workers who inhaled or absorbed PCBs through their skin over many years have shown no adverse human health effects.[67] One recent study even showed slightly lower rates of cancer deaths and deaths in general than expected.[68] Nevertheless, the EPA continues to require the diversion of billions of dollars to eradicate virtually all traces of PCB residues in soil under the conservative assumption that some amount somewhere might potentially cause harm to a dirt-ingesting toddler who, even if exposed to 10 ppm per day, would absorb 125,000 times less than the amount in the daily diet associated with increased cancer incidence among two strains of rats.

Dioxin

For 15 years now, the EPA has clamped down on dioxin, a byproduct of paper bleaching and of incineration of certain materials. Until it was banned as such, it was also a byproduct in the manufacturing of some herbicides, including the notorious Agent Orange. Ever since the chemical was found to be horribly toxic to guinea pigs — albeit far less so to every other animal species tested, including other rodents — the EPA and other environmental organizations have relentlessly attacked it as they have no other chemical save the pesticide DDT. Fear of dioxin contamination led to the evacuation of Love Canal and Times Beach, Mo., and to telling Vietnam vets that they may be at extraordinary risk of disease.

"No human illness, other than the skin disease chloracne, which has occurred only in highly exposed people, has been convincingly associated with dioxin."

But while dioxin was long touted as "the most deadly chemical created by man," decades of scientific scrutiny have found that its only acute human effect is a form of acne. As dioxin expert Dr. Michael Gough noted:

> 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.[69]

The case against dioxin for threatening people is almost as suspect as that against DDT, but this doesn't bother environmentalists. For years they charged that dioxin was a powerful human carcinogen but epidemiological studies failed to back them up. So quietly they began to shift the accusation from the "most deadliest" carcinogen known to man, to the most potentially damaging to unborn children, immune systems and hormones.

A recent dioxin assessment report by the EPA made the shift official. In addition to the old charge of dioxin being a possible human carcinogen — causing as many as one in 1,000 human cancers — the EPA added two newer charges: that it might affect human children in the womb and that it could compromise immune systems at levels approaching those to which Americans are currently exposed. While those human exposure levels are infinitesimal compared to our exposure to many other chemicals, the EPA maintained that what causes illness in some animals at huge doses must also cause sickness in humans at tiny ones.

The assault on chlorine has recently focused on its alleged gender-bending characteristics.

But several scientists at the meeting challenged the EPA's assumption, used in all its policy-making, that there is no threshold below which a harmful chemical causes no harm. One was the University of Wisconsin's Alan Poland, widely known for his discovery of the " dioxin receptor," the molecule in cells to which dioxin must bind before it produces any affects. He said 150 years of science contradicted the EPA no-threshold position.

Regarding dioxin, Mr. Poland said the normal level to which Americans are exposed — four molecules of dioxin per cell — is far below the number required to have an effect, considering that there are about 10,000 receptor molecules per cell. One EPA official complained that the board meeting had unfairly been characterized as negative. In fact, he said, the only problems the SAB found were with the ninth chapter. Of the first eight, it was highly complimentary.

But that's just the point. The first eight chapters were written by scientists outside of the EPA. Only the last chapter, the conclusive one, the one from which EPA was to draw its regulatory policy and from which the media drew the headlines, was the one written by the EPA itself. In that chapter, said Mr. Poland at the meeting, "policy masquerades as science." "This is probably the best data set that the EPA will see in my lifetime," Mr. Poland added. "Yet, despite all of that, the first eight chapters are thrown away."[70]

Board members repeatedly accused the EPA of picking and choosing its data. For example, the largest, most-heavily studied group of persons with known high exposure to dioxin were the members of Operation Ranch Hand, the men who did the actual spraying of Agent Orange on the jungles of South Vietnam. The EPA report duly noted any possible minor abnormality in this group. But it neglected to say the Ranch Handers were strapping specimens of healthy humanity. "The EPA didn't mention that there were no more cancers than would be expected, no affects on the immune and nervous systems, no increase in deaths, and no increased birth defects in their children," SAB member and Office of Technology Assessment official Michael Gough noted. "They mentioned nothing that didn't serve their purpose."[71]

Also unmentioned were follow-up studies conducted in Seveso, Italy, where 37,000 people were exposed to high doses of dioxin following the explosion of an unattended chemical reactor. As the Institute of Occupational Health at the University of Milan found, there were "no increased birth defects due to dioxin exposure."[72] Furthermore, cancer mortality rates were inconclusive.

The balance of evidence does not support a causal association between exposure to organochlorines and increased human breast cancer incidence.

One SAB member, Dr. Knute Ringen of the Center to Protect Workers' Rights in D.C., concluded: "I think that the agency has pretty much come to the end of the line with regard to producing useful decision-making information on dioxin, and that it's time to go on to something else."[73]

GENDER WARS

The assault on chlorine has recently focused on its alleged gender-bending characteristics. Chlorinated organic compounds bind to estrogen receptors in cells, the theory goes, which may lead to changes in those cells, tissues or organs.

Environmentalists blame process-related organochlorines such as dioxin for altering the sexual characteristics of fish. In particular, chlorinated dioxins and furans from pulp mill effluent have been identified as culprits in causing sex changes among fish.[74] As Willes et al. note, however, there is increasing evidence that something other than the usual chemical suspects may be largely responsible for the effects noted — namely, natural plant sterols (phytosterols), which were implicated as a causal factor in the masculinized female mosquitofish observed in a northwest Florida stream receiving pulp and paper mill effluent.[75]

Environmental estrogens have also been accused of causing breast cancer in women. In 1993, a highly publicized report in the *Journal of the National Cancer Institute* found that DDE (a metabolite of the estrogenic pesticide DDT) was present in higher concentrations among a small popula-

tion of Long Island breast cancer victims when compared to a control group.[76] Concentrations of DDE were about 35 percent higher in the women with cancer than in the controls.

It is possible that high blood levels of DDE increase the risk of breast cancer, but the link probably runs in the opposite direction. Chronic diseases like breast cancer mobilize fat from fat storage deposits, which contain fat soluble compounds like DDE. As a result, blood concentration levels of DDE increase. Moreover, certain drugs can also increase blood levels of DDE. In short, despite the media's conventional wisdom, the 1993 *JNCI* study does not prove a causal relationship between DDE and breast cancer.

A larger study also published in *JNCI* reported no association between breast cancer and higher levels of either DDE or PCBs.[77] As toxicologist Michael Gallo of the Robert Wood Johnson Medical Center at Rutgers University noted: "The scare was that these estrogens were so potent that they were causing an increased incidence in breast cancer. This latest study quieted down those fears."[78]

Perhaps the most potent weapon in the anti-chlorine activists' arsenal has been the charge of falling sperm counts.

While several other publications have reported increased concentrations of bioaccumulative organochlorines in human tissues, there is no consistency among these various studies in the association of the increased tissue concentrations and specific human diseases.[79] Nor have increased mammary tumors been shown in laboratory studies, where doses and confounding factors are much easier to control in comparison to epidemiological studies. In short, the balance of evidence does not support a causal association between exposure to organochlorines and increased human breast cancer incidence.

In fact, women produce far more of their own estrogen than they could ever possibly absorb from the environment. Background levels of synthetic estrogens are dwarfed by the body's own production of estradiol. To put it in proper perspective, toxicologist Stephen Safe of Texas A & M University notes that "The average human exposure to estrogens is 99.999 percent from natural sources" such as fruits and vegetables.[80] Even giving women extra doses of their own estrogen, either as post-menopausal hormone therapy or as birth-control pills, increases cancer risk either slightly or not at all.

Safe also points out that some organochlorines such as 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) actually exhibit anti-estrogen activity that may counteract adverse health effects including breast cancer. As he reported at the 1994 annual meeting of the Society of Toxicology, data from several studies of a protein in cells found in breast cancer tumors show that TCDD can block production of the targeted protein. "Dioxin in combination with estrogen blocks all of these (estrogen) responses," Safe told the audience.[81] Other organochlorines such as DDT and PCBs may also act as anti-estrogens.

THE MISMEASURE OF MAN

Perhaps the most potent weapon in the anti-chlorine activists' arsenal has been the charge of falling sperm counts. The alarm over chemically-induced male infertility was prompted by a 1992 study from Copenhagen that claimed to show that sperm concentration per unit volume had fallen by over 40 per cent from 1940 to 1990.[82] A year later, one of the authors of the study, Niels Skakkebaek, penned a follow-up piece with Richard Sharpe of the British Medical Research Council Reproductive Biology Unit in Edinburgh, Scotland, in the journal *Lancet.* The duo speculated that fetal exposure to synthetic estrogens may be the prime suspect in the sperm count crisis.[83]

Unsurprisingly, the *Lancet* article prompted a barrage of alarmist media reports. The BBC aired a documentary entitled "The Assault on the Male;" here in the U.S., Connie Chung devoted her now-defunct investigative show, "Eye to Eye," to the plight of infertile men under chemical siege. As scientists have noted, however, the original study — a "meta-analysis" of 61 studies on falling sperm counts — suffered from numerous statistical and methodological shortcomings.

"There is no conclusive evidence" for blaming exposure to estrogenic chemicals in the environment for falling sperm counts or shrinking penises.

First, the Danish researchers included studies irrespective of their sample size, many of which were so small that they would not normally be considered admissible evidence.[84] In an editorial for the *British Medical Journal,* Stephen Farrow of Middlesex University's Health Research Center noted that one study was of seven men; 11 others were of fewer than 20 men; and another 29 were of fewer than 50 men.[85] These were "given greater weight than they deserved," Farrow wrote, through the misapplication of statistical tests.[86]

After investigating the Skakkebaek data, a different team of researchers showed that nearly all of the alleged decreases could be explained by the changing definition of a normal sperm count over the past 50 years.[87] Bromwich et al. concluded in a study also published by the *BMJ* that "The original evidence does not support the hypothesis that the sperm count declined significantly between 1940 and 1990."[88]

Furthermore, critics who reanalyzed the data have challenged the timing of the decline reported. As reproductive specialists Anna Brake and Walter Krause of Philipps University in Marburg, Germany explained in a letter to the *BMJ,* 48 of the studies used in the meta-analysis were published since 1970 — accounting for 88 percent of the men studied.[89] These studies actually showed a slight *increase* in sperm counts. Krause and Brake concluded that "care should be taken when discussing a causal relation with environmental factors."[90]

The plea for caution fell upon deaf ears at Greenpeace headquarters. Seizing on the Skakkebaek findings, the environmental group launched a

new advertising campaign that publicized the alleged environmental threat to man's virility. "You're not half the man your father was," the ads taunted.

Responsible scientists assailed environmentalists for exploiting the data. As one set of outraged researchers argued, "there is no conclusive evidence" for blaming exposure to estrogenic chemicals in the environment for falling sperm counts or shrinking penises.[91] The hypothesis "is based on evidence too limited to allow firm conclusions to be drawn. It is premature to call for a ban on these or any other chemicals before more research is done. They are misrepresenting this research. They are taking something which is a clearly stated hypothetical link and calling it fact."[92] The identity of these critics? None other than Neils Skakkebaek and Richard Sharpe, whose research prompted the sperm scare in the first place.

RACHEL'S FOLLY

"The prescence of a significant degree of chlorination is not, of itself, sufficient to confer bioaccumulative potential on a compound."

In *Silent Spring,* Rachel Carson was the first to bear witness against chlorinated hydrocarbons like DDT and other "elixirs of death" created by "the ingenious laboratory manipulation of molecules." She condemned these arrogant manipulations, prophesied a man-made cancer epidemic, and popularized the zero-based approach to regulating synthetic chemicals. But there is nothing magical nor artificial about attaching a chlorine atom to a carbon atom, which is all a chlorinated hydrocarbon is. Some chlorine-based compounds like DDT may persist in body fat year after year; some do not. Some cause cancer in laboratory animals fed massive doses; others do not.

Chlorinated compounds comprise all major chemical classifications, including inorganic salts and acids, aromatics and aliphatics. As Willes et al. point out, "the prescence of a significant degree of chlorination is not, of itself, sufficient to confer bioaccumulative potential on a compound."[93] PCBs, chlorinated dioxins, chloroform, and trichlorophenol all may share a chlorine link, but vast differences in their physical and chemical properties lead to vastly different behavior in the environment.[94] Depending on the position and number of substitutions, adding a specific chlorine group to an organic molecule may increase or reduce the chemical reactivity of that molecule. Thus, the attempt to eliminate arbitrarily an entire class of chemical compounds based on a few "bad" molecules is sweepingly overbroad.

A daunting theme runs throughout *Silent Spring* — that man's ingenuity would be his own worst enemy. And therein lies the essence of Rachel's folly. Carson and her intellectual heirs in the environmental movement embrace a mistaken vision of technology. It is an impaired vision that considers only the risks of industrial chemical compounds, and not the risks created by their absence. Like the Luddites before them, modern environmentalists look at only one side of the risk equation.

But as the late Aaron Wildavsky observed, there are few unalloyed good things in the world. Rarely does one find a regulation that has all benefits and no costs, or a substance that poses risk without benefits.[95] "Sunsetting" all uses of chlorine may reduce the hypothetical risks associated with such compounds as dioxin, DDT and PCBs. At the same time, however, a blanket ban on chlorine would increase the enormous risks of waterborne microbial infection here and in underdeveloped countries that can now barely afford chlorine disinfectants (let alone costly partial substitutes such as ozone or ultraviolet light treatment).

Even more alarming, a chlorine phase-out would halt the production of most plastics, pesticides and chlorine-containing drugs like chloroquine, a key anti-malarial drug; halogenated tetracycline-based antibiotics like chlortetracycline; and the family of halogenated antipsychotics such as chlorpromazine.[96] From safe drinking water, clean swimming pools and pest-free crops, to flame retardants and food packaging, quality white paper and bright socks, Saran wrap, plastic bottles, garden hoses, shower curtains, credit cards, window frames and sturdy plumbing pipes, the end of chlorine would spell the end of modern civilization itself.

Like the Luddites before them, modern environmentalists look at only one side of the risk equation.

THE HIGH PRICE OF "PRECAUTION"

Chlorine's critics argue that we can't wait for the scientific evidence to roll in. Demonstrating this "ban now, ask questions later'' approach, a 1993 Greenpeace report attempting to link chlorine and breast cancer declared: "If proof is defined as evidence, beyond any doubt, of a cause-effect link between individual chemicals and the disease, in which all confounding influences have been eliminated, the answer is no . . .''[97] But, it went on, "It is unethical, irresponsible, and unrealistic to require strict proof, because such an approach takes preventative action only after irreversible damage to health and environment have taken place.''

Or as Lois Gibbs, the homeowner whose alarmist calls led to the unjustified evacuation of Love Canal, New York, writes in her recently published book, *Dying From Dioxin: A Citizens Guide to Reclaiming Our Health and Rebuilding Democracy:*

> Government should make environmental regulatory decisions "so that the burden of proof is placed on showing that a chemical or practice is safe, not is harmful . . . . Rather than using all chemicals until they are proven harmful, we should demand that all chemicals be shown to be safe before they are used.[98]

The so-called precautionary principle lends an almost irresistible sense of moral urgency to the environmental movement. Unless such a policy

is adopted, the argument goes, we will be saddled with policies that wait for a "body count" before prudent action is taken. Those who favor the principle favor health; those who oppose it oppose saving our children and our environment. But at what price prudence?

An industry-sponsored study released last year concluded that "about 45 percent of all U.S. industries are direct consumers of chlorine and its coproducts, and that all industries are indirect consumers of chlorine or chlorine-dependent products." The researchers also estimated the total net cost of substitution to consumers in the United States would be slightly over $90 billion, and that employment in chlorine-dependent industries accounted for $33.6 billion in wages in 1990.

The price of precaution can not only be measured in dollars, but in lives. As risk analyst Ralph Keeney has shown, mortality risks induced by economic expenditures are significant. He has estimated that every $7.25 million taken out of the economy by government results in the loss of one life on average. Thus, anti-chemical campaigns that do not take into account the possibility of risk or death associated with implementing bans are of little value to public health at all. As Keeney notes, "if the intent of a proposed regulation is to save lives by making some aspect of life safe, then it would seem to be ridiculous not to consider the potential mortality implications of implementing the regulation itself. These implications include the potential fatalities induced by the cost of the regulation."[99]

The price of precaution can not only be measured in dollars, but in lives.

The precautionary principle is a something-for-nothing proposition. Environmentalists would have us believe that improved health can be attained through regulations and bans at zero cost. They assume costless transitions to chlorine-free substitutes. But government intervention requires resources — resources diverted from other proven health-improving and cost-effective activities. Furthermore, cost-effective alternatives aren't free. The ban on DDT led to increased malarial infections and deaths. Alarm over chlorinated water spawned the deadly Latin American cholera epidemic. The phaseout of chlorofluorocarbons (CFCs), another chlorine-containing culprit, led to increased water pollution by the electronics industry.

Chlorine processes and products didn't simply arise out of thin air to wreak havoc on the environment; they developed over time to replace older, more hazardous technologies. Before the successful widespread introduction of chlorination to purify water, for example, treatment techniques included filtration, followed by chemical precipitation and sedimentation methods.[100] These methods, however, could not guarantee a bacteriologically safe water supply.[101] Chlorine is by far the superior method of disinfection because it is effective against a broad spectrum of pathogens including bacteria, viruses, and protozoa; only state-of-the-art chlorine chemistry provides residual protection, i.e., the ability to prevent microbial

growth after treated water enters the distribution system; and finally, chlorine disinfection technology is far simpler than other disinfection technology.[102]

In most cases, the proposed "cure" for chlorinated organic chemicals is worse than the "disease." Environmentalists claim, for example, that substitutes for water chlorination are cheaper and safer. In fact, they may prove far more odious. Ozonation breaks down very rapidly, for example, and does not guard well against recontamination of water supplies. Moreover, ozone must be generated on site, is not as suitable as chlorine for smaller treatment works, and also results in various mutagenic byproducts.

Lastly, ozone decomposes too quickly to provide any residual disinfection. Chlorine or chloramines must be added to provide residual protection; thus, ozone could not serve as an adequate substitute for chlorine on its own. As a team of international researchers concluded in *JAMA* this year, there simply are "no cheap substitutes as proven and effective as chlorination."[103]

Anti-chemical campaigns that do not take into account the possibility of risk or death associated with implementing bans are of little value to public health at all.

CONCLUSION

The proper way of discriminating among chemicals isn't between chlorines and non-chlorines, or between naturals and synthetics. Rather, our goal should be to use quality science on a case-by-case basis to restrict and seek alternatives to the usage of any chemical, chlorinated or not, synthetic or not, which causes demonstrable harm to humans or their environment. This won't accomplish any political, moral, religious, or social goals. But it will make the world a safer and cleaner place.

Ultimately, however, the war over chlorine and all its diverse compounds, both naturally-occurring and synthetically induced, will not be won with the weapon of "sound science." The conflict is not between those who desire better health and safety and those who do not. It is between those who believe increased wealth and technological progress are the best means of improving health and safety and those who do not. Environmentalists see rapid technological advancement as a threat to human dignity. "Sound science" will not thwart their campaign because science itself is suspect. As long as the environmentalists' view that all synthetic chemicals are "guilty until proven innocent" prevails, no amount of exculpatory evidence will ever be enough to clear an arbitrarily indicted chemical.

As the anti-chlorine activists themselves have framed the debate, "It's either chlorine or us." Chlorine-based products and processes are essential to modern life. Technology-fearing environmentalists are not. The choice should be clear.

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